Evaluation of a New, Improved Surgical Drainage System

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The development of portable suction devices has allowed a vacuum to be applied to closed wound suction systems when a patient is ambulatory. These devices provide a convenient alternative to electrically powered suction machines that confine a patient to bed. In these portable suction devices, the drainage tubes are connected to vacuum reservoirs that function after being evacuated of air. The configuration of the reservoir is usually either a bellows or bulb. Once the reservoir expands to resume its original shape, it exerts no residual vacuum to the drainage tube. In this event, the reservoir must be collapsed again to evacuate accumulated air, which in turn reinstitutes the applied vacuum to the drainage system.

Although the portable suction devices permit patient ambulation, this advantage must be weighed against the distinct drawbacks. First, this nonvented suction may create sufficient vacuum to aspirate tissue into the holes of the drainage tube which limits the efficiency of the drainage system [*1*]. Moreover, encroachment of the tissue into the holes of the tube may result in tissue injury that reduces its resistance to infection.

A new multifunctional drainage system has been developed (Axiom Medical Inc., Paramount, CA) that can be used either as a closed drainage system for the ambulating patient or as a filtered sump drainage system for the patient confined to bed. It is the purpose of this report to describe the system's design, fluid mechanics, operation, and clinical performance.

Design

This drainage system consists of three components: a flat drainage tube, a connecting tube, and a reservoir. The flat drainage portion of the system, which is 11 mm wide and 20.3 cm long, is made of silicone and is radiopaque (Figure 1). Two rows of staggered holes are present on either side of the flat surfaces of the drain that communicate with a separate lumen within the tube and drain the fluid from the wound. Interlocking longitudinal plastic ridges are present on the inner surface of the flat drain which prevent the drainage lumen from collapsing from the vacuum source [*2*]. A separate lumen has been incorporated within the drain that serves as a potential air vent to atmospheric pressure. The exit of the air vent lumen is recessed 9 mm from the open end of the flat drain so that it is not accessible to tissue that may occlude the lumen.

The double-lumen flat silicone drainage tube connects to the double-lumen silicone connecting tube (length 61 cm) by a smooth V-shaped junction that facilitates removal and insertion of the drainage portion of the tube, while ensuring that the drain is not easily dislodged from the wound during clinical use. The air vent lumen of the connecting tube separates from the drainage lumen 3.8 cm from the end of the tube. A removable filter assembly is inserted into the lumen of the air vent. This filter assembly consists of three parts: a female Luer lock, the filter, and a filter cap. The filter has been attached to the air vent system to remove particulate matter and bacteria from the air that passes through the filter. The inner and outer surfaces of the drain and connecting tube are coated with a hydrogel (Hydromer®, Hydromer, Inc., Whitehouse, NJ) that is formed from the reaction of polyvinylpyrrolidone and isocyanate prepolymer. As a hydrogel, it absorbs water and exhibits a low coefficient of friction. Previous investigations performed in our laboratory demonstrated that this coating has two important functions [*3*]. It reduces the coefficient of friction of the surface of the drain, thus facilitating removal of the drain from the wound, and it limits the adherence of blood clots to the drain, thus allowing them to be evacuated easily into the reservoir.

The drainage lumen is attached to a collapsible bulb reservoir. The entrance of the reservoir has a one-way check valve to prevent reflux of fluid collected in the reservoir. A drainage port is incorporated into the other end of the reservoir to permit emptying. The reservoir is calibrated so that the drainage fluid can be easily measured without emptying the reservoir.

The drainage system can function as either a closed suction system or a filtered sump system. For the closed system, the bacterial filter is simply capped before applying

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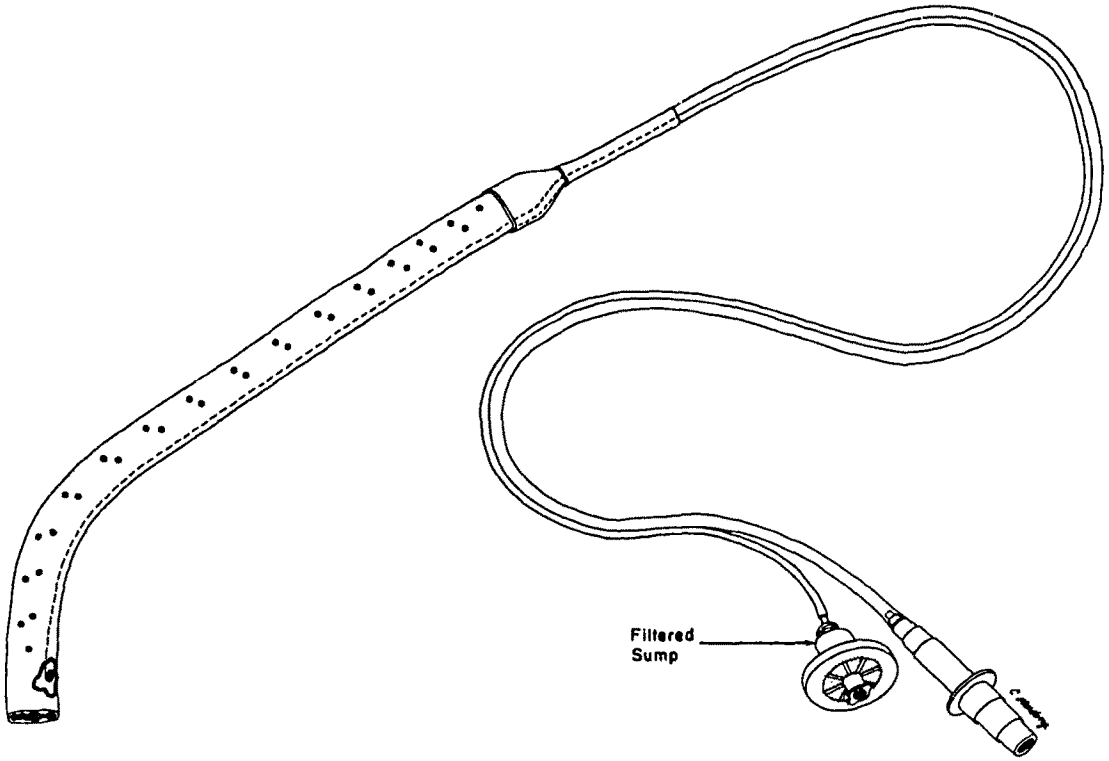

Figure 1. Design of a new surgical suction drain. The exit of the air vent lumen is displayed in the cutaway portion (lower left) of the drainage tube wall.

a vacuum to the system. After removing the cap from the drainage port, air is evacuated from the reservoir by compressing the collapsible reservoir, after which the drainage port is capped. As the reservoir assumes its original shape, a vacuum is applied to the drainage system.

When this system is used as a filtered sump drain, a special plastic adaptor is inserted into the drainage port of the reservoir and then connected with tubing to a calibrated suction outlet or machine. The level of applied vacuum pressure to the drainage lumen is 30 mm Hg. The cap over the filter is removed, providing access for filtered air into the air vent lumen. When converting from sump suction to closed suction, it is important to replace the cap on the filter assembly. If the filter assembly is not capped, the collapsible bulb will become filled with air and no longer serve as a vacuum source. Moreover, fluid will drain by gravity into both the drainage and air vent lumens. When the fluid gains access to the air filter assembly, the wetted filter should be replaced by a new sterile dry filter.

Fluid Mechanics of the Drainage System

A suction drainage system for a wound operates on the principle that a differential pressure exists between the wound and the vacuum source that causes the fluid to move from the wound, a site of high pressure, to the vacuum source, a point of lower pressure. In a closed wound suction system, the wound is sealed so that air is not vented through the skin into the wound. As vacuum is applied to the drain, a pressure differential between the wound and vacuum source is established that evacuates fluid and air from the wound into the drainage tube. After the air and fluid escape from the wound, the applied vacuum causes the edges of the wound to collapse with some invagination of the tissues into the holes of the tube. Eventually, the pressure differential between the wound and vacuum source disappears, eliminating the drain's ability to remove fluid from the wound. By establishing an air vent in the sump drainage tube to atmospheric pressure, it will always maintain a pressure differential between the wound and vacuum source, thus ensuring optimal evacuation of fluid from the wound cavity.

The height of the fluid collection reservoir with respect to the wound has considerable influence on the efficiency of either the closed or vented suction systems. In both systems, a vacuum source of 30 mm Hg is recommended for wound drainage. This pressure is sufficient to lift a column of water 1.34 feet (16.1 inches). When the fluid collection reservoir is 16.1 inches or more above the surface of the wound, the vacuum of 30 mm Hg is not sufficient to evacuate fluid from the wound. Ideally, the fluid collection reservoir should be maintained at or below the level of the wound so that the vacuum of 30 mm Hg is sufficient to evacuate fluids into the collecting reservoir.

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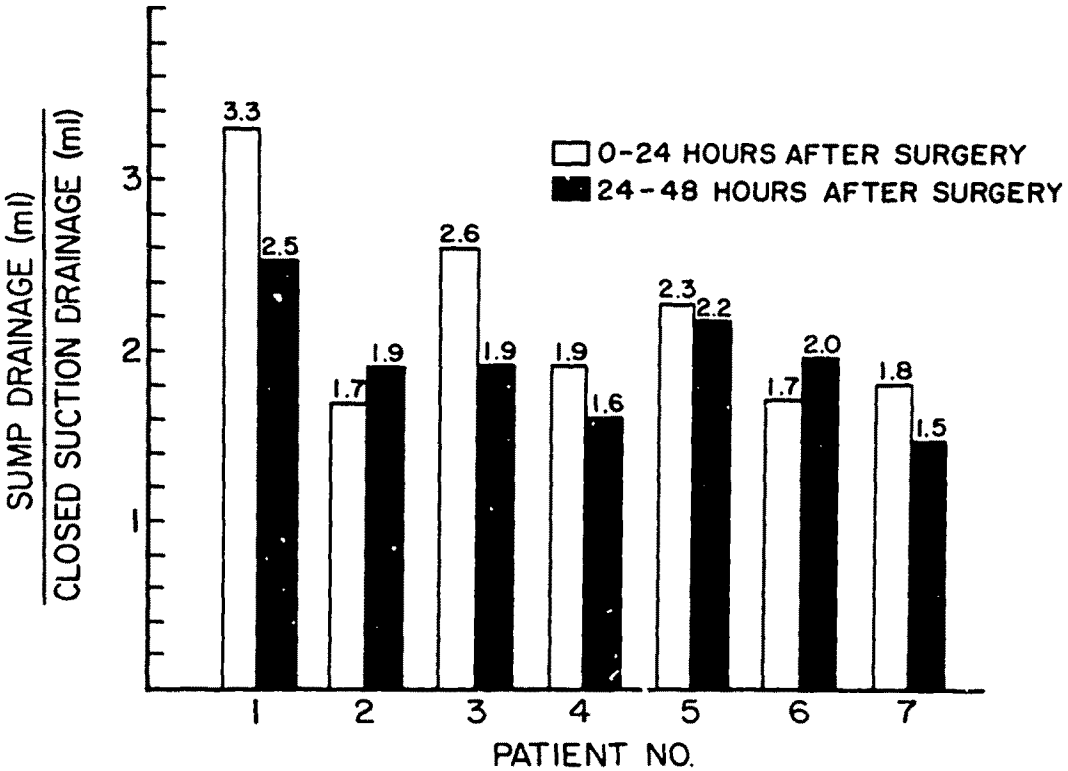

Figure 2. The efficiency of the two drainage techniques was evaluated in each patient by dividing the total volume of fluid collected by air filtered sump drainage by the fluid volume recovered with closed suction drainage.

Operation

At the time of surgery, the drainage system is removed from the sterile package using aseptic technique. The filter assembly is then removed from the drain. The flat drain is placed in the most dependent portion of the wound. Using a no. 11 knife blade, a stab wound measuring 4 mm in length (the external diameter of the silicone connecting portion of the tube) is made through the skin at a site separate from the incision to allow the drain to exit from the wound. A 22.2 cm curved hemostat is then passed through the skin into the wound. The jaws of the hemostat are opened so that one jaw inserts into the air vent lumen and the other into the drainage lumen. The jaws of the hemostat are then closed so that the lumens of the drain are approximated. After grasping the drain, the hemostat and drain are withdrawn through the stab wound, until the smooth V-shaped junction between the flat drain and connecting tube contacts the stab wound. Using a 3–0 braided nylon suture, the connecting tube is secured to the skin.

During the operative procedure and when the patient is confined to bed, the drainage system functions as a filtered sump drainage tube. During either patient transport on a stretcher or when the patient is ambulating, the drainage system operates as a closed suction system using the compressed bulb reservoir as the vacuum source. In either closed suction or sump suction drainage, the reservoir is maintained at or below the level of the patient's wound. When sump drainage is employed, the fluid accumulating in the reservoir must be emptied before its volume becomes so great that the fluid begins to exit into the connecting tube attached to the drainage port. Once fluids enter this tube, the vacuum pressure necessary to evacuate the fluids into the secondary collecting reservoir of the calibrated suction device will be directly related to the location of the collecting reservoir with respect to the patient's wound. As the level of the secondary collecting reservoir increases above that of the wound, the vacuum pressure required to lift a column of fluid into the reservoir becomes greater, subjecting the wound cavity to considerably higher vacuum pressures than 30 mm Hg. These higher vacuum pressures limit the potential benefits of the air vented system and encourage tissue encroachment into the holes of the drainage tubes.

Performance

The effectiveness of the air vent in the drainage system was evaluated in seven patients subjected to reconstruction of large soft tissue defects with large random skin flaps. A constant negative pressure of 30 mm Hg was utilized throughout the study. To compare the efficiency of the vented system to that of the closed suction system, the

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filtered sump assembly was capped and uncapped at 2 hour intervals for 48 hours. The amount of drainage during each 2 hour period was carefully collected and measured using a graduated tube. The efficiency of the two drainage techniques was compared by dividing the total volume of fluid collected by sump drainage by the fluid recovered from closed suction drainage in the same patient during the first (0 to 24 hours) and second (24 to 48 hours) postoperative days. The quotient of this analysis was taken to indicate the efficiency of each drainage technique in the removal of fluids. Statistical analysis of the data was accomplished using the Student's t test.

Results

When sump drainage was employed, the volume of fluid removed was significantly greater than that removed by closed suction drainage ($p < 0.05$) (Figure 2). The efficiency of sump drainage was 1.5 to 3.3 times greater than that of closed drainage during the first two postoperative days. These results confirm the superiority of sump drainage for the removal of fluids from wounds. The benefits of sump drainage of wounds can be realized without the risks of infection by airborne organisms. The attachment of a filter to the sump vent removes particulate matter and bacteria from the air before they pass into the wound.

Comments

There are specific requirements for drainage systems for use in surgery. First, the drain should be extremely flexible and supple so that it conforms to the wound cavity without damaging tissues. A silicone drain made of a nonreactive supple material conforms more easily to the wound cavity than do the stiffer polyvinyl chloride drains. A second requirement is that the drainage tube be radiopaque to confirm its position by appropriate tangential roentgenography of the wound cavity. Moreover, the inner lumen of the tube should not collapse during suction. The longitudinal ridges on the inner surface of the drainage lumen of this tube prevents collapse of the tube during suction. The outer and inner surfaces of the tube should exhibit a low coefficient of friction that facilitates removal of the drain as well as evacuation of blood clots from the drain. The hydrogel coating of silicone drains appears to satisfy the latter requirement. The drainage tube should be able to function as a closed suction system during patient transport and ambulation and not confine the patient to bed. However, it must be easily converted to a sump drainage system to enhance the efficiency of the drain in the removal of fluids from the wound. An air filter must be incorporated into the air vent to remove particulate matter and bacteria from air that is brought into the wound. The drainage system described in this report was specifically designed to satisfy these requirements. Although we believe that this drainage system has significant advantages over other systems, the benefits of the system will only be realized if the health professionals can efficiently and effectively operate it.

Summary

A new, improved drainage system has been specifically designed to provide either closed suction drainage for the ambulating patient or sump drainage for the patient confined to bed. This drainage system is made of silicone that has a hydrogel coating with a low coefficient of friction. This coating facilitates removal of the drain from the wound cavity and reduces the adherence of blood clots in the drainage system. A filter assembly is attached to the air vent lumen to remove particulate matter and bacteria from the air. Clinical evaluation of the filtered sump drainage system has confirmed its superiority over closed suction in its efficiency of removing fluids from the wound.

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