

Extraoral Application

Case 3

The integration of alloplastic implants places special demands on the reconstruction of covered soft tissue. This is especially true in the case of reconstruction of soft tissue over convex implants. Post-operative wound healing problems can only be solved by prompt improvement in wound margin perfusion and by adaptation of the wound margins. If this is unsuccessful, one is almost always faced with loss of the transplant.

A 20-year-old male patient developed osteomyelitis of the right parietal bone following multiple revisions due to intracranial hemorrhages. Prior to reconstruction, expander therapy of the galea was performed in order to improve the supply of soft tissue. Thereafter, resection

of the bone affected by the osteomyelitis and reconstruction of the skull using an individually made titanium implant were performed (Fig. B16.10). Wound closure was achieved by means of a combined rotation and advancement flap plasty using the galea. Postoperatively, there was a wound healing disturbance over the occipital margin of the titanium implant, in response to which an early decision was made to institute vacuum therapy (Fig. B16.11).

For vacuum therapy, a polyvinyl alcohol foam was selected, with dressing change every two days with debridement of the wound margins. This resulted in complete granulation of the wound bed and reduction in wound size within six days (Fig. B16.12). The defect was subsequently covered using a retroauricular full-thickness skin graft (Fig. B16.13).

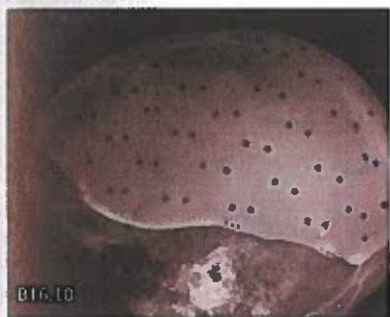


Fig. B16.10 Position of the titanium implant for use in the left parietal bone.

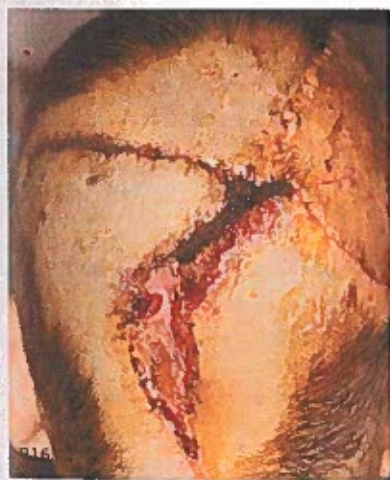


Fig. B16.11 Wound healing disturbance in the area of the implant margin with necrosis of the galea flap edge.



Fig. B16.12 Wound with complete granulation following six-day vacuum seal therapy.



Fig. B16.13 Results following full-thickness skin grafting.

Case 4

The use of vacuum therapy is not confined to treatment of infected and chronic wounds. It is equally possible to devise therapy concepts that, by reducing surgical and anesthesia times, reduce the stress on the increasingly large segment of the patient population made up of older and multimorbid patients.

An 80-year-old female patient presented with an extensive squamous cell carcinoma of the skin of the forehead (Fig. B16.14). Tumor resection started from a central site under inclusion of the external table and, peripherally, with inclusion of the periosteum. In order to shorten the surgical time, primary local plastic coverage

of the 6-cm defect was deferred. Instead, following broad preparation of the peripherally denuded external table (Fig. B16.15), a polyurethane foam dressing was used, with dressing changes twice weekly. Complete granulation of the wound bed was achieved within three weeks of outpatient therapy (Fig. B16.16). Plastic coverage involved a full-thickness skin graft, which was fixated for seven days with a polyvinyl alcohol foam (Fig. B16.17). Thus, the therapy resulted in shortening of the time required for granulation tissue formation and healing of the full-thickness skin graft by about three weeks. In addition, the method was very feasible on an outpatient basis, which significantly enhanced this patient's compliance.



Fig. B16.14 Extensive squamous cell carcinoma of the forehead.



Fig. B16.15 Resection defect.



Fig. B16.16 Granulation after vacuum seal therapy.



Fig. B16.17 Treatment results after full-thickness skin grafting.

Case 5

Application of vacuum therapy is unproblematic in defects of sufficient size and adequately broad surrounding tissue. For wounds on complex surfaces, such as the hands and feet, special dressing systems are commercially available. Corresponding dressing systems for the treatment of wounds of the head and neck, however, have not yet been developed. In addition, treatment of small surface-area wounds in pre-radiated tissues place special demands on the dressing system because of the high priority of avoiding any maceration of the wound margins. The following case will illustrate the options available for the gentle treatment of multiple small surface-area wounds.

A 72-year-old male patient suffering with squamous cell carcinoma (pT4pN0M0) underwent resection of the anterior floor of the mouth with partial mandibular resection and bilateral supraomohyoid lymph node resection followed by radiochemotherapy with a total dose of 61.2 Gy and two cycles of carboplatin. Mandibular reconstruction with a microsurgical iliac crest transplant followed after the first disease-free year. Postoperatively, however, we observed a wound infection above the mandibular reconstruction plate (still *in situ*) with extraoral fistulation.

Although the chronic wound healing problems represented a clear indication for vacuum therapy, this indication was limited by the small surface area of the defects and the prior radiation therapy (Fig. B16.18). In order to protect the surrounding tissue, a foil covering was placed on the skin bridge between the defects. A polyvinyl alcohol foam patch was placed in each of the two wounds and connected with a *trac-pad connector* via a third piece of polyvinyl alcohol foam. Vacuum seal was achieved by a tiled arrangement of adhesive foil dressing, which permitted adequate mobility of the neck (Fig. B16.19). Vacuum therapy was conducted at a subatmospheric pressure of -125 mmHg. In this way, both defects could be supplied by a single therapy unit and the surrounding tissue was adequately protected. Dressing changes were done twice weekly. Following complete granulation of the wound bed, the defects were covered with a full thickness skin graft, which was fixated using vacuum seal for seven days according to the technique described above. This method permitted wound closure without maceration of the surrounding tissue (Fig. B16.20).



Fig. B16.18 Wound prior to beginning vacuum therapy.



Fig. B16.19a Technique of vacuum therapy. Bridging with adhesive drapes and one polyvinyl alcohol foam *in situ* in each defect.



Fig. B16.19b Complete dressing with polyvinyl alcohol foam bridge.



Fig. B16.20 Results following full-thickness skin grafting.

Conclusion

Vacuum therapy permits continuous elimination of secretions and bacterial load, an improvement in microcirculation and the induction of tissue proliferative processes^{1,5}. The development of dressing systems that would permit use of vacuum therapy on mucosal surfaces make it possible to take advantage of these effects in the treatment of intraoral wounds. Both the highly elastic silicone body and the broad seated, stiff dressing plate permit adequate sealing of the wounds against contamination with the bacteria-laden milieu of the oral cavity. An index for the efficacy of the wound seal was the small amount of secretion collected (saliva and wound secretion), of which only about 50 ml were collected over a period of two days. Both systems permitted unhindered food intake and phonation. In addition, it was also possible to integrate alloplastic bone replacement material without prior primary wound closure.

Besides facilitating the therapy of patients with wound healing disturbances, extraoral application of vacuum therapy can also be used prior to elective procedures in order to reduce patients' exposure to surgical and anaesthetic stress. Use of appropriate dressing techniques makes use of this method possible in almost any location of the head and neck. Similarly, there is no restriction in its use in patients with prior radiation exposure to the surrounding tissues. In most cases, use of vacuum therapy results in shortening of patients' duration of therapy.

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Part B / Chapter 17

Vacuum Therapy of Open Abdomen

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At the present time, vacuum therapy of open abdomen is carried out using a system specially designed for this indication (abdominal dressing system). A review of the literature reveals 21 *peer-reviewed* articles (2001-2006, total n=249 treated patients), mostly reviews (n = 5), case series (n = 7) or case reports (n = 6), as well as one letter to the editor. All are of evidence-level 4 or 5 according to the Oxford classification. Only two paper include a comparison with conventional techniques (evidence level 3b).

Introduction

The management of open abdomen in severely injured patients or those with serious intra-abdominal infections represents a significant challenge to the surgeon and may include treatment of abdominal compartment syndrome (ACS), effects on respiration, cardiovascular and renal function, and even "damage control" laparotomy¹⁻³. The life-sustaining emergency operations in patients with severe abdominal injuries are often accompanied by visceral edema, retroperitoneal hematoma or packing of the abdominal cavity. The same applies to re-laparotomies carried out to assess intestinal viability or to control secondary bleeding after damage control laparotomies, or in connection with intra-abdominal infections⁴⁻⁶. The pressure of forced abdominal wall closure or an abdominal infection may lead to ischemia and necrosis of the abdominal fascia. The latter results in abdominal rupture with subsequent development of an abdominal wall hernia⁷.

Laparotomies within the scope of "damage control" with packing, the occurrence of ACS or severe septic intra-abdominal complications require repeated revisions of the abdominal cavity. All these situations result in an open abdomen which does not permit primary closure of the fascia and requires temporary abdominal closure (TAC). TAC should prevent contamination of the abdominal cavity and desiccation of intestine. TAC should also protect the abdominal organs from evisceration and mechanical injury. Currently used TAC techniques include^{5,8,9}:

- The Bogota Bag (a sterile three-liter urine-bag positioned on the viscera covered with damp abdominal pad and Opsite®-drape)
- Absorbable or non-absorbable mesh
- Net + zipper

Vacuum therapy as a TAC option has gained in importance over the last ten years^{10-16,17,33}.

Technique of Abdominal Vacuum Therapy

Abdominal vacuum therapy differs from the customary vacuum therapy of wounds because of the application of perforated thin polyethylene film positioned between the viscera and the anterior peritoneal wall. The latter prevents adherence of the viscera to the peritoneum and

allows the abdominal wall to glide over the bowel loops. At the same time, TAC removal at repeated laparotomies is simple because no adhesions form. The first version of abdominal vacuum therapy, reported in 1995, was the so-called "vacuum pack technique" in which a folded sterile damp foam covered with film to seal the system and vacuum was used^{11,13}. Two drainage tubes are positioned over the sponge^{10,11} and combined using a Y-adapter with a container and suction device. Five years later, use of the conventional black polyurethane foam began^{12,14-16}. Both the foam of early days and the foam of today protect the bowel loops, filter the wound secretion and prevent blockage of the suction line. The foam spreads the negative pressure evenly over the whole wound. The skin may be both sewn together over the foam or left open^{10,11}. The whole system is sealed with a transparent adhesive drape.

Today, there is a commercially available, ready-to-use vacuum therapy set for TAC (Fig B15.1), which differs in some details from the above discussed systems. The perforated foil is equipped with a fixed thin foam in the middle, which, under the negative pressure, adheres to the superposed foam layers, preventing any shift of the film in the abdomen. Perforations in the film allow wound secretion flow along the pressure gradient from the abdominal cavity into the receiving vessel of the vacuum pump. The black foam in lenticular form is positioned over the above mentioned film in two layers and the system is sealed with an adhesive drape. A hole is cut in the center and a self-adhesive *trac-pad connector* is positioned over it. The latter is connected with the container and the vacuum therapy device (Fig B15.2-7).

The pump is normally adjusted to 100-150 mmHg^{10,11,16} but may go up to 175 mmHg^{14,15} and then started. Other authors found a negative pressure of only 75 mmHg satisfactory for continual removal of wound fluid and sufficient for approximating the wound edges.

Course of Therapy

Research groups using all three above-described vacuum therapy alternatives for temporary wound closure¹⁰⁻¹⁶ managed mostly severely injured patients. The duration of open abdomen ranged between 1 and 36 days, while our own experience includes some extremely serious cases of 49 and 72 days before the abdomen could be closed. The dressing was changed every two to five days

on average. Complications such as fistulae^{10,11,15}, intra-abdominal abscess^{11,12}, wound infection or wound dehiscence^{10,12,14,16} and ACS development^{11,15} were noted. The death rate in some series was as high as 44%, explainable by additional severe injuries or multiorgan failure¹².

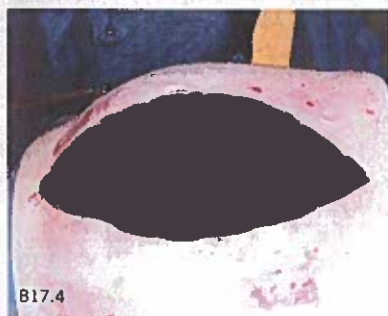
However, these complications and poor outcome were not associated with the vacuum therapy (for further detail, see Part B, Chapter 18 "Vacuum Therapy in the Treatment of Secondary Peritonitis - Preliminary Results of a Comparative Study").



Fig. B17.1 Commercially available abdominal dressing system for treatment of the open abdomen.



Fig. B17.2-7 Anastomotic insufficiency and severe peritonitis after initial damage control operation in the abdominal cavity. Repeated lavages and temporary coverage of the laparostomy by the means of vacuum sealing therapy. After 16 days, stable closure of the fascia without mesh implantation was possible.



Vacuum therapy has become established as an additional therapy option in the management of open abdomen. It meets all requirements for temporary abdominal closure with a very low complication rate. It provides constant medial pressure on the fascial edges and this prevents them from thinning out over time. This also facilitates mobilization of the fasciae and promotes subsequent definitive abdominal wall closure. The negative pressure reported in the literature is non-uniform at 75 up to 150 mmHg. All reports recommend use of continuous suction mode.

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Part B / Chapter 18

Vacuum Therapy in the Treatment of
Secondary Peritonitis - Preliminary
Results of a Comparative Study

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Vacuum therapy has become established as an additional therapy option in the management of open abdomen. Only two papers of 21 *peer-reviewed* articles (2001-2006), both published by the same group (Vienna, Austria), present data of a comparison with conventional techniques (evidence level 3b). These preliminary data will be presented in this chapter.

Introduction

The treatment of open abdomen remains a significant challenge in modern intensive care medicine. Peritonitis is still a potentially life-threatening entity. Briefly, it is an inflammatory condition of the peritoneum, which is a double-layered serous membrane approximately two square meters in surface area lining the abdomen. It consists of visceral and parietal membranes, which face the intra-abdominal organs and the abdominal wall, respectively. The peritoneum serves to protect the viscera by reducing friction as these structures glide against one another.

The serous fluid secreted by the peritoneum assists keeping the peritoneal cavity moist. Furthermore, the peritoneum and fluid secretion maintain the important fluid balance. Immunologically, the peritoneal fluid provides humoral and cell-mediated factors. Fluid is evacuated through the lymphatic system with the help of the pump effect of the diaphragm. This, however, also provides for fast and systematic spread of infection leading ultimately to the complete picture of sepsis should a bacterial infection of the peritoneum occur.

We distinguish between two basic forms of peritonitis, local and diffuse. The local form is the most common, occurring in 85-95% of cases. After a removal of the septic focus and drainage, its prognosis is normally good. Diffuse peritonitis, on the other hand, is a disease of the whole peritoneum with an equal involvement of all four quadrants. The causes of diffuse peritonitis are variable.

Primary peritonitis is the term for a disease pattern. Causes include hematogenous dissemination of pathogens. Most common affected are children, patients with cirrhosis of the liver or within the scope of an HIV infection. Secondary peritonitis is usually seen after perforation of an intra-abdominal hollow viscus due to an inflammatory process or as a result of necrosis. Examples include Crohn's Disease, ulcerative colitis and mesenteric infections. Traumatic opening of a hollow viscus can lead to an extravasation of bacteria into the peritoneal cavity. Postoperative peritonitis is another example of secondary peritonitis. It mostly appears as a consequence of suture insufficiency.

The pattern of a tertiary peritonitis occurs in immunosuppressed patients and is provoked by opportunistic pathogens.

Assessment of patients with peritonitis is facilitated

by use of severity scores, such as the Apache II Score and the Mannheim Peritonitis Index (MPI). The Apache II score can be used in cases of peritonitis right at the time of first operation and consists of 12 physiological parameters (body temperature, heart rate, blood pressure...). Patients with normal values are assigned a score of 0; scores of 1 to 4 are assigned according to severity. Patients' age results in values between 0 and 6 and chronic conditions are factored into the score with five additional points for every serious concomitant disease e.g., hypertension, cirrhosis.

The Mannheim Peritonitis Index can be partly determined intra-operatively. Besides sex, age and the underlying disease, the situation will be evaluated intra-peritoneally and takes into consideration factors such as the consistency of the exsudate as well as the seat and spread of the infection. MPI scores up to 21 are associated with a lethality of approximately 6%; however, with scores of 21-29, it is about 50%. Studies have shown that MPI scores are highly sensitive for mortality. Unlike primary peritonitis, the treatment of secondary peritonitis cannot be exclusively conservative. Since the beginning of the twentieth century, the therapeutic principle in secondary peritonitis has contemplated open treatment. As a result, lethality dropped significantly, whereas under exclusively conservative therapy it was nearly 100%.

The idea of considering the infected abdomen as an abscess, which is opened and allowed to heal as a chronic wound is widely accepted. After the healing process a definitive closure of the abdominal wall takes place, supported by systematic antibiotic therapy. Extensive peritoneal lavage is indicated in patients with severe, secondary peritonitis in order to remove bacteria, toxins and cellular detritus. At the present time, there is no optimal rinsing fluid and addition of antibiotics has not been proven effective.

A few years ago, an open method for the treatment of open abdomen was proposed. With this method, the abdomen is left open after the operation and the site is covered with a moist towel to prevent desiccation of the bowel loops. Subsequent management takes place in the intensive care unit with an Incise-Pouch, an open bag applied over the laparostomy. The advantage of this treatment is the reduction of intra-abdominal pressure, which went hand in hand with improvement in the capability of the respirator. A prime disadvantage of the treatment was the retraction of the abdominal wall, which

impeded the primary abdominal wall closure and required complex reconstruction.

Vacuum assisted closure represents a new concept for the treatment of open abdomen. Initially, the vacuum therapy system had only been used for the treatment of chronic and infected wounds. After lavage, a polyurethane foam is applied over the open abdomen, which is then sealed with a film. A suction of 125 mmHg is applied after fixation of the *trac-pad connector*. This permits evacuation of exudate, bacteria and toxins while at the same time preventing retraction of the abdominal wall. Hypergranulation, however, may promote formation of adhesions between adjacent intestinal loops and/or the abdominal wall so that the abdominal wall cannot close.

This phenomenon stimulated development of specialised abdominal dressing. This form of therapy builds on the vacuum therapy concept. Before insertion of the polyurethane foam, a meshed, non-adherent film with an integrated foam is placed on the intestinal block, preventing adhesions of the abdominal wall and intestinal loops. It is interposed and extends in a para- to retroperitoneal direction. The effect of the drainage persists because the foil is meshed. After placement of the second, adherent film, undertow is produced as with classical vacuum therapy, which removes exudates and draws together the borders of the wound.

Material and Method

A retrospective analysis was conducted at the General Hospital of the Medical University of Vienna together with several other Austrian centres. We reviewed the medical records of surgical patients undergoing treatment with laparostomy between 2001 and 2005. Demographic data, comorbidity, indications for open abdominal wall management and intensive medical data such as Apache II, Mannheim Peritonitis Index and SOFA score were documented. In the abdominal dressing vacuum therapy group (AD) a perforated polyethylene sheet (abdominal dressing) is placed over the bowel and under the fascial edges. Over this, the polyurethane foam is placed. As suction is activated the foam shrinks, pulling the edges of the wound towards the midline. The procedures used in the two control groups for the temporary closure included placement of towels of water tight drape (treated conventionally = CT group) and classic vacuum therapy treatment (= CV group).

Results

Between 2001 and 2005 we identified 62 patients who underwent laparostomy due to peritonitis. Of these, 27 patients were treated conventionally (CT group), while 16 underwent classic vacuum therapy (CV group) and 19 patients were managed using vacuum abdominal dressing (AD group). The groups did not differ in terms of the Apache II or Mannheim Peritonitis Index. In the AD group the SOFA score showed a clear decrease between days one to five. The mortality was 3/19 (15.8%) in the AD group *vs.* 4/16 (25.0%) patients in the CV group and 18/27 (66.7%) in the CT group ($p < 0.0009$ AD *vs.* CT group). There was no significant difference for survivors in terms of the length of ICU stay: 26.6 ± 23.0 days in the CT group; 34.6 ± 30.2 days in the CV group and 38.9 ± 27.2 days in the AD group.

We found a reduction of mortality in the AD group of approximately 40% (AD: 15.8%, CT: 66.6%). Although there was a difference in age in our retrospective study we believe that use of the vacuum abdominal dressing system is the important factor affecting the clinical outcome. These first results indicate the need for further prospective evaluation of the VAC abdominal dressing therapy, to assess whether a new standard in the therapy of the open abdomen will be established.

Discussion and Conclusion

Mortality, though high in all groups, was significantly lower in the CV and AD groups. In patients not suitable for primary closure, we allowed the laparostomy to granulate secondarily through vacuum therapy and the covered it with split-thickness skin.

The data of the analysis are promising. The CV and AD groups both showed an obvious reduction in mortality compared to conventional open treatment. Application of the new technique is much easier and demands on nursing staff are significantly reduced because the dressing requires change every second day and only the seal of the system has to be monitored. Because it is portable, the vacuum method promotes early ambulation and transfer to a regular medical ward. As a consequence, the vacuum technique reduces both the rehabilitation period and the associated costs. Another advantage is the higher likelihood that primary closure of the abdominal wall will be feasible, thereby obviating the need for time-consuming reconstructions. The newer vacuum methods,

especially the use of the abdominal dressing system, have been shown to represent significant improvements in the treatment of secondary peritonitis. These preliminary findings should be confirmed on the basis of further prospective studies.

Acknowledgement

Our efforts were greatly facilitated by the support and new ideas of the nursing staff of the intensive care unit 13 B1 led by A. Raab.

Although there was a difference in age in our retrospective study we believe that the use of the vacuum abdominal dressing system was the important factor affecting the clinical outcome. These preliminary results indicate the need for further prospective evaluation of the VAC abdominal dressing therapy, to assess whether a new standard in the therapy of the open abdomen will be established.

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Part B / Chapter 19

Impaired Wound Healing after Enterostoma Surgery: Successful Treatment with Vacuum-Assisted Closure

H. Riediger, C. Moosmann, E. von Dobschuertz, U.T. Hopt and F. Pfeffer

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Impaired wound healing at the skin-mucosa junction of a new enterostoma can be a major surgical problem. During the early postoperative period persistent stool contamination impairs wound healing and may cause abscesses and phlegmonas as well as peristomal ulcers. If local surgical measures are unsuccessful, further operations including stoma transposition may become necessary. Re-laparotomies may be difficult due to intraabdominal adhesions. We applied vacuum-assisted closure therapy as a local alternative to further surgery in patients with a prior complicated course after enterostoma placement. We applied vacuum therapy in four cases with impaired peristomal wound healing (two ileostomies, two colostomies). Vacuum therapy foam and drape were placed close to the enterostoma with the stoma care unit on top of it. If necessary, further skin incisions were performed in order to approach the skin peristomally and to place the foam subcutaneously. The objective of the treatment was to promote development of granulation tissue and skin peristomally while continuing hygienic stoma care. Median peristomal wound size was 37 cm² (range 4-76 cm²). In two cases the peristomal lesion and the median laparotomy wound were communicating. Length of vacuum therapy was 19 days (median; range: 9-61 days). Vacuum therapy was successful in all cases. Enteric fistulas to the vacuum system did not develop. No further operations were necessary. Finally, regular stoma care could be performed in all cases. Peristomal vacuum therapy can be performed safely in the treatment of peristomal ulcers and impaired wound healing. Vacuum therapy is an ideal method that can avoid further operations in selected patients.

Introduction

Surgery of enterostomies is a common procedure. Normally, wound healing and closure of the gap between the skin and mucosa are prompt and free of complications. Nevertheless, in 25% of cases, complications of varying extent can be observed¹. A significant number of complications (30-40%) occurs during the early postoperative course, within the first 30 days^{2,3}. About 25% of all complications are considered serious¹⁴. The most frequent complications are skin irritations (17%), necrosis (22%), infection (15%), bleeding and retraction⁴. Obese patients and those with chronic inflammatory bowel disease have a significantly elevated risk of complications at the stoma⁵. A further risk factor is the experience and training of the operating surgeon⁴. In rare cases, complicated wound healing and destructive ulcerations around an enterostoma are associated with *pyoderma gangraenosum* in patients with chronic inflammatory bowel disease⁴.

Abscess and phlegmona after surgery of an enterostoma are serious complications. Often, regular stoma care is not possible and further surgical procedures are necessary. In many cases, transposition of the enterostoma is required. In patients with serious concomitant diseases, operations are associated with a high risk. Intraabdominal adhesions due to previous operations increase the risk of abdominal complications.

The vacuum-assisted closure system is a new treatment option to support secondary healing of complicated wounds⁶. Especially in infected wounds, previous results are impressive^{7,8,9,10}.

We applied vacuum therapy in a small patient group with peristomal complications. The aim was to treat the impaired wound healing with simultaneous regular stoma care and to avoid further operations.

Patients and Methods

During the past two years, we used vacuum therapy to treat four patients with impaired peristomal wound healing after enterostoma surgery. In two cases, a terminal ileostomy resulted in anastomotic complications after right hemicolectomy. In one patient (67 years, male) the initial indication for surgery was a malignant polyp at the caecum. Relevant comorbidity included compensated renal insufficiency and anticoagulation therapy because of cardiopathy. In another case (66 years, female), angiodys-

plastic bleeding due to portal hypertension and alcoholic liver cirrhosis were the indication for hemicolectomy.

In two other cases, impaired wound healing of a colostomy was treated with topic negative pressure therapy. In one case (72 years, female), perforated sigmoid diverticulitis was treated with a terminal colostomy. Postoperatively, an extensive necrotising and destructive infection of the abdominal wall developed. Excisional biopsy of this tissue revealed *pyoderma gangraenosum* in this patient with known *polymyalgia rheumatica*. In the last case (63 years, female), bowel obstruction due ovarian cancer made a colostomy necessary. During the postoperative course regional ischemia of the colostomy with phlegmona of the abdominal wall developed.

All patients had complications of a previous laparotomy and/or relevant comorbidity. In all cases minor surgical measures (suture, dressing) were applied without success to treat the peristomal lesions. Vacuum therapy was applied as a last resort in order to avoid surgical transposition of the enterostomy. No further laparotomies were necessary. The intraabdominal situation improved in response to topical negative pressure therapy. The vacuum dressing was applied uniformly. The foam was placed subcutaneously; sometimes it was necessary to make an additional incision for the tube. Adaptation of the skin around the stoma by additional stitches should be done as soon as possible. To avoid fistulas of the bowel, we applied additional gauze between foam and bowel. The adhesive drape was shaped to fit the mucosa. If necessary, additional paste was applied to seal the vacuum dressing.

The regular stoma care appliance was placed on the vacuum dressing. Watertight stoma care is possible even in ambulatory patients.

Results

Median peristomal wound size was at 37 cm² (range: 4-76 cm²). All patients had a median laparotomy and, in both cases of colostomy, the peristomal wound and the laparotomy were communicating. Especially in the patient suffering from *pyoderma gangraenosum*, there was extensive destruction of cutis and subcutis (wound size 76 cm²). In both cases of ileostomy, local defects comprised one-fourth and three-fourths of the circumference. The median time of vacuum therapy was 19 days (range 9-61 days). Dressings were changed every three to five days.

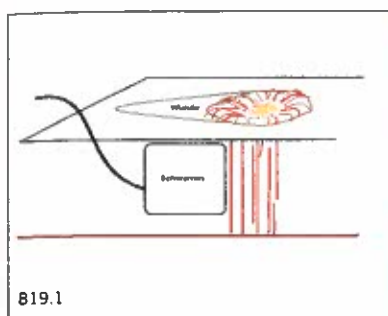


Fig. B19.1 Scheme of vacuum closure dressing next to the enterostoma. The foil separates the foam from the enterostoma.



Fig. B19.2 Regular stoma care is possible. The VAC tube requires an additional incision in some cases.

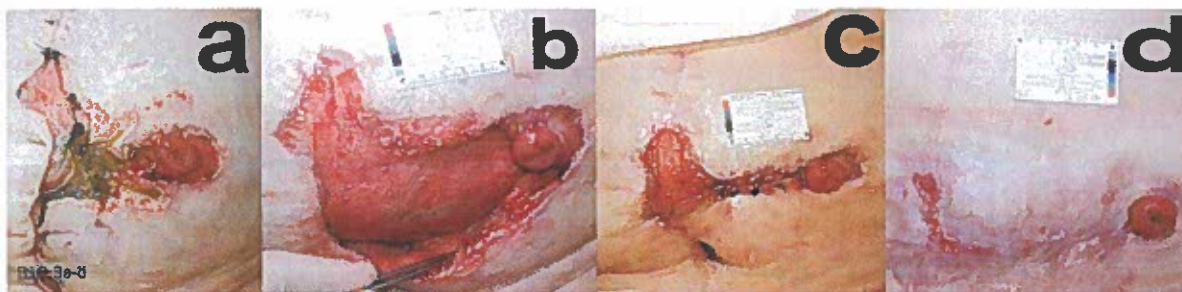


Fig. B19.3a-d Finding after perforated diverticulitis, colostomy and *pyoderma gangrenosum*. Treatment combined immunosuppression and vacuum closure (46 days). Initial finding (a), 17 days of VAC (b), 38 days of VAC (b), seven weeks after VAC (c).

The largest defect was observed in the patient with *pyoderma gangraenosum*. After diagnosis and histological confirmation of the pyoderma, initial therapy was performed with prednisolone (250 mg for three days) and was sequentially switched to cyclosporine A (target range: 100 ng/ml). With regressive findings, we applied topical negative pressure. Re-laparotomies were not necessary in any case. Definitive wound healing was obtained in all patients. Hygienic stoma care was possible in all patients at all times.

Discussion

Surgery on an enterostomy is a common event. Normally, primary wound healing at the skin-mucosa junction is achieved quickly. Impaired wound healing is more frequent in patients with comorbidity and/or previous complicated therapies¹³. Surgical transposition of the enterostomy can be difficult due to intraabdominal adhesions and increases the risk of further complications for the patient.

In these four cases, topical negative pressure treatment was used as a new therapeutic alternative. It is an established procedure in complicated and infected wounds. Reduction of bacterial, improved circulation and faster granulation was demonstrated^{11,12}. Clinical relevance has been demonstrated in various indications. Topical negative pressure therapy has already been used successfully in infected wounds of the sternum after cardiac surgery⁹, infected pilonidal sinus⁶, diabetic foot syndrome^{3,10} and also after gynaecological and abdominal procedures^{3,7}.

Persistent faecal contamination is a significant problem in patients with peristomal ulcerations. If possible, early adaptation of skin around the stoma is an important initial step that facilitates a watertight dressing. The vacuum dressing separates the treatment area into two compartments. Stoma care is possible on top of the foil while topical negative pressure is applied at the wound. Granulating soft tissue permits a stepwise closure of the wound. Ambulation and enteral nutrition is possible during the treatment.

Pyoderma gangraenosum is a feared complication of disturbed wound healing after enterostoma surgery. Lesions can develop quickly as initial erythemas progress to painful ulcerations. *Pyoderma gangraenosum* can develop even after years of regular enterostomy care⁴. Because it is a rare entity, diagnosis and treatment is often delayed and inadequate. Histological confirmation can be

helpful. Initial treatment consists of immunosuppression (cortisone, cyclosporine) and local wound care¹⁵. Surgical procedures may trigger severe progression⁸. The natural course of the disease often takes months. In our opinion, the combination of immunosuppression and vacuum therapy can be adequate and reasonable.

In this patient group, vacuum therapy promoted healing of peristomal wounds and ulcerations that were refractory to common treatments. Previous resolution of intraabdominal issues is obligatory. Topical negative pressure treatment is adequate for stepwise closure of peristomal defects of the abdominal wall. Regular stoma care can be performed at the same time. Surgical transposition of the enterostoma can be avoided by this procedure.

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Vacuum Therapy in the Management of Complex Enterocutaneous Fistulae

C. Willy and G. Bergenthal

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A review of the literature yielded one publication (level 4 evidence) on the use of vacuum therapy in 10 patients who developed enterocutaneous fistulae after abdominal surgery. Good clinical results were reported for these patients. In particular, vacuum therapy enhanced patient comfort and mobility.

All eight *peer-reviewed* publications in the literature (level 4 and 5 evidence, 2000 - 2006, n = 26 patients) focused on the use of vacuum therapy as a last resort in managing high-output enterocutaneous fistulae in individual cases. These articles agree that vacuum therapy makes it possible to reduce the length of bed stay, provide treatment temporarily on an out-patient basis, decrease the number of dressing changes considerably, reduce odour nuisance and pain and thus increase patient comfort. In addition, this therapy offers an excellent healing potential without the need for further surgery.

Introduction

Enterocutaneous fistulae can occur after surgical interventions in association with certain underlying diseases or conditions. Not infrequently, they are seen postoperatively in patients with chronic inflammatory bowel diseases, tumour diseases, diverticulitis, appendicitis, intestinal ischaemia, ulcer perforation, after radiotherapy or in the presence of anastomotic leaks. The seriousness of an enterocutaneous fistula depends on the volume and nature of its output. Low output is defined as less than 200 ml/day, moderate output as 200-500 ml/day, and high output as more than 500 ml/day. To date, conservative management has been the treatment of choice and consists of total parenteral nutrition, the administration of somatostatin analogues, the correction of sometimes massive fluid losses, the prevention of sepsis, intensive wound care and, where necessary, multiple daily dressing changes. When this strategy is used over a prolonged period of treatment, healing rates of 30-78% can be reached. Other patients may benefit from one or more re-operations. Recognising therapeutic failures and determining the best time for surgery are difficult tasks and depend on the subjective assessment of the treating physician.

The use of vacuum therapy in the management of abdominal fistulae remains controversial. Older publications postulated that enterocutaneous fistulae were a contraindication to the use of vacuum therapy². Argenta et al. considered it possible that continuous suction might

prevent closure of the fistula. By contrast, a number of case reports (n=5) and three case series have been published in the more recent literature showing that vacuum therapy had positive effects on the course of treatment and did not cause any of the feared complications.

Literature Review

The publications described below provide useful information on whether topical negative pressure can promote the healing of complex enterocutaneous fistulae (Table B20.2).

Nienhuijs et al. described the use of vacuum therapy in a case series of 10 patients with high-output enterocutaneous fistulae of different aetiologies who developed skin erosions in the region of the abdominal wound during standard conventional therapy with multiple daily dressing changes⁸. Table B20.1 presents the protocol that they used for their patients. Vacuum therapy was continued for a period of 25 days (=median, range: 14-161 days). Four patients received vacuum therapy for another 46 days (22-77 days) on an outpatient basis. As a result of this therapeutic approach it was possible to control fistula output effectively, reduce the number of dressing changes to three per week, prevent an increase in the size of the fistula as well as inflammation of surrounding skin, and achieve the spontaneous closure of the fistula in four of the 10 patients within a median of 73 days. Although the patients had to carry a vacuum therapy

Table B20.1 Protocol for the use of vacuum therapy in the management of complex enterocutaneous fistulae (according to Nienhuijs et al.⁸)

Debride the wound (necrectomy)
Apply a non-adherent dressing to the wound cavity and leave the fistula opening uncovered
Cut a piece of polyurethane foam to the appropriate size
Insert a small piece of foam into the fistula opening
Lay the drainage tubing onto the foam
Cover the wound with a transparent drape
Connect the drainage tubing to the vacuum therapy unit (pump)
Select the appropriate therapy settings (negative pressure of 125 mmHg, intermittent mode)

unit (pump) with them, they reported that this form of therapy was comfortable and made them more mobile. In addition, vacuum therapy reduced odour nuisances more effectively compared to conventional dressings. Many patients consider this to be a major advantage.

Cro et al. also reported on the use of vacuum therapy for abdominal surgery patients³. They described three patients with enterocutaneous fistulae in whom conventional treatment had failed. Vacuum therapy was found to be highly effective in promoting healing of excoriated skin and controlling fistula effluent in all three patients.

Complete healing of the fistula was achieved in two of the three patients. The third patient underwent intestinal reanastomosis once the fistula output fell to less than 200 ml/day. Complete healing of the abdominal wound was then achieved in this case as well.

Erdmann et al., Alvarez et al. and Hyon et al. reported on three patients who developed high-output enterocutaneous fistulae as a result of different underlying diseases^{1,4,7}. Vacuum therapy was used for 42 to 56 days on either an inpatient or outpatient basis. Vacuum dressings were changed every one to two days. All authors agreed

Table B20.2 Publications on the use of vacuum therapy in the management of enterocutaneous fistulas

Year	Author/Journal	Evidence Level	Number of Patients/ Indication	Vacuum Therapy	Course
2003	Nienhuijs et al. ⁸ <i>J Wound Care</i>	4 (case series)	n = 10 enterocutaneous fistulae with postoperative complications	Vacuum therapy provided by a wound nurse according to a treatment protocol, dressing changes every two days	Median duration of vacuum therapy: 25 days, outpatient treatment possible, spontaneous healing of the fistula (n = 4), surgical treatment (n = 5)
2002	Cro et al. ³ <i>Postgrad Med J</i>	5 (case report)	n = 3 enterocutaneous fistulae with postoperative anastomotic failure (n = 2) or abscess formation (n = 1)	3 to 5 weeks of treatment improved the condition of the surrounding skin	Decrease in fistula output, complete wound healing between 3 weeks and 4 months
2000	Hyon et al. ⁷ <i>ASAIO J</i>	5 (case report)	n = 1 high-output enterocutaneous fistula	50 days of treatment, subatmospheric pressures between 350 and 450 mmHg	Immediate reduction in fistula output, initiation of enteral nutrition, complete healing of the wound defect
2000	Erdmann et al. ⁴ <i>Plast Reconstr Surg</i>	5 (case report)	n = 1 high-output enterocutaneous fistula in Crohn's disease	42 days of treatment, dressing changes every two days	Spontaneous wound closure after 8 weeks
2000	Alvarez et al. ¹ <i>Gynecol Oncol</i>	5 (case report)	n = 1 Spontaneous wound closure after 8 weeks	8 weeks of vacuum therapy, incl. 6 weeks of outpatient treatment, daily dressing changes	Complete closure of the fistula
2006	Goverman et al. ⁶ <i>J Trauma</i>	4 (case series)	n = 5 enterocutaneous fistula	Fistula-VAC was changed every three days	All patients had complete diversion of enteric contents allowing for successful skin grafting in all patients
2006	Fritze et al. ⁵ <i>Zentralbl Chir</i>	4 (case series)	n = 5 enterocutaneous fistula	suction: 125 mmHg	n = 3, isolation of the fistula outlet, n = 2 spontaneous closure of the fistula

that vacuum therapy reduced fistula output, enhanced patient comfort and eventually helped achieve complete closure of the abdominal wounds.

Discussion

Since the year 2000, the use of vacuum therapy in the management of enterocutaneous fistulas has been discussed in several case reports and case series. The authors reported good or even excellent results and no complications. Vacuum therapy proved particularly effective in enhancing patient comfort, reducing the length of inpatient hospitalization, and promoting healing without additional surgery^{5,6,9}. The conventional treatment of these wounds involves frequent dressing changes (depending on fistula output), which are uncomfortable for patients and restrict their mobility considerably. In addition, conventional treatment consists of parenteral nutrition and the administration of somatostatin analogues. This is associated with an increase in the length of

hospital stay and considerable costs. By contrast, Nienhuijs et al. emphasised that the use of vacuum therapy was associated with a shorter hospital stay and a lower level of nursing care than conventional treatment and thus with a 40% decrease in costs. The costs of renting vacuum therapy units were considered in this estimation.

It is not always possible to achieve complete healing of enterocutaneous fistulae using vacuum therapy. There is, however, general agreement in the literature that vacuum therapy effectively reduces fistula output and has never caused an increase in fistula size in the cases thus far described. In the authors' opinion, this therapy is not contraindicated in patients with enterocutaneous fistulas. In the early days of vacuum therapy, by contrast, some authors considered enterocutaneous fistulae to be a contraindication to the use of vacuum therapy. A review of the literature shows, however, that this opinion does not reflect the state of the art, not least because complications, undesired side effects or adverse effects on the clinical course have thus far not been reported.

The role of vacuum therapy in the treatment of enterocutaneous fistulae remains controversial. A review of the literature clearly showed, however, that vacuum therapy was successful in patients with high-output fistulae that failed to respond to conventional treatment. Vacuum therapy was found to enhance patient comfort, save costs when it is provided on an outpatient basis, and promote healing without further surgery.

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Part B / Chapter 21

Vacuum Therapy for Sternal Wound Infections after Cardiac Surgery – Experience and Review of the Literature

T. Fleck

(in collaboration with C. Willy)

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There are 48 *peer-reviewed* publications (EbM Level 4 and 5), with 770 patients treated for post-sternotomy mediastinitis with vacuum assisted closure therapy.

There is a consensus that vacuum therapy represents a promising and effective alternative for the treatment of this potentially life threatening surgical complication.

It is reported that use of vacuum therapy, by stabilising the thoracic cage secondary to reduction in sternal migration and sternal shear forces, improves postoperative pulmonary function, reducing the number of pulmonary complications, especially respiratory insufficiency, caused by thoracic instability. Mechanical ventilation and ICU care is not necessary in patients with an open sternum and vacuum therapy. In selected cases ambulatory care is possible. Usually the patients are fully ambulatory on the surgical ward.

Nearly all current studies are retrospective and compare vacuum therapy with a historical collective. However, there is consensus that vacuum therapy, by reducing the duration of treatment, failure of therapy and recurrence rate, results in shortened hospital stays and increased cost efficiency. Based on the above findings, there is compelling evidence that vacuum therapy is more effective than conventional therapies for the treatment of sternal wound infections.

Introduction

Since the introduction of median sternotomy by Julian in 1957, sternal wound infections have remained a significant and potentially life threatening complication after open heart surgery with a reported incidence between 1% and 5%. Despite improvements in antibiotic treatment and techniques of wound care, a 10-20% mortality rate as well as substantial morbidity have remained constant over this time.

The treatment of such infections has evolved over the past decades from closed mediastinal antibiotic irrigation described by Mandelbaum and Shumacker in 1963 to the primary use of pectoralis muscle flaps in 1980 by Jurkiewicz et al.

Today, depending on the severity of infection, established treatment protocols include aggressive surgical debridement, delayed closure and plastic reconstruction with rotational muscle flaps. However, despite these advances, there has been no reduction in the mortality rate and these complications are often associated with a prolonged hospitalisation and increased costs, particularly when the primary therapy has failed.

At the department of Cardiothoracic Surgery of the AKH Vienna, Austria, vacuum therapy has been used as first line therapy in all cases with sternal wound infection or wound dehiscence^{1,2}. Since November 2001, 95 patients were successfully treated with this therapy regimen. Following is a report of our experience and a review of the current literature.

Our Experience

Patient Population

Since November 2001, we used the vacuum therapy system in 95 patients (60 males, 35 females; mean age 65 ± 12 years) with sternal wound infection after cardiac surgery. The primary operation was CABG in 67 patients (71%), valve repair or replacement in 38 patients (40%) and combined procedures in 20 patients (21%). Mean duration between primary operation and the onset of infection was 12.5 ± 6.6 days (range 4-71 days).

Typical signs of infection were the following (Fig B21.1):

- serous or purulent drainage from the incision site with or without partial disruption of the incision
- sternal pain
- sternal instability (positive bimanual sternal compression test)
- elevated or increasing infection parameters (acute phase protein, leukocytes)
- fever, chills, lethargy
- erythematous skin surrounding the incision

Once other origins of infection had been excluded, the indication for revision and vacuum therapy application was established as soon as possible. Delay in diagnosis and immediate treatment increases the chance of involvement of the sternum, prohibiting secondary closure with preservation of the sternum.



Fig. B21.1 Patient after CABG (postoperative day 7) at the time of surgical debridement and vacuum foam implementation. On opening of the wound the ruptured sternal wires and necrotic tissue is seen.



Fig. B21.2 Debridement of the wound and the sternal edges. It is important to debride only clearly necrotic tissue in order to avoid large donor site defects.

At the time of diagnosis, 29 patients exhibited superficial infection (30.5%), while the remainder (66 patients, 69.5%) had deep infection with involvement of the sternum and extension into the mediastinum.

Bacterial culture results revealed *Staphylococcus epidermidis* in 33%, *Staphylococcus aureus* in 17%, coagulase-negative *Staphylococcus spp.* in 16%, *Enterococcus faecalis* in 14% and MRSA in 6%.

Technique of Vacuum Therapy Implantation and Dressing Change

Once sternal infection had been confirmed, all patients underwent surgical debridement under aseptic conditions in the operating theatre. After reopening of the wound and removal of sternal wires in cases of sternal instability, the mediastinum was carefully inspected and samples for bacteriological cultures as well as sternal bone biopsies were taken (Fig. B21.2). Thereafter, debridement with removal only of clearly visible necrotic tissue was performed. At the first dressing change, any remaining necrotic tissue is clearly demarked by the vacuum therapy.

After debridement, a section of vacuum foam was cut and fitted between the sternal edges to prevent shear forces between the bony edges and the underlying right ventricle⁴. In case of incomplete pericardial adaptation, a single layer of non-adherent open foam dressing or a small towel was applied. (Fig. B21.4). After placement of the adhesive drape in strips for better fitting, two *trac pad connectors* were installed proximal and

distal to the wound and connected with the Y-adapter to achieve a more uniform distribution of the vacuum and to increase thoracic cage stability. It is advisable to keep the adhesive drape as small as possible. This is more comfortable for the patient (less sweating) and there is less chance for leakage, for example, from the breast in female patients.

Continuous suction of 125 mmHg or of 75–100 mmHg in subcutaneous cases was started (Fig. B21.4). Patients were ordinarily transferred to the ward between two and four hours after surgery. Sedation and prolonged respiratory support was not necessary (Note: If the vacuum therapy system can not reach or maintain the desired vacuum, check the connecting pieces as they can easily break).

Therapy Duration

The vacuum therapy system was changed every 48–72 hours under aseptic conditions in the operating theatre. After removal of the old dressing the wound was inspected and new material for bacterial cultures and sensitivity tests was routinely obtained. Any detected necrotic tissue was removed.

The mean duration of vacuum therapy was 10.8 ± 8.2 days. A mean of 3.2 ± 3 dressing changes were necessary to VAC removal and definitive surgery (Fig. B21.5). A decline in serum inflammation parameters (CRP and leukocytes), negative bacteriological cultures and resolution of signs of local infection in the wound also were required.

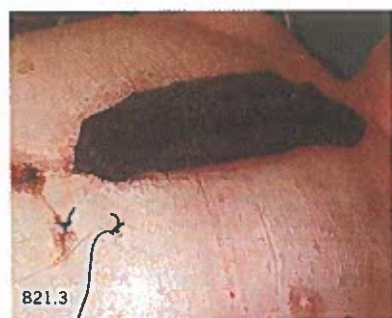


Fig. B21.3 We routinely use one large foam or two medium foams, depending on wound size. It is important to oversize the foam, since the patient's movements may result in migration of an inadequately large foam under the sternum and into the mediastinum, resulting in sternal instability and respiratory insufficiency. In this case, an immediate dressing change is mandatory.



Fig. B21.4 Vacuum foam in situ with two *trac pad connectors* for a more uniform vacuum distribution and enhanced sternal and thoracic stability.



Fig. B21.5 Same patient after three dressing changes (POD 13). There is granulation tissue formation over the whole wound. No necrotic tissue. This patient subsequently underwent re-wiring of the sternum and secondary closure.

Depending on whether the sternum was involved, a secondary closure with rewiring of the sternum was possible in 70 patients (74%), while, in three patients, we used a Ley prosthesis for sternal reinforcement. In the remainder, we used muscle flap reconstruction due to a multiply fractured or osteomyelitic sternum (25 patients, 26%).

The average hospital stay was 27.5 days (beginning with the primary cardiac surgical procedure). We found a statistically significant difference between patients undergoing a secondary closure (mean hospital stay: 23.8 ± 14.3 days) and those treated with muscle flap reconstruction (mean stay: 30.7 ± 9.3 days; univariate ANOVA, $p < 0.001$). In the multivariate logistic regression analysis we found a significant difference in terms of outcome with early recognition of infection and early vacuum foam application¹.

Therapy Concept

Primary closure after surgical debridement in cases of sternal infection is associated with a high recurrence rate. In a recent study, we compared our own treatment modalities and the outcome in the pre-vacuum therapy era with vacuum treatment and were able to show that preconditioning and open wound treatment after surgical debridement was clearly advantageous over debridement and immediate wound closure in terms of infection recurrence¹⁹.

A total of 132 patients with sternal wound infection treated between January 2001 and March 2003 were retrospectively evaluated. Whereas 97 patients were treated with conventional surgical debridement and primary closure, or with wound irrigation with antiseptic solutions in cases of superficial infections, 35 patients were treated with vacuum therapy device application after debridement. Both groups were comparable with regard to age and comorbidities.

Recurrence and therapy failure was observed in 36% of the patients treated with primary closure. In contrast, the vacuum therapy group had a 100% success rate. Furthermore, through preconditioning of the wound, we experienced fewer septic complications after secondary closure or muscle flap reconstruction, which resulted in a decreased ICU stay from four days to one day after muscle flap reconstruction^{4,5,10}.

Recent Literature

Between 1999 to 2006, there were a total of 48 *peer-reviewed* publications addressing the topic of vacuum therapy and sternal wound infection. Hence, vacuum therapy for the treatment of sternal wound infections is a well documented therapeutic modality. The majority of publications, however, are reviews ($n = 8$), case reports ($n = 12$) or case series ($n = 24$), together with two letters and two scientific investigations. Nevertheless, there is a consensus that vacuum therapy is an effective and safe alternative to conventional therapies^{7,8}. It has been reported that the use of vacuum therapy, by stabilising the thoracic cage, may increase postoperative pulmonary function, reducing the risk and occurrence of pulmonary complications, especially respiratory insufficiency caused by thoracic instability.

Another important factor is the stabilisation of the two parts of the sternum by the vacuum foam. This reduces the shear forces between the beating heart and the sternal edges and protects against the rare but fatal complication of right ventricular rupture. The firmness of the vacuum foam acts as a sternal stabilizer, thereby obviating the need for postoperative intubation and sedation of the patient. This, in turn, facilitates early postoperative mobilization and ambulation with the vacuum therapy system in place.

The results derived from this study are in accordance with five other studies with an EbM level of 4 (Oxford Centre), which will be discussed in detail below:

- Historical comparison (*Ann Thorac Surg*, 2000). Poststernotomy mediastinitis, vacuum therapy ($n = 9$) *versus* control (closed drainage, wound irrigation; $n = 11$). Results in the vacuum group: significant reduction of hospital stay and decrease of therapy failure¹.
- Historical comparison (*Eur J Cardiothorac Surg*, 2002). Poststernotomy mediastinitis with osteomyelitis of the sternum, vacuum therapy ($n = 20$) *versus* control (irrigation with Ringer's lactate; $n = 22$). Results in the vacuum group: Significant decrease of therapy duration and hospital stay².
- Historical comparison (*J Thorac Cardiovasc Surg*, 2003). Sternal wound infection, vacuum therapy *versus* control (rewiring and closed drainage). Results in the vacuum therapy group: higher survival rate, less therapy failures, reduced costs³.

- Historical comparison (*Ann Plast Surg*; 2003). Sternal wound infection; vacuum therapy (n = 17) *versus* control (dressing changes twice a day, topical antibiotics; n = 18). Results in the vacuum therapy group: significantly reduced need of further plastic reconstruction, fewer dressing changes, shorter therapy duration¹⁸.
- Historical comparison (*Ann Thorac Surg*; 2005): deep sternal wound infection; vacuum therapy (n = 35) *versus* control (irrigation with Ringer's lactate, n = 33). Results in the vacuum group: shorter time to negative bacterial culture results, faster decrease in CRP levels, shorter hospital stay, ability of all patients to undergo secondary closure and rewiring of the sternum, trend towards higher survival rate⁶. For further results of studies dealing with this topic, see Part B, Chapter 22 "Vacuum Therapy of Deep Sternal Wound Infection Following Cardiac Surgery".
- The uniform negative pressure applied to the wound results in arteriolar dilatation, thus increasing microcirculation and optimising the wound environment. These positive effects on the wound promote granulation, tissue proliferation and accelerated wound healing, which in turn facilitates definitive surgical repair, such as primary closure or plastic reconstructive surgery with muscle flaps.
- Continuous suction decreases excess fluid and edema and reduces bacterial colonization
- Wound management is facilitated by a reduction in dressing changes.

Before application of a vacuum therapy system, aggressive surgical debridement to remove all necrotic tissue is a mandatory precursor for achieving acceptable results. Necrotic tissue delays wound healing and increases the likelihood of bacterial colonization in the wound.

The time interval between the onset of symptoms and initiation of treatment with surgical intervention and vacuum therapy implementation predicts outcome, as a delay in secondary surgery allows the infection to spread into the sternum, jeopardizing secondary closure and preservation of the sternal bone.

Discussion

The use of vacuum assisted closure in the treatment of postoperative sternal wound infections has gained acceptance in a short period of time and represents the standard of care in many cardiac surgery centers^{2,7,8,10}. The vacuum therapy system may offer several advantages when compared with the traditional treatment modalities:

- Stabilisation of the two parts of the sternum by the vacuum foam. This reduces shear forces between the beating heart and the sternal edges and acts to prevent the rare but fatal complication of right ventricular rupture. The firmness of the vacuum foam acts as a sternal stabilizer thereby avoiding postoperative intubation and sedation and by facilitating early postoperative mobilisation and ambulation with the vacuum therapy system in place.

VAC therapy represents a promising new modality for deep sternal wound infections. Currently, all available studies are retrospective (historical comparison with a conventional treatment method). The results show that vacuum therapy is equally or more effective than established therapy methods. Vacuum therapy offers several advantages when compared to other therapies. The majority of studies used a continuous suction strength of 125 mmHg, which has emerged as the accepted vacuum therapy-setting in this indication.

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Part B / Chapter 22

Vacuum Therapy of Deep Sternal Wound Infection Following Cardiac Surgery

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After presenting an overview of available studies dealing with the vacuum treatment of sternal infection following cardiac surgery in Part B, Chapter 21 ("Vacuum Therapy for Sternal Wound Infections after Cardiac Surgery – Experience and Review of the Literature"), further details will be discussed in this chapter.

The technique of vacuum therapy application in patients suffering from deep sternal wound infections, together with the possible complications, safety procedures to prevent them and the kinds of the mechanical forces exerted by the vacuum therapy are explained.

Introduction

Surgical treatment of heart disease has increased during the past decades and cardiac surgeries involving midline sternotomy are among the most commonly performed major operations in the Western world. Together with postcardiotomy heart failure and stroke, postoperative deep sternal wound infection (DSWI) or mediastinitis is regarded as one of the three most serious complications after open-heart surgery. With the large number of cardiac surgery interventions performed and the evolution of resistant pathogens, even relatively infrequent complications such as poststernotomy mediastinitis can become a problem for both patients and the medical profession. Deep wound infection following open-heart surgery is associated with increased morbidity and cost of care^{1,2}. Furthermore, despite control of sepsis and acute wound management the effects of DSWI on cardiac, pulmonary and renal function are probably significant. Despite modern conventional management of DSWI, it has been demonstrated that these patients show a significant increase in late mortality, independent of other factors that affect mortality in this population^{3,4}.

The reported incidence of mediastinitis in the literature varies from 0.16% to 4%⁵ with some reports as high as 8%⁶. In large or high impact studies the mortality rates differ considerably: this may be related to the multifactorial aetiology with both endogenous and exogenous pathways. A faulty sternotomy can be the cause of instability and wound dehiscence with consequent infection, especially when the closing wires break the thin side of the sternum⁷. Gram-positive bacteria are organisms most commonly isolated in mediastinitis. According to international reports, *coagulase-negative staphylococci* (CoNS) have emerged as frequently recognised, often multi-resistant pathogens in deep-seated, potentially life-threatening surgical wound infections⁸.

As CoNS belong to the normal flora of the skin, they are always present and ready to cause infection in susceptible patients. The most important virulence factors for CoNS are hydrophobic adhesion to surfaces, production of slime and genetically mediated antibiotic resistance⁹. These properties, together with the typically slow onset and less severe macroscopic picture, make clinical diagnosis difficult. Consequently, it is important to define the criteria for deep sternotomy infections. Early and accurate diagnosis of deep infection (Fig. B22.1) and identification of the responsible pathogens are crucial in

choosing the appropriate treatment to achieve successful results.

Risk Factors

The overall hospital mortality due to DSWI is usually reported to be in the range of 10-20%¹⁰. The most important risk factors identified in major studies are diabetes, obesity, chronic pulmonary obstructive pulmonary disease (COPD), together with duration of surgery, need for long-term dialysis and the use of internal mammary artery grafts^{1,11-13}. Patients with more than one risk factor show an even higher incidence of DSWI, indicating that a combination of risk factors potentiates the risk of developing postoperative deep wound infection. The highest incidence of DSWI is reported following the use of bilateral internal mammary artery grafts in the diabetic population, reaching up to 12%¹⁴. Hospital mortality is extremely high in the subgroup of patients requiring more than one operation to treat the infection¹⁵. This is probably related to the difficulty in controlling the infection in the mediastinum. Different treatment options have been developed over the years in cardiac and plastic surgery to overcome this ominous complication.

Types of Wound Infection

Median sternotomy wounds can be affected by superficial infection. This kind of infection respects the fascia and does not penetrate down to the steel wires or underlying bone and cartilage. A deep sternotomy infection fulfils the criteria for a complex wound infection, which requires prompt exploration of the wound. The most commonly used definition originates from U.S. Centers for Disease Control and Prevention (CDC)¹⁶. Infection involves the fascia or deeper structures with at least one of the following: Evidence of infection seen at reoperation or spontaneous dehiscence, positive culture of mediastinal fluid and/or positive blood culture and/or chest pain with sternal instability and temperature higher than 38°C.

Sterile dehiscence or a superficial wound infection can proceed to a deep wound infection, but should, when properly diagnosed, be treated without recourse to complex wound therapies.

Classification

Different presentations of deep sternotomy infections



Fig. B22.1 Deep poststernotomy infection.



Fig. B22.2 Polyurethane foam layers in the sternotomy wound.

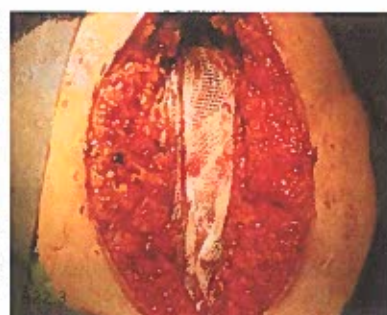


Fig. B22.3 Non-adherent layers under the sternal edges.



Fig. B22.4 Sternal wound ready for vacuum therapy.



Fig. B22.5 Trac-pad connector application.



Fig. B22.6 Non-granulating area ready for revision.

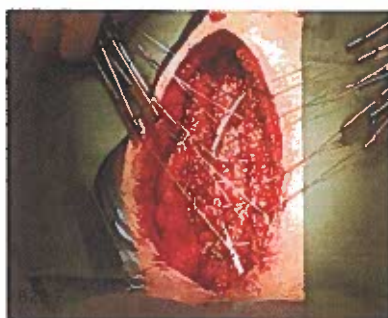


Fig. B22.7 Rewiring of sternotomy after vacuum therapy.

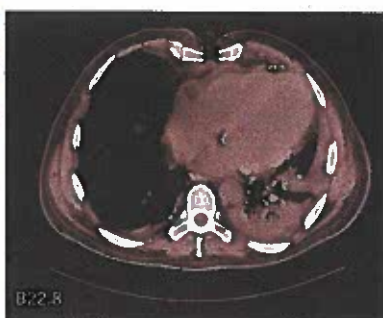


Fig. B22.8 CT-scan during vacuum therapy.



Fig. B22.9 Sternal elastic support.

exist and can be classified into five subtypes. The Oakley classification is based on the time of first presentation, the presence or absence of risk factors, and whether previous attempts to treat the condition have failed. Morbidity and mortality rates increase with higher type in conventional series¹⁷.

Classification of Deep Sternal Wound Infection¹⁶:

Type I: Mediastinitis presenting within two weeks after operation in the absence of risk factors.

Type II: Mediastinitis presenting two to six weeks after operation in the absence of risk factors.

Type IIIA: Mediastinitis type I in the presence of one or more risk factors.

Type IIIB: Mediastinitis type II in the presence of one or more risk factors.

Type IVA: Mediastinitis type I, II, or III after one failed therapeutic attempt.

Type IVB: Mediastinitis type I, II, or III after more than one failed therapeutic attempt.

Type V: Mediastinitis presenting for the first time more than six weeks after operation.

Treatment of Deep Sternal Wound Infection

Shumacker and Mandelbaum were the first to describe the technique of wound debridement, primary sternal closure, and closed mediastinal catheter irrigation in

1963. Since then, several surgical techniques have been proposed, but morbidity and mortality rates have still remained high. Debridement followed by open-chest drainage with saline gauze requires prolonged mechanical ventilation and is associated with a high rate of mortality¹⁹. Closed chest irrigation systems²⁰ with topical antibiotics show a high degree of recurrent infection²¹. Sternal revision, or even radical sternectomy, and bilateral pectoral muscle flaps have been performed with low mortality rates²²⁻²³ and are advocated as the best option for type III mediastinitis, but are known to cause a high degree of chest instability and discomfort²⁴. One option in such cases may be the Ley prosthesis, a 0.5 mm thick titanium alloy plate for stabilising the sternum. It is reported to reduce the need for further surgical procedures²⁵. Furthermore, pedicled omentum transposition²⁶ and reversed rectus abdominis muscle flaps²⁷ are options that can be used in some cases, but are associated with abdominal problems such as ileus or necrosis of the flaps. Because of the extent of the operation, major plastic surgery procedures are associated with a high risk in the acute cardiac patient with mediastinitis. Therefore, new, less invasive alternatives for treating mediastinitis would be desirable, especially if the method results in efficient control of infection and preserves the sternum. The complete restoration of the thoracic cage without instability or upper limb weakness would then be possible. At our institution conversion to vacuum assisted closure (vacuum therapy) for DSWI was made in 1999 and the first 16 patients were carefully monitored and studied retrospectively. Single line vacuum therapy became standard of care and all patients with DSWI are prospectively studied²⁸⁻²⁹.

Application of Vacuum Therapy in the Sternotomy Wound

As soon as DSWI is diagnosed, the patient is taken to the operating room for controlled wound exploration under general anaesthesia with intubation and mechanical ventilation. Classification of mediastinitis is based on the criteria proposed by Oakley. Foreign material, such as steel wires and sutures, is debrided. Five tissue cultures are obtained from different substernal sites of the wound. Debridement of clearly necrotic and infected soft tissue is performed at once, but no deep revision is made around the heart. The sternal and subcutaneous tissues are debrided with a sharp curette and tissue cul-

tures are obtained. Special attention is directed to the left hemisternum and underlying right ventricle by checking for adhesences and sharp edges. Before application of the polyurethane foam the wound is irrigated with saline and checked for hemostasis. The application of the foam layers in the sternotomy wound (Fig. B22.2) can be described as a kind of sandwich. Four layers of Jelonet® paraffin gauze dressing are placed at the bottom of the wound covering and isolating visible parts of the right ventricle, lung tissue and grafts from the sternal edges (Fig. B22.3). A piece of sterile polyurethane foam, with an open pore structure of 400 to 600 µm is trimmed into a single rectangle to fit between the sternal edges. It is cut as a strip, approximately 3 cm wide to allow volume reduction when the vacuum is applied. This layer is used to seal the gap between the sternal bone edges and should not be placed below the level of the sternum.

The second layer of polyurethane foam is placed subcutaneously, covering the wound completely. In the relaxed state the foam should protrude a couple of centimeters over the surface of the skin to allow volume reduction during vacuum therapy. This layer can then be secured subcutaneously with a running suture to the surrounding skin edge in order to facilitate draping and minimize the risk of the foam moving. A skin barrier protector (e.g. Cavilon®) is applied and the open wound is sealed with a transparent adhesive drape (Fig. B22.4). The *trac-pad connector* is applied in the center of the foam (Fig. B22.5) and connected to the dedicated vacuum source. This unit delivers continuous or intermittent negative pressures of -50 to -200 mmHg. Initially, -50 mmHg is applied to allow adjustment of the foam as the air is evacuated. If the wound geometry and foam contraction are considered satisfactory the pump unit is programmed to deliver a continuous negative pressure of -125 mmHg. At this pressure level the foam is firm and works as a splint in the sternotomy. The canister in the pump unit collects exudates from the wound.

The polyurethane foam and Jelonet® layers are changed at least three times a week or more often when necessary depending on the serial C-reactive protein (CRP) levels and tissue culture results. During vacuum therapy, bone and soft tissue necrosis is demarcated by lack of granulation and complementary revisions are made only in these areas during foam changes.

Most patients can be extubated immediately after application of vacuum therapy and leave the intensive care unit after two to three hours. Routine chest radiography

is performed to reveal any residual pleural effusion. The patients are able to ambulate on the ward and receive physiotherapy between foam changes.

The wound is considered to be free from infection when the CRP level, without confounding factors, such as the presence of tissue injury or infection elsewhere, declines to 30-70 mg/l. In such cases, culture biopsies are taken from the sternum and these results guide closure. Furthermore, visual inspection should demonstrate a well-vascularized wound bed covered with granulation tissue. Finally, the sternotomy is rewired with interrupted steel wires. By using partially reinforced wires to secure fractures³⁰, rewiring is performed with special care not to compromise sternal blood flow. The pre-sternal fascia is carefully mobilised to cover the wires and sutured with interrupted reabsorbable sutures. The skin is closed with non-absorbable interrupted sutures.

A 20 F chest tube is placed behind the sternum and a negative pressure of 20 cm H₂O is applied. In addition, two 10 F tubes for passive drainage are located subcutaneously to avoid seroma. These tubes are kept in place until the drained volume falls below 20 ml in 24 hours. The systemic CRP level will rise after delayed primary closure and usually reaches a peak within 72 hours before declining to preclosure levels. The elevation corresponds to the surgical trauma and is not a sign of reinfection. It is important to confirm the decline to preclosure levels, as this indicates successful wound healing and the patient can be discharged.

Granulation Tissue

During negative pressure therapy of the sternotomy wound, bone and soft tissue necrosis are demarcated by a lack of granulation tissue on the sternal edges. This is probably due to insufficient nutritional flow from below; hence, these areas have no potential for healing. Non-viable tissue is frequently found on the sternal edges, on the periostium, on the anterior surface of the sternum and on cartilage (Fig. B22.6). During foam changes these areas can be easily debrided in the operating room under general anaesthesia with a muscle relaxant. In this way, the viable parts of the sternum can be saved and these will increase in vascularity during further negative pressure therapy. Subsequent surgical debridement can be performed in the subcutaneous area during foam changes. The strategy of stepwise, repeated revisions is probably one of the most important factors during vac-

uum therapy for improving both late outcome and the rate of successful delayed primary closure. Appropriate and meticulous debridement in the operating room is also advisable as it is still the cornerstone of this surgical procedure and may reduce the risk of late fistulae and healing problems. During foam change the sternal edges are kept free from underlying tissue with three or four non-adherent layers (Jelonet®) for mechanical protection of the right ventricle and to facilitate later re-approximation of the sternum (Fig. B22.7).

Vacuum Therapy and Peristernal Soft Tissue

The physiological, cellular and molecular mechanisms behind the accelerated growth of granulation tissue under negative pressure are to a large extent unknown. The main effects of vacuum therapy in the peristernal soft tissue are enhanced blood flow and granulation. The microvascular blood response at the wound edge during vacuum therapy can be measured by using a standardized laser-Doppler measurement³¹. The laser-Doppler blood flow was found to be a function of tissue density, applied negative pressure and distance from wound edge. The amount of granulation created, however, is more complex and thought to be related to the specific type of foam used in combination with the vacuum therapy pressure, thereby creating microdeformations and stretching of cells resulting in increased proliferation³².

Antibiotics

When DSWI is diagnosed antibiotic therapy commences with vancomycin intravenously in all patients. If there is a suspicion of gram-negative infection Imipenem is added until the tissue cultures arrive. These are often dominated by coagulase-negative *staphylococci*. The regimen is then changed according to sensitivity of the strains. The intravenous therapy continued for at least seven days after sternal closure or until CRP declines to preclosure levels. Thereafter, an oral regimen continues for four weeks as a combined therapy, depending on the sensitivity of the strains. By obtaining at least five tissue cultures from different substernal sites in the wound, the whole spectrum of bacteria requiring treatment will be revealed. If no bacteria are cultured in any of the sternal tissue cultures, it is most likely a sterile dehiscence. However, several technical aspects have to be considered before employing topical negative pressure to an open sternotomy wound.

Vacuum Therapy and Thoracic Interactions

An important issue is the interaction of the foam with the sternal edges and underlying vital structures. Conventionally treated mediastinitis, because of the risk of right ventricular laceration when the sternum is left open for debridement and packing, is associated with high mortality rates^{33,35}. The potential aetiology of this complication still needs to be addressed when applying vacuum therapy; therefore, special attention should be directed to the left and right hemisternum and their relationship to the right ventricle. Adhesions below the sternal edges are released and four layers of paraffin gauze dressing are used as a buffer, separating underlying structures from the sternal edge. The gauze reduces the formation of adhesions between the sternum and the right heart and the paraffin content facilitates movement. This manoeuvre enables the force of the vacuum to work in the horizontal plane, thereby acting on the sternotomy, rather than vertically on underlying vital structures. This "sandwich" technique is used in all patients with DSWI. The foam is tailored to fit into the sternotomy wound in such a way that the substance defect is completely filled out when negative pressure is applied (Fig. B22.8). To increase safety and comfort for the patient an elastic sternum support is applied, which stabilises the chest and releases the tension from the tissue around the contracted foam (Fig. B22.9). This is particularly important in patients with postoperative coughing, obesity and chronic obstructive pulmonary disease. Currently, there are few publications in the literature reporting the effects of vacuum therapy on pulmonary physiology or lung function, although one case report has indicated improved ventilation and more effective physiotherapy with vacuum therapy³⁶. This was assumed to be the effect of stabilisation and closure of the thoracic cage, compared to the open chest during conventional wound care. Improved lung function has also recently been described in extubated patients undergoing long-term vacuum therapy for large sternal defects³⁷. These studies indicate the clinical benefit of chest stabilisation during vacuum therapy. The main developments in recent years of vacuum therapy in DSWI are the introduction of the non-adherent layers between foam, heart and sternal edges, no substernal foam placement, selective debridement of the non-granulating areas and an elastic thoracic support as soon as the negative pressure is applied.

Comments

Poststernotomy mediastinitis following cardiac surgery is a rare, but devastating and potentially life-threatening, complication. This complication is linked to significant mortality rates following cardiac surgery. Conventional treatment usually involves surgical revision with open dressings employing the closed irrigation or reconstruction with vascularized soft tissue flaps employing the omentum or pectoral muscle. These wound healing techniques may be used as a single-line therapy or as part of a combination of procedures, but there is a considerable lack of consensus regarding the optimal surgical management³⁸. Conventional treatment has disadvantages such as unstable thoracic cage, upper limb weakness, prolonged immobilisation or substantial surgical trauma that might be deleterious in a compromised patient, as reported by Krabatsch³⁹, already in 1995. The rationale for employing an open-pore polyurethane foam in the infected sternotomy wound, sealing it with adhesive drape and applying a negative pressure, is multifactorial. The application of an airtight drape provides a closed and controlled wound, while the active drainage is constant and uniform over the entire wound surface. Furthermore, as the vacuum source evacuates the air from the polyurethane foam it will act as a splint, supporting the sternal edges and providing sufficient stability of the chest to allow ambulation. The entire wound can be sequentially debrided and vascularised, allowing later delayed sternal closure.

Vacuum therapy is a promising and safe treatment option with unique clinical features combining effective drainage and stabilisation of the sternum, together with increased vascularisation, particularly of the soft tissue parts of the sternotomy wound. In order to increase patients' safety and comfort, a non-adherent gauze that reduces the formation of adhesions within the sternum should be used. This manoeuvre enables the force of the vacuum to work in the horizontal plane, thereby acting on the sternotomy, rather than vertically on underlying vital structures. Additionally, an elastic sternum support is applied, which stabilises the chest and releases the tension from the tissue around the contracted foam. Currently, there are few publications in the literature reporting the effects of vacuum therapy on pulmonary physiology or function. They describe improved ventilation and more effective physiotherapy with vacuum therapy as well as improved pulmonary function in extubated patients. All these factors contribute to a high rate of successful delayed closure with total restoration of the anterior thoracic wall.

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Part B / Chapter 23

Diabetic Foot Syndrome

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A review of the literature yielded a total of 24 *peer-reviewed* articles on the use of vacuum therapy for treating diabetic foot ulcers (1999-2006; total of n = 352 patients). These publications provide level 1b to level 5 evidence as defined by the Oxford Centre for Evidence-based Medicine. Three randomized controlled trials (RCTs), albeit with small sample sizes, are among these articles and confirm the results of other studies in which vacuum therapy is shown to be superior to available alternative methods. For example, vacuum therapy has the advantage that the soft foam dressing covers the entire foot ulcer despite the usually uneven surface of the wound and the possible presence of deep pockets. In addition, wound secretion is continuously drained from the wound. Last but not least, the foam dressings cover and close diabetic wounds safely and hygienically and need to be changed only two or three times a week. Vacuum therapy thus makes it possible to provide treatment for ambulatory patients on an outpatient basis. For this reason, it should have a firm place in the treatment algorithm for diabetic foot ulcers.

Introduction

Diabetic foot syndrome (DFS) is characterised by a variety of clinical manifestations ranging from simple superficial ulcers to phlegmonas involving the entire forefoot or lower leg. The Harkless and Wagner classification systems have been used here to describe foot lesions and ulcers^{32,38}. The various grades are defined at the end of this chapter.

Prevalence and Incidence of Diabetic Foot Ulcers

The literature reports prevalence rates of diabetic foot ulcers of about 2-7% and incidence rates of approximately 1.5-8%^{6,20,30,33,42,46,49,58,60}. Of all diabetic patients, approximately 15% develop foot ulcers and about 3%, a diabetic foot. It is estimated that the management of foot problems accounts for 25% of the total costs of diabetes. Diabetics have a risk of amputation that is approximately eight to fifteen times higher than that of non-diabetics. In Sweden, diabetics, who constitute a mere 2.4% of the Swedish population, account for 48% of all leg and foot amputations^{40,41,47,57}. It is assumed that the number of patients with DFS is at least 200,000 in Germany and approximately 40 million⁴ worldwide. The majority of lower leg amputations in Germany are due to diabetic foot problems. Approximately 70% of all am-

putations, corresponding to about 25,000 to 30,000 amputations annually, are performed on only about 5% of the total population. Approximately 15,000 patients require amputation above the ankle¹⁵. Recent studies have confirmed previous findings that the three-year survival rate after major amputation is only 40-50%¹⁹. This rate is considerably lower than that reported for minor amputations and other minor surgical procedures involving the foot. Fully 20% of all hospitalisation days for diabetic patients are due to foot problems, which are the most common cause of hospital admission in diabetic patients in the United States. The costs of treating a 40- to 65-year-old diabetic patient with a new foot ulcer over two years is estimated to be almost USD 28,000 in the United States. The annual costs of neuropathic foot ulcers are approximately USD 10.7 billion, accounting for about 9% of total U.S. healthcare expenditures⁴.

Underlying Causes of Diabetic Foot Ulcers

Contrary to earlier belief, diabetic foot lesions are not caused by microangiopathy¹⁷. Instead, the most common underlying aetiologies are peripheral neuropathy³ or macroangiopathy (peripheral arterial occlusive disease or PAOD), which predominantly affects the lower limb in patients with diabetes mellitus (Fig. B23.1-3)¹¹.



Fig. B23.1 Inflammation of the joints secondary to abnormal patterns of weight-bearing, and to micro- and macrofractures with osteonecrosis and bone marrow edema are the pathomorphological correlates of acute non-septic osteoarthropathy, or Charcot's foot. Among the factors that appear to play a role in the development of Charcot's foot are osseous changes caused by neuropathy and the extent of abnormal weight-bearing (overweight), surgery of the forefoot and midfoot (abnormal axis, immobilisation, etc.), or ill-fitting footwear. Charcot's foot can develop within a few days or weeks and is characterised by visible deformities, increased skin temperature and sometimes redness, and edematous swelling.



Fig. B23.1 Diabetic perforating ulcer (*mal perforans*). When infection extends to deeper tissues (phlegmona, osteomyelitis), diabetic gangrene can develop as a result of microcirculatory dysfunction (capillary and arteriolar thrombosis). Differentiation from Fontaine stage IV PAOD requires not only a clinical but also an angiographic diagnosis. Unfortunately, a false diagnosis can lead to major amputation in many cases.

Fig. B23.2 Diabetic gangrene due to neuropathy. Damage to sensory nerves leads to complete or partial loss of sensations of pain, vibration and tactile discrimination. Patients may thus lack complete information about serious changes in their feet and, as a result of this ignorance, tend to neglect the condition of their feet. It is not unusual for patients with severe inflammation to seek medical attention only after a close family member or friend has noticed the presence of a foul odour.

Fig. B23.3 Burn wound caused by direct exposure of the feet to a heater.

Treatment

Basic Principles

The mainstays of diabetic foot ulcer treatment are:

- wound care (debridement) and relief of pressure
- treatment of infection
- restoration of perfusion
- metabolic control
- treatment of comorbidity
- patient education and instruction on foot hygiene

The emphasis of treatment is on eliminating the underlying pathomechanisms. The relief of pressure is the key to healing neuropathic ulcers. Patients with infection may require bed rest in order to prevent further spread. Antibiotic treatment should be instituted in the presence of infection. Typically, a mixture of pathogenic organisms is identified. Wheat et al. found that *Staphylococcus*

aureus is the most common causative organism in diabetic foot ulcers, followed by *Escherichia coli* and *Pseudomonas aeruginosa*. Oral clindamycin plus ciprofloxacin, which have good bioavailability, are the antibiotics of choice in patients with mild to moderate infections. Severe wound infections and PAOD should be initially treated intravenously. The literature recommends selection of the most appropriate antibiotic(s) on the basis of the results of antibiotic sensitivity testing. Poor arterial supply prevents wound healing and the elimination of infection¹⁴. For this reason, it is essential to rule out insufficient circulation or treat it by interventional radiology or vascular surgery¹⁶. Wound healing will not take place in the presence of infection. Thorough debridement of infected tissue is required until the wound shows healthy granulation. Sharp debridement (with a scalpel or scissors) is indicated for the removal of infected material. This procedure is usually painless in neuropathic patients. If not, local or regional anaesthesia should be used. The remo-

val of necrotic tissue can be performed by a non-surgeon. However, a surgeon should be consulted in cases where bones, tendons and nerves must be debrided (deep debridement).

Treatment Options

Today, a wide variety of local treatment options are available^{6-8,19}. The choice of treatment is mainly determined by empirical evidence and depends on the condition of the ulcer. Different procedures are used at different phases of wound healing (including the inflammatory phase with the removal of necrotic and foreign material; the granulation phase with fibroblast collagen formation; and the epithelialisation phase). Apart from these standard methods, a number of supportive treatments have been proposed. Healing of diabetic wound ulcers is slow: this is due to many factors, not the least of which include a lack of local growth factors, changes in the extracellular matrix, reduced fibroblast activity, a decrease in the antimicrobial activity of the leukocytes, and impaired micro- and macrocirculation. These pathophysiological aspects have become a focus of research in recent years and a number of studies have investigated the topical application of growth factors such as granulocyte colony-stimulating factor (G-CSF) and recombinant human platelet-derived growth factor (becaplermin)^{12,24,36,48,56,59}. Although the adjunctive use of growth factors has been shown to be advantageous in several publications, there still is no definitive proof of an actual benefit for the patient. Other studies have focused on the use of bioengineered tissue (Dermagraft®) and hyperbaric oxygen therapy (HBO)^{1,2,37,38}.

Interdisciplinary Cooperation

It is not surprising that the quality of DFS treatment is particularly high when the approach to care is interdisciplinary, involving diabetologists, angiologists, radiologists, and (plastic) surgeons²⁹. As early as 1986, Edmonds et al. showed that a specialised foot clinic for diabetic patients that brought together the skills of chiropodists, shoe-fitters, nurses, physicians and surgeons was able to increase the rate of ulcer healing and decrease the number of amputations^{32,44}. Similar results have been reported by a group of German diabetologists since autumn 1999. This group established a new decentralised treatment system in a collaborative effort to pool the locally available diagnostic and therapeutic skills that are needed in the management of diabetic patients.

According to information provided by the German Diabetes Society in 2001, there are approximately 85 diabetic foot clinics in Germany that provide outpatient care. It is clear that interdisciplinary cooperation in conjunction with specialist medical care can play a key role in assisting at-risk patients. Interdisciplinary exchange should be possible in both the outpatient and the inpatient setting. A particularly promising approach is close cooperation and communication between specialist nursing services and diabetic foot departments or specialist practices²⁹.

Vacuum therapy is usually the same in both inpatient and outpatient settings. Owing to the high safety levels of vacuum therapy, it is possible to provide this form of treatment on an outpatient basis. Vacuum therapy should definitely be included in the treatment algorithm for diabetic foot wounds.

The Role of Vacuum Therapy

Literature Review

Reports in the literature have documented the successful use of vacuum therapy in a vast majority of cases for reducing the size of a wound until closure occurs or the wound is either converted into a superficial lesion or can be closed by means of plastic surgery (using split-thickness skin grafts, secondary sutures, or myocutaneous flaps). It should be noted, however, that only a small number of these studies and reports have been published in *peer-reviewed* journals. From 1990 to 31 May 2006, a mere 24 articles explicitly addressed the use of vacuum therapy for diabetic foot wounds (total of 352 patients). They include six case reports, eight reviews, one guideline article, six case series and three RCTs (though with small sample sizes and a follow-up rate of sometimes less than 80%)^{23,43}. Additionally there exists one Cochrane review^{27,28}. It is important to note, however, that the efficacy of vacuum therapy, especially in the management of diabetic foot wounds, has been emphasized in many non-*peer-reviewed* and less well-known journals and at an untold number of scientific congresses. Although only a few articles in the literature compare the effects of different treatments, an attentive reader can find a wealth of information and obtain a more detailed picture of the use of vacuum therapy for DFS. Differences in patient populations make it difficult to compare the available studies. Hardly any study provides a clear-cut

classification of ulcer severity. In addition, the sample size is usually extremely small. There is, for example, one RCT that studied as few as ten patients. In the most recent RCT of DFS (Armstrong, 2005)⁹, which incidentally included the highest number of patients, researchers enrolled 162 patients into a 16-week, 18-centre, randomized clinical trial in the USA investigating whether vacuum therapy improves the proportion and rate of wound healing after partial foot amputation in patients with diabetes. Inclusion criteria consisted of partial foot amputation wounds up to the transmetatarsal level and evidence of adequate perfusion. Patients who were randomly assigned to vacuum therapy ($n = 77$; no exact data about foam material and pressure values in the full paper) received treatment with dressing changes every 48 hours. Control patients ($n = 85$) received standard moist wound care according to consensus guidelines. Wounds were treated until healing or completion of the 112-day period of active treatment. The analysis showed that more patients healed in the vacuum therapy group than in the control group (43 [56%] *versus* 33 [39%], $p = 0.040$). The rate of wound healing, based on the time to complete closure, was faster in the vacuum therapy group than in controls ($p = 0.005$). The rate of granulation tissue formation, based on the time to 76-100% formation in the wound bed, was faster in the vacuum therapy group than in controls ($p = 0.002$). The frequency and severity of adverse events (of which the most common was wound infection) were similar in both treatment groups. Altogether, the results of all the studies show uniformly that vacuum therapy has the potential to reduce effectively the size of even severe foot ulcers within a few weeks.

Advantages of Vacuum Therapy

Diabetic foot wounds usually have an uneven surface and are associated with marked formation of new tissue. An advantage of vacuum therapy is that the soft foam adapts perfectly to the wound bed and negative pressure can be applied uniformly to all points of a wound irrespective of the latter's contours and the formation of pockets^{5,18,26-28,43}. This prevents fluid accumulation and accelerates the reduction in wound volume. It goes without saying that radical debridement must always precede the implementation of vacuum therapy. Some research groups reported wound closure in up to 90% of cases, with inadequate debridement being the cause of non-healing

wounds in most of the remaining cases. In addition, vacuum therapy offers a high level of patient comfort. Negative pressure is applied through a closed system that covers wounds safely and hygienically. Dressings need to be changed only two or three times a week. Vacuum therapy thus offers considerable advantages, especially for ambulatory patients^{34,55,61}. A large number of patients can receive treatment on an outpatient basis. From a clinician's point of view, these advantages make vacuum therapy unique compared to alternative forms of treatment. Although a wide variety of treatment options are already available, vacuum therapy is a valuable contribution to the therapeutic spectrum of diabetic foot wounds^{13,14,25,44,45}. Due to the small sample size and methodological limitations, however, the evidence of the reported results is limited. Nevertheless, all available studies have shown beneficial effects of vacuum therapy and no contradictory evidence has thus far been provided^{13,14,25}.

Vacuum Therapy for the Treatment of Diabetic Foot Syndrome

It should always be borne in mind that radical surgical debridement must precede the institution of vacuum therapy for managing diabetic foot wounds (or any other wound). In addition, the responsible clinician should re-evaluate his or her treatment approach when there are no evident signs of improvement in the wound over a period of two or three weeks after the beginning of vacuum therapy.

Following Soft-Tissue and Bone Debridement

Vacuum therapy involves the removal of debris, excess fluid and bacteria from the wound environment. After "preliminary" wound cleansing, vacuum therapy provides a "final" cleansing and prepares the wound for closure. Once healthy granulation tissue has formed, the wound can be closed by secondary suture or skin grafting. A fusion operation should be performed when bones (of the hind- or midfoot) are involved. Negative pressure not only drains fluid from the wound but also reduces tissue edema by applying suction pressure to soft tissues. Vacuum therapy can significantly reduce the level of nursing care especially in the case of heavily exuding soft-tissue defects since the foam dressings must only be changed after four to seven days.

Following Amputation

In the presence of infected tissue, amputation wounds



Fig. B23.5 Soft-tissue and bone wound after partial amputation of the forefoot in a 62-year-old female patient with phlegmona of the forefoot.



Fig. B23.6 Vacuum therapy accelerates the removal of infection and promotes granulation tissue growth.



Fig. B23.7 Osteomyelitic changes of the mid-foot in a 55-year-old male diabetic patient.



Fig. B23.8 Vacuum therapy was instituted after bone debridement with removal of the distal tarsal row. After eight days, the acute infection was under control.



Fig. B23.9 Amputation in a 59-year-old male diabetic patient with phlegmona of the forefoot.



Fig. B23.10 Use of a vacuum therapy system until successful elimination of infection.



Fig. B23.11 After wound bed preparation and before definitive closure.



Fig. B23.12 A 48-year-old female diabetic patient with a heel ulcer after minor trauma.



Fig. B23.13 Use of vacuum therapy over a period of 16 days for wound size reduction.



Fig. B23.14 Granulation and epithelialisation of the ulcer site after vacuum therapy.

are not primarily closed due to bacterial colonisation. Vacuum therapy is a suitable form of treatment in the management of these wounds. When vacuum therapy is used after bone debridement or amputations, care must be taken to ensure that the bone is covered with soft tissue. This is important because, although vacuum therapy can keep the resection margins clean, granulation tissue grows on bone only to a limited extent. In addition, vacuum therapy is effective in eradicating infection after the removal of foci of osteomyelitis⁴⁴.

For Wound Preparation Prior to Wound Closure

Extensive soft-tissue debridement usually results in large defects that require skin grafting. Vacuum therapy promotes the formation of granulation tissue that levels uneven surfaces. It thus improves the take of split-thickness skin grafts and functional outcome.

For Skin Graft Fixation

Vacuum therapy can also be used for encouraging the postoperative fixation of split-thickness skin grafts^{31,35}. The negative pressure system is re-applied to the wound immediately after graft placement. A non-adherent dressing is placed between the graft and the polyurethane foam in order to prevent the skin graft from adhering to the foam dressing and the granulation tissue from growing into the foam. The graft will thus remain on its recipient bed when the dressing is removed. Whereas a negative pressure of 125 mmHg is used for all of the aforementioned indications, 75 mmHg was found to be the optimum level of sub-atmospheric pressure for securing split-thickness skin grafts. Higher levels of negative pressure can lead to the development of excessive granulation, with the result that granulation tissue grows into the pores of the foam and the skin graft is lifted from its bed at dressing change.

Recommended Protocol

Since vacuum therapy creates areas of negative and positive pressure when levels of 75 to 200 mmHg are applied to the surface and environment of a wound, lower levels of negative pressure (between 75 and 100 mmHg) should be applied to patients with an ankle-brachial index (ABI) of less than 0.9 even in the absence of clinical signs of a relevant arterial circulation problem. When the amount of fluid decreases during the application of vacuum therapy, intermittent suction (for example the ten-minute ON/ten-minute OFF intermittent cycle) can often help to further encourage granulation tissue formation especially in difficult circulation conditions.

Diabetic foot syndrome (DFS) can lead to severe, limb-threatening wound infections. With the advent of specialist treatment centres, diabetic patients can today benefit from improved and standardised care. Early recognition of risks and the effective use of state-of-the-art treatment regimens can help prevent amputations and preserve patients' quality of life. Wound infections must be addressed in a coordinated way. Apart from revascularisation, surgical debridement and antibiotic treatment, vacuum therapy plays an important role in the management of diabetic foot wounds. Today it has a firm place in the treatment of wound infections associated with DFS.

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Ulcer characteristics according to the Harkless and Wagner diabetic foot ulcer classification system

Grade 0	Hyperkeratosis
Grade I A/B	Superficial skin lesion without involvement of underlying structures
Grade II A/B	Deep ulcer involving tendon, bone and joint capsule with moderate soft-tissue infection
Grade III A/B	Deep ulcer with abscess formation or osteomyelitis and major soft-tissue infection
Grade IV A/B	Gangrene localised to the toes or portions of the forefoot with or without abscess formation or osteomyelitis and with or without soft-tissue infection
Grade V A/B	Gangrene with involvement of the entire foot

A: without peripheral arterial occlusive disease = good prognosis

B: with peripheral arterial occlusive disease = poor prognosis

Part B / Chapter 24 Lower Leg Ulcer - The Role of Vacuum Therapy

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There are only nine *peer-reviewed* publications referring to the topic vacuum therapy. Those are – without exception – reports of experience of the Evidence-Level 4 and 5 (Oxford Centre). These studies report concurringly that vacuum therapy is integrated firmly in an overall algorithm of treatment.

Introduction

Lower leg ulcer is a substance defect affecting the pathologically altered tissue of the lower leg. The main cause of venous leg ulcer is chronic venous insufficiency, which is, in turn, the most frequent disorder of the venous system. A stasis ulcer, which, despite adequate phlebological therapy, does not show any tendency to heal within three months or has not healed completely within twelve months, is considered to be resistant to therapy. This is usually due to disturbances of circulation:

- 72% of all leg ulcers are associated with venous insufficiency (venous stasis ulcers)
- 15% are associated with both venous and arterial disorders (mixed stasis ulcers)
- 7% are associated with arterial disorders only
- 6% are due to other, rare causes

Because venous leg ulcers make up the large majority of stasis ulcers of the lower extremity, the following comments relate primarily to this type of lower leg ulcer. Venous stasis ulcers represent the final stage of chronic venous insufficiency (CVI), called "severe" or degree III disease in the classification of Widmer. Pathophysiologically, venous leg ulcers can be seen as the final phase of a multifactorial chain of events. Chronic hypertension of the venous system of the lower extremities associated with venous hypervolaemia caused by insufficiency of the sub-, trans- and epifascial veins and the resulting disturbances of micro- and macrocirculation are implicated together with secondary popliteal and femoral venous insufficiency, as well as the postthrombotic or the arthrogenic congestion syndrome³. Long-term

venous stasis and recurrent inflammation lead to transformation of the connective tissue of the epidermis, dermis, subcutis and the underlying fascia. Ultimately, this results in the development of lipodermatosclerosis and may progress to the venous compartment syndrome⁶. The chronic gaiter or cuff ulcer represents the most serious form of chronic venous congestive syndrome (Fig. B24.1).

The prevalence of venous leg ulcers correlates closely with age. While hardly ever seen in patients under the age of 40 years, it increases significantly in advancing age. By age 80 years, its prevalence falls in the range of 0.29-3.38% according to different studies^{1,7}. The average prevalence in an eight-population comprehensive meta-analysis of collectives of between 12,000 and 434,699 persons published between 1984 and 1996 was 0.29%. A study of 12,156 patients from 161 nursing homes with an average age of 77.5 years in the German state of Northern-Rhine-Westphalia returned a prevalence of 2.68%¹⁵.

The costs associated with a four-month treatment of patients with venous leg ulcers in the United Kingdom are estimated at 250-2,500 GBP for dressing materials alone, with average costs of treatment estimated at 1,067 GBP a year. In the USA, medical costs including doctor's visits were estimated at 40,000 USD per patient. Similar estimates have been published for Germany and France^{5,13,16}. Venous leg ulcers make up 57-80% of all chronic ulcerations and are the most frequent non-spontaneously healing wounds (arterial ulcerations, 4-30%; mixed arterial-venous ulcerations, ca. 10%; remaining forms ca. 10%). In the USA, costs for treating this entity amount to about 3 billion USD with the loss of about 2 million



Fig. B24.1 Extensive bilateral gaiter ulcer.



Fig. B24.2 Healing process with vacuum therapy.

working days per year¹⁹. The annual costs for Germany are estimated at about 1-1.25 billion Euro (including medical costs, 1.6 million hospital days, 2.4 million lost working days and the fact that affected persons apply for retirement an average 7.2 years earlier than normal)²⁰. The aging of the population in western countries will mean a further increase of the frequency of leg ulcers.

Therapy Principles

The therapy of venous stasis ulcers represents a medical challenge. Whenever possible, therapy should be causal, including stage-appropriate surgical therapy of varicose veins¹⁰⁻¹². Dissection or ligation of insufficient perforating veins together with phlebectomy is of great importance. An individualised combination of supportive, surgical and conventional therapeutic procedures is recommended as further treatment. This includes excision of the ulcer, the fasciotomy or fasciectomy for release of the chronic venous compartment syndrome, primary or secondary covering of the defect and compression therapy. Tangential debridement, known as "shaving", is given in the guidelines as the surgical method of the choice. Because it is a more invasive procedure, fasciectomy should be done only in cases of extensive ulceration, deep-seated sclerosis with tendon involvement or trans-fascial necrosis.

Application of Vacuum Therapy

Vacuum therapy has been successfully used in several phases of the treatment of venous stasis ulcers¹². Positive effects of the vacuum therapy, such as reduction of edema, drainage of wound secretion and acceleration of granulation tissue formation are the reasons for recommending vacuum therapy following ulcer excision/shaving or fasciectomy/fasciotomy. The securing of meshed skin transplants is another indication for vacuum therapy.

The application of vacuum therapy should be based on the following criteria. For conditioning of extensive, possibly highly infected and moderately to heavily secreting ulcers, a polyurethane (PU) foam should be employed with a continuous suction pressure of 125 mmHg for three to five days. The black PU foam conveys wound secretion from the wound's surface faster because of its hydrophobic properties and its larger pores. Lesions affecting both legs can be treated with a single vacuum source (therapy unity, Fig. B24.3) attached using an



Abb. B24.3 V.A.C.® Freedom™ with 300 ml-canisters

Y-connector. The use of the easily transportable V.A.C.® Freedom™ therapy unit is recommended for ambulatory patients.

Because of its hydrophilic properties, the white polyvinyl alcohol (PVA) foam is suitable for the support of meshed skin grafts. Its range of pore sizes prevents granulation tissue from the wound from growing into the foam, preventing avulsion of the upper cell layers or of the graft during removal of the foam. Alternatively, the PU foam can be used together with non-adhering silicone gauze covering the graft. The recommended therapy duration is five days at 75 mmHg continuous suction. The recommended thickness of the skin graft is about 0.3-0.4 mm. The mesh ratio should be about 1:1.5 to 1:3. Although individual publications have described enhanced formation of granulation tissue with intermittent suction, use of this modality can only be recommended to a limited degree because of inadequate data. There is a relatively higher risk of loss of suction, with resulting inadequacy of the vacuum bandage, especially when loss of suction is due to leaks in the sealing film. Furthermore there could be a relaxation of the mesh graft during "off" phases and the patient's movements might cause shifts of the graft.

The compression bandage should be applied while vacuum therapy is in progress. Cotton bandage padding, consisting of several layers, is advisable especially in the area of the *trac-pad connector* to prevent pressure changes. Subsequent application of a compression bandage is also advisable. Careful compression therapy together with encouragement of ambulation accelerates the healing of venous ulcers and reduces the rate of recurrence. Local therapy with coated gauze products can be continued after the removal of the vacuum bandage. It is recommended to wear several layers of cotton padding under the compression bandage in order to prevent development of a secondary lesion.



Fig. B24.4 Ulcer surgery during a treatment session: shaving (after repairing the vascular situation with stripping of varicose veins and phlebectomy).



Fig. B24.5 Ulcer surgery during a treatment session: shaving followed by mesh grafting.



Fig. B24.6 Vacuum therapy to attach the mesh-graft transplant.



Fig. B24.7 Status after five days of continuous vacuum therapy at 75 mmHg.



Fig. B24.8 Vacuum therapy, cotton padding, compression bandage.

Peer-Reviewed Literature

Only nine *peer-reviewed* publications dealing with this topic appeared in the international literature between 1997 and 2006 (total of $n = 92$ patients). They report clinical experience in the sense of *reviews* (evidence level 5) and *case series* (evidence level 4)^{9,12,18,21-26}.

The therapy of the chronic leg ulcer represents an interdisciplinary challenge independent of the convalescence. Vacuum therapy, in addition to the established causal treatment methods, is a modular, practicable and, in several phases of the treatment concept, effectively used modality, which can shorten the duration of treatment, increase patients' comfort and lower rates of recurrence.

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Part B / Chapter 25

Vacuum Assisted Management of Infected Blood Vessels and Vascular Grafts

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Infections affecting vessels and vascular grafts are life-threatening complications in vascular surgery. Our experience supports the emerging trend toward expanding the indications for vacuum therapy in this group of patients. Early publications on management of these patients with vacuum therapy are in accordance with our own findings. In addition, vacuum therapy has advantageous effects on wound healing in vascular surgery. To date, the results of 86 patients have been reported in ten articles (EbM level 4 or 5; 2001-2006). In most cases, polyvinyl alcohol or polyurethane foams were in direct contact with the vessel or graft. Secondary closure was possible in a majority of cases, while split skin grafts were used at times. In some cases, the wound was definitively closed using a sartorius or rectus femoris muscle flap. All ten reports agreed on the ability of vacuum therapy to produce early granulation to cover the graft or exposed vessel. In most cases, it was possible to save the reconstruction as well as the limb.

Introduction

Infections affecting vascular grafts are feared complications and pose an enormous challenge in vascular surgery. They are a rare occurrence^{13,16}, but, when they do occur, they can threaten the viability of an extremity. They can cause bleeding, systemic sepsis, septic peripheral emboli as well as ischaemia of an extremity – or even threaten the life of the patient. The incidence of deep wound infections is approximately 0.6 to 2%. Two-thirds of cases involve the groin. Overall mortality ranges up to 10-30%, with 30-70% seen in connection with infected aortic grafts. Infection-related amputations is required in 20-40% of cases.

Management of graft infections mandates adequate local debridement with careful excision of necrotic and infected tissue. If prosthetic material is present, it is generally removed, necessitating other reconstructive modalities⁹. Many authors favor extra-anatomic bypasses using autologous or biologic material in these situations¹⁵. A femoral approach is most frequently used for catheter-based as well as open vascular interventions. The anatomic region itself brings an increased risk of infections.

Infected pseudoaneurysms or infected haematomas are becoming increasingly common due to the general increase in catheter-based vascular interventions¹⁸. Local infections are more commonly seen after bypasses originating from the inguinal arteries. Perivascular infections are frequently seen in intravenous drug addicts⁶. Injection of illegal drugs, poor hygiene and compromised general living conditions add to the possibility of abscesses. These patients generally are seen late in the course of the infection, and call for rapid, simple and definitive therapies. The classical management of an infected infra-inguinal graft consists of tunnelling an extra-anatomic graft through non-infected tissue followed by local debridement and wound drainage. In case the vessels can be salvaged, the wound is lightly packed with moist gauze for local control. Usually the graft and defect must be covered with a muscular flap^{1,15,18}.

Evidence for the benefit of vacuum therapy in the management of other infected wounds has been amply documented since the 1990s¹⁹⁻²¹. It would seem that the time has come for expanding the indications for this modality to vascular surgery as well. Previously, exposed vessels, grafts or patches were considered to be contraindications for using vacuum therapy. Today, however, it is possible to treat both acute and late vascular infections

using vacuum therapy. It seems that this group of patients particularly benefits from management with vacuum therapy. The wound still has to be reopened, thoroughly debrided and irrigated as before, but temporary coverage of vessels and grafts, minimizing the wound cavity and preparing the area for early definitive closure are some of the clear advantages of the vacuum therapy system. To date, few publications have addressed the use of vacuum therapy on infected vessels and graft material^{2,5,7,8,9,11} (see Table B25.1).

4 Case Reports

Infected Seroma with Septic Peripheral Embolisation

This is a 65-year-old patient with endocarditis and septic cerebral embolisation. CT scan suggested a mass in the proximal thigh. Needle aspiration showed an abscess (*Staphylococcus aureus*; Fig. B.25.1), thought to have been caused by septic embolisation. Operative management was chosen via inguinal access. The vessels were controlled. A septic seroma was detected dorsal to the artery and vein. The cavity was irrigated and a polyvinyl alcohol foam inserted. As the seroma was in contact with the vessels, they were surrounded by the foam. The remaining cavity was filled with polyurethane foam. Suction of 100 mmHg was applied. After two dressing changes, the wound was successfully closed secondarily (Fig. B25.2 and 3).

Mycotic Aneurysm of Femoral Artery

A 36-year-old drug addict was admitted for an infected femoral aneurysm following inadvertent drug injections into femoral artery instead of vein. The aneurysm had been resected and end-to-end anastomosis performed in an outside hospital. After several bleeding episodes, the patient was sent to our unit. At operation, the artery was seen to be destroyed by infection, and the femoral bifurcation had to be resected. Arterial reconstruction was performed using bovine heterograft. Intraoperative biopsies showed a MRSA infection. The reconstruction was covered with polyvinyl alcohol foam and intravenous antibiotic therapy initiated. Cardiac examination revealed a 3/6 systolic murmur. Transoesophageal echocardiography showed degeneration of the aortic valve, but no abscess formation. As endocarditis was clinically suspected, appropriate antibiotic therapy was initiated. The polyvinyl alcohol foam was changed every two to three

days. After four dressing changes, the wound was successfully closed secondarily.

Infection after Femoral Endarterectomy

A 47-year-old male was admitted from another unit after endarterectomy and patch angioplasty of the femoral bifurcation. Two reoperations had been performed due to early thrombosis of the reconstructed vessel. After these interventions, a wound infection as well as re-thrombosis were diagnosed. At operation, we explored the infected incision and encountered a thrombosed femoral artery with infected patch material. As we did not want to sacrifice the profunda femoris artery, which was in the infected region, we decided on a reconstruction using bovine heterograft. A bypass from the external iliac artery to the superficial femoral artery was performed, and the profunda femoris was anastomosed to the graft. A sartorius muscle flap was used to cover the graft. Blood circulation was adequate. We covered the exposed graft with polyvinyl alcohol foam, which was changed twice at three-day intervals. Suction was applied at 100 mmHg. The area was ultimately covered with a split-skin graft, which again was covered with polyvinyl alcohol. Recovery was uneventful with no evidence of re-infection at follow-up.

Infection of a Peripheral Graft

A 70-year-old patient was admitted for infection of an extra-anatomic femoral-popliteal bovine heterograft bypass graft. The infection was peri-prosthetic. The affected soft tissue was debrided and excised and the graft mobilised and placed so that it was covered by uninfected tissue. The relatively superficial wound was covered with

white polyvinyl alcohol foam, which remained in contact with the graft. Granulation was eventually observed, and the wound bed finally covered with a split-skin graft (Fig. B25.16-19).

Review of Literature

Table B25.1 shows studies reporting the use of vacuum therapy in connection with infected blood vessels or vascular grafts. Author and journal are included, as well as level of evidence, number of patients, indications for vacuum therapy, technical details (if available) and results.

Summary

- Every infection after vascular procedure has to be individually evaluated
- Applying polyvinyl alcohol foam directly to an exposed vessel or reconstruction is possible and often advantageous, saving time and effort
- Low suction does not harm blood vessels or grafts
- Suction should be used in continuous mode rather than intermittently
- Lower suction than the usual 125 mmHg is employed (we recommend 50-100 mmHg to avoid bleeding)
- If possible, early cover with muscle is advantageous (exposed grafts cannot be covered with split skin graft)
- Side branches of graft veins or homografts should not be ligated but oversewn
- In florid infections, one should keep in mind the possibility of septic emboli and risk of endocarditis



Fig. B25.1 CT of pelvis. Perivascular haematoma with a diameter of 3-4 cm.



Fig. B25.2 Surgical view. Haematoma exposed laterally. Trimming of polyurethane foam.

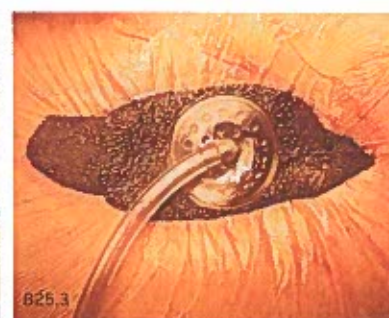


Fig. B25.3 Vacuum therapy system on femoral vessels.



Fig. B25.4 Acute ischaemia of left leg. Blotchy skin.



Fig. B25.5 20.5 Surgical view. Femoral artery patch seen on the bottom of the wound.

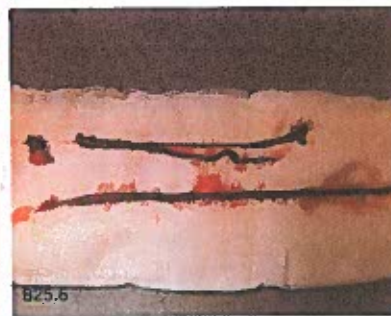


Fig. B25.6 Extracted thrombus material after thrombectomy.



Fig. B25.7 Recovery of leg and foot.



Fig. B25.8 Surgical view. Reconstruction using heterograft (from external iliac artery to superficial femoral artery). Profunda femoris separately anastomosed on graft. State of wound after two days of vacuum therapy.



Fig. B25.9 Detail of heterograft. Situation after first two days of vacuum therapy. Early granulation seen.



Fig. B25.10 Sartorius muscle mobilised.



Fig. B25.11 Surgical view. Sartorius muscle covering the reconstruction.



Fig. B25.12 Vacuum therapy with polyvinyl alcohol foam and suction system.



Fig. B25.13 Surgical view. Granulation tissue seen. (Editor's comment: because identical tissue formations are seen after 90 minutes of continuous suction with 125 mm Hg in pig tissue (see also Chapter 7 in Part A for details), it is probably the imprint of the sponge that can be seen in tissue here). The reconstruction itself is no longer visible after three dressing changes at two-day intervals.



Fig. B25.14 Split-skin graft.



Fig. B25.15 Vacuum therapy used to fixate the skin graft.



Fig. B25.16 Redness and swelling around extra-anatomic bypass.



Fig. B25.17 Infected bypass graft. Situation after debridement.



Fig. B25.18 Therapy with vacuum foam.



Fig. B25.19 Surgical view. Clean wound. Granulation seen. Bypass re-tunnelled in the ventral aspect of the wound.

Discussion

A search of the literature shows few publications on the use of vacuum therapy with infected blood vessels or vascular grafts (see Table B25.1). Initial results of applying polyvinyl alcohol foam directly to exposed vessels have been published (five retrospective case series and one case report, EbM level 4 or 5, additionally one letter and three reviews).

Particular problems directly related to the use of vacuum therapy have not been reported to date. Generally, wound closure has been reported to be straightforward without need of extensive soft-tissue reconstructions. Our own experiences support these findings. In some of our cases, imminent amputation was avoided after vacuum therapy. In our opinion, a commonly presented contraindication for vacuum therapy, namely “exposed blood vessels or grafts”, should be re-examined – as suggested at a recent consensus conference²⁸.

Infected wounds around blood vessels or vascular grafts are a challenge for the surgeon. These patients clearly benefit from management with vacuum therapy. Wound debridement, temporary cover of the reconstruc-

tion and gradual closing of the defect are clear advantages^{9,20-23}. For high-risk surgical patients with a fully exposed infected prosthetic vascular graft, vacuum therapy along with aggressive debridement and antibiotic therapy may be an effective alternative to current management strategies^{8,12,17}.

Table B25.1 Published *peer-reviewed* literature on the subject vacuum therapy and infections in vascular surgery

Year	Author/Journal	Evidence-Level	Number of Patients / Indication	Vacuum Therapy	Course
2001	Demaria et al. ⁵ <i>J Wound Care</i>	5 (case report)	n = 1 Bypass infection (<i>vena saphena magna</i>)	PU-foam 150 mmHg, continuously	After 23 days wound closure by <i>skin graft</i>
2003	Demaria et al. ⁷ <i>J Cardiovasc Surg</i>	4 (case series)	n = 4 Infection following emergency operation at <i>a. femoralis</i>	PU-foam 150 mmHg, continuously	Wound closure by <i>secondary suture</i> or <i>skin graft</i>
2003	Heller et al. ¹⁰ <i>Eur Surg</i>	4 (case series)	n = 36 (Infection 13x, wound healing problems 11x, exposed prosthesis 3x, in 8 cases direct coverage of vessels by the foam)	PVA-foam, no further details given	<i>Secondary suture</i> in 25 cases, <i>skin graft</i> n = 9, muscle flap n = 2
2003	Pinocy et al. ²¹ <i>Wound Repair Regen</i>	4 (case series)	n = 24 Bypass infection	PVA-foam	n = 21/24 wounds wound closure after 2 weeks, n = 3 spontaneous healing of the wound
2003	Colwell et al. ⁴ <i>Ann Plast Surg</i>	4 (case series)	n = 4 Bypass infection	vacuum therapy (3 - 14 days), no further details given	Closure of all wounds , smaller wounds by <i>sartorius-flap</i> , bigger wounds by <i>musculo- cutaneous rectus femoris flap</i>
2004	Karl et al. ¹² <i>Zentralbl Chir</i>	4 (case series)	n = 7 Graft infection 4x stage II according to Szilágyi Graft infection 3x stage III according to Szilágyi	PU-foam 125 mmHg, continuously	Stage II Szilágyi: 1x preservation of graft and extremity Stage III Szilágyi: 4 x preservation of graft and extremity
2005	Dosluoglu et al. ⁸ <i>Vasc Surg</i>	4 (case series)	n = 4 Infections, fully exposed synthetic bypass grafts	No details given	Mean duration of vacuum therapy 22.8 days (range: 6 to 53 days), with time to total wound closure of 30 to 63 days (mean: 41 days). There were no reinfections with 11 to 25 months' follow-up (mean: 18.3 months).

Vacuum therapy makes it possible to extend treatment to deeper structures, i.e. in the case of infections reaching to the vessels or the bypass graft materials. In all cases reported to date this obviated the need for more involved surgical procedures. Studies characterized by high EbM levels comparing the results of vacuum therapy with those of conventional measures, however, are not available:

- Each case is individual and must be treated individually
- The application of the vacuum therapy system to vessels and vascular prostheses is possible and in individual cases would be considered the method of choice for cleansing and conditioning the wound.
- The vascular wall and perfusion are not negatively impacted by the suction
- To date, good results have been reported for use of the continuous suction mode
- The suction should be set lower than the usual 125 mmHg (in our experience, 50-100 mmHg is adequate)
- Whenever possible, the prompt coverage with muscle material is ideal. Exposed graft material cannot be covered with split-thickness skin grafts.
- Branches of venous bypasses or homografts should not be ligated but perforated and oversewn.
- In cases of florid infections of the vessels and vascular prostheses, the risk of septic embolisms and bacterial colonisation of the heart valves should always be kept in mind.

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Part B / Chapter 26

Lymphocutaneous Fistulae

C. Willy and M. Engelhardt

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Vacuum therapy can be used for the management of lymphocutaneous fistulae. The successful treatment of seven patients with lymphocutaneous fistulae of the groin has been reported in the *peer-reviewed* literature (2000 - 2006, two case reports [level 5 evidence] and 1 case series [level 4 evidence]).

Introduction

Axillary and inguinal lymph node dissections as well as surgery of the infra-inguinal vessels can cause injury to efferent lymphatic vessels. This can lead to lymphostasis or a lymphocele when the skin is intact or to a lymphatic fistula when a wound is present. A wide variety of therapeutic options have been developed in the past and range from the use of compression dressings to scab formation, the use of fibrin glue and, where possible, ligation of leaking lymphatic channels.

Vacuum therapy is described here as a further non-invasive method of treating lymphocutaneous fistulas.

Literature Review

To date, the use of vacuum therapy for the treatment of lymphocutaneous fistulae has been reported in only seven cases (level 4 and 5 evidence)^{1,2,3}. The paper by Greer et al.¹ describes the treatment of a 49-year-old female patient with bilateral lymphocutaneous fistulae after aortobifemoral bypass and the treatment of a 77-year-old female patient who developed a fistula after evacuation of haematoma following femoral puncture. In both cases, it was possible to close the fistulae using vacuum therapy alone. Unfortunately, the research group provides no information on the level of negative pressure and the type of suction that was used.

Steen Voorde et al. report a patient who underwent an ilioinguinal node dissection for a regional metastasised melanoma². Unfortunately, a deep wound infection occurred with extensive skin necrosis and production of abundant wound fluid (750 ml daily). Despite dressing changes six times daily, the wound deteriorated, necessitating further operative debridement. In theatre, the authors failed to identify the lymphatic fistula and therefore were unable to close it. Therefore vacuum therapy was started. After 11 days of vacuum therapy, the lymphatic leakage completely stopped. Concurrent successful management of the wound with split skin graft therapy led to a complete closure of the wound. The treatment was not painful, dressing changes could be done in the ward, and there were no complications.

The third group, Rau et al.³, retrospectively investigated clinical and diagnostic data from eight patients (1995 - 2005) with penile cancer and postoperative lymphocutaneous fistula. Four of these eight patients were treated by vacuum therapy. Their data show that,

despite higher primary introduction costs, vacuum therapy is advisable and resulted in a shortened hospitalisation and reduced overall costs per patient.

Discussion

Lymphocutaneous fistulae are rare complications of general and vascular surgery as well as of interventional radiology. They can, however, significantly lengthen hospital stays. The wide variety of treatment methods devised to date indicates that no one single method has been successfully used in a large enough number of cases. For this reason, vacuum therapy is described here as an interesting alternative to other treatment options for this indication. Moreover, it appears necessary to consider and discuss the special level of negative pressure and mode of suction that should be used in the management of lymphocutaneous fistulae.

One of the advantages of vacuum therapy is that it is a non-invasive method that can be used outside the operating theatre and can also be combined with surgical procedures such as the attempted ligation of lymphatic vessels or scab formation.

Greer et al. believe that granulation tissue grows as a result of vacuum therapy and covers open lymph channels until the fistula is eventually closed. The information provided in Part A of this book suggests, however, that vacuum therapy actually has a different underlying mechanism in this case. The key to success seems to be the tissue compression caused by vacuum therapy. At first glance, this appears to be illogical since the application of suction can be expected to drain lymphatic vessels and thus to stimulate lymph flow. Findings discussed in Chapter 6 and 7 of Part A, however, show that the foam is actually sucked into the tissue. This causes compression of the tissue at the pore walls and low suction in the area of the pores. It should also be borne in mind that the suction-induced reduction of foam size results in tension on the wound edges, meaning that the tissue is further re-approximated. As reported by Wackenfors et al.⁴, this leads to hypoperfusion in the tissue close to the wound edges, including lymph vessels. The size of this area depends on the level of negative pressure applied. The same research group reported that the extent of the hypoperfused area was 1.8 cm from the wound edge at a negative pressure of 50 mmHg, 1.9 cm at 100 mmHg, and 2.5 cm at 200 mmHg in subcutaneous fat tissue.

These experimental results suggest that a high level of negative pressure should be used in order to apply high local pressure to the tissue. In addition, the foam should be sutured or stapled in situ at the wound edges in order to maximise the reduction in wound size. Since a hyperaemic response with hyperperfusion and the re-

opening of closed vessels is not desired in the treatment of lymphocutaneous fistulas, intermittent treatment should not be used. Therefore, from the theoretically point of view, a continuous negative pressure of 200 mmHg should be recommended.

Vacuum therapy can be used for the treatment of lymphocutaneous fistulae. The results of experiments support the assumption that the compressive effect of vacuum therapy is the key to successful treatment. A continuous negative pressure of 200 mmHg appears to be most effective for this indication.

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Part B / Chapter 27

Vacuum Therapy and Mesh-Graft Take Rates in Patients with Chronic Wounds - The Dermatological Point of View

J. Dissemond, A. Körber and S. Grabbe

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Vacuum-assisted closure (VAC) is an established therapeutic option for the management of acute and chronic wounds. In recent years, however, some data have been published concerning vacuum therapy in patients undergoing skin graft transplantation. To date, 14 scientific *peer-reviewed* articles with evidence levels from 1b to 4 reporting a total of 605 documented graft transplantations fixed postoperatively with vacuum therapy have been published (in all, there are 31 *peer-reviewed* papers, EbM-level 1b-5, > 1000 patients, 1998-2006). The results of our own and other clinical investigations demonstrate the benefit of vacuum therapy for take rates in skin grafting especially in patients with chronic leg ulcers (for additional information, see Part B, Chapter 9).

Introduction

In socioeconomic terms, patients with chronic wounds generate ongoing costs resulting not only from outpatient and inpatient treatment and other prescribed therapies but also from illness-related periods of disability and premature withdrawal from working life. One innovative therapeutic option for the treatment of patients with such wounds is vacuum therapy¹. Although available evidence-based data concerning its effectiveness in modern wound management of chronic wounds is insufficient, vacuum therapy is regarded as a first-line treatment method in the phase of granulation.

In recent years, vacuum therapy has increasingly been used for mesh-graft fixation in patients with chronic wounds. According to various clinical investigations in very inhomogeneous patient collectives, skin transplantation fails in 10% to 67% of all patients despite optimized preoperative wound-bed preparation^{2,4}. One major reason for this may be the accumulation of wound secretion beneath skin grafts. The present discussion addresses the postoperative use of vacuum therapy to prevent these complications and to optimise treatment results in patients with chronic leg ulcers.

Own Investigation

We retrospectively documented the take rate of 74 consecutive mesh-grafts transplanted in 54 patients of the Department of Dermatology, University of Essen (Germany) from April 2003 to April 2005. We began using vacuum therapy in the summer of 2004 and compared the take rates of patients who received postoperative vacuum therapy for mesh-graft fixation (Fig. B.27.1) with those who had received only conventional postoperative care with occlusive gauze and compression. Included in the study were 54 patients (31 [55.5%] female, 23 [44.5%] male; mean age 68.5 years, range 39-92 years). Forty-six (85.2%) patients suffered from a venous leg ulcer, three (5.6%) patients had a mixed leg ulcer and five (9.3%) patients had developed a leg ulcer in the course of vasculitis. Fifteen of a total 74 operations were performed on patients suffering from diabetes mellitus. Moreover, 31 of the 74 operations were done on patients with a dermatoliposclerosis of the lower leg. The mean wound size of both patient groups was comparable. After achieving granulation of the ulcers to the level of the skin surface, a modern phase-adapted moist wound manage-

ment was successfully conducted prior to mesh-graft transplantation in all patients. All mesh-graft transplants were taken by using a Wagner dermatome with a graft thickness of 0.4 mm. The grafts were meshed at a proportion of 1:3. After application of a polyvinyl alcohol foam immediately after mesh-graft transplantation the vacuum unit was set to a negative pressure of 125 mmHg.



Fig. B27.1 Chronic leg ulcer patient with postoperative vacuum therapy.



Fig. B27.2a-c Leg ulcer patient at her first visit in our clinic (a). The same patient with a viable mesh-graft one week (b) and two weeks (c) after transplantation and fixation with vacuum therapy for seven days.

In the first group of 46 patients, transplantations were followed by postoperative care with lanolin-coated gauze (e.g. MepitelTM) and compression. Patients were immobilised until the first change of dressing between the fifth and seventh postoperative day. In the following group of 28 transplantations, the vacuum device was attached to the mesh-graft site immediately after the operation. As in the first group, the first change of dressing took place between the fifth and seventh postoperative day. However, patients were not immobilised this time. In their subsequent course, both patient groups received a regular application of non-adhesive wound gauzes.

Graft viability was evaluated by a physician between the tenth and fourteenth postoperative day before discharge of the hospital. A mesh-graft was regarded to have taken when a fully viable area of at least 50% was assessed (Fig. 2a-c).

Results

A total of 54 patients with 74 mesh-grafts were evaluated in our investigation. Altogether, 28 mesh-grafts were treated with postoperative vacuum therapy and 46 mesh-grafts without postoperative vacuum therapy. The overall take rate was 77.0% amounting to 57 out of a total of 74 mesh-grafts (Table B27.1). The statistical analysis of the two patient groups with and without postoperative vacuum therapy showed a significantly higher rate of take in the group using postoperative vacuum therapy ($p = 0.01$). Of a total of 46 mesh-grafts without vacuum therapy, only 31 (67.4%) were more than 50% viable. By contrast, viability was assessed in 26 of 28, i.e. in 92.9% of mesh-grafts treated with vacuum therapy. The statistical analysis of the subgroup of patients suf-

fering from dermatoliposclerosis was made by dividing the entire patient population into two subgroups, one with and the other without dermatoliposclerosis. The analysis revealed a significantly lower take rate in patients with dermatoliposclerosis ($p = 0.03$). In these patients, only 20 of 31 mesh grafts (64.5%) were viable compared to 37 out of 43 (86.0%) transplants in the non-dermatoliposclerosis subgroup. In patients with dermatoliposclerosis, five of seven (71.4%) grafts were considered to have taken in patients treated with vacuum therapy, while all transplants (100%) had taken in patients without dermatoliposclerosis (Table B27.2). Pre-existing diabetes mellitus was likewise associated with a lower, yet statistically non-significant difference in the graft take rate. Only nine of 15 (60.0%) mesh-grafts in diabetic patients were viable, in contrast to 48 out of 59 (81.4%) mesh-grafts in patients not suffering from diabetes. When vacuum therapy was applied to grafts in diabetes patients, all three transplants (100%) were considered viable, while grafts in patients of the same group not treated with vacuum showed viable grafts in only six of 12 (50.0%) cases (Table B27.2). This was the poorest result seen in

Table B27.1 Results of all investigated patients ($n = 54$ with $n = 74$ wounds) in our own investigation.

Parameter	Total	Take rate	
		absolute	(%)
With vacuum therapy	28	26	92.9* ($p = 0.01$)
Without vacuum therapy	46	31	67.4
Dermatoliposclerosis	31	20	64.5* ($p = 0.03$)
No dermatoliposclerosis	43	37	86.0
Diabetics	15	9	60.9
Non-diabetics	59	48	81.4
≤ 70 years	39	33	84.6
> 70 years	35	24	68.6
Male	31	23	74.2
Female	43	34	79.1
All	74	57	77.0

Table B27.2 Results of vacuum therapy *versus* non-vacuum therapy groups in our own investigation.

Parameter	With VAC			Without VAC		
	Total	Take rate		Total	Take rate	
		absolute	(%)		absolute	(%)
Fibrosis	7	5	71.4	24	15	63
No fibrosis	23	23	100	22	16	73
Diabetics	3	3	100	12	6	50
Non-diabetics	25	23	92	34	25	74
≤ 70 years	16	14	87.5	17	13	76
> 70 years	12	12	100	29	18	62
Male	13	11	84.6	17	11	65
Female	15	15	100	29	20	69
All	28	26	92.9	46	31	67.4

a subgroup. Finally, the entire patient population was divided into two age groups, namely, patients 70 and younger and patients over 70 years of age. The analysis showed a clearly better graft take in patients aged 70 and younger. However, this difference did not reach statistical significance. In patients older than 70 years, 24 of 35 (68.6%) transplants were assessed as viable, while this was the case for 33 of 39 (84.6%) mesh-grafts in patients aged 70 and less. In the patient group aged 70 years and younger, mesh-grafts that were treated postoperatively with vacuum therapy showed a take rate of 14 out of 16 (87.5%). However, grafts in patients over 70 years of age who did not receive the vacuum therapy procedure were observed to have taken in just 18 of 29 transplants (62%).

Discussion

Our retrospective analysis of skin grafts in patients suffering from chronic leg ulcers has shown that mesh-grafts fixed with postoperative vacuum therapy are associated with a significantly higher take rate than conventionally treated mesh-grafts. The extensive studies on the established use of the vacuum therapy technique in the wound-healing phase of

granulation have resulted in guidelines that recommend vacuum therapy in acute and chronic wounds, burns, diabetic ulcers as well as open foot wounds¹. However, there have been very few reports on the postoperative application of vacuum therapy (Table B27.3).

One challenging problem in the use of mesh-grafts arises from the postoperative accumulation of fluid beneath the graft, which makes it difficult to attach the transplant to the underlying tissue. This problem is solved by postoperative vacuum therapy, which facilitates efficient and firm fixation of the mesh-graft to the wound bed and prevents clinically relevant accumulation of interstitial fluid without limiting the patient's mobility. Vacuum therapy entails a number of advantages for patients suffering from chronic leg ulcers. The wound is mechanically cleansed of secretion and microorganisms, thus requiring far less frequent changes of dressings and allowing even strongly secreting wounds to be treated. The sealed system acts as a physical barrier against most exogenous influences, especially against bacterial superinfections. The negative pressure generated by the vacuum source (therapy unit) pulls the wound edges together towards the center. This is thought to support physiologi-

Table B27.3 Current publications on mesh-graft take rates in patients with chronic wounds by postoperative use of vacuum therapy.

Year	Author	Evidence-Level	Number of patients	Indication	VAC	Results
2006	Koerber et al. <i>submitted</i>	2 c	n = 74	Leg ulcers	5 day vacuum therapy after grafting versus no vacuum therapy	Significant improved take rates with VAC (90.5%) vs. no VAC (67%)
2005	Haslik et al. ³⁶ <i>J Wound Healing</i>	4	n = 42	Acute wounds, burns, hydradenitis suppurativa, tumour defects, chronic ulcers	125 mmHg, continuous suction	Take rate 88.1%, particularly suitable in difficult recipient areas
2004	Carson et al. ¹¹ <i>Ostomy Wound Manage</i>	4	n = 50	Chronic wounds, non healing wounds, leg ulcers	Skin grafting 1:1.5 and vacuum therapy for 7 days	Take rate of 100% after 6 months
2004	Mang et al. ¹¹ <i>Zentralbl Chir</i>	4	n = 3	Vacuum therapy before and after skin grafting	Vacuum therapy before and after skin grafting	Improved take rate, but no standardization
2004	Moisisdis et al. ¹⁴ <i>Plast Reconstr</i>	3a	n = 20	Acute and chronic wounds, leg ulcers	50% of each wound was treated with VAC for 5 days after grafting	Improved take rates but not significant. Significant in quality of tissue
2004	Stone et al. ²⁵ <i>Wounds</i>	3b, case controlled study, versus traditional cotton bolster	n = 21	Soft tissue loss and fasciotomy site	Vacuum therapy unit, 25 mmHg	Viable option for securing STSG and ensuring graft survival
2003	Isago et al. ²⁴ <i>J Dermatol</i>		n = 10	Trauma and burn wounds	Vacuum therapy unit, 25 mmHg	High utility as evidenced by a survival rate of 95% or higher of the grafted areas, remove hematomas and pull the whole skin graft onto the grafting site with uniform force for adhesion
2002	Scherer et al. ¹⁰ <i>Arch Surg</i>	2c	n = 61	Burn injuries, leg ulcers	Split-thickness skin grafts and VAC	VAC provides a safe method for securing STSGs. Improved graft survival.
2001	Sposato et al. ¹⁰ <i>Br J Plast Surg</i>	4	n = 9	Leg ulcers	Skin grafting with postoperative VAC	Take rate of 63%
2001	Chang et al. ²¹ <i>Burns</i>	4	n = 8	Burn wounds	No detail	Average success rate approximately 97%, appropriate alternative method for grafts on uneven or mobile surfaces
2000	Avery et al. ²² <i>Brit Jour Oral Maxillofac Surg</i>	4	A certain part of 300	Acute and chronic wounds	50 – 100 mmHg	Reduced time to skin grafting, an increase in the rate of graft take

cal wound contraction, to reduce the interstitial edema and to stimulate microcirculation. The resulting prolonged increase in cutaneous perfusion has been demonstrated in investigations using laser Doppler flow^{6,7} (see Part A, Chapter 6). It is further assumed that the immediate increase in blood flow velocity results from the negative pressure and that an improved microcirculation is made possible by the reduction of wound edema. Thus, vacuum therapy both facilitates wound cleansing and enhances wound granulation. The negative mechanical pressure applied to the tissue induces fibroblast proliferation and leads to enhanced capillary formation⁸. This theory concerning mechanical stimulation may explain the increased epithelialisation rate at the graft donor site observed in animal experiments as well as in controlled clinical studies. Attaching the vacuum therapy device to the mesh-grafted leg ulcer during the operation enables sterile sealing of the site on the operation table.

Since vacuum therapy is generally recognised as a method of first choice due to its granulation tissue-enhancing qualities in chronic leg ulcers, its successful postoperative use has now been increasingly reported. For example Pfau et al. found in 11 patients with acute and chronic wounds at "difficult body sites" that skin graft take in 85-100% of the patients was attained when a polyvinyl alcohol sponge was applied and a Redon drainage system was created postoperatively⁸. Halter et al. likewise used a polyvinyl alcohol foam and a Redon drain to treat 35 patients suffering from leg ulcers and obtained similar results⁹. Within a period of 30 months, there was 75% healing in 32 of 35 ulcers. An obvious drawback of the Redon drainage system (vacuum source) is the uncontrollable and unmonitored pressure situation in which an initially high pressure steadily falls. Today, the most commonly used vacuum therapy system generates a pressure of constant intensity and sounds an alarm signal in the event of pressure loss. It is important to control and monitor the pressure since a pressure drop would impair the beneficial effects of the vacuum therapy. Furthermore, other case series, some with quite heterogeneous patient groups, also revealed improved take rates under postoperative vacuum treatment in acute and chronic wounds as well as an unproblematic postoperative patient mobilization¹⁰⁻¹⁴.

Sposato and co-workers documented that postoperative vacuum therapy after ambulatory skin transplantation in patients with chronic leg ulcers was successful in seven of nine (78%) patients¹⁰. Mang et al. reported on

the pre- and postoperative therapeutic benefit of vacuum therapy in three patients suffering from leg ulcer, necrobiosis lipoidica and basal cell carcinoma¹¹. Scherer et al. demonstrated the advantage of postoperative vacuum therapy over bolster dressing in burn patients and patients with traumatic injuries. In the vacuum therapy group, repeated transplantations were clearly less frequent, whereas the side effects of both treatments were similar¹². Carson et al. treated 70 patients suffering from different types of wounds larger than 14 cm². These wounds were mostly decubital ulcers, diabetic feet or traumatic ulcers, whereas only seven were venous leg ulcers. A total of 50 patients received a skin transplant followed by postoperative vacuum therapy and an additional silver-coated wound dressing applied between the transplant and the black polyurethane foam. The foam was left in place for seven days with a negative pressure of 125 mmHg. The retrospective evaluation of these patients showed a take of all transplants for at least six months. Of the remaining 20 patients, five died and 10 had complete healing under conservative wound care. However, three diabetics did not respond to preoperative vacuum treatment and underwent amputation¹³. The optional insertion of a silver-coated dressing between foam and transplant is feasible and may be appropriate in infected wounds. Unfortunately, the authors failed to mention why these modifications were made and whether or not the final results could have been attained without the silver-coated wound dressing. Compared to our study, this investigation was carried out in notably younger patients with an average age of 54 years. The influence of age, dermatoliposclerosis and diabetes mellitus was not analyzed. In addition, the results do not reveal which patients were actually transplanted and for which indication.

Moisisidis et al. wanted to study whether skin graft take is improved qualitatively or quantitatively with vacuum therapy compared with standard bolster dressings. A blinded, prospective, randomized trial was conducted with 20 patients who had wounds requiring skin grafting with a mean wound size of 128 cm². After grafting, each wound half was randomized to receive either a standard bolster dressing or a vacuum therapy. After two weeks, wounds that received a vacuum therapy had a greater degree of epithelialisation in six patients (30%), the same degree of epithelialisation in nine patients (45%), and less epithelialisation in five patients (25%) compared with their respective control wounds. Graft quality following

topical negative pressure therapy was subjectively determined to be equivalent or better in 17 patients (85%). The authors' conclusion was that, although the quantitative difference in graft take was not significant, the qualitative graft take was found to be significantly better with the use of vacuum therapy compared with standard bolster dressings¹⁴.

In conclusion, the results of the above mentioned clinical investigations were obtained in distinctly heterogeneous patient groups predominantly suffering from traumatic wounds and are hence only in part comparable to the findings in our patient population with chronic leg ulcers. But the demonstrated benefits of postoperative vacuum therapy may indicate that this method is suitable in other indications as well.

In our cohort the only two patients that failed to respond to vacuum therapy suffered from extensive dermatoliposclerosis. Dermatoliposclerosis, also known as hypodermatitis sclerodermiformis, was first described by Huriez in 1955 as a chronic inflammatory disorder affecting the dermis, subcutis and potentially the fascia. This disorder presents with painful indurations of the lower legs and poses a grave therapeutic challenge especially in the treatment of patients suffering from venous leg ulcers. According to recent investigations, one promising therapeutic option in patients with extensive dermatoliposclerosis is a combined shave operation, i.e. a surgical removal of the sclerotic tissue down to the fascia, the perilesional sclerotic skin and a subsequent wound closure^{15,16}. It seems appropriate to complement the combined shave operation with a mesh-graft transplantation and postoperative vacuum therapy. This appears to be an interesting option that requires further investigation.

The distinctly divergent, yet not statistically significantly different take rates in patients over and under the age of 70 may well have multifactorial causes. Apart from the malnutrition very frequently found in the elderly and the age-related rise in co-morbidities, concomitant medication may also negatively affect wound-healing and may thus represent an important factor responsible for lower take rates¹⁷⁻¹⁸. The analysis of patients with and without diabetes shows a clearly facilitated take in healthy patients. The known cause of diabetes-related interference with wound-healing also seen in well-controlled diabetes lies in diabetic micro- and macroangiopathy, progressively developing over many years, and involving a modified vasoreaction, cytokine expression and immune dysregulation^{19,20}.

Vacuum therapy provides a safe and effective option for mesh-graft fixation in patients with chronic wounds. The results of our own and other investigations demonstrate better and partly significantly different take rates of mesh-grafts in patients with chronic wounds treated with and without postoperative vacuum therapy. Especially the subgroups of patients with leg ulcers who are older than 70 years or suffer from either dermatoliposclerosis or diabetes mellitus differed distinctly and in part statistically significantly from the respective subgroups that did not receive vacuum therapy. Moreover one major advantage of postoperative vacuum therapy is that it does not further limit the patient's mobility.

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Part B / Chapter 28

Role of Vacuum Therapy in Palliative Treatment of Wounds

C. Wiedeck, P. Ziegler and W.-J. Stelter

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Since its introduction about twelve years ago, vacuum assisted closure (VAC) therapy has developed from a fringe therapy concept, not to be taken seriously, to an established gold standard in the treatment of both acute and chronic wounds and tissue defects. Only as a result of its increasing acceptance and broad spectrum of indications has it become clear that vacuum therapy, besides its clear efficacy in a therapeutic and curative setting, also has a palliative role for patients, their families and the medical professionals who treat them. The drainage principle, which is the basis for this closed, hygienic system, makes it possible to control symptoms and reduces subjectively stressful factors. Even if complete healing cannot be achieved, there is a clear benefit for the patient. To date, no *peer-reviewed* article has dealt with this topic.

The Development of the Palliative Concept in Wound Treatment

Definition

Palliation is defined by the WHO as "the improvement of the quality of life in patients and their families who are confronted with problems arising from a life-threatening disease by means of prevention and reduction of suffering, by early recognition and competent assessment and treatment of pain and other physical, psychosocial and spiritual suffering" (WHO, 2002).

While it is customary and ethically required to attempt adequate palliation in patients with malignant disease, particularly when the prognosis is grave, the same urgency has not attached to allaying pain in patients with problematic wound healing. On the contrary, there are no clearly developed concepts of palliative wound and defect treatment and it is frequently the case that, once successful treatment appears impossible, patients are supplied with the simplest and least expensive dressings. Sometimes, even obsolete methods and those known to be worthless are used.

The Need for Palliation in Wound Therapy and Septic Surgery

What are the Concerns of Patients with Problematic Wounds?

First, we must differentiate between different wound situations. The patients presenting to our outpatient wound clinic with chronic wounds complain first and foremost about their dependence on caregivers and physicians in both a temporal and spatial as well as a therapeutic sense. Closely related are feelings of social immobility and loneliness. Patients with malignant, ulcerating wounds suffer most from the fear of unpleasant odours and the repulsive appearance of their wounds. For the most part, they insist on keeping their dressings as fresh and clean as possible, with no hint of odour due to secretions and will even accept more frequent and painful dressing changes. The patients of our surgical intensive care unit, insofar as they do not require mechanical ventilation, are most frightened of the pain of dressing changes and the potential need for brief anesthesia and sedation.

What are the Concerns of Patients' Families and Caregivers?

We must not forget that it is not only patients who are affected by the problems of painful, foul-smelling or otherwise difficult wounds. Family members, too, may often find the odour and disfigurement as intolerable as the patients themselves; and this is complicated further by feelings of sympathy and even guilt regarding these irrepressible feelings of repulsion.

Nursing staff and physicians often harbour similar emotions, although they may, to a certain degree, become used to such wound conditions. Often, they may experience feelings of helplessness and frustration at the lack of therapeutic success.

The vacuum therapy offers hope for resolving these problems in the clinical routine: Dressing changes are required less frequently and the intervals between dressing changes are less painful. Odours are significantly reduced and, in terms of aesthetics, the wound is hidden from direct view, yet there are no ugly bandages. Secretions do not escape, hence, the dressings and bed remain dry. Bedridden patients dislike lying in a bed that is wet with secretions or antiseptics or other solutions and are bothered by the frequent changes in bed linens, to say nothing of the damage to the skin caused by the damp environment.

Ambulatory patients enjoy increased mobility due to prolongation of the intervals between dressing changes and less dependence on home health aides and physicians' office visits. All patients who gave their opinion about this therapy concept reported feeling relieved at the tight fixation of the dressing, which, once it is put in place, does not shift and, at worst, may lose its seal. Hospitalised patients can often be discharged from the in-patient ward despite large, non-healing wounds. Vacuum therapy allows cancer patients to be discharged home, where they can be treated in a dignified setting despite exulcerating, foul-smelling wounds or fistulae.

Development of Indications for Palliative VAC

We have used vacuum assisted closure therapy at the Municipal Hospitals of Hoechst since the end of the 1990s. Initially, the indications were simple and limited to superficial, extrafascial wounds. At that time, vacuum therapy still had a marginal role and numbers of patients

were small. Use of vacuum therapy for palliative purposes in wound therapy would have been unthinkable. Increasingly positive therapeutic experience and improved handling of the materials and equipment have resulted in a rapid expansion in indications for this method.

During this time, emphasis has shifted to treating extensive wounds with a focus on septic surgery under intensive care conditions. The number of patients with simpler and smaller wounds has gone up, but there has been a simultaneous decrease in the duration of therapy. In more severe cases, the number of therapy days has increased due to both an increase in the number of patients and improved survival. However, the indications for vacuum therapy expanded rapidly in the public scientific forum. The same process helped to crystallise notions of absolute and relative contraindications for the procedure, the latter of which were generally accepted with little controversy, while the palliative aspect was almost completely ignored. It has, however, been our experience that reasonable palliative indications for vacuum therapy apply particularly in situations that are generally considered contraindications for this procedure. Current indications for palliative vacuum therapy are:

- Exulcerating, neoplastic wounds in the (pre-)final disease stage
- Extensive surface wounds without possibility of reconstruction due to:
 - Localisation
 - Age of the patient
 - General health
 - Underlying disease
 - Chemical factors (small bowel secretion, radiation damage etc.)
- Socially limiting wounds and defects
- Wounds and defects in moribund patients
- Frequent, very painful dressing changes
- Immobilising wounds and defects

It rapidly became clear that the palliative aspect of wound treatment is not restricted to life-threatening or life-limiting situations but is relevant for situations in "routine" wound management.

Own Experiences (Case Reports)

In 2005, we used VAC therapy in a total of 16 patients with either exclusively palliative intention or converted to palliation after initially treating with a more hopeful prognosis. In seven other patients, the therapy was used exclusively for control of symptoms.

Case 1

Generalised Skin, Subcutaneous Fat and Muscle Necrosis

Diagnosis

Wegener's granulomatosis
 Recurrent sepsis
Salmonella typhimurium enteritis
 Disseminated intravascular coagulation (DIC)
 Acute renal failure
 Fungal pneumonia

Histology

Necrotising vasculitis

Bacteriology

Enterococcus faecium
Escherichia coli
Candida glabrata

Clinical Course

This young 36-year-old patient had already been diagnosed with Wegener's granulomatosis and he had already experienced recurrent sepsis while on immunosuppressive therapy. The current admission was also for treatment of sepsis. Two days after admission, the patient developed a map-like pattern of necroses, first affecting the thigh, then spreading to the buttocks (Fig. B28.1 and 2). MRI showed viable muscle without evidence of fasciitis. A biopsy obtained from the distal thigh showed necrosis limited to the skin and subcutaneous tissue.

We performed a resection of the entire necrotic tissue area including subjacent fascia with subsequent vacuum therapy. The tissue underlying the fascia remained viable.

Subsequent procedures revealed continued spread of necrotic tissue. After the soft tissue had been stripped down to the final layers overlying the large vessels and



Fig. B28.1 Map-like pattern of necroses, first affecting the thigh.



Fig. B28.2 Necroses, spreading to the buttocks.



Fig. B28.3 Soft tissue had been stripped down to the final layers.

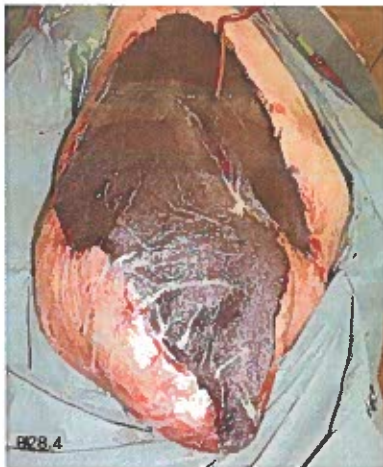


Fig. B28.4 Above-knee amputation.



Fig. B28.5 Left mastectomy with removal of 1.5 kg of tumor tissue. Subsequent unsuccessful attempt to close the wound by a full-thickness skin transplant.



Fig. B28.6 Palliative vacuum therapy to close the wound.

nerves (Fig. B28.3), the patient underwent above-knee amputation (Fig. B28.4). At this point, it was clear that the prognosis was grave, because the necroses had spread to the abdominal wall including the peritoneum and new necrotic zones had formed over the entire lateral thoracic wall. Vacuum therapy was continued with the exclusive purpose of facilitating the care of this terminally ill patient and making it possible for him to receive visits from his family.

Case 2

Extensive Post-Mastectomy Soft Tissue Defect

Diagnosis

Osseous, hepatic, lymphogenic and pleural metastatic left mammary carcinoma (cT4d cN3 M1 G III, estrogen receptor and progesterone receptor IRS 0, Her2/newly negative). TNM classification: ypT4 NX, MX, Grade III.

History

Patient noticed the tumor 2.5 years earlier during lactation. First diagnosis three months before inpatient admission; status post radiochemotherapy, nevertheless progression

Surgical Treatment

Left mastectomy with removal of 1.5 kg of tumor tissue. Subsequent unsuccessful attempt at closure with a full-thickness skin transplant.

Clinical Course

An undifferentiated mammary carcinoma had been diagnosed in this 34-year-old female patient three months prior to inpatient admission. At the time of diagnosis, the tumor had already metastasised extensively. The patient underwent palliative radiochemotherapy but rapid progression continued. The patient herself had noticed a lump about 2.5 years earlier while lactating but a punch

biopsy at that time was negative. On admission, examination revealed a huge and painful tumor of the left breast with threatened exulceration and an extensive mastectomy with removal of tissue to the chest wall was performed. An attempt at closure with a full-thickness skin graft was unsuccessful. The remaining large defect was extremely foul-smelling, painful and heavily draining, such that use of conventional dressing materials required dressing changes every three to four hours. Under such conditions, the parents could not consider permitting the patient's young son to visit his mother. Despite the presence of a clear contraindication, we decided to proceed with vacuum therapy of the wound, though under minimum suction, in order to keep the risk of

any proliferation of malignant tissue as low as possible. Dressing changes were also performed less frequently than usual and the patient received prior medication for analgesia and sedation. As a result, the wound was externally dry, nearly odor-free and visually tolerable for the patient. The odour and appearance had been so repugnant for the patient that she no longer wished to eat or receive visitors. With intensive pain therapy and further palliative measures, such as insertion of chest tubes for drainage of malignant pleural effusion, the patient remained able up to the point of her death to receive visits from her family, including her young son, and friends.

Vacuum therapy allows for safe control of symptoms and pain reduction in both hospitalised and ambulatory patients with catastrophic wounds. This therapeutic concept not only provides palliation for the patient but can represent a real improvement for the patient's family and friends, as well as for nursing and medical personnel. Vacuum therapy does not require significant work from nursing staff, does not affect positioning requirements (water mattress in intensive care medicine, decubitus prophylaxis) or ambulation, and prevents secondary damage (skin maceration etc.). In such cases, only vacuum therapy assures a dignified end of life and a humane death in the company of one's family. Palliation in the field of wound treatment, while not an absolute requirement, is an ethical expectation. One can hope that, like adequate pain management, vacuum therapy will become a standard aspect of palliative wound therapy.

Part C

Case Reports

Teil C

Case Reports

Traumatology / Orthopedic Surgery / Plastic Surgery - Hand Surgery

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The following section includes 30 case presentations taken from the fields of trauma surgery, orthopaedics, plastic surgery, abdominal and thoracic surgery, vascular surgery and dermatology. The sequence of the disciplines follows the order of Part B. Cases have been selected that, in the opinion of the authors, are of especial interest on technical, historical, didactic or medical grounds.

◆ Case 1 - The "Historical" Case - C. Willy

History

A 34-year-old Palestinian male was referred to us from Jerusalem in November 2000. He had undergone vascular reconstruction in the popliteal region of the left leg after gunshot wounds to both knee areas. He had no bone involvement.

Clinical Findings

The patient had bilateral compartment syndrome on admission to the emergency room. All wounds were closed (no open treatment of war wounds!).

Therapy / Course

Second-look surgery of all (sutured) soft-tissue wounds, soft-tissue debridement and dermatofasciotomy of all four compartments on the left side and dermatofasciotomy of the anterior compartment on the right side (Fig. C1.1-6).



Fig. C1.1 Findings on admission. All wounds were closed. Compartment syndrome on both sides.

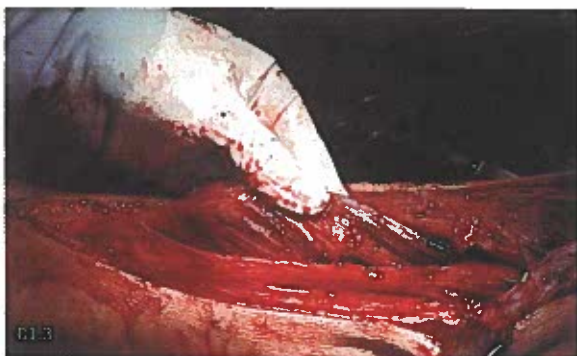


Fig. C1.3 Debridement of the left lower leg. Excision of necrotic muscle tissue.

Comments

An excessive amount of foam was used. Today, the wounds would be managed using polyurethane (PU) foam and one therapy unit with a Y connector or two units if the limbs were to be treated separately. It should also be noted that large surfaces covered by polyvinyl alcohol (PVA) foam can be drained using a single *trac-pad connector*, provided a lower negative pressure (< 150 mmHg) is used. Stoma paste is no longer used in our hospital to seal the foam dressings more securely. Experience has shown that stoma paste becomes increasingly dry and hard with time. There were even cases where hardened stoma paste had caused pressure damage.



Fig. C1.2 Lateral fasciotomy on the left side. The incision extends from the proximal tibia to the forefoot.



Fig. C1.4 PVA foam, which was the only type of foam available at that time, was used for sealing the lateral wound of the left leg. A tube was incorporated into the foam. The fasciotomy wound extended from the tibia to the forefoot. Fluid was removed transcutaneously from the wound through the tubes. Pieces of foam were cut to the size and shape of the wound and stapled *in situ*. Stoma paste was spread around the wound edges to level uneven surfaces and ensure a good seal.



Fig. C1.5 Vacuum therapy was also used for closing the medial fasciotomy wound.



Fig. C1.6 The sealed dressing. Since it was assumed at that time that each piece of foam required its own drainage, a total of 15 foam pieces (on both legs) had to be drained. Redon drains were usually employed for this purpose, and thus 15 were inserted. Time and again, small leaks caused a loss of suction and required the replacement of drains. This type of vacuum source thus required 24-hour attention.

◆ Case 2 - Osteomyelitis of the Patella - J. Kelm and K. Anagnostakos

History

A 66-year-old female patient suffering from destructive osteomyelitis of the patella and a prepatellar skin defect (Fig. C2.1) after a burn injury with consecutive, unsuccessful mesh-graft transplantations.

Clinical Findings

A strain of *Pseudomonas aeruginosa* was isolated from the wound.

Therapy / Course

The infection was treated surgically by patellectomy (Fig. C2.2), debridement, soft tissue reconstruction of the extension apparatus, and vacuum therapy (negative pressure 125 mmHg, continuous mode). Two weeks later, a second operation with arthrotomy was necessary because of a subsequent substance defect of the extension mechanism. After debridement the joint defect was closed by mobilizing the vastus medialis muscle and the quadriceps tendon. After conditioning of the soft tissues by means of further vacuum therapy (negative pressure 125 mm Hg, continuous mode), it was possible to cover the soft tissue with a mesh-graft transplant from the right upper arm (Fig. C2.3). The extremity was then immobilized by means of a Mecnron-splint for six weeks. The surgical treatment during the whole in-patient stay was supported by adjuvant oral antibiotics (levofloxacin based on culture and sensitivity). Inflammation parameters decreased constantly and there were no complications during postoperative treatment (Fig. C2.4-6).

Comment

Osteomyelitis of the patella is quite rare in adults¹. Depending on clinical and radiologic findings as well as the agent, its virulence, stage of the infection, effects on soft tissue and the patient's general physical condition, there exist a variety of therapeutic alternatives (intravenous antibiotics according to sensitivities, surgical treatment with debridement, lavage, irrigation-suction drainage and patellectomy)³. The most frequent pathogenic organisms isolated in cases of osteomyelitis of the patella are strains of *Staphylococcus aureus*³. The literature includes only two cases in which strain of *Pseudomonas aeruginosa* was responsible for osteomyelitis of the patella^{2,4}. Due to the agent's resistance,

one patient developed encephalopathy during treatment⁴.

In the case described above, enucleation of the patella was necessary for eradication of the infection because of the distinct local findings. Although little is known regarding the use of vacuum therapy in septic orthopaedic surgery and there is a need for studies with larger numbers of patients to establish an indication for this method, vacuum therapy seems to be an effective option in the treatment of difficult infections of the musculoskeletal system.

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Fig. C2.1 Initial findings of osteomyelitis of the patella caused by *Pseudomonas aeruginosa* with distinct necroses of the soft tissue in the region of the extension mechanism.



Fig. C2.2 Eighteenth postoperative day after enucleation of the patella. Soft tissues conditioned by vacuum therapy. Arthrotomy due to substance loss in the medial part of the primarily reconstructed extension apparatus.



Fig. C2.3 Mesh-graft transplant of the contralateral upper arm (enlargement factor: 1.5, layer thickness: 0.3 mm) after having achieved tension-free secondary reconstruction of the extension apparatus with joint closure.



Fig. C2.4 A 100% take rate of the transplant with almost perfect epithelization on the ninth postoperative day after mesh-graft transplantation.



Fig. C2.5 Completely epithelialized transplant on the eighteenth day after mesh-graft transplantation.



Fig. C2.6 State of healing after six months.

◆ **Case 3 - Vacuum Therapy as a Medical Treatment Option in Wound Healing Complications After Achilles Tendon Reconstruction**
K. Anagnostakos, J. Kelm and E. Schmitt

Background

The purpose of this report is to describe our experience with the successful application of vacuum assisted closure in the treatment of postoperative wound healing complications after Achilles tendon reconstruction.

History

A 66-year-old male presented to our hospital suffering from an old Achilles tendon rupture. He had been having complaints for about one year and predisposing factors (corticosteroids, diabetes mellitus, rheumatic arthritis) were excluded by history. The patient was treated with warfarin because of cardiac rhythm disturbances. The injury was confirmed by magnetic resonance imaging (MRI) and reconstructed by an augmented tenoplasty. The ankle was postoperatively immobilized in a lower leg splint at 15° plantar flexion. Since there were no complications during the patient's stay in hospital, he was discharged after 12 days. Initially, there were no complications. However, 11 weeks after surgery, the patient returned to our clinic.

Clinical Findings

The patient returned to our clinic suffering from an open wound and local inflammatory signs. Operative debridement and *jet-lavage* followed. In addition, the wound was treated with vacuum therapy with application of a polyvinyl alcohol (PVA) foam and an initial negative pressure of 200 mmHg. No pathogenic organisms were identified on wound cultures. The histological examination revealed moderate chronic and active cicatricial, granulating, non-specific inflammation as well as a number of fresh necrosis with focal bleeding and fibrin deposits.

Therapy / Course

Adjuvant systemic broad-spectrum antibiotics were started to eradicate the infection. After three, six and 14 days, the foam was exchanged, the wound was opened, cleaned and reduced in size in proximal to caudal direction under progressive wound sealing. As soon as the granulation tissue started to proliferate (Fig. C3.1), the negative pressure was reduced to 150 and then 100 mmHg.

Since the local wound conditions improved and inflammation parameters decreased, the patient was discharged from the hospital after three weeks. After further successful ambulatory wound conditioning by means of vacuum therapy, it was possible to apply a mesh-graft transplant (Fig. C3.2) from the right upper left thigh (enlargement factor 1.5; layer thickness 0.3 mm). Vacuum therapy was restarted with a negative pressure of 150 mmHg (Fig. C3.3); the foam was exchanged only once after five days. There were no complications during the healing process or during the subsequent routine follow-up for 31 months (Fig. C3.4).

Comments

Wound healing complications after Achilles tendon surgeries are quite frequent. The complication rate is about 5%³, with trophic skin defects being the most frequent complications reported¹. The healing of tendons requires an intact peritendineum. If the peritendineum is destroyed or incompletely reconstructed, wound healing is protracted⁴. Heugel et al.⁴ reported on the successful use of vacuum therapy in the treatment of protracted wound healing of the Achilles tendon after burns. Adequate vascularization was achieved within 12 days by applying negative pressure, and the defect was covered by mesh-graft transplantation.

We used vacuum therapy in the treatment of infection after Achilles tendon reconstruction due to its effects on proliferation of granulation tissue and its bacterial clearance function¹. We exchanged the foams at regular intervals and constantly inspected the secretion drained from the wound. We observed that a thin granulation layer had started covering the tendon without tissue desiccation. There were no local irritations of the skin caused by high negative pressure. When we were content with the conditioning of the wound bed, we placed a mesh-graft transplant on the new granulation layer. Vacuum therapy then kept the foam optimally positioned in the wound bed, enabling adequate drainage of wound secretion from the wound. Nursing care was reduced to one single exchange of the bandage before attachment of the

transplant to the skin. This underscores vacuum therapy's contribution to minimization of costs.

Conclusion

Vacuum therapy appears to be an efficient therapy option even in the fields with problematic tissue perfusion. After wound preconditioning, the growth of the mesh-graft transplant can be optimised and costs can be minimized because the therapy can be continued on an outpatient basis.



Fig. C3.1 Beginning formation of granulation tissue after continuous application of vacuum therapy.



Fig. C3.2 Mesh-graft transplantation (enlargement factor 1.5; layer thickness 0.3 mm) from the ipsilateral upper left thigh.



Fig. C3.3 Vacuum therapy with a polyvinyl alcohol foam, covering the mesh-graft, continuous pressure of -150 mmHg.



Fig. C3.4 Local findings 2 1/2 years after the end of therapy.

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◆ **Case 4 - Limb Salvage in a Case of Arterial Obstructive Disease and Exposed Tibial and Fibular Bone Using Vacuum Therapy and Split-Thickness Skin Grafting**
A. Grimm, M. Leffler, U. Kneser and R. E. Horsch

History

A multimorbid 79-year old female patient suffered from an extensive circular ulcer on her left lower leg following an impact trauma more than 15 months previously. She initially underwent several conservative treatment attempts. However, due to progressive deterioration of the patient's general condition along with an increasing soft tissue infection of her lower leg in combination with her history of arterial obstructive disease there was serious consideration of limb amputation. Because there was no possibility for surgical revascularisation, above-knee amputation was contemplated. The patient's medical history includes cardiomyopathy with chronic heart failure, chronic renal failure, renal anemia, struma nodosa, osteoporosis and weight loss of 20 kg within the last few months.

Clinical Findings

On admission the patient was in poor general health. Inflammatory serum parameters including elevated CRP and leukocytosis were found. Wound extension included nearly the whole lower leg and the wound was superinfected. Almost all flexor and extensor tendons were exposed in the wound bed. The tendons were partly desiccated and necrotic. Especially the anterior tibial and gastrocnemius muscles were exposed, as well as long portions of the Achilles tendon and the distal tibial and fibular bone (Fig. C4.1). Due to the circular wound, the distal foot was highly edematous with livid skin colour. Furthermore, there was phlegmonous inflammation of the whole foot and lower leg. The patient strictly refused above knee amputation. Therefore an effort was made to clean the wound and induce granulation tissue via vacuum therapy on a trial basis.

Therapy / Course

Initially, extensive radical debridement with the resection of any necrotic tendons, fascia and muscle portions as well as parts of the necrotically disintegrated tibial and fibular periosteum were performed. Afterwards the defect was vacuum sealed with a large polyurethane foam and continuous suction was applied (125 mmHg).

As early as postoperative day 6 an unexpected improvement of the wound conditions was seen. After the vacuum dressing was removed, induction of granulation tissue was visible. Vacuum therapy was performed for a total of 21 days. During that time two more surgical debridements were done. After three weeks the wound had improved and a clean, transplantable wound bed with dense granulation tissue was observed. In contrast to our expectations vacuum therapy had also led to successive closure of the exposed bone via granulation tissue overgrowth (Fig. C4.2).

Due to the size of the defect and the unstable surrounding tissue, skin for the skin graft was taken from the patient's back. The split-thickness skin graft was meshed extensively (5:1 and 3:1) and fixed. A polyurethane foam was adapted above the skin graft and continuous suction (125 mmHg) was applied. After four days the vacuum seal was removed and 90% of the split-thickness skin graft had healed. After additional local debridement and vacuum therapy for another seven days, progressive re-epithelialization was achieved. Once again minor remaining necrosis was removed, and after seven days of vacuum therapy a small area was additionally grafted with split skin from the thigh. At the end of the operation a polyurethane foam was again adapted above the skin graft and continuous suction (125 mmHg) was applied. After removing the foam on postoperative day 7 a 100% take of the skin graft was seen. The patient was discharged seven weeks after admission with an almost completely healed wound (Fig. C4.3). Serum parameters were normal and the edemous appearance of the leg had completely disappeared. At the time of discharge, the patient was completely ambulated with physiotherapeutic support. On follow-up examinations one year later, wound conditions were unchanged, with the soft tissue of the lower leg still covered.

Comment

Large wounds and soft tissue defects of the lower leg with exposed bone or tendons after soft tissue inflammation or infection, burns or radical surgical debridements are



Fig. C4.1 Preoperative view: superinfected wound with exposed bone of tibia and fibula, exposed muscles, and exposed flexor and extensor tendons.



Fig. C4.2 After three weeks of vacuum therapy and radical surgical debridement: induction of granulation tissue on the wound ground has been achieved. A split-thickness skin graft was performed.



Fig. C4.3 Situation at the time of discharge: complete re-epithelialisation of the whole wound has been achieved.

a serious clinical problem. Moreover, especially in cases of chronic wounds in older patients, vascularization of the leg is often critical because of a history of arterial obstructive disease. The possibilities of covering the soft tissue by means of tissue transfer from the local environment are limited. Especially in cases of extensive burns or in older patients with other severe medical problems, free tissue transfer is not always possible. Therefore, amputation is the only remaining possibility if the wound conditions lead to severe infection and sepsis which could

be life-threatening. Introduction of vacuum therapy via insertion of a plastic foam into the wound with air-tight sealing and creation of a vacuum has considerably changed the treatment regime for these severe complex wounds.

Our case report demonstrates that vacuum therapy could result in limb salvage in a wound condition that usually leads to leg amputation. We showed that, with vacuum therapy, complete coverage of the wound and exposed bone and tendon structures with granulation tissue can be achieved even in a poorly vascularized region such as the lower leg. In addition to radical surgical debridement, vacuum therapy represents a supportive treatment option even in therapy-resistant problematic wounds.

◆ Case 5 - Care of an Amputation Stump - G. Bergenthal and C. Willy

History

In August 2002, an 18-year-old female motorbike passenger was brought to the emergency room after she was injured in an accident. She had been thrown from the motorbike and run over by a truck. The patient was responsive at the scene of the accident. She was intubated by the emergency physician and taken to the hospital by helicopter.

Examination findings

The patient sustained an extensive soft-tissue avulsion injury. She had a degloving injury of the leg, commencing at the level of the left gluteal fold and medially limited by the external genitalia. In addition, the patient had an extensive degloving injury of the left upper thigh, a comminuted fracture of the femur at the junc-

tion of the middle and distal thirds, a type III to IV open fracture of the proximal tibia, and discontinuity of the femoral artery and tibial nerve at the level of the knee joint (Fig. C5.1). The patient was in severe hypovolemic shock. There were no signs of sufficient nutritive perfusion in the periphery of the leg. The mangled extremity severity score (MESS) was 8.

Treatment/Course

On admission, an emergency amputation of the left leg was performed. In addition, open wound treatment was instituted after vaginal tamponade and insertion of a rectal tube. Daily revisions and dressing changes were performed (Fig. C5.2-3). Hyperbaric oxygen therapy was commenced on the fourth postoperative day for suspected soft-tissue infection. The extensive degloving injury,



Fig. C5.1 Findings on admission. Comminution of the knee, discontinuity of the tibial nerve at the level of the knee joint, and rupture of the superficial femoral artery (mangled extremity severity score: 8).



Fig. C5.2 Second postoperative day. After amputation. Second-look surgery, before debridement.

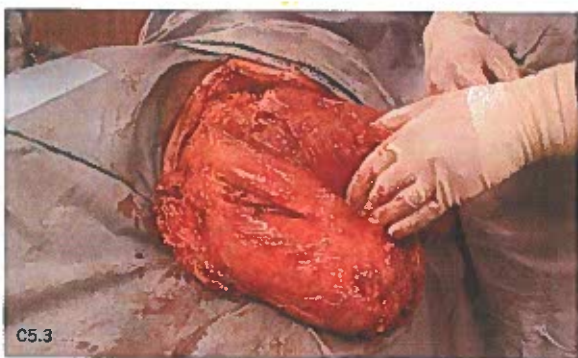


Fig. C5.3 Second postoperative day. After amputation. Second-look surgery, after debridement.



Fig. C5.4 Tenth postoperative day. Institution of vacuum therapy with 7.5 cm by 15 cm pieces of PVA foam with drainage tubes embedded in the foam. At that time, it was believed that each drainage tube required its own suction source due to the low transmission of the suction force in PVA foam. For this reason, a manifold was connected to a single source of suction.

which extended from the perineal area to the level of the gluteal fold in the dorsal direction, required a double-barrel colostomy on the fifth postoperative day in order to protect the wounds against bacterial colonization. On the tenth postoperative day, the decision was made to institute vacuum therapy using polyvinyl alcohol (PVA) foam (Fig. C5.4). The foam dressing was changed twice. On the 18th day post surgery, the clean wound was covered with mesh-grafts (Fig. C5.5-7). Polyurethane (PU) foam was placed onto the split-thickness skin grafts and a protective Mepitel non-adherent dressing (Fig. C5.7-10). The wound was assessed for the first time after five days (on the 23rd postoperative day; Fig. C5.11). The skin graft adhered well (> 95% take rate) and the remaining minor wound healed by secondary intention.

At clinical follow up six months after the accident, the amputation stump had healed and a prosthesis had been fitted.

Comments

This was the first case where polyurethane foam was used as the material of choice in our hospital. Since then (2002) we have increasingly been using PU foam. It is evident that it is much easier for clinicians to handle this type of foam and use it for large wounds.

Fig. C5.5 Eighteenth postoperative day after three dressing changes. The presence of a clean wound and granulation tissue provided a good basis for meshed split-thickness skin grafts.



Fig. C5.6 Eighteenth postoperative day after application of meshed split-thickness skin grafts.



Fig. C5.7 Eighteenth postoperative day. The meshed split-thickness skin grafts were covered with a protective Mepitel non-adherent dressing in order to prevent tissue from growing into the PU foam.



Fig. C5.8 Eighteenth postoperative day. A large (60 cm by 30 cm by 2.5 cm) piece of PU foam was cut to the size of the amputation stump and placed onto the non-adherent dressing.



Fig. C5.9 Eighteenth postoperative day. The PU foam was cut to the size and shape of the amputation stump.



Fig. C5.10 Eighteenth postoperative day. The PU foam was placed under negative pressure. A single *trac pad connector* was used to maintain the target pressure of 125 mmHg. A flat piece of foam was cut and shaped to fit the stump and then attached to the remaining skin using standard skin staples. After the foam dressing was sealed, negative pressure was applied. The wound was thus hygienically covered. Despite the difficult site of repair, it was possible to maintain an air-tight seal. Since the wound was covered with a dry and securely fitted dressing, it provided a high level of patient comfort. In addition, the dressing helped shape the amputation stump.



Fig. C5.11 Twenty-third postoperative day. Removal of the PU foam and the protective Mepitel dressing.



Fig. C5.12 Six months after the accident. The patient had already been fitted with a prosthesis.

History

A 38-year-old Afghan soldier sustained a deep penetrating wound to the right forearm without bone involvement while he was attempting to remove a mine.

Examination findings

Treatment was instituted approximately 18 hours after the incident. Blood flow was adequate. Motor abilities and sensation were difficult to assess due to pain (the post-operative patient showed non-relevant partial loss of sensation in the area of the ulnar nerve). Radiological examination revealed no bone damage but the presence of foreign bodies (clay and soil particles, small stones).

Treatment/course

On the day of admission, the patient underwent surgical excision of the wound edges and extensive debridement. A counter-incision was made to remove tissue fragments and foreign material. After *jet lavage*, vacuum therapy with polyurethane foam was instituted.

Systemic antibiotics were administered. *Second-look* surgery, further debridement, further *jet lavage*, partial wound closure, and vacuum therapy and afterwards and flap surgery were performed (fig. C6.1-13).

Comments

Surgery was performed under deployment conditions in a field hospital (ISAF, Kabul, Afghanistan). Contaminated war wounds are particularly suited for treatment with vacuum therapy since they can be covered safely and hygienically using this technique. We can thus perhaps modify the long-standing principle of military surgery that wounds must not be closed. It is at least possible to seal war wounds. This has the additional advantage that a wound can be more easily observed and managed during emergency repatriation when it is covered with a sealed vacuum dressing. Even in the case of heavily exuding wounds, a vacuum dressing usually does not need to be changed in the confined space of an aircraft.



Fig. C6.1 Findings on admission. The first step of treatment was to clean the skin with a brush and povidone iodine in the emergency room.



Fig. C6.2-3 Radiographs of the forearm were taken in two planes. At the mid-shaft level, foreign bodies can be seen predominantly between the bones on the dorsal and volar sides of the forearm.

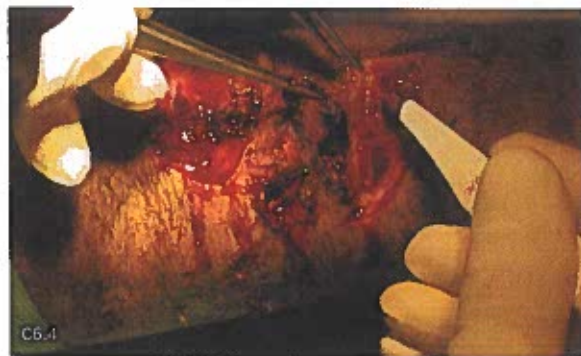


Fig. C6.4 Surgical excision of the wound edges and debridement.



Fig. C6.5 Extension of the wound in the proximal and distal directions and removal of numerous loam particles and small stones.

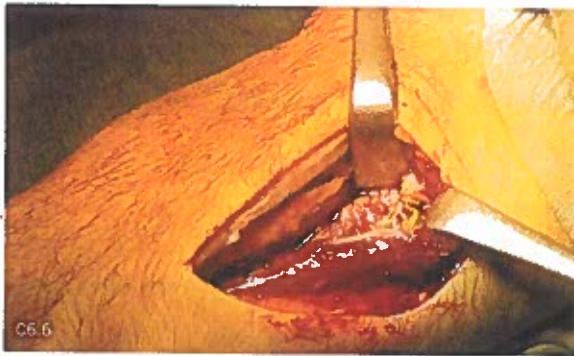


Fig. C6.6 Counter-incision and removal of further foreign bodies.



Fig. C6.7 Jet lavage.



Fig. C6.8 After debridement and jet lavage. The picture shows a large soft-tissue defect with exposed extensor tendons.



Fig. C6.9 PU foam is placed into the wound between the bones. In the picture, the foam can be seen between the extensor tendons.



Fig. C6.10 At the end of surgery. The foam dressing was sealed. The bridging technique was used to treat three wounds with only one vacuum therapy unit.



Fig. C6.11 First postoperative day. The wound was clean and required only minimal redebridement. Jet lavage and vacuum therapy were repeated.

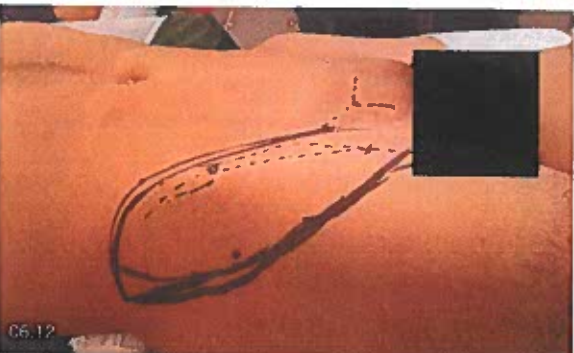


Fig. C6.12 Flap surgery was prepared (third postoperative day, the wound was clean and healthy).



Fig. C6.13 The 5 cm by 6 cm large defect with exposed tendons was completely covered with a flap.

◆ Case 7 - Gunshot Wound of the Forefoot - C. Willy

History

A 63-year-old hunter was brought to the hospital after he shot himself through the forefoot in a self-inflicted accident. Treatment was instituted approximately three hours after trauma.

Examination Findings

The patient sustained a gunshot injury. The entry wound was on the dorsal side of the forefoot, the exit wound on the plantar side. Blood flow was adequate. It was impossible to assess the patient's motor abilities. Normal sensation in the region of the lateral sole of the foot, hypaesthesia in the medial region. Radiological examination revealed a comminuted fracture of the first digit, a shattered second digit, fracture-dislocations of the third and fourth digits, and a subcapital fracture of the fifth digit (Fig. C7.1 and 2).

Treatment/Course

Surgical excision of the wound edges and extensive debridement of the plantar and dorsal sides of the forefoot. Thorough lavage. An external fixator was applied to the proximal phalanx of the first digit and the calcaneus.

Provisional stabilisation of the fourth and fifth digits with K-wire. Vacuum therapy was instituted. First, polyvinyl alcohol foam was placed into the wound in the dorso-plantar direction. The entire wound was then covered with a piece of foam. The foam dressings were changed seven times. At each dressing change, wound size was found to be reduced. After three and a half weeks of treatment, the wound was finally closed by secondary suture. Uneventful wound healing and ambulation (Fig. C7.3-9).



Fig. C7.1 Findings on admission. Comminuted fracture of the first digit, shattered second digit, fracture-dislocations of the third and fourth digits, and subcapital fracture of the fifth digit. Foreign material and bone fragments along the path of the bullet in the region of the second and third digits.



Abb. C7.2 Postoperative control x-ray. An external fixator was used from the proximal phalanx of the first digit to the calcaneus. Temporary stabilisation of the fourth and fifth digits using K-wire.



Fig. C7.3 Third postoperative day. The picture shows the dorsal site at the time of the second dressing change after several debridements and the application of an external fixator.



Fig. C7.4 Third postoperative day. The picture shows the plantar site at the time of the second dressing change.

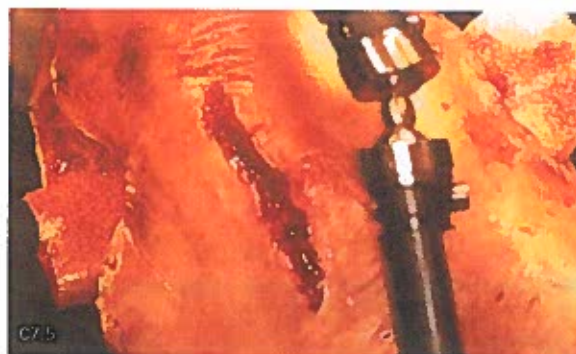


Fig. C7.5 Insertion of the polyvinyl alcohol foam in the dorsoplantar direction along the path of the bullet.



Fig. C7.6 Eighth postoperative day. The plantar defect is completely covered with polyvinyl alcohol foam.



Fig. C7.7 Eleventh postoperative day. The foam becomes increasingly smaller. The picture shows the dorsal side of the foot.



Fig. C7.8 Two and a half months after trauma. The picture shows the plantar side of the foot. The wound had been closed by secondary suture after three and a half weeks.



Fig. C7.9 Two and a half months after trauma. The picture shows the dorsum of the foot.

◆ Case 8 - Fournier Gangrene Following Anorectal Abscess - T. Karl

History

A 73-year-old male presented with a one-week history of perineal pain, constipation and dysuria. His past medical history was significant for hypertension, type IIb diabetes mellitus and coronary artery disease. Because of absolute tachyarrhythmia he was taking oral anticoagulants.

Findings

Rectal endosonography showed the typical formation of an abscess at 5 o'clock in the lithotomy position.

Therapy/Course

One day after admission to the hospital the abscess was opened and a thread was laid in. The following day the patient developed a septic illness and was transferred to the intensive care unit. Computed tomography of the pelvis the same day showed a huge anorectal abscess. On day four after admission local revision with drainage of the abscess and placement of an anus praeter followed. Later the patient developed Fournier's gangrene. Therefore one week later the complete skin and subcutis of the external genitalia had to be stripped. Initial bacteriology of the wound showed *E. coli*, *Streptococcus anginosus* and *Bacteroides fragilis*. Vacuum therapy was started two days later.

Because of the localization of the wound and the previous operations, application of vacuum therapy was difficult. The external genitalia had to be covered without promoting granulation of the glans penis. The pararectal abscess had to be drained with a polyurethane foam while the anus praeter had to be left uncovered. Together, this required a complex technique and combination of different materials.

Despite these difficulties, adequate seal was obtained with vacuum therapy system. Seven polyurethane changes followed in the next 16 days. By this time, good granulation was seen and the wound was free of fibrin and necrosis. Although the local result was satisfactory and still improving, a progressive failure of multiple organs occurred (heart/circulation, lungs, kidneys and liver). Three days later the patient died despite continued intensive care.

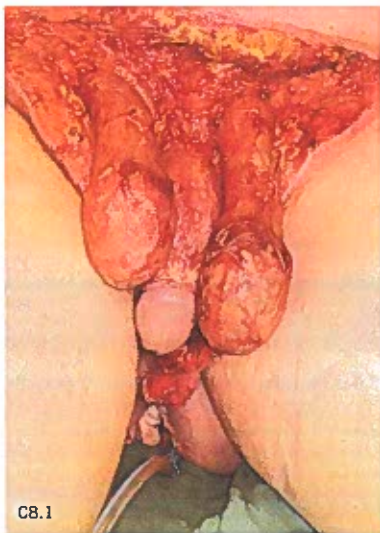


Fig. C8.1 After one week, the skin and subcutis of the external genitalia were completely stripped.



Fig. C8.2 Pararectal excisions.



Fig. C8.3 Skin protection before application of the vacuum therapy foam by hydrocolloid-dressing (Comfeel®, Coloplast, first-degree pressure sore) and additional thin polyurethane foam (Allevyn thin®, Fa. Smith & Nephew).

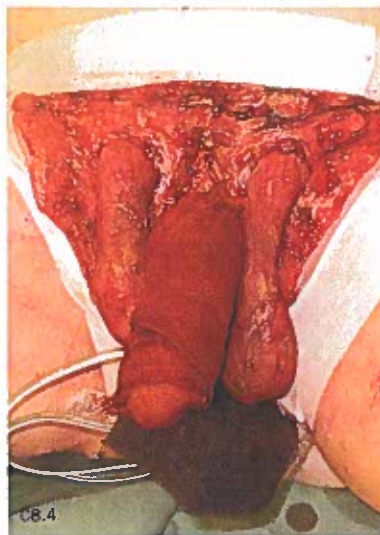


Fig. C8.4 After application of PU-foams dorsal, insertion of two Redon-drainages into the pararectal wounds and application of the adhesive drapes now supine position of the patient. Skin protection ventral. To avoid granulation tissue on the penis protection by PVP iodine gauze.



Fig. C8.5 After application of the vacuum therapy polyurethane foam and adhesive drapes, two trac-pad connectors were attached.



Fig. C8.6 Site after application of the negative pressure (125 mm Hg, continuous suction).

◆ Case 9 - Extensive Soft Tissue Damage of the Pelvic Floor - W. Lange

History

A 45-year-old male patient had a luxation fracture of the tenth and eleventh thoracic vertebrae with consecutive paraplegia below T11 including vesical and rectal paralysis. At eight months after the accident decubitus ulcers were diagnosed on both sides in the area of the *tuber ischiadicum*. Plastic reconstructive surgery of these ulcers was initially successful, however, in the subsequent years additional operations were performed to treat recurrent ulcers. A few years later, the patient suffered from a fracture of the femoral neck, which required surgery. Approximately three years later, both hip joints had to be removed because of an infection of the osteosynthesis material concurrent with extensive soft tissue damage. The following year plastic surgical treatment of a new decubital ulcer was carried out. Due to urethral destruction with perineal fistulas caused by the perforation of a penile prosthesis, the prosthesis was removed and an ileum conduit was inserted to ensure urinary flow. Subsequently, reconstructive surgical treatment of the decubitus was retried. Finally, the patient was admitted to the hospital with seriously high fever and anaemia.

Diagnostic findings

In the area of the pelvic floor, we found a large, infected soft tissue defect extending to the sockets of the explanted hip joints with accompanying fistulation involving both the urinary bladder and the rectum (Figs. C9.1-3).

Treatment / Course

After eight previous attempts at reconstructive surgery together with the existing incontinence and extensive rectal fistula formation another reconstructive operation did not seem reasonable. Therefore, as a first step, an abdominoperineal excision of the rectum was performed, placing the terminal colostomy at the left side of the hypogastrium opposite the urostomy. After adequate preparation of the patient, which included cleansing of the soft tissue damage with activated charcoal dressings, the above described operation was performed. Surgery proceeded without any complications. Two days after the operation vacuum therapy was started (Figs. C9.4-5) using a continuous suction of 125 mmHg. Redressing of the wound was conducted every second day. Wound healing proceeded satisfactorily with a continuous decrease in secretion and wound size (Figs. C9.6-8). During this time the patient's overall condition improved. After approximately 10 weeks of vacuum therapy, reduction of the tissue damage allowed a change-over to the battery-operated Mini-VAC system (Fig. C9.9). The patient was then discharged and continued to receive ambulatory wound treatments. Dressing changes were performed three times a week (Fig. C9.10).



Fig. C9.1 Diagnostic findings on admission: extensive, infected tissue damage at the pelvic floor (lateral position).



Fig. C9.2 Diagnostic findings on admission: perineal soft tissue damage reaching into the antra of the replaced hip joints (lithotomy position).

Comment

The case report presented here shows that extensive and complicated soft tissue damage can be successfully treated vacuum therapy, demonstrating, in particular, that it is even possible to use the small, battery-powered and portable vacuum therapy unit. In this case report, vacuum therapy offered the patient a relatively comfortable and less invasive therapeutic alternative to reconstructive surgical treatment. This treatment option should be considered in similar cases in the future.



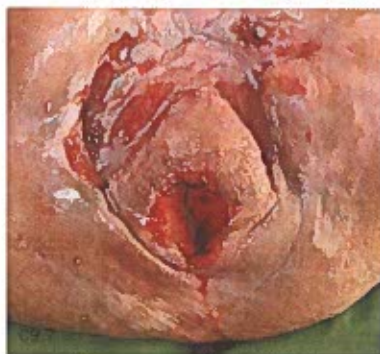
Fig. C9.3 Diagnostic findings on admission; detailed view (lithotomy position).



Fig. C9.4 Second postoperative day after abdominoperineal resection of the rectum before application of the vacuum system (lithotomy position).



Fig. C9.5 Second postoperative day after abdominoperineal excision of the rectum after application of the vacuum therapy system (lithotomy position, continuous suction of 125 mmHg).



Figs C9.6-8 Documentation of wound healing: decrease of the antra and of the soft tissue damage respectively (in-patient treatment).

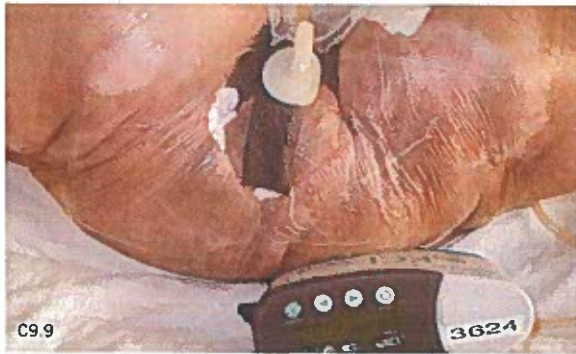


Fig. C9.9 Changeover to the portable vacuum therapy unit approximately 10 weeks after surgery (lithotomy position).



Fig. C9.10 Continuous reduction of the soft tissue damage (out-patient treatment).

◆ **Case 10 - Circular Soft Tissue Defect in a Third-Degree Open Fracture of the Lower Leg - M. Schofer**

History

A 29-year-old female automobile driver involved in a motor vehicle accident suffered, among other serious injuries, a third degree open fracture of her right lower leg and was transported by helicopter from the scene of the accident to our hospital.

Clinical Findings

The patient presented with a third-degree open fracture of the right lower leg including a contaminated circular soft tissue injury.

Therapy / Course

The patient was taken to the operating room the same

day. The fracture was stabilized by external fixation and the lower leg wound was thoroughly debrided. Wound closure was achieved by application of a vacuum dressing. Three weeks into vacuum therapy the muscles and tendons were sufficiently overgrown with healthy granulation tissue and the defect was covered with a free myocutaneous flap using the latissimus dorsi muscle. A skin mesh-graft covered the remaining wound. Healing of the soft tissue following these procedures was without complication. Due to delayed healing of the fracture, the external fixation was replaced by a tibial nail five month after the accident. The function of the right lower leg remains very good. Due to the extensive scarring the patient was provided with a "lifelike orthosis" (Figs. C10.1-8).



Fig. C10.1-2 Extensive wound debridement of the circular soft tissue defect of the right lower leg. Osteosynthesis by external fixation.

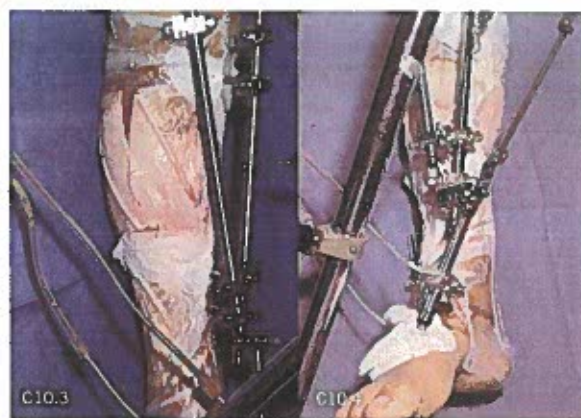


Fig. C10.3-4 Closure of the debrided area by application of a circular vacuum dressing.



Fig. C10.5-6 Transplantation of a free myocutaneous flap (latissimus dorsi muscle) and coverage of the remaining wound with skin mesh-graft after three weeks of vacuum therapy.



Fig. C10.7-8 Cosmetic result of the soft tissue injury; x-ray after replacing the external fixation by a tibial nail.

◆ **Case 11 - Reduction of Edema in "Complex Regional Pain Syndrome"**
(CRPS; Reflex Sympathetic Dystrophy [RSD]) - U. Ziegler

History

A 39-year-old white female patient with persistent CRPS over six months caused by a bruise of the right hand was treated with negative pressure therapy with continuous negative suction strength of 125 mmHg in an "anatomical" foam dressing, the vacuum hand dressing kit.

Therapy / Progress

For skin protection, a perforated silicone film was applied between the foam and the skin. After five days' treatment, a nearly normal contour of the hand was observed and a compression bandage for the hand was applied. A four-week treatment was followed by intensive physiotherapy. During the course of therapy, the patient was followed for pain therapy by the department of anaesthesiology (Figs. C11.1-4).

Comment

Enormous edema of the whole hand may persist after both surgical intervention and minor hand injuries in all types of CRPS. Application of the bandage and physiotherapy is difficult unless the edema has resolved: negative pressure therapy with reduction of the edema can facilitate the treatment of CRPS.



Fig. C11.1 Swollen hand and wrist in a patient with Complex Regional Pain Syndrome.



Fig. C11.2 Covering the intact skin with silicone film to protect the skin from maceration.

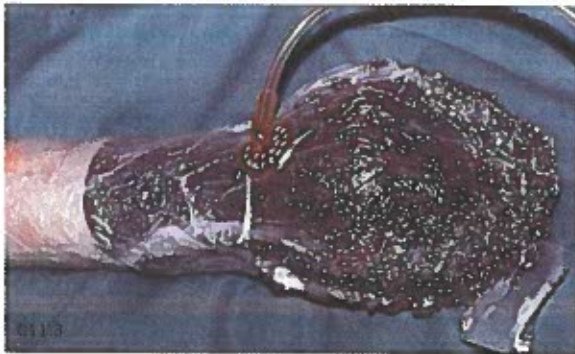


Fig. C11.3 "Anatomical" hand foam dressing after application.



Fig. C11.4 Satisfactory reduction of the edema after negative pressure therapy.

◆ Case 12 - Negative Pressure Therapy in Acute Frost Bites - U. Ziegler

History

Application of negative pressure to wounds can promote granulation tissue through branching and extension of capillaries. This effect was used to the treatment of acute frost bites affecting the lower extremities of a medical student to rescue intact tissue threatened by overwhelming edema. During a winter tour in the Italian Alps, the 28-year-old's mountain boots filled with snow, resulting in IIb and III degree frostbite injury. The student underwent conservative treatment at the local hospital.



Fig. C12.1 IIb and III degree frostbite on the first to fifth digits – dorsal view.

Therapy / Course

Three days after returning home, the blisters were surgically opened and an “anatomical” shoe vacuum foam dressing was applied. Every second day the foam was changed in the operating room under anesthesia. After 10 days of vacuum therapy, an open wound treatment was performed. In the end, only the nails on parts of the distal second to fourth phalanges were lost. Vacuum therapy is useful in both frostbite and burn injuries by reducing edema and facilitating tissue rescue at early stages. (Fig. C12.1-6).



Fig. C12.2 IIb and III degree frostbite on the first to fifth digits – plantar view.



Fig. C12.3 After the surgical debridement, preparation for dressing. Interdigital application of PU foam.



Fig. C12.4 Protection of the intact skin on the foot with silicone foil.



Fig. C12.5 The applied dressing under negative pressure of 125 mmHg.



Fig. C12.6 Viable toes with partial skin maceration on the first through fourth digits.

◆ **Case 13 - Negative Pressure Therapy in Hand Surgery Patients with Severe Infections**
U. Ziegler

Severe infections of the fingers, hand, forearm and upper limb in hand surgery patients can be successfully treated with negative pressure vacuum therapy.

In the period of January 2000 to May 2004 we treated a total of 28 patients with infected soft tissue defects in the hand/forearm region in the Department of Plastic and Hand Surgery of the University Clinic of Würzburg (Germany). Patients included 10 individuals with wounds secondary to dog, fish and human bites, as well as six burns, one instance of paravasation (dorsal surface of the hand) following chemotherapy and 11 cases of local infection after injury (e.g. wooden spoon, circular saw injury etc.). Patients underwent serial debridement, *jet-lavage* and topical negative pressure therapy. Patients' average age was 54.3 years. All patients responded to this therapy supplemented with systemic antibiotic therapy. All defects could be covered with split-thickness skin grafts, local flaps or secondary sutures.

Wounds were prepared for secondary coverage within an average 8.3 days (average number of dressing changes and debridements = 2.3). Threatened infections in patients with severe tissue defects secondary to bites can be treated directly after injury at the first operation with the vacuum therapy. Prophylactic antibiotic therapy is instituted at this time. An early *second look* operation on the same day (in cases with poor circulation) or next day is necessary to remove necrotic tissue, which can promote infection. Foam application and maintaining the vacuum on fingers or the hand can be technically difficult, but, with increasing experience and more refined application techniques, the vacuum can be maintained over a long period of time. If pain should occur during vacuum therapy, patients can receive analgesics, while, in some cases, application of a cast or reduction of the vacuum to 75 mmHg can alleviate the pain (Figs. C13.1-4).



Fig. C13.1 Cellulitis/lymphadenitis and bacterial flexor tenosynovitis of the right hand after a wooden spoon injury in a diabetic patient.



Fig. C13.2 Situation following debridement and application of the foam dressing.



Fig. C13.3 Clean wound after four days of treatment with negative pressure.

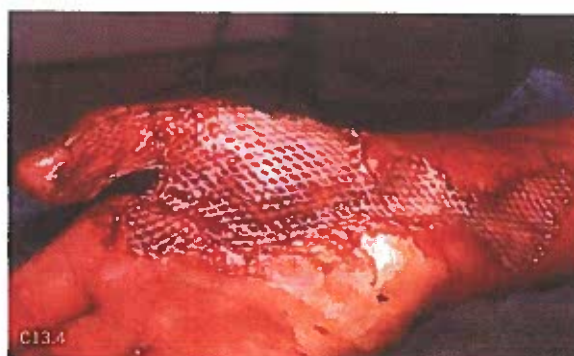


Fig. C13.4 Split-thickness skin graft after five days of combined vacuum therapy.

◆ Case 14 - Therapy of an Impalement Injury with Vacuum Therapy and Dynamic Graciloplasty - G. Zoech and R. Schiessel

History

A 29-year-old man suffered a sacro-perineal impalement injury in a traffic accident in November 1999. The patient's car went into a skid and hit a crash barrier. Elements of the barrier broke, went through the back of the driver's seat, impaling the soft tissue of the pelvis in dorso-cranial direction.

Clinical Findings

The gluteal muscles were detached lateral to the sacrum which was not fractured; there was no damage to the sciatic nerve. The anal canal together with sphincter apparatus was completely disrupted.

Therapy / Course

During an acute operation the first objective was to create a colostomy, followed by cleansing and draining the wound. The patient overcame the acute phase without problems. However, the extensive sacral wound was infected and secreting massively and did not show any healing tendency. Therefore, 15 days after the accident the decision was taken to apply vacuum therapy. The wound was debrided under general anaesthesia and black polyurethane foams were put into the wound cavities extending laterally on both sides. A drain was put into the rectum. Change of dressing was done every three days. The foams were measured smaller every time in order to encourage flap adherence to the bottom of the wound. Anaesthesia was no longer necessary. The wound cavities quickly formed sufficient granulation tissue. After 29 days the detached soft tissue was conditioned such that direct closure of the wound could be done. The sacral wound had been stable for 17 weeks at which time a dynamic graciloplasty to reconstruct the disrupted anal sphincter was performed. Here, the left gracilis muscle at the inner surface of the upper leg was tied in a loop around the anal canal preserving the neuro-vascular bundle. With use of a pacemaker providing a stimulating pulse permanent muscle stimulation is produced, creating permanent tone and closing the anal canal. For defecation the pacemaker is switched off by a permanent magnet and the patient is able to evacuate faecal material, usually after an enema. This operation proceeded without complication and there was primary wound heal-

ing. Finally, after 16 weeks, the colostomy was closed.

Outcome / Comment

Care of perineal wounds and reconstruction of the anal sphincter muscle usually require extensive surgery. Soft tissue defects after extensive tumor resections, trauma or tissue breakdown after infections have to be reconstructed with musculocutaneous flaps in the greater number of cases if reconstruction of the continence organ is intended as a one-stage procedure. If there are extensive wounds without significant loss of tissue, fast wound healing without loss of tissue to infection and without extensive scar formation has high priority.

In the case presented here, normal tissue at the perineum was obtained and the defect was closed directly after conditioning by means of vacuum therapy. The patient is continent after this graciloplasty, with the latest follow-up taking place in December 2004, five years after the accident. The pulse generator was changed in May 2002 and a ventral hernia was closed in December 2004. The patient is fully able to work.

Since there was no soft tissue defect, no flap was necessary. Vacuum therapy alone made possible quick retention-free healing of the wound without extensive scarring in the anal canal area. That is why it was possible to carry out a problem-free sphincter reconstruction by means of dynamic graciloplasty without extensive reconstruction of surrounding soft tissue. Massive perineal scar formation would have compromised the function of the gracilis muscle too much to obtain sufficient continence.

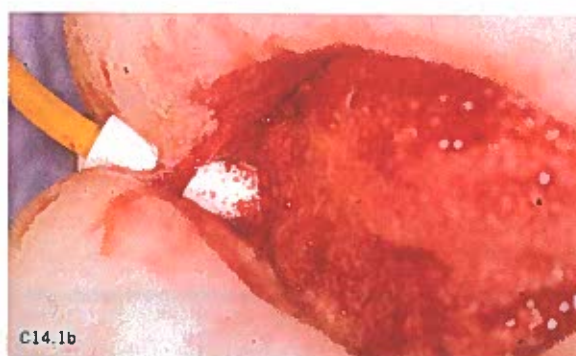


Fig. C14.1a-b 14-day-old sacral wound seen from the perineum; the anal canal is completely disrupted. The wound has been cleaned and granulation tissue has developed. The rectum ends in wound.



Fig. C14.2 Wound before split-thickness graft. The skin edges reach each other distally.

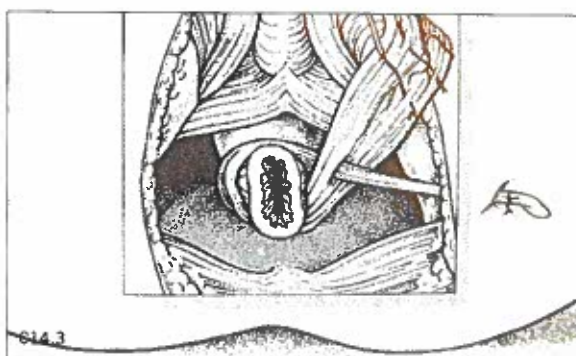


Fig. C14.3 Operative site with graciloplasty. The gracilis muscle has been isolated preserving the neuro-vascular bundle and tied subdermally around the "neo" anus.



Fig. C14.4 Perianal wound healed following graciloplasty.



Fig C14.5 Situation five years after the injury.

◆ Case 15 - Necrotising Infection of the Lower Limb - G. Zoech

History

A 41-year-old patient had already undergone multiple operations for necrotising infection in the right leg at our department.

Clinical Findings

There were vertical wounds both at the inner and outer surface at different healing phases (Fig. C15.1). The medial wound continued secreting extensively but was already covered with a split-thickness graft, which was healing (Fig. C15.2). The wound bed preparation of the fibular wound was done with vacuum therapy and thereafter be covered with a split-thickness graft. Vacuum dressing should be applied in such a way that the healing graft is not damaged, while promoting healing in a short time in the wound to be treated. First, the anterior skin bridge was covered with hydrocolloid dressing (Fig. C15.3). The healing split-thickness graft at the medial surface was covered with Mepitel® (Fig. C15.4). On top of this we placed a polyurethane vacuum foam. The foam was

placed directly on the wound. After fixing it with an adhesive drape, an opening in each dressing was cut ventrally (Fig. C15.5). A third foam was put across the lower leg anteriorly and was also fixed with drape. The *trac-pad* was connected to this “bridging foam” (Fig. C15.6). Fig. C15.7 shows the system in operation.

Therapy / Course

After three vacuum dressing cycles the fibular wound was covered with enough granulation tissue that it could be closed with split-thickness grafts (Fig. C15.8). The grafts healing on the tibial aspect of the right lower leg had not been damaged (Fig. C15.9). A fresh split-thickness graft was fixed by vacuum therapy for five additional days after which vacuum therapy was concluded. After three more weeks both the outer and inner surfaces of the lower leg were healed (Fig. C15.10-11). It is possible to treat wounds of different healing phases with a single vacuum dressing using an interposed gauze technique.

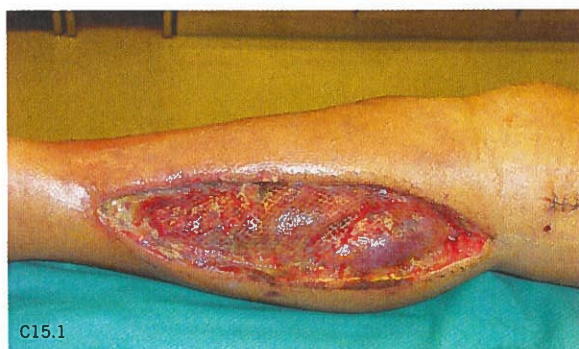


Fig. C15.1 The medial wound at the start of vacuum therapy.

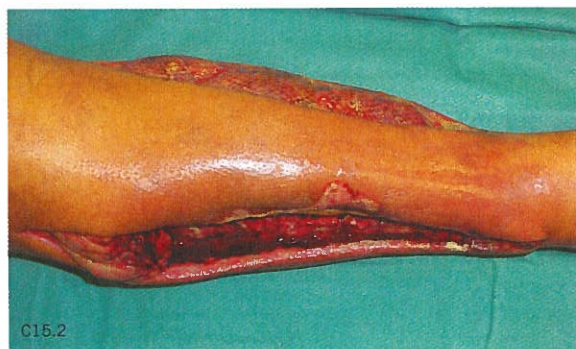


Fig. C15.2 Medial and lateral aspect of right lower leg when starting vacuum therapy.



Fig. C15.3 Protecting the skin bridge with hydrocolloid drape.



Fig. C15.4 Protecting the “old” split-thickness graft with Mepitel®.



Fig. C15.5 Foams are fixed with adhesive drapes, with two openings for the bridging foam.



Fig. C15.6 Bridging foam fixed, with opening for the *trac-pad* connector.

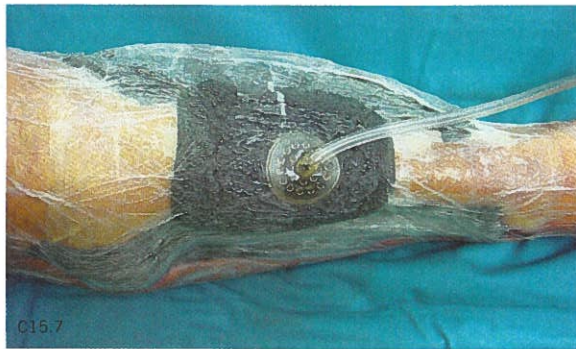


Fig. C15.7 Foam soaked, system sealed and working.

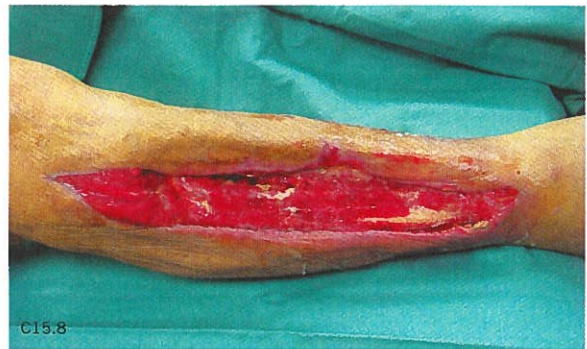


Fig. C15.8 Wound after three vacuum therapy cycles and before transplantation of the split-thickness graft showing good granulation.



Fig. C15.9 Split-thickness graft after three vacuum therapy cycles.



Fig. C15.10 Median view with split-thickness graft healed at three weeks after ending vacuum therapy.



Fig. C15.11 Lateral view at the same time.

◆ **Case 16 - Vacuum Therapy on Inner Surfaces - A New Therapy Option in Colorectal Anastomotic Insufficiency - M. Rexer, D. Ditterich and H. Rupprecht**

History

After neoadjuvant preoperative treatment, a deep anterior rectum resection with primary descendo-rectostomy was performed in a 51-year-old male patient secondary to rectal carcinoma located in the lower third. Due to radiogenic fibrosis of the connective tissue of the pelvis, recognisable during the operation, a protective loop ileostomy was placed during the same session. In spite of this, and with target drainage still in place, anastomotic insufficiency with presacral abscess formation developed subsequently.

Clinical Findings

Computed tomography showed presacral abscess formation, which connected with the intestinal lumen through a small fistula and seemed to be sufficiently included in the target drainage. At endoscopy, an anastomotic insufficiency was demonstrated, with a whitish-grey environmental reaction within the abscess cavity.

Therapy / Course

As the patient did not consent to an ablative measure, we recommended vacuum therapy applied transluminally in a proctoscopically assisted and endoscopically controlled manner. As a drainage medium we selected a polyurethane (PU) foam cut to size corresponding to the wound cavity, into which a drainage tube (12 Charriere) had been integrated and, for reasons of safety, had been

connected (after cutting off the *trac-pad connector*) with the foam through a seam. The drainage tube guarantees adequate drainage of secretion and can be sealed tightly through the action of the anal sphincter.

After thorough lavage under visual control, the foam/drainage apparatus is inserted by means of a sufficiently large-calibre proctoscope (or anal speculum) into the target cavity and evacuated by means of the therapy unit (suction force: 125 mmHg). The system is sealed by the natural action of the anal sphincter. After placement, the correct position of the foam must be checked using flexible endoscopy.

The foam drainage arrangement was exchanged every two to three days. For the initially applications, we used short mask anaesthesia. Subsequent renewals of the

foam were carried out with local anaesthetising agents (e.g. Xylocaine® gel). In the case described here, the patient was already afebrile after the first application of the system and remained so throughout the subsequent course. In the wound cavity, which had up to then not been granulating, there was a steady increase in healing tendency, directed towards the intestinal lumen. Within four weeks, the wound cavity had been reduced through the vacuum therapy to one third of its original size. An attempt to close the remaining cavity by injecting

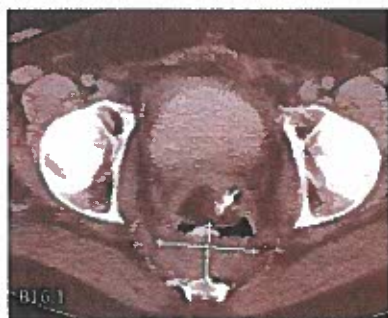


Fig. B16.1 Computed tomography showed presacral abscess formation connected with the intestinal lumen through a small fistula and apparently sufficiently included in the target drainage.



Fig. B16.2 As the patient did not consent to an ablative procedure, we recommended transluminal vacuum therapy using a proctoscopically-assisted and endoscopically-controlled approach.



Fig. B16.3-4 After thorough lavage under visual control, the foam/drainage arrangement is inserted by means of a sufficiently large-calibre proctoscope (or anal speculum) into the insufficiency cavity and evacuated by means of a VAC-ATS® therapy unit with a suction force of 125 mmHg. The system is sealed by the natural function of the anal sphincter.

Fig. B16.5 After placement, the correct position of the foam must be checked through a flexible endoscope.



Fig. B16.6 The foam drainage arrangement was exchanged every two to three days. For the first placements, we used brief mask anaesthesia. Subsequent renewals of the foam were carried out with local anaesthetising agents (e.g. Xylocaine® gel).

Fig. B16.7 Within four weeks, the wound cavity was reduced through the vacuum therapy to one third of its original size.

Fig. B16.8 The attempt to close the remaining cavity by injecting fibrin failed due to the rigid, fibrotically altered connective tissue of the environment of the wound. CT imaging of the remaining wound cavity.

fibrin failed due to the rigid, fibrotically altered connective tissue of the environment of the wound. The final closure of the insufficiency was achieved after another three months of conservative therapy. After a total of four and a half months, the ileostomy was reduced with fully preserved continence of the natural closing organ. Vacuum therapy spared the patient from abdominoperineal rectal exstirpation in spite of an initially progressing septic complication.

Comment

Anastomotic insufficiency after preceding colorectal surgery occurs in 5-15% of patients. For the patient, it is certainly one of the most severe, and, for the surgeon, one of the most challenging complications in the minor pelvis. The currently available therapies, such as intermittent endoscopic lavage or CT-controlled drainage, with or without previous application of an ileostomy,

aim at a secondary healing through continuous removal of septic wound secretions. Although the focus is sufficiently cleansed by means of lavage, the chemotaxins and growth factors necessary for secondary healing are at the same time removed from the wound area. Sometimes, the wound cavity becomes anergic and easily reinfected after removal of the drainages. By means of transluminal application of vacuum therapy, as was published for the first time by Weidenhagen et al. in 2003, a granulation-stimulating effect with simultaneous wound cleansing in the septic focus can be achieved. This can be carried out either with an exclusively endoscopic approach or in a proctoscopically-assisted and endoscopically-controlled way. According to the recent publication of Weidenhagen et al. and ourselves, the application of the principles of septic surgery of the surface of the body to the inner surface of the bowel offers the abdominal surgeon new therapeutic possibilities for treating

septic complications of colorectal surgery. In the treatment of anastomotic insufficiency, the vacuum therapy unites three essential therapeutically efficient principles:

- ◆ Local infection control through sufficient drainage of the wound cavity
- ◆ Reduction in size through stimulation of granulation
- ◆ Achievement of wound healing directed towards the intestinal lumen.

Especially patients with primarily disturbed wound healing, such as, in our case, radiogenic fibrosis or immunodeficient concomitant diseases, will profit from improved septic treatment strategies. In case of deep insufficiency, the wound situation can be proctoscopically adjusted and be treated under visual control. Regular flexible endoscopy including the wound cavity will certainly be necessary for judging the success of the therapy. Vacuum therapy on the inner surfaces could extend the treatment possibilities of septic colorectal surgery.

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◆ Case 17 - Intra-abdominal Vacuum Therapy of Parenchymal Organs - L. Lablér

History

A 24-year-old woman involved in a motor vehicle accident suffered a moderately severe traumatic brain injury with cerebral contusions as well as serial rib fractures and a ruptured spleen. The patient also suffered a severe skin decollement with soft tissue defects and second and third degree burns on the back and extremities. The patient's management followed the ATLS (Advanced Trauma Life Support) guidelines. Because of hemorrhagic shock and a diagnosis of free fluid by means of FAST (focused abdominal sonography in trauma), a splenectomy was performed and the patient was transferred to the intensive care unit for the post-operative phase. During the subsequent course, an infection of the laparotomy wound developed.

Clinical Findings

The cause was serious peritonitis as a result of an overlooked pancreas rupture diagnosed later by computed tomography (CT) in connection with an attempt to locate the focus of infection (Fig. C17.1). The infectious situation with development of edema resulted in an acute abdominal compartment syndrome.

Therapy / Course

Re-laparotomy followed in order to achieve decompression. At the same time, the pancreas rupture was addressed by lateral pancreatectomy (Figs. C17.2 and 3). Because of the necrotising pancreatitis a series of second look operations had to be carried out. The resulting open abdomen situation was treated from the beginning with



Fig. C17.1 The previously overlooked pancreatic rupture, later diagnosed at CT imaging.



Fig. C17.2 Intraoperative site with severe peritonitis as a result of the pancreatic rupture.



Fig. C17.3 Partial resection of pancreas after traumatic pancreatic rupture.

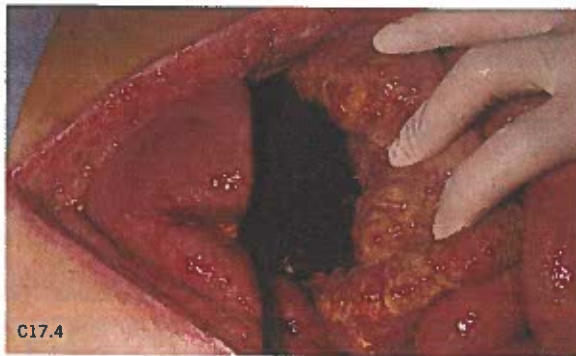


Fig. C17.4 Black vacuum foam in the *bursa omentalis*.

vacuum therapy (abdominal foam; 75-100 mmHg). The dressing change was performed as a part of planned second look operations periodically each three days combined with the customary drainage of the omental bursa. It was noticed, in the course of the therapy, that debris from the omental bursa was not being sufficiently evacuated. Further, it was observed that, as a result of the suction, a part of the secretions were spread among the bowel loops leading to a dissemination of the inflammation. The vacuum therapy system was therefore modified using an additional black foam and the latter, matching the wound geometry in the omental bursa, was positioned on the infected pancreas (Fig. C17.4). The foam was connected with a separate drainage tube leading sideways through the left abdominal wall. The original vacuum therapy foam was used unaltered as the abdominal wall closure (suction: peripancreatic: 75 mmHg, abdominal wall: 50 mmHg only, in order not to promote excessive formation of granulation tissue).

The arrangement of both foams remained in place a total of 14 days and was changed every 48 hours during planned re-operations. The fluid loss through both foams was quantified and replaced by infusion. The drainage volumes from both systems, in spite of unequal suction, were roughly comparable (about 1100 ml/24 h from the abdominal foam before placement of the peripancreatic foam; approximately 700 ml/24 h at the beginning and about 200 ml/24 h at the end of the combined application per each foam). Both vacuum foam systems worked without interruption and without technical problems. Formation of fistulae communicating with the bowels or pancreas or intraabdominal abscesses were not observed. The arrangement allowed for efficient removal of secretions and debris from the affected abdominal compartment and supported a faster and improved formation of a local granulation layer which covered the pancreatic lesion. After 72 days of treatment with an open abdomen we achieved a tension free fascia closure (a total of 30 planned revision operations were necessary). Because of post-traumatic cholecystitis, an open cholecystectomy was carried out in the course of a planned revision intervention (on day 41).

Comments

Vacuum therapy represents a therapy option for a temporary open abdomen closure within the framework of abdominal compartment syndrome (ACS) management

after damage control laparotomy in cases of pronounced edema where a tension free closure of the abdominal wall fascia is not feasible or, in view of planned revision interventions due to severe intraabdominal infections, is pointless.

Unlike other wounds where secretions flow directly into the foam, intra-abdominal secretions follow the force of gravity and are efficiently removed, e.g. through Douglas' pouch drainage. In case of severe intra-abdominal infections, however, the behaviour of the infected fluid must be considered. Following suction, this fluid spreads intra-abdominally between the bowel loops and along the polyurethane foam and might thus contribute to a dissemination of the local infection.

The use of additional intra-abdominal vacuum foam during an open abdomen situation in case of a severe intra-abdominal infection represents an application of the vacuum therapy that has not, to our knowledge, been reported in the literature. Use of an additional, separate intra-abdominal vacuum foam system within the compartment formation for preventing the spread of infection within the abdominal cavity under simultaneous application of the abdominal dressing system can be considered a type of surface vacuum therapy.

◆ Case 18 - Wound Infection After Lung Transplantation - T. Fleck

History

In 2004 and 2005 we treated four patients (one female, three males; mean age 39.3 ± 15.3 years) with deep wound infection after lung transplantation via clamshell incision.

Clinical Findings

All four patients experienced a complicated postoperative course due to their disease (pulmonary hypertension) and rejection episodes. After a mean of 37 ± 11 days they developed a wound infection in the clamshell incision with positive bacterial colonisation (*Staph. aureus*, *Staph. epidermidis* and *Enterococcus faecalis*, respectively).

Therapy / Course

After reopening the wounds, an aggressive debridement of all necrotic tissue and removal of suture material was performed (Fig. C18.1). Thereafter, a large foam was fitted into the wound, while the *trac-pad connector* was placed in the middle of the wound (Fig. C18.2). Therapy settings were 75 to 100 mmHg in continuous mode. Every 48 hours we performed a dressing change under aseptic conditions in the operating room due to the immunocompromised status of the patients.

When the wound was macroscopically free of infection and the bacterial cultures were negative a secondary closure was performed after a mean 16 ± 9.5 days. A mean 6 ± 4.5 dressing changes were necessary until these conditions were present (Fig. C18.3).

The main advantage of the vacuum therapy is the avoidance of wound retraction in the thoracotomy which is very common but hinders secondary closure.

Comments

Wound infections or dehiscence are relatively common, particularly in immunocompromised patients. In order to enhance wound healing the immunosuppression is often reduced or stopped, which, in turn, increases the risk of rejection episodes. With vacuum therapy we achieved acceptable wound conditions and healing in a short period of time without any reduction in immunosuppression.



Fig. C18.1 Patient after bilateral lung transplantation via clamshell incision and deep wound infection with *Staphylococcus epidermidis*.



Fig. C18.2 Vacuum foam in situ. The *trac-pad connector* is placed in the middle of the wound to achieve an even vacuum distribution.



Fig. C18.3 Wound after 10 days of vacuum therapy at the time of foam removal and secondary closure.

◆ Case 19 - Vacuum Therapy for the Treatment of a Wound Dehiscence After Thoracoabdominal Aortic Aneurysm Repair - T. Fleck

History

A 65-year-old male patient with known liver cirrhosis (Child-Pugh B) underwent replacement of his thoracoabdominal aorta. He had previously stent graft placement in the proximal descending aorta. Due to an increased diameter of 11 cm surgery was mandatory.

Current problems

Due to his liver disease and the associated problems with wound healing, the patient developed sterile wound dehiscence over the entire thoracoabdominal incision (Fig. C19.1).

Therapy / Course

As surgical revision with primary closure of the wound would be not successful, we decided to implant a vacuum therapy system with the aims of protecting the wound from infection, and of optimising and preconditioning the wound for secondary closure, when the overall condition of the patient would permit.

Accordingly, on postoperative day 10, we opened the entire wound, debrided necrotic tissue and implanted two large foams. As the wound was very large we used

two *trac-pad connectors* to assure uniform vacuum distribution (Fig. C19.2). The vacuum was set to 100 mmHg continuous suction mode during the first week, in order to reduce any bacterial colonisation. During the second week, we changed the setting to 100 mmHg intermittent mode (5 min ON, 5 min OFF) to increase granulation tissue formation and wound perfusion. After 22 days, we were able to perform a secondary closure.

Comments

Particularly in immunocompromised patients, wound dehiscence without bacterial co-infection is common. In order to prevent superinfection in these wounds (these patients are especially prone for developing infections with MRSA) and to avoid multiple dressing changes, contamination and, frequently, unsuccessful surgical revisions, we recommend the use of the vacuum therapy system.

It is important to note, however, that such immunocompromised patients do not show the type of reaction to vacuum therapy to which we are accustomed in terms of the speed of granulation tissue formation, which takes longer and develops more discretely.



Fig. C19.1 Patient with liver failure and sterile wound dehiscence after replacement of the thoracoabdominal aorta.



Fig. C19.2 Vacuum therapy *in situ* in the entire thoracoabdominal incision with two *trac-pad connectors* for optimal vacuum distribution.

◆ Case 20 - Vacuum Therapy in Sternal Wound Infections

I. Kutschka, S. Dziadzka, A. El Essawi, P-J. Flory and W. Harringer

Background

Postoperative sternal bone infection is a life-threatening complication following cardiac surgery^{2,5,6}. Affected patients usually have one or more risk factors, such as diabetes, obesity, chronic obstructive pulmonary disease, or older age, which were all shown to statistically increase the risk of sternal wound infections². An additional risk factor might be a reduced blood supply of the sternal bone due to the preparation of one or both internal thoracic arteries. Severe infections may lead to sternal bone necrosis and concomitant mediastinitis. Several therapeutic strategies, such as repeated irrigation and drainage or direct reconstructive surgery using pedicled muscle flaps or omentum transfer have been used in the past⁷. While instability of the sternal bone without relevant infection or bone necrosis can be treated successfully with primary re-wiring, "open" wound management may be required for deep infections³. Particularly serious situations are recurrent infections with markedly reduced and sequestered bone structure. Vacuum therapy can be used in these patients to combat the infection and prepare the wound for reconstructive surgery under elective conditions.

We describe the follow-up of 10 patients, who underwent vacuum therapy for severe sternal infection following cardiac surgery. Two cases with a special risk profile and complicated course are described in detail.

General Experiences

Ten patients (four male, six female; mean age 68 ± 8.1 years) with severe sternal infection following cardiac surgery underwent vacuum therapy. All patients underwent coronary artery bypass grafting with use of a pedicled left internal thoracic artery (ITA) as a bypass graft. In one patient both ITA's were used. Vacuum therapy was used as the initial therapy for wound infection in seven cases, while three patients received vacuum therapy for recurrent infection following omentum transfer ($n = 1$) or irrigation and re-fixation of the sternum ($n = 2$). Four patients suffered from insulin dependent diabetes and two patients received steroids for chronic obstructive pulmonary disease.

The mean body mass index of this group of patients was markedly increased (30.4 ± 5.1). Start of vacuum therapy was 18.1 ± 8.4 days following cardiac surgery. After obtaining microbiological samples, wound debridement including *jet lavage* was performed. The first vacuum therapy dressing was then placed in the operating room. At the end of the operation all patients were extubated. Further changes of the vacuum therapy dressings were performed on the ward using low doses of intravenous analgesics. All patients received initial intravenous antibiotic therapy consisting of flucloxacillin and ceftriaxone, with subsequent adjustment of the antibiotic regimen based on the microbiological analysis. Serum CRP levels were measured before vacuum therapy and on days 1, 4, 7 and 14 days following surgery. On day 8, vital capacity (VC) and one-second forced expiratory volume (FEV_1) were measured for each patient individually with and without vacuum stabilisation of the thorax and compared to preoperative data.

Mean duration of vacuum therapy was 20 ± 11 days. No prolonged mechanical ventilation was necessary and no major pulmonary complications occurred. One patient developed pneumonia, which was successfully treated with intravenous antibiotics. Serum CRP levels decreased rapidly from 28.5 ± 9.7 mg/dl preoperatively to 18.7 ± 11.2 mg/dl (day 1), 12.6 ± 10.5 mg/dl (day 4), 8.5 ± 6.9 mg/dl (day 7) and 5.8 ± 2.2 mg/dl (day 14, Fig. C20.1). Sternal infection and open wound therapy led to a significant deterioration of lung function compared to preoperative values (pre-CABG, Fig. C20.2a). Vacuum therapy significantly increased the individual FEV_1 and VC compared to open wound management without vacuum therapy and unstable chest (Fig. C20.2b). The most frequently found bacteria were *Staphylococcus epidermidis* (70%) and *Staphylococcus aureus* (30%). Combined infections were seen in three patients with additional detection of *Enterococcus* ($n = 2$) or *Enterobacter cloacae* ($n = 1$).

Seven patients received re-wiring and secondary wound closure following vacuum therapy. Three patients developed extensive structural bone defects, which required

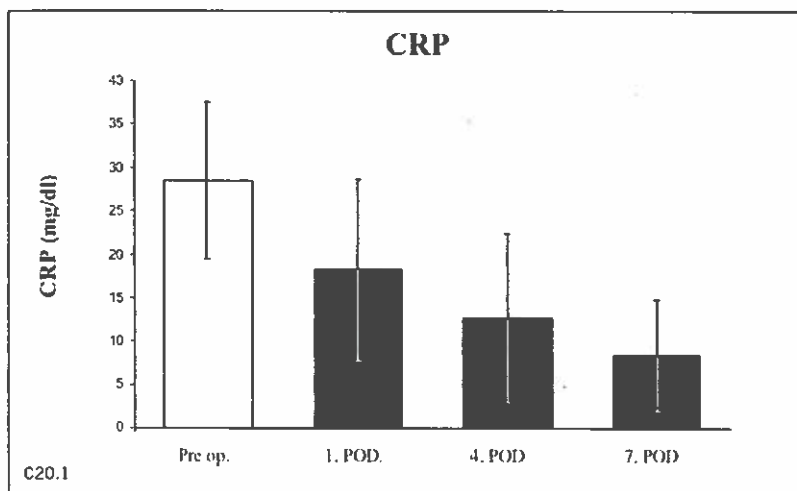


Fig. C20.1 C-reactive protein (CRP) levels preoperatively and after start of vacuum therapy (mean values $\pm$ standard deviation, POD: postoperative day.)

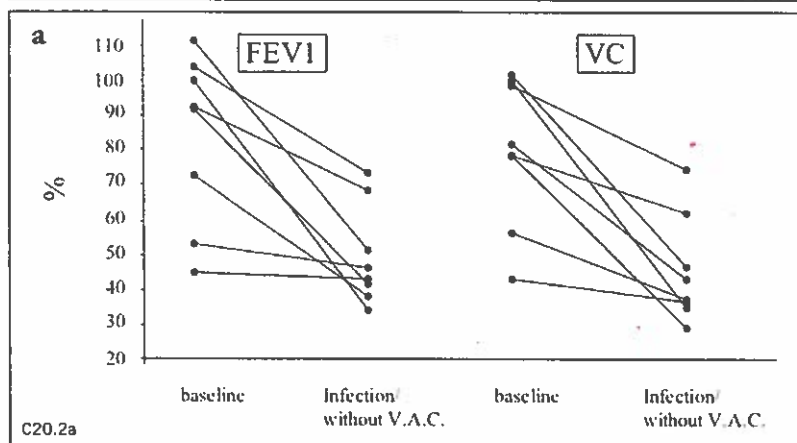
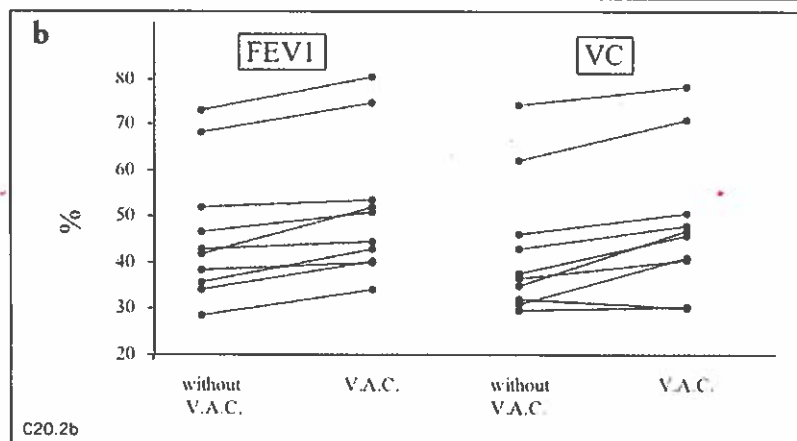


Fig. C20.2a-b

a) Spirometry data before cardiac surgery (baseline, left) and with sternal wound infection and open wound management without vacuum therapy (right). Statistics: paired t-test, $p = 0.01$.



b) Spirometry data, 8 days after start of vacuum therapy. Individual values with (left) and without vacuum dressing (right). Statistics: paired t-test, $p = 0.02$.

Data for a and b are shown in percent of the calculated individual target.

VC: vital capacity.

FEV₁: one-second forced expiratory volume.

reconstructive surgery. In two cases a bilateral pectoralis major flap and, in one case, a pedicled latissimus dorsi musculocutaneous flap were used for wound coverage. In nine patients complete wound healing was achieved. Only one patient developed a fistula in the lower part of the wound, which took three months to heal.

Case Report 1 - History

We describe the postoperative course of a 72-year-old lady with a special risk profile and a complicated course following coronary artery bypass grafting. In 1980 the patient underwent amputation of the right breast for breast cancer followed by radical irradiation of the axilla and the right chest wall. This resulted in marked scar formation on the right side of the chest. Additional risk factors for complicated wound healing were insulin dependent diabetes, obesity and mild renal insufficiency. Due to bilateral varicosis the left internal thoracic artery (ITA) had to be used for bypass grafting. The right ITA was already destroyed by earlier irradiation. Unfortunately, the reduction in sternal blood supply secondary to loss of both ITA's increased the risk of sternal wound healing problems. This might have significantly contributed to the following complicated course. Coronary bypass grafting with median sternotomy was performed in June 2005.

Therapy / Course

The patient was re-admitted 30 days later with sternal bone instability and wound infection. Surgery including debridement and extensive lavage was performed immediately. The upper part of the sternal bone was necrotic and had to be removed. Vacuum therapy was started and dressings were changed at two-day intervals. *Klebsiella oxytoca* was detected and confirmed with repeated microbiological testing. Antibiotic therapy consisted of flucloxacillin and gentamycin. During the next days of vacuum therapy we observed a rapid reduction in inflammatory parameters and negative microbiological wound probes after two weeks. Thirty days after initiation of vacuum therapy, wound conditions were amenable for reconstructive surgery. After removal of remaining necrotic bone we decided to use a pedicled musculocutaneous latissimus dorsi flap for wound closure. The scar tissue of the right upper chest wall, caused by earlier irradiation, was removed and also bridged with the flap to avoid impairment of the pedicle (Fig. C20.3). A small area at the back had to be covered with an autologous

skin graft. With the exception of some sterile pleural effusion the postoperative course was uneventful. Graft perfusion was regular. The patient was discharged 26 days following reconstructive surgery with complete wound healing.

Case Report 2 - History

A 61-year-old man underwent coronary bypass grafting in February 2003. Due to varicosis we opted for complete arterial revascularisation. Both internal thoracic arteries and the left radial artery were used for grafts to the anterior and lateral wall of the heart. Additional risk factors for complicated wound healing were mild diabetes, severe obesity (BMI 35) and chronic obstructive pulmonary disease. Seventeen days following surgery the patient was re-admitted with a severe sternal wound infection. Following debridement and lavage we opted for retrosternal irrigation, drainage and re-wiring. Microbiological samples of the wound revealed a resistant type of *Staphylococcus epidermidis*. Antibiotic therapy consisted initially of amoxicillin/sulbactam and was switched later to imipenem and vancomycin according to the sensitivity testing. Fifteen days later the sternum was again unstable. We found several transverse fractures of the sternal bone but no ongoing infection and decided on a second re-fixation attempt using the Robicsek technique for parasternal stabilisation*. Only four days later re-infection with fever and highly increased inflammatory parameters occurred. The complete wiring was found to be broken or had cut through the bone. The left part of the sternal bone was necrotic and had to be removed completely (Fig. C20.4a). Over the next three weeks vacuum therapy was performed with change of dressings every second day (Fig. C20.4c). Intravenous analgesics were given prior to each dressing change. Twelve days later microbiological testing was negative and inflammatory markers were back to normal levels. After a total of 57 days following coronary surgery, reconstructive surgery using a bilateral musculocutaneous pectoralis flap was performed. To avoid tension in the area of the sternal defect, the pectoralis major muscle was completely mobilised on both sides. Lateral incisions of 10 cm were made on both sides for strain reduction and covered temporarily with alloplastic skin replacement material (Epigard®, Fig. C20.4d). Two weeks later the lateral wounds were closed. After a total hospital stay of 84 days the patient was discharged with healed wounds.

Comment

Sternal wound infection is a severe complication following cardiac surgery. Earlier studies have reported a significant mortality rate of up to 30%^{2,5,6}. The main goal in these cases is to achieve fast control of the infection to prevent life-threatening mediastinitis and sepsis. Compared to difficult and time-consuming re-wiring procedures, vacuum therapy provides an optimal control of the acute infection and is less traumatic for the patient¹. As shown in our second case and well described before², re-fixation of the bone and direct wound closure carries a high risk of reinfection. Only the vacuum therapy achieved complete infection control in this patient. For successful direct re-fixation of the sternum extensive debridement of the bone is necessary. This might also include removal of healthy bone, which is essential for later bone healing. Since vacuum therapy is a special type of open wound management, bone and tissue sparing debridement is possible. Necrotic tissue can be removed

later step by step after clear demarcation of sequesters. In this study seven of 10 patients had successful delayed re-fixation of the sternal bone following temporary vacuum therapy. Further advantages of vacuum therapy include a complete removal of contaminated allogenic osteosynthesis-material from the wound and stabilisation of the chest wall to maintain reasonable respiratory function. The vacuum stabilisation of the chest led to an individual improvement of respiratory function of 10-20%, which might prevent pulmonary complications due to long term ventilation in these critically ill patients⁴.

Temporary vacuum assisted closure is a reasonable strategy in patients with recurrent infection or large wound defects. We believe that vacuum therapy is a safe and very effective therapy for the initial treatment of patients with sternal bone infection. It is very useful for cleaning and preparing wounds for further reconstructive surgery.



Fig. C20.3a-d Reconstruction of a sternal wound following cardiac surgery in a patient with breast amputation and irradiation of the right chest 25 years ago. A: Wound four weeks after vacuum therapy and surgical debridement, subtotal sternal resection. B: Pedicled musculocutaneous latissimus dorsi flap. C: Site after wound closure. D: Patient four weeks after reconstructive surgery.

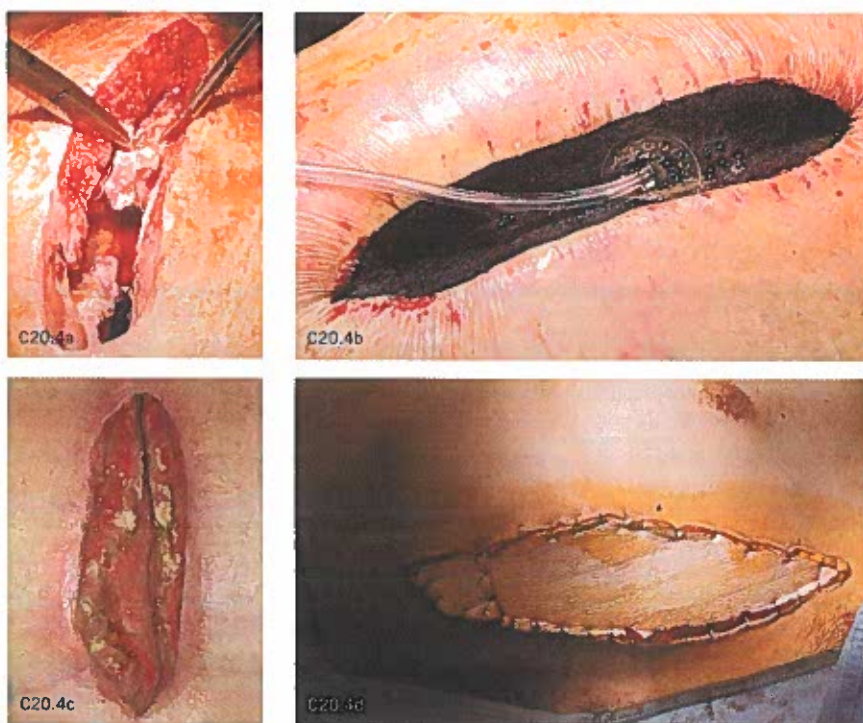


Fig. C20.4 A: Severe sternal re-infection four days following re-fixation of the sternal bone. The wiring is broken and has cut through the necrotic bone. B: Placement of polyurethane foam. C: Wound after eight days of vacuum therapy. D: Bilateral musculocutaneous pectoralis flap for vacuum therapy wound closure. Lateral incisions for strain reduction, covered temporarily with alloplastic skin replacement material.

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◆ Case 21 - The Vacuum Therapy System as a Bridging Measure prior to Sternal Closure

T. Fleck

In some patients it is not possible to close the sternum at the conclusion of an operation due to diffuse bleeding or hemodynamic instability. In the past, the sternum was left open with only a dressing over the wound or the skin was closed in a single layer. There are several disadvantages of this technique, namely:

- ◆ High risk of infection because the wound remains open
- ◆ Because of frequent dressing changes and irrigation of the wound the skin is often injured
- ◆ There is no thoracic cage stability. Therefore patients require more invasive respiratory support
- ◆ Because of thoracic instability, the sternal edges can be compromised and injury to the right ventricle may occur when the patient is moved

Because of the above mentioned issues, we have used the vacuum therapy system as a bridging measure to sternal closure in six patients.

Two Case Reports

The first patient was a 55-year-old male, who had undergone an ascending aortic replacement in 2003 for an acute type A dissection. In May 2004 he required re-operation due to an infected pseudoaneurysm at the aortic anastomosis.

As the entire mediastinum was involved and we had to replace the ascending aortic prosthesis, we decided not to close the sternum, but to implant a vacuum therapy system to have the ability to inspect the mediastinum and the newly implanted Dacron prosthesis.

After three vacuum dressing changes and a total of eight days on the vacuum therapy system, bacterial cultures were negative, the infection had resolved and we were able to close the sternum.

In this case we did not use a suction pressure of 125 mmHg as this might induce bleeding and might impair the chest tubes. We routinely use 75 mmHg in these cases and increase to 125 mmHg during the treatment if there is no bleeding and the patient can be weaned from the respirator.

The second patient was a 66-year-old male who had undergone emergency surgery due to an acute myocardial

infarction with ventricular rupture. Due to severe hemodynamic instability at the end of operation, the patient did not tolerate any re-approximation of the sternum. Therefore, we implanted a vacuum therapy system with 75 mmHg of suction (intermittent mode), in order that the chest tubes could drain.

After two vacuum dressing changes and a total of five days on vacuum therapy, the patient was stabilised such that sternal closure could be performed on postoperative day 5.

◆ Case 22 - Use of the Vacuum Therapy System in Neonates and Young Infants after Cardiac Surgery - T. Fleck

Introduction

We evaluated our preliminary results with three neonates or young infants (mean age 27 days) who underwent vacuum therapy for the treatment of sternal wound infections and infection of the groin after repair of complex congenital heart defects or cardiac transplantation.

Therapy / Course

The mean age of our three patients was 27 days (range: 14-34 days). Infection began a mean 8.8 days (range 5-14 days) after closure of the sternum. In two patients the sternum was left open after surgery and was subsequently closed two and four days, respectively, after surgery. In patient 3 MRSA was isolated in blood cultures after the second operation, which subsequently involved the sternal wound.

One patient had an infected left groin, which had been used for central venous access during surgery.

The mean vacuum therapy duration was 11.3 days, ranging from 10 to 12 days. After three dressing changes (every 48 to 72 hours) the infection resolved and a

secondary closure was feasible in all three patients. The groin was infect free and the defect much smaller due to granulation tissue formation so that the vacuum dressing was removed after 12 days and the wound granulated completely during the next two weeks. Isolated specimens were *Candida albicans*, *Staphylococcus aureus* and MRSA respectively.

Comments

Vacuum therapy was well tolerated by the children and no changes in heart rate, blood pressure or respiration pattern were observed, which could have been an indicator for pain experienced by the neonates.

No blood loss occurred during debridement, vacuum therapy or secondary closure. None of the three patients required transfusions.

It is important to note that no hemodynamic changes such as impaired ventricular compliance and filling, elevated pulmonary venous pressure and reduced cardiac output were experienced with a vacuum of 50 mmHg.



Fig. C22.1 The vacuum therapy dressings in place and connected via the Y piece.

◆ Case 23 - Vacuum Therapy and Bronchus Stump Insufficiency

D. Ditterich, M. Rexer and H. Rupprecht

History

A 75-year-old male patient underwent a resection of the right lower pulmonary lobe in combination with an extended resection of the thoracic wall and Gore-Tex® plasty for treatment of advanced bronchial carcinoma. On the third day after the operation, the patient, who was still in the intensive care unit and required artificial respiration, suffered an air leakage equivalent to 40% of inspiratory volume as well as a tension pneumothorax with simultaneous increase of fever. An immediate revision was necessary.

Findings

After opening of the wound and removal of the Gore-Tex® material, an extended bronchus stump insufficiency with abundant putrid secretion was found. After thorough lavage of the pleural cavity, the stump was

overstitched several times with Prolene threads in single-knot technique (Fig. C23.1). Overstitching of the stump alone failed to provide sufficient sealage. By tamponade of the immediate environment of the stump, it was possible to achieve a condition sufficient for the patient's respiration. The challenging problem now consisted in creating a temporary closure of the wound, while at the same time assuring sufficient drainage of the pleural cavity.

Therapy / Course

To solve these problems, we used a vacuum dressing in the area of the remaining thoracic cavity, proceeding as follows. First, we covered the remaining, ventilated pulmonary portions with microporous silicone foil (Mepitel®) in order to protect the parenchyma against the direct suction effect of the foam and to avoid a granulating-in of the remaining lung. Then, we loosely filled the remain-



Fig. C23.1 Operative site after overstitching of the bronchus stump.

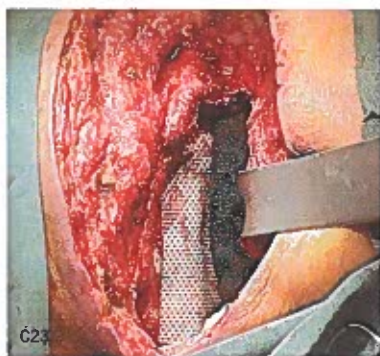


Fig. C23.2 Covering the remaining lung with Mepitel® and placement of the intrathoracic polyurethane foam.



Fig. C23.3 Filling the wound cavity with the polyurethane foam.



Fig. C23.4 Vacuum therapy with 50-75 mmHg.

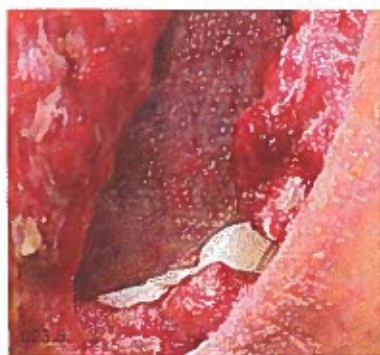


Fig. C23.5 Clean wound site on the 11th day. No secondary parenchymal fistula.

ing cavity above our tamponade with the polyurethane (PU) foam used for the vacuum therapy (Fig. C23.2). We did the same with the overlying skin defect (Fig. C23.3) and evacuated the system with a suction force of initially 50 mmHg (Fig. C23.4). The evacuation of the wound space counteracted the slippage of the tamponade, comparable to the commercial vacuum packing of foods, e.g. peanuts. We changed the dressing system every two to three days. When, 11 days after the first vacuum application, no secondary fistula had occurred in the area of the ventilated pulmonary portions (Fig. C23.5), we increased the applied suction force to 75 mmHg.

At each dressing change, we observed increasingly clean conditions and continuous granulation of the wound cavity. The stump insufficiency, which could not be sealed by overstitching alone, was completely closed by the tamponade. After four months, the patient, with the fistula closed, could be extubated. Free, unhindered spontaneous breathing was possible. The wound situation was further treated by means of vacuum therapy. Unfortunately, we cannot report the final result because the patient died of thoracic metastasis of the vertebral column, which had occurred in the meantime.

Comment

Bronchial stump insufficiency after resective surgery of the lungs is, with a frequency of 0.5-2%, a rare, but serious perioperative complication, for which a lethality of 22-39% is indicated in literature. One possibility for controlling this complication consists in overstitching the leakage with or without shortening of the stump. If the insufficiency leads to the development of a pleural empyema, an open treatment regime has to be used, according to the criteria of septic surgery. The application of a thoracic window or drainage with intermittent lavage of the pleural space can be considered. If, however, the bronchus stump insufficiency causing the septic condition cannot be tightly closed, only plastic methods (muscular-flap or omentum plasty) are available for sufficient covering of the stump. Early postoperative stump insufficiency constitutes a particularly grave problem because, especially in case of artificially respirated patients, a relevant air leakage can drastically restrict open methods, due to the reduction of hemoglobin oxygenation. In the case described by us, the option of a primarily open method with temporary application of a thoracic window or an intermittent lavage/suction treatment was excluded due to the relevant air leakage,

which in a septic situation drastically reduced the chances of favorable outcome. Furthermore, the infected wound conditions did not allow a muscular-flap or omentum plasty. Therefore, as a last resort, we carried out the attempt with vacuum therapy.

According to our literature research, ours is the first description of the application of a vacuum dressing technique inside the chest cavity with remaining, ventilated pulmonary tissue. When treating early bronchus stump insufficiency with a septic pleural concomitant complication, we were able to profit from three basic characteristics of vacuum therapy:

1. Sufficient drainage of the wound cavity through open wound treatment in the closed system
2. Elimination of the remaining wound space for sealing the stump insufficiency
3. Partial restoration of physical integrity through a tight dressing system

With the suction forces used in this case (50-75 mmHg, continuous), we did not find, during the entire therapy period, any secondary parenchymal fistula formation. We succeeded in sealing the bronchus stump with functional efficiency while at the same time cleansing the wound cavity in a hygienically acceptable way. Furthermore, we achieved granulation tissue formation in the wound cavity. In our opinion, vacuum therapy is a useful supplement to septic surgery for treating the thoracic cavity, even with remaining preserved and ventilated pulmonary tissue.

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◆ Case 24 - Diabetic Foot Syndrome I - T. Othman

History

A 64-year-old type 2 diabetic presented with a secondarily healing wound after partial resection of the third and fourth metatarsal heads and amputation of the adjacent digits. Prior to presentation in our department, the patient had been receiving treatment in another hospital, where a below-knee amputation had been recommended.

Clinical Findings

Advanced cellulitis of the foot was observed and radiographs indicated the presence of osteomyelitis. On examination the wound edges were necrotic with a putrid fibrin layer. Two fistulae were identified, both with contact to bone. The plantar fistula was 7.8 cm long and ran tangentially, while the second fistula was situated on the dorsal aspect of the foot and measured 4.5 cm in depth. The microbiology report confirmed the presence of *Pseudomonas aeruginosa* in the wound. Peripheral vascular disease was also diagnosed (see Fig. C24.1-3).

Therapy / Course

Revascularisation or vascular intervention was not appropriate due to multiple peripheral arterial stenoses confirmed by angiography. First stage wound treatment consisted of a radical curette debridement supplemented by biosurgical management utilising *Lucilia sericata*. Vacuum therapy was then applied implementing the Mini-VAC® system with application of continuous suction of 125 mmHg (see Fig. C24.4-6). The system remained in place for an average of four days (range: three to six days), with a two- to three-day treatment pause within the cycle. A treatment cycle was initiated twice, each lasting about 14 days. The total length of vacuum therapy application was 62 days. The patient continued with a further 35-day outpatient treatment schedule in accordance with the Homecare Programme.

Total resolution of the dorsal fistula was achieved after 31 days of vacuum therapy (see Fig. C24.7). After a further 31 days, closure of the plantar fistula was also complete. During the treatment, the area was twice examined using a fistulogram. This examination was indicated due to the convoluted pathology of the plantar fistula and to determine that healing was taking place. A

further three months were required until the total epithelialisation of the wound area was completed. The foot was also regularly examined with radiographic imaging during the treatment cycle. Advanced sclerosis and stabilisation of the bone can be observed (Fig. C24.4-12).

Comment

In this case there was no record of osteohistology and radiographs constituted the only available imaging. In clinical practice, the presence of osteomyelitis cannot always be positively confirmed at radiography. However, in this particular case, a diagnosis of osteomyelitis was made based on the presence of typical clinical changes observed during the course of treatment.

The manufacturer's instructions state that this form of therapy should not be used in the presence of untreated osteomyelitis. How does one define "treated osteomyelitis"? In these cases, should only surgical intervention be considered as fulfilling the criteria for treatment or is antibiotic therapy also appropriate? Regular debridement was undertaken throughout the course of treatment together with local antiseptic measures. Antibiotic therapy was also prescribed for a limited period. It has been shown in this case that the total resolution of two fistulae with bone contact and concurrent osteomyelitis was achieved using the vacuum therapy method in conjunction with appropriate medication. Thus, the lower limb was preserved and amputation was avoided. This was an interesting case due to the difficult position and extent of both fistulae and was further complicated by osteomyelitis. In this case, the successful application of vacuum therapy avoided the necessity of an amputation.



Fig. C24.1 Initial findings at time of first presentation – dorsal view. The yellow arrow indicates a deep fistula reaching down to infected osseous structures.

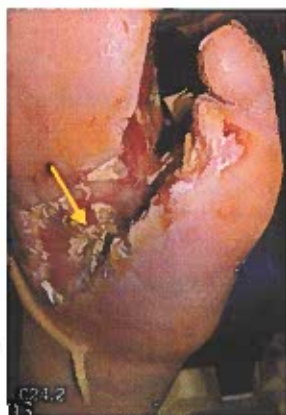


Fig. C24.2 Initial findings at time of first presentation – plantar view. The yellow arrow indicates a deep fistula reaching down to infected osseous structures.



Fig. C24.3 Initial findings – dorsal view. Lysis of the metatarsal basis of the third and fourth toes. Lysed and demineralized areas of the intermediate cuneiform bone.



Fig. C24.4 Vacuum therapy with 125 mmHg.



Fig. C24.5 Following one month of therapy – plantar view. The wound has been cleansed over wide areas but the fistular formation still remains (arrow).



Fig. C24.6 Following one month of therapy – dorsal view. The wound has been cleansed over wide areas but the fistular formation still remains (arrow).



Fig. C24.7 Three weeks later, closure of the dorsal fistular tract.



Fig. C24.8 Increase epithelialisation with closure of the plantar fistular opening.



Fig. C24.9 Dorsal view showing nearly complete epithelialisation.



Fig. C24.10 Sclerosed margins at the metatarsal basis of the third and fourth toes.



Fig. C24.11 Final findings after a total of six months of therapy (including 62 days of vacuum therapy, 35 of which were outpatient) – ventral view.



Fig. C24.12 Final findings after a total of six months of therapy – dorsal view.

◆ Case 25 - Diabetic Foot Syndrome II - S. Wu and D. G. Armstrong

History

The patient is a 62-year-old non-insulin-dependent diabetic male referred to the clinic with a six month history of a non-healing wound following a transmetatarsal amputation. The wound had been recalcitrant to healing despite numerous attempts at closure utilizing surgical techniques and other advanced wound healing agents. Past medical history is significant for hypertension and hypercholesterolemia. Patient has no known drug allergies.

Clinical Findings

Dorsalis pedis and tibialis posterior pulses were biphasic on Doppler. Negative pressure wound therapy was applied following debridement of the wound.

Therapy / Course

The dressing was changed every two to three days and the patient was followed in the clinic on a weekly basis for wound evaluation. The patient ambulated well with walker assistance and used a portable negative pressure wound therapy unit (VAC^{Freedom}™). The patient's wound was very well healed at 12 weeks. Negative pressure wound therapy was discontinued at 12 weeks to allow the patient to heal and epithelialize secondarily.



Fig. C25.1 Chronic, non-healing wound following transmetatarsal amputation.



Fig. C25.2 The wound following debridement.



Fig. C25.3 Application of negative pressure wound therapy.



Fig. C25.4 Patient ambulates with walker carrying a portable negative pressure wound therapy device (VAC^{Freedom}™) on a shoulder strap.



Fig. C25.5 The wound following two weeks of negative pressure wound therapy.



Fig. C25.6 The wound following four weeks of negative pressure wound therapy.



Fig. C25.7 The wound following eight weeks of negative pressure wound therapy.



Fig. C25.8 The wound following 12 weeks of negative pressure wound therapy.

◆ **Case 26 - Third Degree Infection of a Vascular Prosthesis after Implantation of a Biaxillo-Femoral Bypass - T. Karl**

History

A 53-year-old female patient presented with progressive inguinal swelling four years after implantation of an aortic-biiliac bifurcation prosthesis for treatment of peripheral arterial occlusive disease. The patient's past medical history was also significant for type II diabetes mellitus.

Clinical Findings

The patient's complaints were caused by a covered ruptured bilateral femoral aneurysm.

Therapy / Course

The bypass was partially resected and an extra-anatomical biaxillofemoral bypass was implanted (8 mm silver prosthesis). Postoperatively the patient developed reversible kidney failure and ischemic colitis, together with a bilateral inguinal infection of the wound. At 24 days

after the first operation a revision was necessary. Intraoperatively, a third-degree infection of the prosthesis was found. At places, the bypass material was no longer covered by tissue on both sides of the flanks. We performed a necrectomy and sealed the wound with a vacuum system. After repeated surgical debridement and vacuum therapy for 11 days closure by means of secondary suture was done. After another 36 days the remaining defect at the lower abdomen could be covered by mesh-graft transplantation. The patient was discharged from the hospital on the 85th postoperative day.

After 15 months of postoperative follow-up there is no evidence of a persistent infection of the prosthesis.



Fig. C26.1 24th postoperative day following implantation of the biaxillofemoral bypass.



Fig. C26.2 Intraoperative site before vacuum sealing of the wound.



Fig. C26.3 Following the application of the vacuum therapy dressing.



Fig. C26.4 83rd postoperative day following implantation of the biaxillofemoral bypass, 12th postoperative day after mesh-graft.

◆ Case 27 - Vacuum Therapy and Polyvinyl-Pyrrolidone-Iodine Hydrogel in Mesh-Graft Transplantations - T. Karl

History

On 30 November 2004, a 73-year-old female patient was admitted to the hospital with a left lateral tibia head fracture. Osteosynthesis followed on 6 December 2004. In addition, the patient also suffered from a large venous stasis ulcer of the right leg with distinct dermatolipofasciosclerosis of eight years duration.

Clinical Findings

Venous stasis ulcer of the right leg 20 x 18 cm in size with regional dermatolipofasciosclerosis (Hach stage III). Phlebography showed evidence of postthrombotic syndrome with old occlusion of the popliteal vein up to the external iliac vein. An arterial cause of the ulcer was excluded since all pulses and Doppler closing pressures were normal.

Therapy / Course

On 22 December 2004, median fasciotomy, shaving of the ulcer and simultaneous mesh-graft transplantation were performed (4/10 mm, 1:3). A 1-mm layer of Polyvinyl pyrrolidone-iodine-(PPI)-hydrogel was placed on the mesh-graft. The wound was sealed with a vacuum system for five days (PVA-foam, 75 mmHg continuous suction). Upon discharge on the twentieth post-operative day complete healing of the mesh-graft had been achieved.

Comment

The PPI-Hydrogel (Repithel®) is a new product for moist wound treatment. It combines the advantages of moist wound treatment with secure anti-infective prophylaxis. The basic component of Repithel is a polyacrylate. It serves as carrier for water and PVP-iodine impregnated hydrosomes. Because of its flexible structure the polyacrylate clings to the wound and takes up cell- and tissue detritus from the wound.

The hydrosomes are built of phospholipid bilayers in which water and PVP-iodine are enclosed. Because of its physiochemical character the hydrosomes prefer to link to bacteria and fungal cells. The PVP-iodine is directly passed to the micro-organisms. Therefore, a very low con-

centration of iodine is sufficient to kill multiresistent pathogens quickly and effectively. A 2004 study showed a significantly higher mesh-graft take rate than was achieved with exclusive application of gauze dressings¹.

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Fig. C27.1 Intraoperative findings after debridement.



Fig. C27.2 Following mesh-graft transplantation.



Fig. C27.3 Following application of the PVA vacuum foam.



Fig. C27.4 Wound condition at the fifth postoperative day.

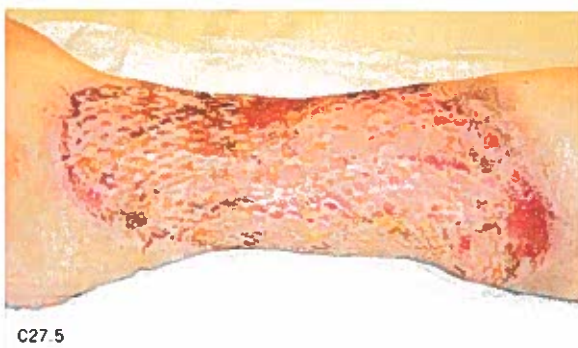


Fig. C27.5 Wound condition at the eleventh postoperative day.



Fig. C27.6 Eleventh postoperative day, before discharge of the patient.

◆ Case 28 - Vacuum Therapy for Ulcer Therapy in Calciphylaxis

D. Dill-Müller and A. Wagner

History

This is a 58-year-old male who in 1994 first presented with acute renal failure. This was followed in 1998 with the first diagnosis of chronic interstitial nephritis secondary to long-term abuse of analgesics. The patient was started on hemodialysis at this time. The patient's medical history is further significant for renal hypertension, renal anemia and renal osteopathy with secondary hyperparathyroidism, as well as hypertensive cardiac disease with compensated cardiac insufficiency. Since 2001, the patient has suffered from a painful ulceration of the left calf, which was clinically diagnosed as secondary to allergic vasculitis and previously treated with topical and systemic glucocorticoids.

Clinical Findings

Skin findings

Significant for a partially necrotic ulcer, 14 x 18 cm in diameter, on the left calf, characterised by bizarre margins that end in livedo, bluish discolourations of the surrounding skin (Fig. C25.1a+b). There was pronounced pain, both at rest and upon being touched. The remaining integument was within normal limits. Pedal pulses were palpated bilaterally.

Histopathology

Ischaemic necrosis of the epidermis; blood vessels of the dermis with medial calcification and intimal fibrosis (Fig. C25.2a), calcifying panniculitis of the subcutis (Fig. C25.2b).

Diagnostic imaging

Doppler ultrasound and angiography excluded therapeutically relevant stenoses of the large vessels. Soft tissue radiography demonstrated extensive calcification of the arteries of the lower extremities. Ultrasound of the skin and subcutis failed to visualise calcium salt conglomeration of the subcutis. Ultrasound and nuclear medicine scan of the parathyroid glands provided no evidence for adenoma.

Laboratory findings

Pathological findings included: Creatinine (↑), urea (↑),

parathyroid hormone (mild: ↑), calcium (↑), calcium phosphate products (↑), hemoglobin (↓), red blood cell count (↓), hematocrit (↓), fibrinogen (↑). Within normal limits: Iron, Protein C and S, complement factors C3 and C4, anticardiolipin-antibody, circulating immune complexes, ANA, anti-DNA, total cholesterol. Streptococcus serology, cryoglobulins, c-ANCA, p-ANCA: negative. Immune electrophoresis in serum and urine: no paraproteins detected. No APC-resistance. (The most important differential diagnoses were thus excluded through laboratory or histological findings, including: Necrotising vasculitis, pyoderma gangraenosum, Protein C/S- deficiency, necrotising erysipelas, antiphospholipid syndrome, cryoglobulinemia, cumarin necrosis.)

Therapy / Progress

After confirmation of the characteristic histological findings, initial surgical debridement was performed. Local therapy with polymer foam wound dressings impregnated with silver ions and active charcoal failed to promote formation of granulation tissue suitable for transplant. The necrotic zone showed centrifugal expansion (Fig. C25.3). Hemodialysis was intensified using a low-calcium dialysate, while, at the same time, a low phosphate diet was started and oral phosphate binding agents were substituted with sevelamer (RenaGel®)⁷, a calcium- and aluminum-free preparation. Following repeated debridement, vacuum therapy for conditioning of the crural fascia was started and continued for five days. During therapy, the skin around the bizarrely shaped ulcer margins was covered with a thin hydrocolloid strip in order to prevent maceration or erosion upon removal of the vacuum dressing foil (Fig. C25.4; this advice applies to any type of vulnerable or irritated periwound skin during vacuum therapy). The patient now underwent mesh-graft transplantation with repeated vacuum therapy using a PVA foam for a further seven days. Suction strength was set at 125 mmHg in continuous suction mode using a vacuum therapy unit. The split-thickness skin showed a take rate over 90% (Fig. C25.5). The healing of the donor site on the thigh proceeded normally under semi-permeable foil dressings. With the initiation of vacuum therapy, use of opiate analgesics was gradually reduced and completely discontinued prior to discharge from the

hospital. Fourteen months later, the patient presented with recurrent ulcerations on the right lower leg. The transplanted site on the left leg, however, remained stable and unremarkable (Fig. C25.6). The new ulcerations, which covered a smaller surface area, were successfully treated using the same method.

Comment

Calciphylaxis is a late sequela of terminal renal insufficiency with metastatic deposits of calcium salts in multiple organs, including the heart, lung, stomach and kidneys, as well as in the arterial vessels and in the connective tissue of the skin and subcutis. The vascular changes are described in the literature as uraemic calcifying arteriolopathy^{1,2}. Although calcinosis of the vessels is frequently seen, the acute form of calciphylaxis is

quite rare. It occurs almost exclusively in hemodialysis patients (1-4% of long-term dialysis patients over one year), but may also be seen infrequently following kidney transplantation, as well as in primary hypoparathyroidism or in malignant disease. The cutaneous manifestations of this often life-threatening complication are characterised by acute disturbances of microcirculation that resemble *livedo racemosa*, associated with severe pain, rapidly progressing necroses and ulcerations. Most often affected are the lower extremities with large, confluent lesions, followed by the lateral thigh and hip region and, less commonly, the abdomen and shoulder region, often with a symmetrical pattern of involvement. Wound infections and consecutive sepsis, together with involvement of internal organs are blamed for the high mortality rate of about 80%³.



Fig. C28.1a+b Venous stasis ulcer of the left calf with necrosis and surrounding livedo-like circulation disturbance. Overview (a) and detail (b).

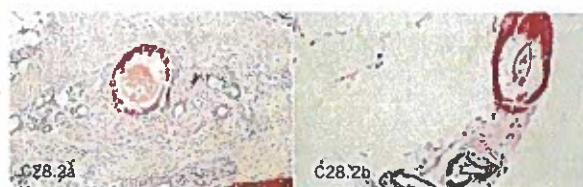


Fig. C28.2a+b Histology of the skin from the ulcer: blood vessels of the dermis exhibit medial calcification and intimal fibrosis (left). There is also calcifying panniculitis (right). HE stain, 400x.



Fig. C28.3 Findings prior to the second debridement. Progressive necroses and ulcerations.



Fig. C28.4 Vacuum therapy after split-thickness skin transplantation with PVA foam. The ulcer margins are protected with hydrocolloid strips beneath the foil dressing.



Fig. C28.5 Findings six weeks after transplantation.



Fig. C28.6 Findings 14 months after the transplantation (left leg). For the first time, the patient has new ulcerations on the right lower leg.

Various aspects have been discussed in the pathogenesis. Secondary hyperparathyroidism with compensatory increase in the secretion of parathyroid hormone as a consequence of the disturbed endocrine function of the kidney (reduced production of vitamin D₃), increased serum concentrations of calcium, phosphate, calcium-phosphate products and vitamin D have all been implicated as "tissue-sensitizing" factors. Other non-specific "precipitating" factors, such as minitrauma, use of corticosteroids or immunosuppressants among others, may trigger deposit of calcium salts in the tissues as the solubility limits of this electrolyte are exceeded^{2,3,4,5}. Histology primarily shows calcification of the media and intimal fibrosis of the smaller arteries and arterioles of the lower dermis, which lead to reduced circulation and ischemic necroses. In addition, calcification may occur in the subcutaneous septa resulting in the picture of calcifying panniculitis². This little-known diagnosis should always be suspected in patients with renal insufficiency presenting with acute skin necroses and ruled out with appropriate biopsies and interdisciplinary diagnostics. The medical management consists in intensification of the dialysis, attention to oral phosphate binders, improvement in circulation with intravenous prostaglandin derivatives and consideration of subtotal parathyroidectomy⁶. The dermatological and surgical management includes debridement of all ulcerations and complete necrectomy. With small defects, secondary healing with appropriate application of modern wound dressings and antiseptic local therapy can be expected. Ulcerations with surface areas over 10 cm² require early defect closure with a synthetic matrix or split-thickness skin graft in order to prevent septic complications. The combination with vacuum therapy⁸ improves infection prophylaxis and promotes the take of skin transplants⁹ in wound beds with compromised microcirculation. The long-term stabilisation of cutaneous findings in the present case might indicate that the biophysical effects of vacuum therapy¹⁰ exert a positive local influence on the so-called precipitating factors in the tissue and, together with intensified dialysis and medical regulation of the calcium-phosphate metabolism, slow the progression of calcifications. The prognosis of patients with calciphylaxis is considered unfavourable. The cause of the high mortality lies in wound infections and sepsis. In this and many other comparable cases, vacuum therapy has been shown to be a management option that helps lessen pain and improves circulation. This justifies the early use of this method for infectious prophylaxis.

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◆ Case 29 - Vacuum Therapy for the Treatment of Acne Inversa

C. Richter, H. Pillekamp and R. Schiener

History

A 46-year-old patient in good general health has suffered for 15 years from *acne inversa*. Previous operations had been performed in the areas of the left axilla and both inguinal regions, with conventional secondary wound healing. The average duration of wound healing was approximately 10 weeks.

Clinical Finding

The patient presented with a 5 x 7 cm infected area in the right axilla, painful to pressure with isolated scar strands and purulent secretion (Fig. C29.1). Bacterial examination revealed abundant *Staphylococcus aureus*.

Therapy / Course

We excised the entire area down to the subcutis under general anesthesia (Fig. C29.2). After careful cauterisation to stop bleeding, vacuum therapy was chosen due to the expansion of the wound (Fig. C29.3). Therapy was performed with a continuous vacuum pressure of 100 mmHg. Wound dressing was changed on the third and sixth postoperative days. Therapy was continued using silicone-coated foam dressing. A mesh-graft transplant was refused by the patient (Fig. C29.4).

Comment

Vacuum sealing represents a new therapeutic option in the treatment of *acne inversa*, which could possibly shorten time for granulation and facilitate the attachment of mesh-graft transplants.

Background

Etiology

Hyperkeratosis of the hair follicles leads to development of comedos with resulting infection and segmental rupture of the follicle epithelium. This results in an inflammatory reaction of the connective tissue with cutaneous and subcutaneous nodules. Genetic factors, androgens, secondary bacterial colonies, nicotine abuse, and various medications can play a role in the progression of the disease.



Fig. C29.1 Preoperative findings of the right axilla showing inflamed, painful infiltrations.



Fig. C29.2 Intraoperative findings after radical excision.



Abb. C29.3 Status at application of vacuum therapy.



Fig. C29.4 Results six days after operation: there is granulation without any signs of inflammation.

Regions frequently affected by *acne inversa* include the axillae, inguinal and perianal regions, mons pubis, proximal sides of the thigh, penis, scrotum, labia majora and the gluteal region. Initially there is development of comedos, followed by *acne inversa*, which is characterised by erythematous and indurated areas, accompanied by inflammatory nodules, abscesses, and fistulae.

Complications

Severe *acne inversa* is usually combined with impairment of general health. Due to the resulting scarring, contractures appear with accompanying restrictions of motion. In rare cases perineal fistulae arise and malignant transformation with development of carcinoma (Marjolin's ulcer) has been described.

Therapy

Numerous therapeutic options have been proposed for *acne inversa* including systemic antibiotics, systemic retinoids, and hormonal therapy with anti-androgens (a combination of cyproterone acetate with ethinyl estradiol). Dapsone (diaminodiphenyl sulfone) has also been described in individual cases as therapeutically effective. Frequently, only a reduction of the disease symptoms could be achieved. Surgical therapy is thus the therapy of choice. After an extensive excision, if necessary down to the fascia, either a primary wound closure can be performed or the wound can be left open for secondary wound healing. Alternatively, for acceleration of the healing phase, a covering with mesh-graft transplants can be performed after a phase of granulation of three to four weeks. To reduce the time of healing, vacuum therapy is recommended. Vacuum therapy can be used immediately after surgical treatment to promote granulation, or as a therapy option for the attachment of mesh-graft transplants in concave wounds as in the example of the axilla.

A prerequisite for its application is careful cauterization, since otherwise the danger of postoperative bleeding exists. Another important prerequisite is that the area surrounding the wound is dry, since otherwise an adequate seal is not guaranteed. A disadvantage of the method is the initially painful change of the wound dressing. Typically, dressing changes are better tolerated later on. Reports of cases of the use of vacuum therapy in the treatment of *acne inversa* are very rare in the literature. Only in one case study described by Elwood et al. is there a recommendation for the use of vacuum ther-

apy for a mesh-graft covering of a wound after excision of the affected skin area⁵.

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◆ Case 30 - Treatment of a Soft Tissue Defect of the Heel

D. Dill-Müller and A. Bonowitz

History

This example describes the use of vacuum therapy in a case of a deep tissue defect following tumor resection on the lateral aspect of the heel.

Findings

Extensive, deep tissue defect with involvement of the periosteum of the calcaneus. No contamination with pathogenic bacteria.

Therapy / Course

Following tumor resection surgery, the patient was left with a defect on heel measuring 8 x 6 x 3.5 cm (Fig. C30.1), which was conditioned using vacuum therapy (suction strength, 125 mmHg, intermittent mode) and finally closed using a full-thickness skin graft. The dressing set specially designed for this purpose (Fig. C30.2)

consists of several 1-cm thick slices of polyurethane (PU) foam, which, when cut concentrically, can be fitted into the defect (Fig. C30.3a). Once in place, a foil heel cap with an integrated PU foam strip and adhesive margins is fitted over the heel and attached (Fig. C30.3b). A longitudinal extension of the dressing is laid in bow-like fashion over the lateral surface of the ankle to the dorsum of the foot and, at its free end, is connected to the vacuum source using a *trac-pad connector* (Fig. C30.3c). When the vacuum is applied, the excess foil segment of the heel cap is occluded (Fig. C30.3d) and there is tight contact between the PU foam and the wound surface. The heel dressing is delivered in sterile package for one-time application and can be applied by a single person with little effort, seals immediately, and increased both patient comfort and therapeutic safety.



Fig. C30.1 Postoperative wound defect.

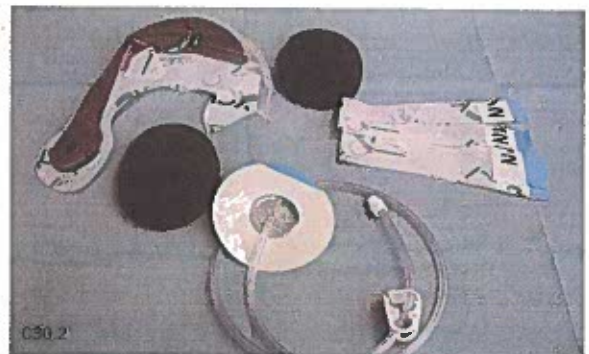


Fig. C30.2 Dressing kit with heel foam (VAC^{GrandFoam Heel Dressing}, KCI)



Fig. C30.3a Application of the heel dressing. Adaptation of the PU foam.



Fig. C30.3b Fixation of the heel dressing, drawn over to the dorsum of the foot.



Fig. C30.3c Application of the *trac-pad connector* on the dorsum of the foot.



Fig. C30.3d Vacuum therapy with applied suction.



Fig. C30.4 Granulation tissue after 14 days of vacuum therapy (125 mm Hg).



Fig. C30.5 Findings after 50 days: definitive wound closure using a full-thickness skin graft. A small central defect in the graft secondary to early weight-bearing. Healing by secondary intention.

The full-thickness skin graft healed completely under renewed vacuum therapy (PVA foam, suction at 125 mmHg, continuous mode). A small central defect developed secondary to premature weight-bearing. Healing was by secondary intention (Fig. C30.4-5). Ambulation with an orthopedic shoe with reduced heel pressure was possible throughout the entire period of vacuum therapy. Thus, partial outpatient treatment of heel defects is possible even during the conditioning phase.

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Part D

Practical Advice

Part D

Practical Advice

by D. Ditterich - T. Karl - L. Labler - W. Lange - F. v. Luebken - P. Mauckner - T. Othman
M. Schofer - T. v. Stein - W.T. Stoeckel - R. Trautvetter - C. Volkering - C. Willy - S.C. Wu

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The practical advice in this part of the book cover the entire range of vacuum therapy applications. They provide help and guidance for a number of common problems, including skin protection, sealing, pain management, the application of foam dressings to difficult anatomical sites, and the handling of TRAC pads, adhesive drape and foam.

Skin Protection

◆ Tip 1 - Preventing Skin Maceration - T. Karl

Question

What can be done to prevent the skin maceration that sometimes occurs when vacuum therapy is used?

Background

Skin maceration occurs occasionally, especially in the case of heavily exuding wounds.

Answer

When vacuum therapy causes maceration of periwound skin, cut an adherent polyurethane dressing to the exact wound dimensions and apply it in such a way that it extends about 4 cm beyond the wound edges. Then simply place an adhesive polyurethane drape over the polyurethane foam dressing (Figs. D1.1-5).



Fig. D1.1 Wound conditions prior to dressing application.



Fig. D1.2 Cut an adherent polyurethane dressing to the appropriate size and place it over the wound edges and the periwound area.

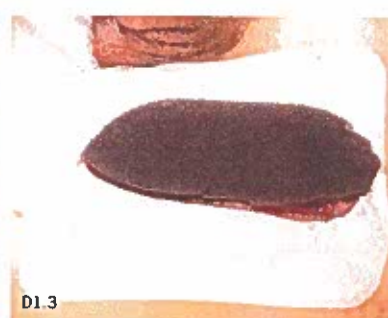


Fig. D1.3 Place the polyurethane foam over the wound.



Fig. D1.4 Cover the wound with an adhesive transparent polyurethane drape.



Fig. D1.5 Apply the vac-pad connector.

◆ Tip 2 - Enhancing the Seal and Providing Maximum Skin Comfort - M. Schofer

Question

What can be done to enhance the seal in the presence of irregular surfaces and at the same time provide maximum skin comfort?

Background

When a transparent drape is applied to an uneven surface (scars, skin folds, etc.), obtaining an airtight seal may be impossible. Even hydrogel strips may not help in the case of particularly difficult areas.

Answer

Stoma paste can be used to level uneven surfaces and obtain an airtight seal. Remove the plunger of a disposable syringe and squeeze stoma paste into the syringe barrel. Spread paste around the soft-tissue defect or on the uneven surface. Cover the wound with the dressing and the adhesive drape and apply negative pressure as per normal (Figs. D2.1-5). Stoma paste is contraindicated in patients with a history of hypersensitivity or allergic reactions to the paste or any ingredient of the paste. It is important to note, however, that the paste becomes increasingly dry and hard with time. According to the literature, there are even cases where high pressure levels caused pressure damage in the area under the paste.



Fig. D2.1 Squeeze stoma paste into the barrel of a disposable syringe.



Fig. D2.2 Spread paste around the soft-tissue defect.

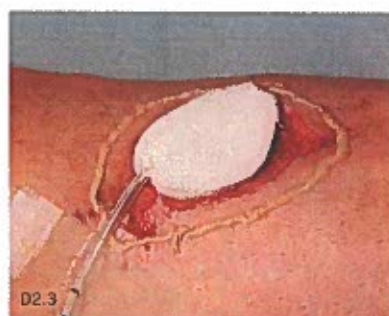


Fig. D2.3 Cover the wound with polyvinyl alcohol foam.



Fig. D2.4 Place a polyurethane drape over the foam.



Fig. D2.5 Apply negative pressure as usual.

◆ Tip 3 - Protecting the Skin with Non-adherent Material - P. Mauckner

Question

What can be done to obtain a secure seal in the presence of macerated wound edges and at the same time ensure optimal skin protection?

Answer

Protect the wound edges with non-adherent polyurethane foam exactly trimmed to fit the defect (Fig. D3.1). Fix the foam in place with an adhesive transparent drape. Cut an appropriate opening in the drape. Since these dressings are permeable to air, they must be completely covered with an adhesive drape.

Another option is to use a liquid skin protectant such as 3M™ Cavilon™, which can be applied through an applicator or as a spray. Once the skin protectant has started to dry, the wound can be covered with a transparent drape in the usual way.

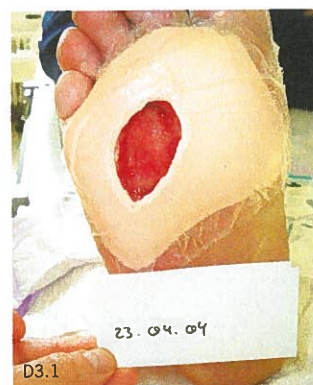


Fig. D3.1 Use a non-adherent polyurethane foam to protect the wound edges, and fix it in place with an adhesive transparent drape.

◆ Tip 4 - Bridging (I) - C. Willy

Question

How can two adjacent wounds be treated with a single suction source?

Background

When two wounds are close to one another and separated by intact skin, they can be treated with a single vacuum therapy unit together with two *trac-pad connectors* and one Y-connector. It is, however, also possible to use a technique known as bridging.

Answer

Fill both wounds with foam and connect the two foam pieces with an additional strip of foam (bridging; see Figs. D4.1-4). Seal the whole area *in situ* with a drape and apply the *trac-pad connector*.

Intact skin between the wounds should be protected. For this purpose, seal both wounds with adhesive drape, which normally also covers the tissue between the wounds. Cut two bigger holes through the drape and create a bridge with an additional strip of foam. In most cases, excess pieces of foam can be used for this purpose. Seal the bridge and apply the *trac-pad connector*. When this technique or the approaches described below are used, the bridge should be large enough to accommodate the entire 4-cm diameter *trac-pad connector* on the foam and thus prevent pressure sores (tissue necrosis). In the present case, a hydrocolloid dressing was used to protect the skin. Adhesive transparent drape, however, can be used as well (see also Tips 1 and 2).

This technique is also useful for wounds in anatomically difficult locations (the genital area, the heel, etc.) since it allows the *trac-pad connector* to be placed at a more convenient site (see Tip 24).



Fig. D4.1 Place polyurethane (PU) foam on both wounds to the left forearm. Protect the area between the two wounds (here it is covered with a hydrocolloid dressing).



Fig. D4.2 Seal the entire area.



Fig. D4.3 Make two holes in the adhesive drape over the wounds and create a PU bridge between the wounds. Use excess pieces of foam that are large enough to ensure full contact between the *trac-pad connector* and the foam in order to prevent pressure damage due to the firm connector's edge.

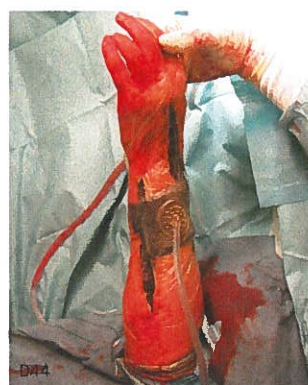


Fig. D4.4 Only one source of suction is required to obtain an airtight seal and an effective vacuum.

◆ Tip 5 - Bridging (II) - P. Mauckner

Question

How can two adjacent wounds be treated with a single suction source? (this supplements the previous tip and focuses on larger distances between the wounds to be connected.)

Answer

By using several pieces of foam that are connected with each other, we can evenly distribute negative pressure over large distances (see also Chapter 7 in Part A). There is almost no loss of suction when black foam is used. A considerable decrease in suction force, however, can be observed at a distance of only a few centimeters from the *trac-pad connector* when white foam is used at a negative pressure level of more than 125 mmHg. Several wounds can be connected with one or more foam bridges in order to be treated simultaneously. As already described above, it is important to protect intact skin between the wounds.

Comments

If the bridging technique is not suited to treating several wounds in different locations simultaneously (wounds to both extremities in a wheelchair patient, large distances between wounds, etc.), Y-connectors can be used to treat multiple wounds on the same patient with a single source of suction.

◆ Tip 6 - Preventing Skin Damage Due to the *Trac-Pad Connector*

S. C. Wu and D. G. Armstrong

Problem

Clinical options when the wound is smaller than the *trac-pad connector*.

Comments

If the wound is smaller than the *trac-pad connector*, the periwound skin should first be protected with extra drape, and second, be protected from contacting the center of the *trac-pad connector* by applying another larger piece of polyurethane foam.

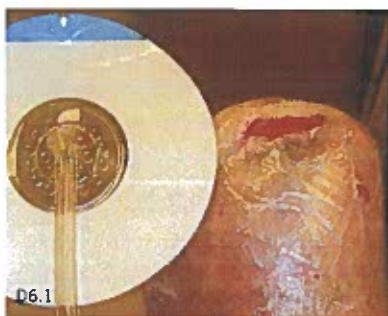


Fig. D6.1 The wound is smaller than the *trac-pad connector*.



Fig. D6.2 Condition the peri-wound skin with skin prep.



Fig. D6.3 Apply excess semi-occlusive drape to protect the periwound skin from maceration.



Fig. D6.4 Cut the polyurethane foam to approximate the shape of the ulcer.



Fig. D6.5 Place a second larger piece of polyurethane foam adjacent to and touching the original piece of foam.



Fig. D6.6 Cover the foams in total with adhesive drape.



Fig. D6.7 Cut a 1.5-cm diameter opening in the adhesive drape centered over the foam. Place the *trac-pad connector* over the drape opening such that the suctioning center of the *trac-pad connector* does not touch the skin.



Fig. D6.8 Engage suction at the desired pressure setting.



Fig. D6.9 Place the *trac-pad connector* tubing under the patient's pants, extending from the ankle to the waist, and connect it to the mobile VAC[®] vacuum therapy unit.

Maintaining Airtightness

◆ Tip 7 - Preventing Leaks in Anatomically Difficult Areas - T. Karl

Question

How can a secure seal be obtained and maintained in anatomically difficult areas?

Background

It is often challenging to apply a vacuum therapy dressing to an anatomically difficult site (the genital region, the forefoot, etc.). This often requires special measures to prevent leaks and securely seal the dressing.

Answer

In many cases, a secure primary seal can be obtained and maintained in difficult anatomical areas when self-adhesive polyurethane foam dressings and gel strips with adhesive coating on both sides are placed onto the site prior to the application of the vacuum therapy dressing. Thin strips of adhesive transparent drape, cut for this purpose, can also be used and gradually adapted to uneven surfaces where required. A vacuum dressing can thus be gradually secured with overlapping (tiled) pieces of adhesive PU drape.

◆ Tip 8 - Preventing Leaks Around the *Trac-pad Connector* - C. Willy

Question

How can leaks be prevented around the *trac-pad connector*?

Background

Before a *trac-pad connector* is handed to a physician by a scrub nurse and placed on a sealed wound, the backing paper must be removed from the adhesive surface of the *trac-pad connector*. Since the adhesive layer is thin, additional stabilisation is required to prevent it from curling and sticking to itself. For this reason, the manufacturer has fitted the *trac-pad connector* with an additional stabilising layer that makes the *trac-pad connector*. Full contact between the circular, even *trac-pad connector* and the wound is thus difficult to achieve on convex surfaces and leaks may result.

Answer

Apply only a few millimetres of the *trac-pad connector* to the surface to be treated. Gradually remove the stabilising layer as you gently press the *trac-pad connector* in place. This procedure is not required for even surfaces, but it does help prevent leaks on curved surfaces with a small radius.

◆ Tip 9 - Using the "Sandwich Technique" - C. Willy

Question

How can transcutaneous drainage tubes be embedded into the adhesive drape without causing leaks?

Background

Although a wide variety of sophisticated products are available, it may be necessary to place an additional drainage tube deep into the wound. This may be the case, for example, if a drainage tube is used instead of a *trac-pad connector* for instillation therapy and therefore must be inserted deep into the wound. A drainage tube can be placed either through the foam into the wound, between the foam and the wound edges, or transcutaneously at a site close to the wound. In any case, the drainage tube must be embedded into the adhesive drape in order to ensure that a secure seal is obtained (for further details on vacuum instillation therapy, see Chapter 5 in Part A).

Answer

A good seal can be obtained using the sandwich technique, which involves placing the drainage tube between two layers of adhesive drape. Proceed as shown below (Figs. D9.1-4).



Fig. D9.1 Place the drainage tube in the peri-wound area.



Fig. D9.2 Cover the skin with a strip of adhesive transparent drape. Fold the drape back to create a "drainage mesentery". Press the drainage tube onto the adhesive drape.



Fig. D9.3 Cover the drainage tube with a second layer of adhesive drape. The drainage tube is now "sandwiched" between two layers of adhesive drape.



Fig. D9.4 Gently press the second layer of adhesive drape around the drainage tube and the skin in order to secure the tube and allow the two drape layers to stick to each other. This is known as the "sandwich technique" since there are two layers of adhesive drape (like two slices of bread) with a drainage tube (like a layer of food) between them.

◆ Tip 10 - Checking for Leaks - C. Willy

Question

How can leaks be detected?

Background

A complete seal cannot always be achieved. The vacuum therapy unit automatically stops in the presence of a large leak. In this case, vacuum therapy cannot be continued.

When small leaks are present, the therapy unit compensates for the loss of suction and increases the pressure. Once the target pressure is reached, however, the suction force tends to decrease again, with the consequence that the therapy unit again begins to operate at a slightly higher pressure. The pump is thus activated continually, and the noise can be a nuisance to the patient. In both cases, an attempt should be made to detect the leak. It is, however, not always possible to identify leaks by listening for a whistling noise, which is typically heard in the presence of a leak.

Answer

Separate the *trac-pad connector* tube from the drainage-tube. Attach a syringe to the *trac-pad connector* tube and inject 20-40 ml of povidone iodine or another coloured solution in retrograde direction through the tube into the wound. Once the foam and the wound are saturated with the solution, a small amount of the coloured liquid will escape through the leak, which can thus be easily detected (Fig. D10.1).



Fig. D10.1 Inject a coloured indicator solution (e.g. povidone iodine) through the *trac-pad connector* tube. A small amount of the liquid escapes through the leak. The picture shows how liquid escapes at the lower right portion of the foam after the injection of approximately 35 ml of an indicator solution.

Pain Management

◆ Tip 11 - Reducing Pain During Dressing Changes - T. Karl

Question

How can pain be reduced during dressing changes?

Background

The removal of dressings, especially polyurethane foam dressings, can be painful.

Answer

Remove the polyurethane adhesive drape at the wound edges. Inject a local anaesthetic (e.g. 0.25% or 0.5% bupivacaine solution) into the wound base and the foam approximately 30-60 minutes before the planned removal of the dressing. Alternatively, disconnect the tubes and instill the local anesthetic down the dressing tube. You can also inject the local anaesthetic through the adhesive drape into the foam. Furthermore, the modern vacuum instillation therapy provides an elegant and simple method of introducing a local anaesthetic into the wound before a treatment or intervention is performed.

◆ Tip 12 - Foam Injection with Saline or Lidocaine - W.T. Stoeckel and J.A. Molnar

Question

How it is possible to reduce discomfort during dressing changes?

Background

Often, the removal of the vacuum therapy dressing can be performed at the bedside with minimal discomfort. Vacuum therapy foam changes are routinely done for chronic wounds in the home setting with rare instances of complication. There are, however, situations in which the removal of the foam from a wound bed can be more difficult and the adherence of the foam to the underlying tissue can create patient discomfort.

Answer

Some of this discomfort can be allayed by instilling saline into the foam dressing prior to removal. Simple injection of normal saline solution into the foam several minutes prior to a dressing removal can help to dissolve adherent clot and loosen the foam from the wound bed making the foam removal process more patient friendly. For patients who seem to have significant discomfort, adding an ampule of lidocaine to the moistening solution is equally safe and can provide sufficient analgesia to make bedside vacuum therapy removal tolerable.

Difficult Anatomical Sites and Other Special Cases

◆ Tip 13 - Diabetic Foot Syndrome – Wound Treatment Following Toe Amputation

W. Lange

Problem

Patients with diabetic foot syndrome (DFS) require airtight sealing of their wounds following toe amputation.

Background

In the treatment of DFS airtight sealing of the area surrounding the wound with adhesive drapes can be technically challenging. In many cases, a primary seal cannot be achieved due to dry skin and remaining viable toes.

Response

One suggestion for overcoming these technical challenges is to cut the foil into strips (about 5 x 20 cm or even smaller), so that they can be applied in an imbricated manner. Then, the entire forefoot can be sealed. Gauze should then be placed between the toes to avoid maceration. Briefly, the wound is overlaid with strips of bonding sheet (highly secreting wounds can be temporarily padded with a swab). Next, the bonding sheet across the wound can be cut out (if applicable, the swab can be removed) so that the foam can be placed into the wound bed. Finally, the wound can be resealed in an imbricated manner (Figs. D13.1-4).



Fig. D13.1-2 Diabetic foot, wound treatment after amputation of the third and fourth toes; before (left) and after (right) application of the Mini-VAC system.

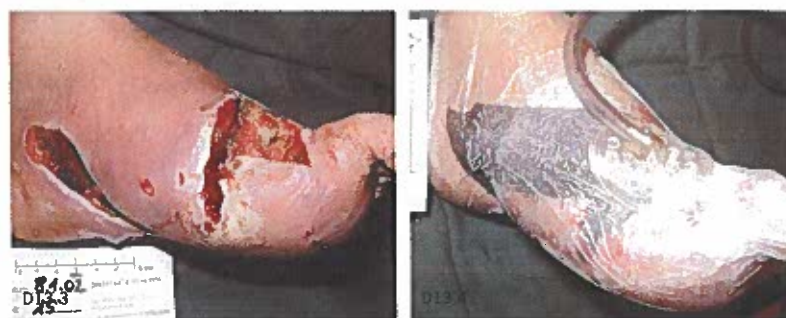


Fig. D13.3-4 Diabetic foot, wound treatment after amputation of the big toe and incision of the plantar arch; before (left) and after (right) application of the Mini-VAC system.

◆ **Tip 14 - Maintaining Airtightness Between the Toes in Diabetic Foot Patients**

T. Othman, J. Smentek, H. Huege, R. Bakker and G. Friese

Question

How can airtight seal be obtained when a wound is located between the toes?

Answer

When a wound defect is located between the toes (for example after a toe amputation), fill the wound with foam. Apply a gel strip to the sides of the adjacent toes and skin folds. Use an additional piece of foam to create a bridge. When negative pressure is applied, the gel strip helps seal difficult sites. Cover and secure the bridge with overlapping pieces of adhesive drape (Figs. D14.1-5).

Alternatively, you can seal the entire forefoot. It should be noted, however, that this procedure is associated with an increased risk of skin maceration. Place foam dressings, such as Mepitex®, between the toes in order to prevent maceration (Fig. D14.6).



Figs. D14.1-5 Picture of a diabetic foot after the amputation of the second digit (1). Apply adhesive drape to the area between the toes and cut a piece of foam to the size and shape of the wound. Use a small probe to apply strips of adhesive drape or gel to contoured skin surfaces (2). Place an additional piece of foam to a convenient site (on the forefoot) to permit the use of a *trac-pad connector* (3-5).

Fig. D14.6 Alternatively, take appropriate measures to prevent skin maceration in the area between the toes and seal the entire forefoot.

◆ Tip 15 - Managing Deep Wound Cavities with Vacuum Therapy

P. Mauckner

Question

How can a deep wound cavity at an amputation site be closed as quickly as possible?

Background

Wound cavities left to heal by secondary intention in patients with diabetic foot syndrome (DFS) occur predominantly in association with metatarsophalangeal joint resections or with forefoot, Lisfranc or Chopart amputations. Vacuum therapy is used to reduce the treatment period and to avoid or minimize the number of skin grafts especially in weight-bearing areas.

Answer

Institute vacuum therapy in the usual way and fill the entire wound cavity with foam. Once the entire wound cavity is lined with granulation tissue, gradually reduce the size of the wound and shape the wound cavity using adhesive drape. First, cover the wound with adhesive drape (Fig. D15.2). Cut a hole in the drape, preferably using a number 11 scalpel and forceps. Ensure wound approximation. Then, place one or more pieces of foam through the drape hole into the cavity. In contrast to the initial phase of treatment, leave a gap between the foam and the wound edges. Note: Do not pack the foam into any areas of the wound. The use of suction further reduces the size of the wound cavity. Repeat this procedure with pieces of foam of decreasing size until the wound edges are approximated. Simply place the foam on the approximated wound edges that are protected by adhesive drape. The suction force is thus applied only to the small gap between the wound edges. Use for example Leukostrip wound closure strips to ensure that the wound edges are held together securely for about another 14 days (Figs. D15.1-6).



Fig. D15.1 After forefoot amputation and debridement.



Fig. D15.2 Approximate the wound edges using adhesive drape (no foam).



Fig. D15.3 Cut a hole in the drape over the wound.



Fig. D15.4 Place the foam into the wound cavity and cover the wound with adhesive drape. Create a hole in the drape.



Fig. D15.5 Use a piece of foam that is large enough to prevent the *trac-pad connector* from causing pressure marks and necrosis at the wound edges.



Fig. D15.6 Place the foam under negative pressure.

Comments

In many cases, it is not necessary to amputate all toes. Dressing application in the presence of large wound cavities and individual toes requires that the remaining toes and the area between the toes be sealed as well. Proceed as follows. Dry the entire area. Cover the area between the toes and the sides of the adjacent toes with several small strips of adhesive drape. Note: Do not wrap the drape around the toes. Cut a hole in the drape over the wound. Cut a small piece of foam to the size of the wound and place it into the wound. Secure the foam with an additional strip of drape. Cut a hole in this drape over the wound. Use an additional strip of foam so that the *trac-pad connector* can be applied on the dorsal aspect of the foot.

◆ Tip 16 - Securing Foam and Skin Grafts - C. Willy

Question

When vacuum therapy is used to hold a meshed graft in place and increase graft take, is it necessary to secure the entire foam and the whole graft at the wound edges?

Background

Especially on uneven surfaces, soft polyurethane (PU) foam can help gently press the meshed graft onto the wound and thus ensure full contact between the graft and the underlying wound bed even in highly contoured areas until the graft has taken (four to five days). The application of constant gentle pressure and the immobility of the foam prevent the graft from being subjected to shearing forces.

Answer

Whereas it is often not necessary to fix the foam in place using stitches or staples, there are sites where it is advisable to secure the entire meshed graft. When vacuum therapy is used to secure a meshed graft, it should be borne in mind that the application of suction causes a reduction in the volume and surface area of the foam. If the foam is not fixed, it will therefore shrink and retract from the wound edges. As a result, it can detach an unsecured meshed graft from the underlying wound bed, causing undulations in a previously well-fitted graft. In our own patient population, there was one case in which a skin graft was applied to a convex surface and was displaced despite partial fixation (Fig. D16.1). In cases like this, the foam should be secured in place in order to prevent the graft from moving under the dressing.



Fig. D16.1 A 20 cm by 17 cm defect on the lateral thigh of a 41-year-old female patient was covered with a meshed graft. Two strips of skin were harvested and placed on the wound. They were attached to the wound edges using a continuous suture. Excess skin was trimmed off and used to cover small residual defects without further fixation. The foam was not secured in place. When the dressing was changed for the first time after five days, there were a few sites where the graft had failed to take (at 1 o'clock in the picture), where undulations had been induced (at 3 to 6 o'clock), or where the wound was either uncovered or covered with a double layer of grafted skin (from the middle to the lower region of the wound at 6 to 7 o'clock). The unsecured foam had moved on the concave surface of the wound (extending from the ventral to the dorsal side of the thigh) and caused a displacement of the skin graft.

◆ **Tip 17 - Obtaining a Secure Seal Around External Fixator Screws - C. Willy**

Question

How can a secure seal be obtained if the Schanz screws of an external fixator protrude through the wound and the foam?

Background

Fractures are often associated with large soft-tissue defects. In some of these cases, the Schanz screws of an external fixation system must be inserted through the wound and require special precautions when the adhesive drape is applied.

Answer

Cut a piece of foam to the appropriate dimensions and place it on the wound. Apply a white gel strip around the Schanz screws in close proximity to the foam. Spread the gel over and around the screws and ensure that each screw is completely covered with gel. Cut adhesive drape into several small pieces. Place the pieces of drape onto the wound in such a way that they slightly overlap each other. The adhesive drape can thus be applied more easily to the convex surface of the wound. Place one or two additional strips of drape on the gel layer over the screws in order to ensure the integrity of the seal (Figs. D17.1-5).

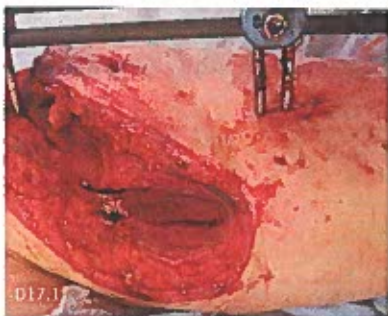


Fig. D17.1 Deep soft-tissue defect over an open fracture of the proximal humerus. Two Schanz screws protrude from the cranial portion of the wound.

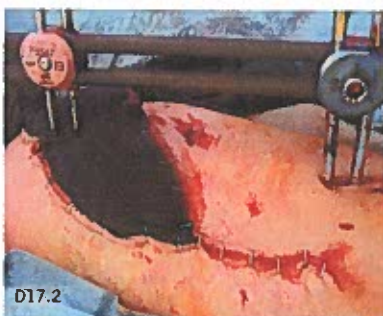


Fig. D17.2 Place a piece of PU foam into the wound. The Schanz screws are incorporated in the foam.



Fig. D17.3 Apply a strip of gel to the screws. Completely cover and connect both screws with a layer of gel.



Fig. D17.4 Successively apply small pieces of an adhesive drape.



Fig. D17.5 Apply suction. The wound is tightly sealed.

◆ Tip 18 - Vacuum Therapy and Simultaneous Use of an External Fixation

L. Labler

Question

How do you seal the vacuum therapy dressing properly when the soft tissue injury dimensions around the external fixator are very large?

Background

Large soft tissue defects are often localised over fractures and, thus, the external fixator has to be positioned in an area of extensive soft tissue injury (e.g. degloving injury). In cases of soft tissue trauma with open wounds or in the scope of traumatic decollement of extremities, vacuum therapy may be applied as a temporary coverage. The avulsed skin areas are completely de-fatted and re-planted to the injured body part as either a skin graft or a mesh-graft and fixed by means of vacuum therapy. If there is an indication for immobilisation of the extremity or an accompanying extremity fracture requires external fixation with a fixator, technical problems frequently occur secondary to the tightness of the dressing in the area of the points of the Schanz's screws leading to failure of the therapy.

Answer

To avoid possible leaks around the Schanz's screws of the external fixator of this large wound area, the whole extremity was packed into a black foam dressing ("extra large"), as might otherwise be used in patients with large-dimensioned burn wounds (Figs. D18.1-6).



Fig. D18.1 A 76-years female patient after a motor vehicle accident. A complete circular skin decollement on left lower extremity.



Fig. D18.2 After complete stepwise surgical debridement, the degloved skin was fully de-fatted and replanted.



Fig. D18.3 The de-fatted skin was sutured and equipped with relaxing stab incisions. Immobilisation was performed by a fixator overlapping the joint.



Fig. D18.4 In order to further fix the sutured skin, we chose the vacuum therapy. The extremity including the external fixator are wrapped with the black PU foam. The whole system was finally wrapped in the transparent foil.



Fig. D18.5 Suction was adjusted to 125 mmHg negative pressure. The proximal and distal connections were tight when the suction was started. The whole dressing, even in the areas above the external fixator, was leak-free. The first dressing change took place after five days. Necrotic skin areas, which did not survive, were debrided and covered with a skin mesh-graft.



Fig. D18.6 Medial view of the dressing system.

◆ Tip 19 - Inserting an Additional Drainage Tube for Instillation Therapy - C. Willy

Question

What can be done to ensure that a solution that is instilled into a deep wound reaches the site where it is needed?

Background

Usually, two *trac-pad connectors* are used for instillation therapy. One pad is used for removing fluid from the wound, the other for instilling a solution. The solution passes through the foam until it reaches the surface of the wound. Depending on wound dimensions, gravity and the pressure of the fluid, the solution is distributed throughout the wound. As a result of this passive distribution, there is no guarantee that a sufficient amount of the instilled solution reaches the target site within a period of 5-30 minutes.

Answer

Insert an additional drainage tube through the wound or skin and place it at the target site (Figs. D19.1-2; see also Chapter 5 of Part A for further information on vacuum instillation therapy).



Fig. D19.1 A 51-year-old patient with post-traumatic osteitis of the ulna and the radius. After hardware removal and debridement, instillation therapy was used in conjunction with vacuum therapy until an external fixator was applied. An additional tube was inserted through the skin in order to ensure that the instilled solution (160 mg of gentamycin in 250 ml of sodium chloride) entered deep into the wound and reached the area between the bones.



Fig. D19.2 An additional tube, generally, allows a solution to be instilled manually or automatically (if using the VAC[®]-therapy unit).

◆ **Tip 20 - Treatment of Deep-Seated Bone and Soft Tissue Defects in Chronic Infection - M. Schofer**

Question

Is there a way to accelerate healing of deep-seated bone and soft tissue defects in chronic infection?

Background

Chronic infections often cause deep-seated bone and soft tissue defects. Effective use of vacuum therapy requires thorough excision of infected and necrotic tissue.

Answer

Treatment of bone infections requires patience. Infected tissue needs to be debrided thoroughly and often repeatedly. It is not quite clear whether the bone actually clears the infection or whether the infection simply becomes quiescent, since chronic osteitis quite frequently relapses even after long disease-free intervals. However, if the local findings (cultures, radiography, clinical appearance of the wound) and the systemic investigations (temperature, WBC, biochemistry) suggest an overcome (quiescent) infection, a final bone and soft tissue debridement is performed to remove the last vestiges of necrotic tissue. Once healthy, bleeding bone appears, the defect is filled using autologous spongiosa. In order to accelerate closure of the soft tissue defect, vacuum therapy is applied. According to the size of the initial wound, final wound closure may require further plastic surgery (Figs. D20.1-12).



Fig. D20.1 Chronic osteitis of the proximal tibia following medial transfer of the tibial tuberosity.



Fig. D20.2 Radiography after several interventions. Note the large bone defect partly filled with antibiotic pellets.



Figs. D20.3-4 Radiographic and clinical appearance suggest successful treatment.



Figs. D20.5-6 The large cavity of the tibial metaphysis was filled with autologous spongiosa. Subsequent vacuum therapy was applied to treat the remaining soft tissue defect.



Figs. D20.7-8 Final closure of the wound was performed using a pedicled medial gastrocnemius muscle flap and skin mesh-graft.



Figs. D20.9-12 The final cosmetic and functional result.



Abdominal Dressing System

◆ Tip 21 - Wound Dehiscence With Exposed Intestines After Laparotomy - W. Lange

Question

How can the abdomen be closed temporarily, when vacuum therapy abdominal dressing foam is not available for use on a dehiscence wound following laparotomy?

Background

Abdominal dressing is unavailable.

Answer

As an alternative to the abdominal dressing foam the exposed intestines can be covered with a silicon mesh (e.g. Mepitel®; Fig. D21.1) followed by PU foam.



Fig. D21.1 Postoperative wound dehiscence with exposed intestines; covering of the intestines with Mepitel mesh before application of the vacuum dressing.

◆ Tip 22 - Using Additional Drainage Tubes with Abdominal Dressing - C. Willy

Question

Is it possible to close an open abdomen using only an abdominal dressing or should one or two additional drainage tubes be inserted deep into the abdomen?

Background

It is usually sufficient to follow the manufacturer's instructions and use only one abdominal dressing to close the abdominal cavity. An additional drainage tube is not required in the majority of cases.

Answer

Experience has shown, however, that large amounts of fluid can accumulate in the pouch of Douglas. In a patient with four-quadrant peritonitis, residual irrigation solution and other fluids were not removed through the abdominal dressing during the 24 hours after initial surgery and copious irrigation. Second-look surgery showed a large amount of fluid in the pouch of Douglas. Whereas fluid that accumulates in existing cavities and similar areas due to gravity can usually be removed by drainage tubes, it cannot be safely drained using vacuum therapy. One or two additional drainage tubes (Charrière 20 to 26) should therefore be inserted into the abdominal cavity if peritonitis or other infectious conditions make it necessary to leave an abdomen open. Additional drainage tubes, however, are not required after laparotomy for abdominal compartment syndrome alone. Thomas Wild in Vienna recommends leaving the ends of the additional drainage tubes between the two pieces of foam comprising the abdominal dressing system.

◆ **Tip 23 - Applying the Double-Layered Foam of the Abdominal Dressing - R. Trautvetter**

Question

How can the lateral skirt of the double-layered drape be easily placed directly on the intestine or other organs?

Background

The lateral skirt of the drape extends approximately 25 cm beyond the foam and needs to be spread as smoothly as possible into the four quadrants laterally and craniocaudally. Depending on local conditions, it can be difficult to apply the adhesive drape subperitoneally. Tangential folds can lead to fluid accumulations and thus to an unsuccessful treatment.

Answer

Use forceps with wet swabs to apply and smooth down the adhesive drape over an abdominal dressing. Radial folds can help drain the site.



Fig. D23.1 Open abdomen before closure with an abdominal dressing.



Fig. D23.2 Use wet swabs to smooth down the adhesive drape.



Fig. D23.3 After application of the adhesive drape.

General Handling Advice

◆ Tip 24 - Placing the *Trac-pad Connector* in a Convenient Location - R. Trautvetter

Question

How can an inconvenient location for the *trac-pad connector* be avoided?

Background

Depending on their respective locations, a *trac-pad connector* and the tubing can make it difficult for a patient to wear therapeutic shoes, thus delaying ambulation. In addition, they can cause pressure and pain, or even damage when they are applied on the dorsal trunk.

Answer

Apply a transparent hydrocolloid dressing or a piece of adhesive drape on intact skin. Place an additional piece of foam on this site in order to move the *trac-pad connector* and/or the tubing to a suitable location. (This technique has led the manufacturer to develop what is known as a heel dressing.)



Fig. D24.1 The wound is on the plantar surface of the foot. Use an additional piece of foam and place the *trac-pad connector* and/or the tubing on a more convenient site. Protect the skin under the additional piece of foam with excess adhesive drape or a hydrocolloid dressing.

◆ Tip 25 - Handling of the Adhesive Drape - P. Mauckner

Question

How can complete adhesion of the drape be achieved?

Answer

When adhesive drape is used to secure the foam, take care to first apply the drape directly to the wound edge. Then fit the drape along the contours of the foam dressing before the foam is collapsed. Instead of applying one large piece of drape to secure the foam, use small pieces of drape that are shorter than the length or width of the foam. Apply these pieces loosely to the edges of the foam. When negative pressure is applied, shearing forces will thus be prevented from damaging the wound edges or from detaching the foam from the wound edges and exposing them.



Fig. D25.1 Apply pieces of drape loosely in order to avoid skin tension and damage. The two green arrows mark sites where the drape is loosely applied. This technique allows the adhesive drape to be fitted to the shape of the foam before the latter collapses.

◆ Tip 26 - Wound Evaluation Under the Vacuum Therapy Foam

W.T. Stoeckel and J.A. Molnar

Question

How easy is it to assess the wound during vacuum therapy?

Background

There is often a tendency for the clinician to avoid evaluation of a wound under the vacuum therapy system, assuming it is too difficult to take the dressing down for wound assessment.

Answer

However, if one simply incises the vacuum therapy foam and adherent drape using a scalpel or scissors in an appropriate strategic location, it is quite easy to evaluate the wound and simply patch the incised area with additional adherent drape. In this way, one does not lose the seal in the periphery that was most difficult to obtain during the original application. Patient discomfort is also minimised as complete takedown of the dressing is unnecessary. With some experience, one may find that using this technique is easier than taking down a traditional gauze dressing. Use of this technique is particularly important when vacuum therapy is used for acute extremity burn injuries in which timely serial evaluations are necessary for determining the need for escharotomy or fasciotomy.

◆ Tip 27 - Preventing Disconnection of Y-Connectors - R. Trautvetter

Question

How can a disconnection of Y-connectors be prevented?

Background

When Y-connectors are used, a single therapy unit is sufficient for applying negative pressure to several vacuum dressings simultaneously. The connectors' own weight, the rigidity of the tubing systems and patient movements can cause disconnection of the bayonet fittings and, thus, a loss of vacuum, especially when several Y-connectors are used.

Answer

Simply secure the Y connectors to a suitable plate.



Fig. D27.1 Y-connectors connect three tubes through which fluid is drained from the wound. The Y-connectors are securely attached to a plate.

◆ Tip 28 - Preventing Hypergranulation - P. Mauckner

Question

How can different rates of granulation tissue formation in different parts of the wound be managed?

Background

Depending on wound bed conditions and perfusion, granulation tissue formation, which is encouraged by vacuum therapy, will take place at different rates in different parts of the wound. As a result, the pattern of granulation tissue development can be extremely heterogeneous. Whereas some parts of the wound will require continued vacuum therapy, other parts may already be covered with granulation tissue and would be at the risk of hypergranulation if vacuum therapy were continued.

Answer

If some parts of the wound are covered with granulation tissue that has reached the level of the surrounding skin and other parts require the continuation of vacuum therapy, place a hydrocolloid or other dressing on the area that has granulated to skin level. Acting as a barrier to new tissue growth, this dressing prevents hypergranulation and at the same time allows epithelium to spread from the wound edges.

◆ Tip 29 - Prevention of Foam Formation In the Canister (I) - C. Volkering

Question

What should be done if the canister is filled with large amounts of bubbles that cause the vacuum therapy unit to erroneously report that the canister is full?

Background

When fluid with a high protein content (wound fluid containing blood, ascites, etc.) is removed from the wound and foam is produced, the vacuum therapy unit may notify the user that the canister is full even if the latter is filled with only a small amount of wound fluid. In such cases, the canister is usually changed, which incurs increased costs in the long run.

Answer

Add a few drops of dimeticone to the tube behind the connector. Dimeticone is an anti-foaming agent and as such can prevent foam formation by changing the surface tension of gas bubbles.

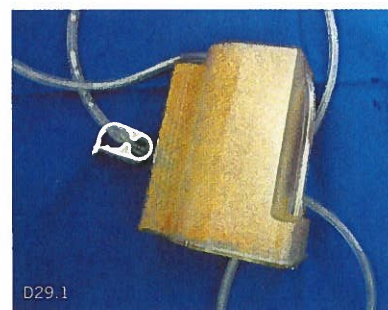


Fig. D29.1 Completely "filled" canister.

◆ Tip 30 - Prevention of Foam Formation In the Canister (II) - D. Ditterich

Question

What other options exist for avoiding foam in the canister?

Background

In our general surgery patients undergoing vacuum therapy treatments, we are often confronted with the problem of suctioning off very large quantities of secretions. If the exudate is rich in protein, large-bubbled foam often develops at the applied pressures of 75-150 mmHg, very quickly obstructing the secretion-collection bottles. This problem arises mainly when vacuum therapy is applied for open abdomen, as part of the septic shock, or in case of secondary closure of the abdominal wall with mesh implantation.

Safety features in the device (e.g. VAC^{ATS}) prevent the further use of the canister. Most of the methods currently used for foam reduction (e.g. intermittent bottle changing, insertion of an additional secretion-collecting container) are risky from a hygienic point of view and, in addition, conflict with the law on product liability.

Answer

Before connecting a new secretion-collecting container with the *trac-pad connector*, you can fill the hose system under sterile conditions with 5-10 ml of a silicone-based de-foaming agent (e.g. Sab Simplex®) or alcohol (which will denature the protein molecules in the protein-rich secretion and is, in our opinion, more efficient and cheaper). This will considerably reduce the foam formation so that the canister can be used for a significantly longer time.

◆ Tip 31 - Responding to the Error Message "canister full" - P. Mauckner

Question

What should be done if the canister is blocked with a blood-containing fluid that causes the vacuum therapy unit to erroneously report that the canister is full?

Background

If blood is drained from the wound, it can coagulate in the tube or at the opening of the *trac-pad connector* (Fig. D31.1). This causes the system to generate the message "canister full". In this case, changing the canister will have little effect.

Answer

Disconnect the tubing while the unit is operating. Inject 10 ml of NaCl into both openings of the tubing and reconnect the tubing. Temporarily increase the level of suction. If this fails to clear the blockage, change the dressing and, where necessary, control the bleeding.

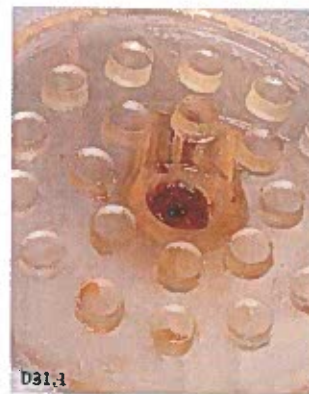


Fig. D31.1 Blockage in the *trac-pad connector* opening.

◆ Tip 32 - Managing Uncovered Parts of the Wound - P. Mauckner

Question

Must a vacuum dressing be completely changed if parts of the wound surface are not covered by foam once negative pressure has been applied?

Background

This problem can occur when the foam is not firmly secured to the wound edges.

Answer

In general, uncovered parts of the wound pose no problems for the patient but can reduce the effectiveness of treatment. Use scissors or a scalpel and cut a hole through the adhesive drape over the uncovered parts of the wound. Cut an additional piece of foam to the appropriate size and place it on the uncovered part of the wound. Re-cover this area with adhesive drape.

◆ Tip 33 - Securing the Foam - E. v. Luebken

Question

How can a piece of foam be secured to the wound edges?

Background

The foam is secured to the wound edges in order to encourage wound contraction once the foam shrinks under suction. In other words, the foam is sutured or stapled in situ at the wound edges and thus helps pull the wound closed when the foam becomes smaller.

Answer

You can attach the foam to the wound edges with sutures or staples. Alternatively, you can cut a piece of foam to the size and shape of the wound and place it onto the wound. When this "simple" measure is used to reduce the wound surface, tension is applied to the wound edges via the adhesive drape. Although the drape does not become smaller in size, it adapts to the uneven surface of the shrinking foam and helps apply tension to the wound edges as soon as the foam is under negative pressure.

Comments

In our patient population, we usually do not secure the foam with either sutures or staples in more than one-third of patients receiving vacuum therapy.

◆ Tip 34 - Closing the Skin Over a Foam Dressing - F. v. Luebken

Question

Is it possible to close the skin over a piece of foam that was placed deep into the wound?

Background

A foam dressing that reaches to the level of the surrounding skin has the advantage that it can be inspected. Infection-induced discoloration of PVA foam, blood accumulations and loss of suction can thus be easily detected. If a piece of foam is inserted deep into the wound and the skin over the foam is closed, this is no longer possible. Closure of the skin has the additional disadvantage that it requires the placement of a drainage tube that must usually be inserted in the periwound area. This results in further tissue injury and complicates sealing.

Answer

In general, it is possible to close the skin over the foam. The aforementioned aspects (the role of the foam as an indicator of problems and the difficulties in sealing the system), however, should be well-considered. When the foam remains in the wound and the skin is closed, it is usually impossible to securely seal the wound area over the foam with a suture alone. An adhesive drape must be placed over the area in the majority of cases.

Comments

We usually do not close the skin over a wound filled with foam.

◆ Tip 35 - Treating Fistulae With Vacuum Therapy - T. Othman

Question

How can a deep fistula be filled with foam?

Answer

Assess the depth of the fistula and cut a piece of foam that has the same width as the fistula but slightly longer. Attach a piece of thread to the foam to mark the exact depth of the fistula. Carefully pack the fistula with the foam piece. Pull the thread gently until it is approximately 0.5 cm above the level of the skin surrounding the fistula. Cut off the thread. Apply the tubing and the vacuum source. In the case of a narrow fistula tract, it is advisable to use polyvinyl alcohol foam, which has a higher tensile strength than polyurethane foam (Fig. D35.1).

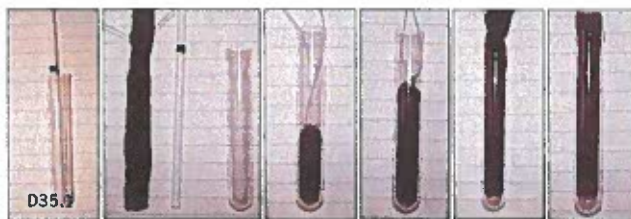


Fig. D35.1 Assess the depth of the fistula and cut a piece of foam to the appropriate size. Attach a piece of thread to the foam. Carefully pack the foam into the wound. Pull the thread gently until it is above skin level. The foam now conforms perfectly to the shape of the wound and is in full contact with the entire wound surface.

◆ Tip 36 - Increasing the Size of the Foam - C. Willy

Question

What, other than using a second piece of foam, can be done to increase the size of a foam piece that is too small?

Background

A piece of foam that has been applied to a wound may prove to be of an inappropriate size. If a package has been opened and the foam piece is too small, you can increase its size easily by using a simple trick. (This applies at least to commercially available 3.3-cm-thick foam).

Answer

Use a scalpel to split the foam in half lengthwise but do not cut through, leaving it hinged on one side. The piece of foam is now almost twice its original size and no additional costs have been incurred (Figs. D36.1-2).



Fig. D36.1 Split the piece of foam in half lengthwise but do not cut through.

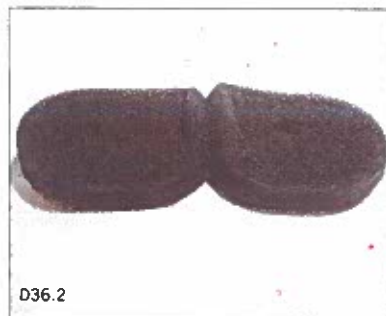


Fig. D36.2 The foam is now almost twice as large and half as thick as before.

◆ **Tip 37 - Cutting a Hole in Adhesive Drape Before *Trac-pad Connector* Application**
F. v. Luebken and C. Willy

Question

How should an opening be made in the adhesive drape to ensure reliable suction?

Background

The *trac-pad connector* must be placed over a hole in the adhesive drape to transmit negative pressure to the foam. Whereas some users make an X-shaped cut in the drape, others prefer to cut a hole in the drape.

Answer

Cut a 1- or 2-cm-wide hole in the drape. When you make an X-shaped cut in the drape and then apply negative pressure, the foam will collapse and the drape along the cuts may stick to itself. In this case, it would be impossible to transmit negative pressure (Figs. D37.1 and 2).



Fig. D37.1 An X-shaped cut was made in the drape.



fig. D37.2 An approximately 1- or 2-cm-wide hole was cut in the drape.

◆ Tip 38 - Combining Vacuum Therapy and Hyperbaric Oxygen (HBO) Therapy

T. v. Stein

Question

Can vacuum therapy be continued during a hyperbaric oxygenation session?

Background

Hyperbaric oxygen (HBO) therapy is increasingly used as an effective adjunctive therapy in the treatment of chronic inflammatory diseases of soft tissue and bone. HBO therapy appears to be particularly beneficial when areas of compromised blood flow are involved. A literature review and our own experience show that HBO therapy has established itself as an effective option for the following conditions:

- ◆ air or gas embolism
- ◆ carbon monoxide poisoning
- ◆ clostridial myositis
- ◆ crush injury, compartment syndrome and other acute traumatic ischemias
- ◆ decompression sickness
- ◆ enhancement of healing in selected problem wounds
- ◆ intracranial abscess
- ◆ necrotising fasciitis/myositis
- ◆ chronic osteitis/osteomyelitis
- ◆ radiation-induced bone and soft-tissue complications
- ◆ compromised skin grafts and flaps
- ◆ severe burns

In general, successful treatment requires surgery (debridement, irrigation, use of antiseptics and, where necessary, local antibiotics and vacuum therapy). When HBO therapy is used as an adjunct, the question arises whether vacuum therapy must be discontinued for a session in the pressure chamber.

Answer

You can combine vacuum therapy and hyperbaric oxygenation under the following conditions. Always apply the vacuum dressing in such a way that an airtight seal is maintained. Otherwise, there may be a valve effect. If a commercially available therapy unit (with a pump) is used as the vacuum source, disconnect the patient from the therapy unit prior to a hyperbaric oxygenation session. In many cases, the application of negative pressure can be interrupted for 1.5 or 2 hours without problems. If the discontinuation of vacuum therapy is unacceptable (heavily exuding wounds, skin graft fixation, etc.), suction must be produced by alternative vacuum sources (temporary use of the suction equipment in the hyperbaric chamber, use of a drainage system). In the presence of a leak, permanent suction must be applied during a session since a valve effect around the leak can cause undesired changes (clotting, inflation of the drape). Regularly check the airtightness of the seal during a session in the pressure chamber and take remedial action where necessary.

◆ Tip 39 - Choosing Between Continuous and Intermittent Therapy - C. Willy

Question

When should continuous therapy be used and when should intermittent therapy be chosen? What pressure settings are recommended?

Background

State-of-the-art vacuum therapy units offer a wide variety of settings. You can choose negative pressure levels between 50 and 200 mmHg and operate the system in the continuous or the intermittent mode. When you use intermittent therapy, the active or ON phase and the inactive or OFF phase can last between 1 and 10 minutes each. Continuous suction at a negative pressure level of 125 mmHg is, however, applied in the majority of cases.

Answer

The following statements can be made on the basis of recent experience and the literature, which has already been discussed elsewhere in this book (see also Chapters 6 and 7 of Part A).

- ◆ There are no major differences between negative pressure levels of 50, 75 or 125 mmHg in their potential for encouraging granulation tissue formation¹.
- ◆ The size of the hypoperfused area close to the wound increases with increasing negative pressure⁴.
- ◆ When the level of negative pressure is increased, subcutaneous tissue is more vulnerable to hypoperfusion than muscular tissue⁴.
- ◆ Intermittent therapy can stimulate granulation tissue formation faster than the application of continuous negative pressure².
- ◆ Intermittent therapy is ideally provided with cycles of 2 minutes ON and 5 minutes OFF (Morykwas et al.) or with cycles of 10 minutes ON and 10 minutes OFF (Wackenfors et al.)^{3,4}.
- ◆ Nowhere in the literature has an author shown to date that continuous therapy is more suitable for particular conditions.

A number of recommendations emerge from these findings. In this context, the author wishes to point out that he, too, has always used continuous negative pressure at 125 mmHg. During the preparation of this book, however, he began to question the reasons behind using this mode and pressure setting. A review of the experience and recommendations that have been reported in the literature (sometimes without explanations) allows the following conclusions to be drawn.

- ◆ A negative pressure level of 50 or 75 mmHg should be used for tissues that are characterised by critical nutritive perfusion or are tender to pressure (e.g. elderly patients with sacral pressure ulcers, impaired healing of large wounds involving subcutaneous fat, peripheral soft-tissue wounds with exposed small vessels such as the digital arteries of the foot, etc.). Low levels of negative pressure should also be used when dressings are applied circularly.
- ◆ Higher pressure levels (100 or 125 mmHg) are suitable for adequately perfused wounds (e.g. young patients with large soft-tissue defects and exposed muscle tissue).
- ◆ In the majority of cases, intermittent suction appears to produce better results than continuous negative pressure. Some authors recommend that negative pressure should be provided continuously during the first two or three days for the initial removal of wound fluid and then the settings should be changed to the intermittent mode. The reasons for this advice, however, are not explained. The question is whether intermittent therapy alone has the potential to remove wound fluid adequately.
- ◆ Intermittent therapy should be provided on the basis of either two-minute ON/five-minute OFF cycles or ten-minute ON/ten-minute OFF cycles, which have been established in the literature^{3,4}.

It would be desirable if future publications included detailed information on what therapy settings (level of negative pressure and mode of suction) were used and on whether instillation therapy was used in conjunction with vacuum therapy. Without these data, an accurate comparison of available studies is often impossible. It would be sufficient to abbreviate the entire mode of therapy like this: 75-I-2-5 (negative pressure of 75 mmHg, two-minute ON/five-minute OFF intermittent cycle) or 125 C (negative pressure of 125 mmHg, continuous mode).

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Part E

Chapter 1 - 2

1. Reading up on "Vacuum Therapy" on the Internet
2. *Peer-reviewed* Literature on the Subject "Vacuum Therapy"

Part E / Chapter 1

Reading up on “Vacuum Therapy” on the Internet

S. Benesch and C. Willy

Over the past decade the Internet has become the first source of information for many researchers, superseding the traditional and time-consuming literature research in libraries. The modern scientist usually opens his notebook, connects to the Internet and logs on to online libraries such as the National Library of Medicine¹ (Medline) or – even more modern – the Cochrane Library², the "reliable source of evidence in health care". Furthermore, the Internet now can be used as a medium of knowledge transfer and medical training. As an example, the online seminars of WebSurg's World Virtual University³ are partially accredited for purposes of continuing medical education (CME). It was the purpose of the following article to search Websites addressing vacuum therapy.

A search run on Google⁴ with the keywords "vacuum-assisted closure" returned about 440,000 results, while "vacuum therapy" returned 6,130,000 results, "vacuum-therapy" 636 and "topical negative pressure" 2,390,000 hits. For the search run using the keywords "vacuum therapy" the results were poor because mostly sites dealing with erectile dysfunction etc. were listed. Nevertheless, using the keywords "vacuum-assisted closure" OR "topical negative pressure" it is possible to find an endless number of relevant Websites.

Looking back to May 2005 (the publication date of the German edition of this book), there were only a few relevant Web publications. Approximately one year ago, using the keywords "topical negative pressure" returned only non-relevant pages. Additionally, it is interesting that the formerly most comprehensive website "www.web-vacuumtherapy.co.uk" (Fig. E1.1)⁵ today no longer exists. Apart from the disadvantageous page layout (black background, blue and white font colours) this Website contained comprehensive information about vacuum therapy, which was useful for both physicians and patients. For example, the topic "Clinical Applications" contained articles with practical tips for dressing changes (wound preparation, foam size, bridging technique etc.) and hints for dealing with special situations (tunnel technique, incontinence etc.) as well as complications. In addition, the articles contained recommendations on how

to treat special wound types (e.g. dehiscent wounds, trauma wounds). The site was complemented by an extensive bibliography and a list of links dealing with wound management. As noted, however, this Website is closed.

Today, one of the most comprehensive Websites is "www.kci1.com", the Website of this company, which is the market leader in vacuum therapy technology (Fig. E1.2)⁶. Besides providing information about their products, the KCI Website also offers valuable clinical information and literature on vacuum therapy, vacuum therapy guidelines⁷ and CPT Codes as well as FAQ.

Broad information can also be found at other Websites. The highest-ranked site is entitled "An introduction to the use of vacuum-assisted closure"⁸. This is a subsite of an online resource for dressing materials and practical wound management information called "World Wide Wounds – The Electronic Journal of Wound Management Practice"⁹ and contains a very good introduction into the history of vacuum therapy, its clinical uses and the costs of treatment ostensibly based on a considerable body of literature references. One very interesting PDF-paper is published by Simon Higgins¹⁰ reports on "The Effectiveness of Vacuum-Assisted Closure (VAC) in Wound Healing". He found evidence that vacuum therapy "may have advantages compared to other forms of wound dressing" but indicated the lack of multicenter randomized trials (August 2003). Similar results could be found in a PDF-paper called "Vacuum Assisted Closure Therapy for Wound Care"¹⁰. Altogether, only few other Websites offer overviews about the history, indications, therapeutic options of valuable information level¹²⁻¹⁵.

In the meantime, innumerable Websites have appeared dealing with the above mentioned search terms. The majority show abstracts of full-paper references as well as reports, abstracts and comments derived from scientific meetings.

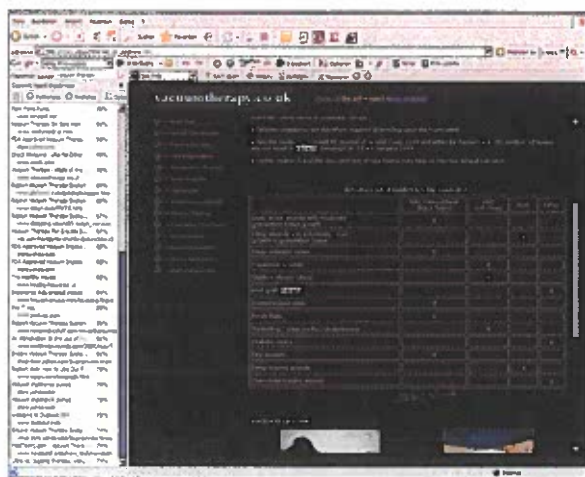


Fig. E1.1 The former most comprehensive web-site on the subject "vacuum therapy" (www.vacuumtherapy.co.uk). It not longer exists.



Fig. E1.2 Homepage of the company KCI

1. <http://www.ncbi.nlm.nih.gov>
2. <http://www.cochrane.org>
3. <http://www.websurg.com/>
4. <http://www.google.com>
5. <http://www.vacuumtherapy.co.uk>
6. <http://www.kci1.com/>
7. http://www.kci1.com/2-B-128_Clin_Guidelines_Blue_Book_1-05.pdf
8. <http://www.worldwidewounds.com/2001/may/Thomas/Vacuum-Assisted-Closure.html>
9. <http://www.worldwidewounds.com/>
10. <http://www.med.monash.edu.au/healthservices/cce/evidence/pdf/c/991fr.pdf>
11. http://www.health.gov.on.ca/english/providers/program/mas/tech/reviews/pdf/rev_vac_120104.pdf
12. http://www.etsr.org/bulletin12_1/section5.php (Banwell et al)
13. <http://www.aetna.com/cpb/data/CPBA0334.html> (Swift et al)
14. <http://www.jcn.co.uk/journal.asp?MonthNum=01&YearNum=2001&Type=backissue&ArticleID=314>
15. <http://www.npwmt.com>

Part E / Chapter 2

***.Peer-reviewed Literature on the Subject
“Vacuum Therapy”***

Compiled by A. Winter and C. Willy

Peer Reviewed Literature "Vacuum Therapy"

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Fifteen years after its introduction, vacuum therapy is now a well-established method for managing many different types of wounds. This book reflects the development of this novel and revolutionary wound therapy and covers both theoretical and practical aspects in depth. It is designed to be read and used by a wide audience with varying levels of expertise. It provides an extensive introduction for those as yet unfamiliar with vacuum therapy and offers a wealth of information and practical guidance to those with wide expertise and experience.

The chapters in this book address the entire spectrum of indications for the use of vacuum therapy and cover a wide range of medical and surgical disciplines including

- ▶ trauma surgery / orthopaedics / plastic surgery
- ▶ abdominal surgery / thoracic surgery
- ▶ vascular surgery and
- ▶ dermatology.

In addition, the book features a comprehensive collection of case reports of scientific and educational value.

Equally useful is the extensive practical guidance that is provided on many aspects of particular relevance to the clinician, for example on how to

- ▶ protect the skin
- ▶ prevent leaks and maintain the seal
- ▶ reduce pain, and
- ▶ manage difficult anatomical sites.

Particular attention is drawn to special dressing techniques (e.g. abdominal dressings, bridging, the sandwich technique, etc.) and the most appropriate therapy settings (level of negative pressure and mode of suction).

The contributions reflect not only the results of countless discussions between health care professionals from different care settings but also the latest knowledge of vacuum therapy based on a thorough review of the international literature. Great care was taken to cite information only from reliable sources such as *peer-reviewed* journals. The appendix to this book provides a list of relevant *peer-reviewed* publications (as of 30 June 2006) and an overview of useful websites on vacuum therapy.



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