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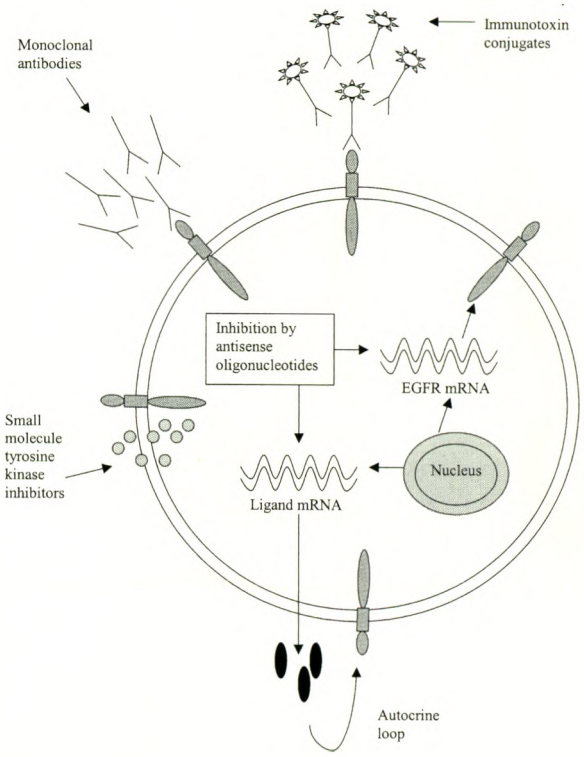

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Petitioner - Avation Medical, Inc.
Ex. 1094, p. 1
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

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continued on next page

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 2
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

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The Journal of
UROLOGY®

Volume 169 June 2003 Number 6

CLINICAL UROLOGY

This Month in Clinical Urology. *J. Y. Gillenwater* 1971

This Month in Investigative Urology. *A. Atala* 1973

Review Articles

Tumor Markers in Diagnosis of Primary Bladder Cancer. Systematic Review. *A. S. Glas, D. Roos, M. Deutekom, A. H. Zwinderman, P. M. M. Bossuyt and K. H. Kurth* 1975

Improving and Predicting Radiosensitivity in Muscle Invasive Bladder Cancer. *A. J. Colquhoun, G. D. D. Jones, M. Al Moneef, K. J. Bowman, R. C. Kockelbergh, R. P. Symonds, W. P. Steward and J. K. Mellon* 1983

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Erectile Dysfunction in Elderly: Epidemiology, Etiology and Approaches to Treatment. *A. D. Seftel* 1999

Original Articles

Randomized Controlled Trial of Zoledronic Acid to Prevent Bone Loss in Men Receiving Androgen Deprivation Therapy for Nonmetastatic Prostate Cancer. *M. R. Smith, J. Eastham, D. M. Gleason, D. Shasha, S. Tchekmedyian and N. Zinner* 2008

Multiple Arteries in Live Donor Renal Transplantation: Surgical Aspects and Outcomes. *B. Ali-El-Dein, Y. Osman, A. A. Shokeir, A. B. Shehab El-Dein, H. Sheashaa and M. A. Ghoneim* 2013

Quality of Life, Pain and Return to Normal Activities Following Laparoscopic Donor Nephrectomy Versus Open Mini-Incision Donor Nephrectomy. *K. T. Perry, S. J. Freedland, J. C. Hu, M. W. Phelan, B. Kristo, A. H. Gritsch, J. Rajfer and P. G. Schulam* 2018

Management of Lymphoceles After Renal Transplantation: Laparoscopic Versus Open Drainage. *T. F. Fuller, S.-M. Kang, R. Hirose, S. Feng, P. G. Stock and C. E. Freise* 2022

Conversion of Calcium Oxalate to Calcium Phosphate With Recurrent Stone Episodes. *N. Mandel, I. Mandel, K. Fryjoff, T. Rejniak and G. Mandel* 2026

Urinary Response to Oral Oxalate Load in Recurrent Calcium Stone Formers. *M. S. Krishnamurthy, K. A. Hruska and P. S. Chandhoke* 2030

Immediate Closure of Nephrostomy Tube Wounds Using Tissue Adhesive: Novel Approach Following Percutaneous Endourological Procedures. *M. Sofer, A. Greenstein, J. Chen, A. Nadu, I. Kaver and H. Matzkin* 2034

Laparoscopic Pyeloplasty for Secondary Ureteropelvic Junction Obstruction. *C. P. Sundaram, R. L. Grubb, III, J. Rehman, Y. Yan, C. Chen, J. Landman, E. M. McDougall and R. V. Clayman* 2037

Simplified 5-Step Model for Training Laparoscopic Urethrovesical Anastomosis. *R. Katz, A. Nadu, L. E. Olsson, A. Hoznek, A. de la Taille, L. Salomon and C.-C. Abbou* 2041

Comparison of Quality of Life Following Laparoscopic and Open Prostatectomy for Prostate Cancer. *I. Hara, G. Kawabata, H. Miyake, I. Nakamura, S. Hara, H. Okada and S. Kamidono* 2045

Positive Surgical Margins in Laparoscopic Radical Prostatectomy: Impact of Apical Dissection, Bladder Neck Remodeling and Nerve Preservation. *R. Katz, L. Salomon, A. Hoznek, A. de la Taille, P. Antiphon and C. C. Abbou* 2049

Laparoscopic Radical Nephrectomy: Incorporating Advantages of Hand Assisted and Standard Laparoscopy. *L. E. Ponsky, E. E. Cherullo, K. L. W. Banks, M. Greenstein, S. B. Streem, E. A. Klein and C. D. Zippe* 2053

Editorial: Laparoscopy and Urologic Oncology—I Now Pronounce You Man and Wife. *L. G. Gomella* . 2057

Mayo Clinic Scottsdale Experience With Laparoscopic Nephron Sparing Surgery for Renal Tumors. *S. D. Simon, R. G. Ferrigni, D. E. Novicki, D. L. Lamm, S. S. Swanson and P. E. Andrews* 2059

Laparoscopic Radical Prostatectomy: Decreasing Learning Curve Using Mentor Initiated Approach. *M. D. Fabrizio, I. Tüerk and P. F. Schellhammer* 2063

Endoscopic Extraperitoneal Radical Prostatectomy: Initial Experience After 70 Procedures. *J.-U. Stolzenburg, M. Do, R. Rabenalt, H. Pfeiffer, L. Horn, M. C. Truss, U. Jonas and W. Dorschner* 2066

Cover: Methods of inhibiting the epidermal growth factor receptor (page 1983).

PLEASE NOTE THE CME ENROLLMENT FORM AND QUESTIONNAIRE PRINTED ON PAGES 2348 AND 2349 IN THIS ISSUE

Contents continued on page A10

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 4
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

Contents continued from page A6

Oncological Safety of Laparoscopic Surgery for Urological Malignancy: Experience With More Than 1,000 Operations. *J. Rassweiler, A. Tsivian, A. V. R. Kumar, C. Lymberakis, M. Schulze, O. Seeman and T. Frede* 2072
Renal Cell Carcinoma With Retroperitoneal Lymph Nodes: Role of Lymph Node Dissection. *A. J. Pantuck, A. Zisman, F. Dorey, D. H. Chao, K.-R. Han, J. Said, B. J. Gitlitz, R. A. Figlin and A. S. Belldegrun* 2076
Heterozygosity or Homozygosity for 2 HLA Class II Haplotypes Predict Favorable Outcomes for Renal Cell Carcinoma Treated With Cytokine Therapy. *J. A. Ellerhorst, W. H. Hildebrand, J. W. Cavett, M. A. Fernandez-Vina, S. Hodges, N. Poindexter, H. Fischer and E. A. Grimm* 2084
Molecular Detection of von Hippel-Lindau Gene Mutations in Urine and Lymph Node Samples in Patients With Renal Cell Carcinoma: Potential Biomarkers for Early Diagnosis and Postoperative Metastatic Status. *S. Ashida, M. Furihata, M. Tanimura, O. Sugita, M. Yamashita, T. Miura, M. Moriyama and T. Shuin* 2089
Immunocytochemical Analysis of Prostate Stem Cell Antigen as Adjunct Marker for Detection of Urothelial Transitional Cell Carcinoma in Voided Urine Specimens. *L. Cheng, R. E. Reiter, Y. Jin, H. Sharon, J. Wieder, T. F. Lane and J. Rao* 2094
Multitarget Fluorescence In Situ Hybridization Assay Detects Transitional Cell Carcinoma in Majority of Patients With Bladder Cancer and Atypical or Negative Urine Cytology. *M. Skacel, M. Fahmy, J. A. Brainard, J. D. Pettay, C. V. Biscotti, L. S. Liou, G. W. Procop, J. S. Jones, J. Ulchaker, C. D. Zippe and R. R. Tubbs* 2101
Grade Progression and Regression in Recurrent Urothelial Cancer. *A. Borhan, J. E. Reeder, M. J. O'Connell, K. O. Wright, L. L. Wheeless, P. A. di Sant'Agnese, M. L. McNally and E. M. Messing* 2106
Intravesical Bacillus Calmette-Guerin Therapy for Stage T1 Grade 3 Transitional Cell Carcinoma of Bladder: Recurrence, Progression and Survival in Study of 57 Patients. *M. Peyromaure, F. Guerin, D. Amsellem-Ouazana, D. Saighi, B. Debre and M. Zerbib* 2110
Is There Therapeutic Role for Post-Chemotherapy Retroperitoneal Lymph Node Dissection in Metastatic Transitional Cell Carcinoma of Bladder? *P. Sweeney, R. Millikan, M. Donat, C. G. Wood, A. Siefker-Radtke, C. A. Pettaway, H. B. Grossman, C. P. N. Dinney, D. A. Swanson and L. L. Pisters* 2113
Combined Laser Treatment for Penile Carcinoma: Results After Long-Term Followup. *T. Windahl and S.-O. Andersson* 2118
Histology and Clinical Outcomes in Patients With Bilateral Testicular Germ Cell Tumors: Memorial Sloan Kettering Cancer Center Experience 1950 to 2001. *J. M. Holzbeierlein, P. C. Sogani and J. Sheinfeld* 2122
Is Post-Chemotherapy Resection of Seminomatous Elements Associated With Higher Acute Morbidity? *A. A. Mosharafa, R. S. Foster, B. C. Leibovich, R. Bihrle, C. Johnson and J. P. Donohue* 2126
Improved Clinical Staging System Combining Biopsy Laterality and TNM Stage for Men With T1c and T2 Prostate Cancer: Results From SEARCH Database. *SEARCH Database Study Group: S. J. Freedland, J. C. Presti, Jr., M. K. Terris, C. J. Kane, W. J. Aronson, F. Dorey and C. L. Amling* 2129
Percent of Prostate Needle Biopsy Cores With Cancer is Significant Independent Predictor of Prostate Specific Antigen Recurrence Following Radical Prostatectomy: Results From SEARCH Database. *SEARCH Database Study Group: S. J. Freedland, W. J. Aronson, M. K. Terris, C. J. Kane, C. L. Amling, F. Dorey and J. C. Presti, Jr.* 2136
Should Positive Surgical Margin Following Radical Prostatectomy be Pathological Stage T2 or T3? Results From SEARCH Database. *SEARCH Database Study Group: S. J. Freedland, W. J. Aronson, J. C. Presti, Jr., C. J. Kane, M. K. Terris, D. Elashoff and C. L. Amling* 2142
New York University Nerve Sparing Algorithm Decreases Rate of Positive Surgical Margins Following Radical Retropubic Prostatectomy. *O. Shah, D. A. Robbins, J. Melamed and H. Lepor* 2147
Modifying American Society for Therapeutic Radiology and Oncology Definition of Biochemical Failure to Minimize Influence of Backdating in Patients With Prostate Cancer Treated With 3-Dimensional Conformal Radiation Therapy Alone. *E. M. Horwitz, R. G. Uzzo, A. L. Hanlon, R. E. Greenberg, G. E. Hanks and A. Pollack* (Editorial Comments by F. A. Critz, L. Potters and M. W. Kattan, and F. A. Vicini and L. Kestin) 2153
Hazard Rates of Disease Progression After External Beam Radiotherapy for Clinically Localized Carcinoma of Prostate. *C. J. Rosser, L. B. Levy, D. A. Kuban, R. Chichakli, A. Pollack, A. Lee and L. L. Pisters* 2160
Is There Optimal Time for Intracavernous Prostaglandin E1 Rehabilitation Following Nonnerve Sparing Radical Prostatectomy? Results From Hemodynamic Prospective Study. *P. Gontero, F. Fontana, A. Bagnasacco, M. Panella, E. Kocjancic, G. Pretti and B. Frea* 2166
Early Catheter Removal After Radical Retropubic Prostatectomy: Long-Term Followup. *M. O. Koch, A. H. Nayee, J. Sloan, T. Gardner, G. R. Wahle, R. Bihrle and R. S. Foster* 2170
Incidence and Causes of Erectile Dysfunction After Pelvic Fractures Associated With Posterior Urethral Disruption. *O. Z. Shenfeld, D. Kiselgorf, O. N. Gofrit, A. G. Verstandig, E. H. Landau and D. Pode* (Editorial Comments by G. H. Jordan and J. W. McAninch) 2173
Significance of Measuring Time Course of Serum Malondialdehyde Concentration in Patients With Torsion of Testis. *E. O. Kehinde, O. A. Mojiminiyi, A. H. Mahmoud, K. A. Al-Awadi, A. Al-Hunayan and A. E. Omu* 2177

Contents continued on page A12

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 5
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

Contents continued from page A10

Urethrorectal Fistula: Transanal, Transsphincteric Approach With Locally Based Pedicle Interposition Flaps. *D. J. Culkin and C. E. Ramsey* 2181
Continent Lower Urinary Tract Reconstruction in Cervical Spinal Cord Injured Population. *J. N. Zommick, A. R. Simoneau, D. G. Skinner and D. A. Ginsberg* 2184
Hautmann and Studer Orthotopic Neobladders: Contemporary Experience. *K. S. Lee, J. E. Montie, R. L. Dunn and C. T. Lee* 2188
Enterocystometry: Impact of Filling Rate. *M. S. El-Bahnasawy and H. S. Shaaban* 2192
Incidence and Significance of Positive Urine Cultures in Patients With Orthotopic Neobladder. *D. P. Wood, Jr., F. J. Bianco, Jr., J. E. Pontes, M. A. Heath and D. daJusta* 2196
Treatment of Radiation Induced Hemorrhagic Cystitis With Hyperbaric Oxygen. *J. M. Corman, D. McClure, R. Pritchett, P. Kozlowski and N. B. Hampson* 2200
Bullous Lesion in Prostatic Urethra: Morphological Change Caused by Putative Chlamydial Infection. *K. Kamura, T. Nishimura, T. Okamoto, M. Noguchi and K. Hamaguchi* 2203
Penile Calciphylaxis: Analysis of Risk Factors and Mortality. *E. Karpman, S. Das and E. A. Kurzrock* . 2206
Urodynamic Effect of Acute Transcutaneous Posterior Tibial Nerve Stimulation in Overactive Bladder. *G. Amarenco, S. S. Ismael, A. Even-Schneider, P. Raibaut, S. Demaille-Wlodyka, B. Parratte and J. Kerdraon* 2210
Effects of Ejaculation by Penile Vibratory Stimulation on Bladder Capacity in Men With Spinal Cord Lesions. *L. Læssøe, J. Sønksen, P. Bagi, F. Biering-Sørensen, D. A. Ohl, E. J. McGuire and J. K. Kristensen* 2216
Longitudinal Assessment of Bowel Related Symptoms and Fecal Incontinence Following Radical Perineal Prostatectomy. *P. Dahm, A. D. Silverstein, A. Z. Weizer, M. D. Young, J. Vieweg, D. M. Albala and D. F. Paulson* 2220
Intraoperative Nerve Stimulation With Measurement of Urethral Sphincter Pressure Changes During Radical Retropubic Prostatectomy: Feasibility Study. *C. P. Nelson, J. E. Montie, E. J. McGuire, G. Wedemeyer and J. T. Wei* 2225
Macroplastique Implantation System for Treatment of Female Stress Urinary Incontinence. *J. T. N. Tamanini, C. A. L. D'Ancona, V. Tadini and N. R. Netto, Jr.* 2229
Preoperative Urodynamic Evaluation May Predict Voiding Dysfunction in Women Undergoing Pubovaginal Sling. *E. A. Miller, C. L. Amundsen, K. L. Toh, B. J. Flynn and G. D. Webster* 2234
Transvaginal Tape Lysis for Urinary Obstruction After Tension-Free Vaginal Tape Placement. *A. J. Croak, V. Schulte, S. Peron, C. Klingele, J. Gebhart and R. Lee* 2238
Management of Vaginal Erosion of Polypropylene Mesh Slings. *K. C. Kobashi and E. Govier* 2242
Bone Anchor 4-Corner Cystourethropexy: Long-Term Results. *A. Tsivian, A. Shtricker, S. Levin and A. A. Sidi* 2244
Outcome of Urethral Reconstructive Surgery in Series of 74 Women. *A. J. Flisser and J. G. Blaivas* . . . 2246
Pregnancy Outcomes After Vasectomy Reversal for Female Partners 35 Years Old or Older. *P. N. Kolettis, E. S. Sabanegh, J. G. Nalesnik, A. M. D'Amico, L. C. Box and J. R. Burns* 2250
Combination Treatment With α-Blocker Plus Anticholinergic for Bladder Outlet Obstruction: Prospective, Randomized, Controlled Study. *A. Athanasopoulos, K. Gyftopoulos, K. Giannitsas, J. Fisfis, P. Perimenis and G. Barbalias* 2253

Sexual Dysfunction in 1,274 European Men Suffering From Lower Urinary Tract Symptoms. *G. Vallancien, M. Emberton, N. Harving and R. J. A. van Moorselaar for Alf-One Study Group* 2257
Laboratory Evaluations of Erectile Dysfunction: Evidence Based Approach. *J. Bodie, J. Lewis, D. Schow and M. Monga* 2262
Editorial: Male Sexual Dysfunction—How Little Do We Know? *T. F. Lue* 2265

Quantitative Somatosensory Testing of Penis: Optimizing Clinical Neurological Examination. *C. B. Bleustein, H. Eckholdt, J. C. Arezzo and A. Melman* 2266
Blood Gas Changes in Corpora Cavernosa: Metabolic and Histomorphometric Implications in Patient With Erectile Dysfunction. *F. Sasso, R. Falabella, G. Gentile, C. Servello and G. Gulino* 2270
Influence of Paternal Age on Down Syndrome. *H. Fisch, G. Hyun, R. Golden, T. W. Hensle, C. A. Olsson and G. L. Liberson* 2275
Regret in Men Treated for Localized Prostate Cancer. *J. C. Hu, L. Kwan, C. S. Saigal and M. S. Litwin* 2279

Urologists at Work

Management of Obliterated Urinary Segments Using Laser Fiber for Access. *M. A. Thomas, A. M. Ong, P. A. Pinto, K. H. Rha and T. W. Jarrett* 2284
Novel Technique of Renal Entrapment for Morcellation. *H. M. User and R. B. Nadler* 2287
Vattikuti Institute Prostatectomy: Technique. *M. Menon, A. Tewari, J. Peabody and Members of VIP Team* 2289

Case Reports

Nutcracker Syndrome. *G. Yu and S. Bo* 2293
Laparoscopic Distal Ureterectomy for Low Grade Transitional Cell Carcinoma. *E. Gerber, C. Z. Dinlenc and J. R. Wagner* 2295

Contents continued on page A14

Petitioner - Aviation Medical, Inc.
Ex. 1094, p. 6
Aviation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

Contents continued from page A12

Renal Cell Carcinoma With Tumor Thrombus Extension Into Proximal Pulmonary Artery. *J. A. Wieder, H. Laks, D. Freitas, A. Marmureanu and A. Belldegrun* 2296
Unusual Mass of Spermatic Cord. *J. Braeckman, P. Van Tichelen and G. Dervaux* 2298
Incisional Bladder Hernia After Rectus Fascial Sling. *A. Gomelsky and R. R. Dmochowski* 2299
Vaginal Granulation Tissue Secondary to Bone Anchors: Experience in Two Patients. *D. S. Stember, H. M. Scarpero and V. W. Nitti* 2300
Priapism Following Ingestion of Tamsulosin. *P. R. Dodds, S. J. Batter and S. R. Serels* 2302

Letters to the Editor

Re: Outcome of Endoscopic Treatment for Vesicoureteral Reflux in Children Using Polydimethylsiloxane. *P. Dewan* 2303
Re: Chromophobe Renal Cell Carcinoma in Patient With Birt-Hogg-Dube Syndrome. *M. M. Walther and R. L. Grubb* 2303
Re: Effect of Nonsteroidal Anti-Inflammatory Agents and Finasteride on Prostate Cancer Risk. *R. S. Pruthi, J. E. Derksen and K. Gaston* 2304
Re: Chromogranin A Concentration as Serum Marker to Predict Prognosis After Endocrine Therapy for Prostate Cancer. *M. Yashi and A. Tokue* 2305
Re: Lymphatic Mapping and Gamma Probe Guided Laparoscopic Biopsy of Sentinel Lymph Node in Patients With Clinical Stage I Testicular Tumor. *S. Horenblas* 2305
Re: Androgen Imprinting of Brain in Animal Models and Humans With Intersex Disorders: Review and Recommendations. *K. J. Zucker* 2306

PEDIATRIC UROLOGY

Role of Gadolinium Enhanced Magnetic Resonance Imaging for Children With Suspected Acute Pyelonephritis. *A. C. Weiser, S. A. Amukele, J. C. Leonidas and L. S. Palmer* 2308
Measuring Glomerular Filtration Rate With Cystatin C and β-Trace Protein in Children With Spina Bifida. *A. Pham-Huy, M. Leonard, N. Lepage, J. Halton and G. Filler* 2312
Aerosol Transfer of Bladder Urothelial and Smooth Muscle Cells Onto Demucosalized Colonic Segments: Pilot Study. *A. T. Hafez, D. J. Bägli, A. Bahoric, K. Aitken, C. R. Smith, D. Herz and A. E. Khoury* (Editorial Comment by R. W. Grady) 2316
Modified Cecal Flap Neoappendix for Malone Antegrade Continence Enema Procedure: Novel Technique. *A. C. Weiser, J. A. Stock and M. K. Hanna* 2321
Mathieu Urethroplasty as Salvage Procedure: 20-Year Experience. *L. Emir and D. Erol* (Editorial Comment by A. B. Belman) 2325
Prospective Evaluation of Human Chorionic Gonadotropin in Differentiation of Undescended Testes From Retractile Testes. *O. F. Miller, J. A. Stock, B. G. Cilento, I. M. McAleer and G. W. Kaplan* . . . 2328
Outpatient Management of Phimosis Following Newborn Circumcision. *H. J. Blalock, V. Vemulakonda, M. L. Ritchey and M. Ribbeck* 2332
Pelviureteral Junction Obstruction: Correlation of Renal Cell Apoptosis and Differential Renal Function. *G. Lama, F. Ferraraccio, F. Iaccarino, I. Luongo, A. Marte, P. F. Rambaldi and M. Esposito-Salsano* 2335
PIC Cystogram: Novel Approach to Identify "Occult" Vesicoureteral Reflux in Children With Febrile Urinary Tract Infections. *J. N. Rubenstein, M. Maizels, S. C. Kim and J. T. B. Houston* 2339
Interobserver and Intra-Observer Agreement in Interpreting Urodynamic Measurements in Children. *M. Venhola, M. Reunanen, S. Taskinen, T. Lahdes-Vasama and M. Uhari* 2344

CME Enrollment Form and Questionnaire 2348

INVESTIGATIVE UROLOGY

Review Article: Cyclooxygenase-2 as Potential Target in Prevention and Treatment of Genitourinary Tumors: Review. *R. S. Pruthi, E. Derksen and K. Gaston* 2352
Laparoscopic Ureterocalicostomy: Feasibility Study. *E. E. Cherullo, I. S. Gill, L. E. Ponsky, K. L. W. Banks, M. M. Desai, J. H. Kaouk, A. M. Meraney, M. Skacel and G. T. Sung* 2360
DNA Mismatch Repair Genes in Renal Cell Carcinoma. *M. Deguchi, H. Shiina, M. Igawa, M. Kaneuchi, K. Nakajima and R. Dahiya* 2365
Induction of Apoptosis in Human Bladder Cancer Cells In Vitro and In Vivo Caused by FTY720 Treatment. *H. Azuma, S. Takahara, S. Horie, S. Muto, Y. Otsuki and Y. Katsuoka* 2372
Association of V89L SRD5A2 Polymorphism With Prostate Cancer Development in Japanese Population. *Z. Li, T. Habuchi, K. Mitsumori, T. Kamoto, H. Kinoshitu, T. Segawa, O. Ogawa and T. Kato* 2378
Characterization of Escherichia Coli Strains Causing Urinary Tract Infections in Patients With Transposed Intestinal Segments. *S. J. Keegan, C. Graham, D. E. Neal, G. Blum-Oehler, J. N'Dow, J. P. Pearson and D. L. Gally* 2382

Contents continued on page A16

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 7
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

Contents continued from page A14

Signaling Through PI3K/Akt Mediates Stretch and PDGF-BB-Dependent DNA Synthesis in Bladder Smooth Muscle Cells. *R. M. Adam, J. A. Roth, H.-L. Cheng, D. C. Rice, J. Khoury, S. B. Bauer, C. A. Peters and M. R. Freeman* 2388
Editorial: Phosphoinositide Signaling in Urological Disease. *D. Theodorescu* 2394

Functional Response of Bladder Strips From Streptozotocin Diabetic Rats Depends on Bladder Mass. *M. W. F. Bezuijen, M. C. Levendusky and P. A. Longhurst* 2397
Acute Intravesical Infusion of Cobalt Solution Stimulates Hypoxia Response, Growth and Angiogenesis in Rat Bladder. *R. Buttyan, P. Chichester, B. Stisser, S. Matsumoto, M. A. Ghafar and R. M. Levin* 2402
Expression of Nitric Oxide Synthase Immunoreactivity in Human Female Intramural Striated Urethral Sphincter. *K. M. T. Ho, M. C. Borja, K. Persson, A. F. Brading and K.-E. Andersson* 2407
Modulation of Ca^{2+} Sensitivity Regulates Contractility of Rabbit Corpus Cavernosum Smooth Muscle. *R. Takahashi, J. Nishimura, K. Hirano, S. Naito and H. Kanaide* 2412

UROLOGICAL SURVEY

Urological Oncology: Testis Cancer and Advances in Oncological Therapy. *J. P. Richie* 2418
Adrenal and Renal Physiology, and Medical Renal Disease. *W. S. McDougal* 2422
Voiding Function and Dysfunction, Bladder Physiology and Pharmacology, and Female Urology. *A. J. Wein* 2424
Renal Transplantation and Renovascular Hypertension. *D. A. Goldfarb* 2433
Book Reviews. *A. M. Shanberg, and D. Y. Deng and T. F. Lue* 2437

Subject Index to Abstracts in Volume 169 2439

Information for Authors 2450

Index, Volume 169 2455

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Petitioner - Avation Medical, Inc.
Ex. 1094, p. 8
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

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URODYNAMIC EFFECT OF ACUTE TRANSCUTANEOUS POSTERIOR TIBIAL NERVE STIMULATION IN OVERACTIVE BLADDER

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ABSTRACT

Purpose: Of the various treatments proposed for urge incontinence, frequency and urgency electrostimulation has been widely tested. Different techniques have been used with the necessity of surgical implantation (S3 neuromodulation or sacral root stimulation) or without requiring surgery (perineal transcutaneous electrostimulation). Recently peripheral electrical stimulation of the posterior tibial nerve was proposed for irritative symptoms in first intention or for intractable incontinence. Clinical studies have demonstrated good results and urodynamic parameters were improved after chronic treatment. However, to our knowledge no data concerning acute stimulation and immediate cystometry modifications have been reported. We verified urodynamic changes during acute posterior tibial nerve stimulation.

Materials and Methods: A total of 44 consecutive patients with urge incontinence, frequency and urgency secondary to overactive bladder were studied. There were 29 women and 15 men with a mean age ±SD of 53.3 ± 18.2 years. Of the patients 37 had detrusor hyperreflexia due to multiple sclerosis (13), spinal cord injury (15) or Parkinson's disease (9), and 7 had idiopathic detrusor instability. Routine cystometry at 50 ml. per minute was done to select the patients with involuntary detrusor contractions appearing before 400 ml. maximum filling volume. Repeat cystometry was performed immediately after the first study during left posterior tibial nerve stimulation using a surface self-adhesive electrode on the ankle skin behind the internal malleolus with shocks in continuous mode at 10 Hz. frequency and 200 milliseconds wide. Volume comparison was done at the first involuntary detrusor contraction and at maximum cystometric capacity. The test was considered positive if volume at the first involuntary detrusor contraction and/or at maximum cystometric capacity increased 100 ml. or 50% during stimulation in compared with standard cystometry volumes.

Results: Mean first involuntary detrusor contraction volume on standard cystometry was 162.9 ± 96.4 ml. and it was 232.1 ± 115.3 ml. during posterior tibial nerve stimulation. Mean maximum cystometric capacity on standard cystometry was 221 ± 129.5 ml. and it was 277.4 ± 117.9 ml. during stimulation. Posterior tibial nerve stimulation was associated with significant improvement in first involuntary detrusor contraction volume ($p < 0.0001$) and significant improvement in maximum cystometric capacity ($p < 0.0001$). The test was considered positive in 22 of the 44 patients.

Conclusions: These results suggest an objective acute effect of posterior tibial nerve stimulation on urodynamic parameters. Improved bladder overactivity is an encouraging argument to propose posterior tibial nerve stimulation as a noninvasive treatment modality in clinical practice.

KEY WORDS: electrical stimulation, urodynamics, tibial nerve, urinary incontinence

For many years peripheral electrical stimulation has been widely used to treat urinary disorders.[1–4] Different stimulation modalities for various pathological conditions were tested. Chronic perineal muscles stimulation proved to be safe and effective for stress urinary incontinence.[1] Acute perineal nerve stimulation (dorsal nerve of the penis) was effective for decreasing detrusor hyperreflexia in spinal cord injury cases.[5] Chronic electrical stimulation of perineal skin/sacral dermatomes was used to manage urge incontinence and many studies have had good and consistent results.[4,6–8] Recently sacral neuromodulation with surgical implantation of an S3 stimulator was proposed to treat various urinary symptoms, especially intractable urge incontinence and urinary frequency. More recently posterior tibial nerve stimulation has been used as a chronic treatment to improve urge incontinence and frequency.[9,10] Surprisingly sparse urodynamic data on the efficacy of chronic posterior tibial nerve stimulation are available. Moreover, urodynamic parameters evaluations have only been reported before and after chronic treatment with posterior tibial nerve stimulation.[9] Indeed, to our knowledge no study has been performed to determine urodynamic effects following acute posterior tibial nerve stimulation. We studied by urodynamic investigation possible detrusor activity modifications during acute tibial nerve stimulation in a population presenting with symptoms (urge incontinence and frequency) secondary to overactive bladder.

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MATERIAL AND METHODS

Study design and subjects. The study group consisted of 44 patients with a history of voiding dysfunction. There were 29 women and 15 men with a mean age ±SD of 53.3 ± 18.2

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 9
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

years. All patients had irritative symptoms with urge incontinence, urgency and frequency. These patients had demonstrable overactive bladder on routine cystometry with involuntary detrusor contraction appearing before 400 ml. maximum filling volume. The etiology was multiple sclerosis 13 cases, spinal cord injury in 15, brain lesion (brain injury, stroke or Parkinson's disease) in 9 and idiopathic instability in 7 without apparent neurological disease. All patients provided a clinical history and underwent examination, urinalysis and urodynamic studies. All patients provided consent to participate in the study. The study was approved by the local ethics committee.

Procedure. The urodynamic methodology complied with International Continence Society recommendations. Cystometry was performed with the patient supine through a double lumen 8Fr catheter with computerized analysis of results. Cystometry was done using normal saline at 25C to 30C. The filling rate was 50 ml. per minute. The study inclusion criterion was involuntary detrusor contraction during the filling procedure before 400 ml. maximum cystometric volume. Water filling was stopped if leakage occurred or a cystometric volume of 400 ml. was achieved. Volume at the first involuntary detrusor contraction and at maximum cystometric capacity were noted.

Repeat cystometry at a 50 ml. per minute filling rate was performed immediately after posterior tibial nerve stimulation. Stimulation was done using a self-adhesive surface stimulation electrode without an implanted needle electrode. Contact electrodes were placed with electrode gel on the ankle skin with the negative electrode behind the internal malleolus and the positive electrode 10 cm. above the negative electrode. The correct position of the negative electrode was determined by visualization of rhythmic flexion of the toes secondary to plantar muscle contraction during stimulation delivered at 1 hz. The intensity level was then chosen as the intensity immediately under the threshold determining motor contraction. In addition, no pain was to be noted during the stimulation procedure, which necessarily had to be comfortable for the patient. Stimulation frequency during cystometry was then applied at 10 Hz. and a pulse width of 200 milliseconds in continuous mode. This second cystometry during posterior tibial nerve stimulation was started immediately after determining the chosen stimulation. Neurostimulation was continuous during the whole second study.

A comparison was done between volume at the first involuntary detrusor contraction and at maximum cystometric capacity for standard cystometry and for cystometry during posterior tibial nerve stimulation. If on the second cystometry during stimulation the first involuntary detrusor contraction occurred at a volume that was 100 ml. or 50% more than the first involuntary detrusor contraction volume on standard cystometry, the test was considered positive (fig. 1). Likewise the test was also considered positive if maximum cystometric capacity following posterior tibial nerve stimulation increased more than 100 ml. or more than 50% volume compared with standard cystometry. Otherwise the test was considered negative. For statistical study of different associations the Student test for patient age, and volume at the first involuntary detrusor contraction and at maximum cystometric capacity was used with significance considered at $p < 0.01$.

RESULTS

Mean first involuntary detrusor contraction on standard cystometry was 162.9 ± 96.4 ml., while it was 232.1 ± 115.3 ml. during posterior tibial nerve stimulation (table 1, fig. 1). Mean maximum cystometric capacity on standard cystometry was 221 ± 129.5 ml., while it was 277.4 ± 117.9 ml. during stimulation (table 1, fig. 2). During stimulation improvement was significant for the first involuntary detrusor contraction and for maximum cystometric capacity (each $p < 0.0001$).

Regarding the increase of more than 50% in first involuntary detrusor contraction volume during stimulation compared with standard cystometry the test was positive in 21 of

TABLE 1. *Urodynamic parameters before and during posterior tibial nerve stimulation in 44 patients with overactive bladder*

	Mean Vol. ± SD (range) (ml.)
First involuntary detrusor contraction:	
Baseline	162.9 ± 96.4 (2–375)
Posterior tibial nerve stimulation	232.1 ± 115.3 (55–400)*
Max. cystometric capacity:	
Baseline	221 ± 129.5 (14–400)
Posterior tibial nerve stimulation	277.4 ± 117.9* (70–400)

* Student test $p < 0.0001$.

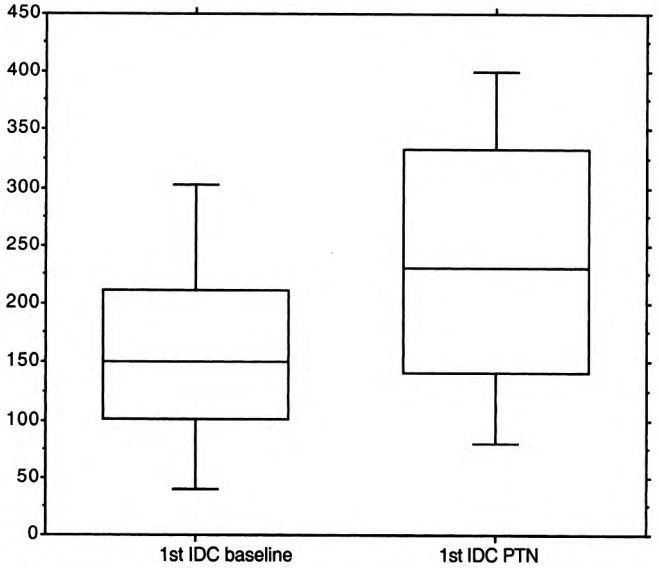

FIG. 1. Improvement in bladder volume at first involuntary detrusor contraction (*1st IDC*) following surface stimulation with 10 Hz. for 200 milliseconds of posterior tibial nerve (*PTN*) at ankle during mid fill cystometry in patients with overactive bladder (Student test $p < 0.0001$).

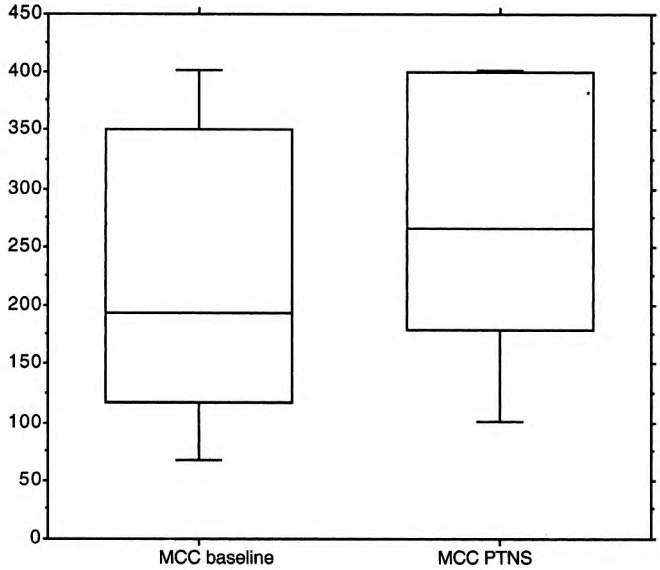

FIG. 2. Improvement in maximum cystometric capacity (*MCC*) following surface stimulation with 10 Hz. for 200 milliseconds of posterior tibial nerve (*PTN*) at ankle during mid fill cystometry in patients with overactive bladder (Student test $p < 0.0001$).

Petitioner Aviation Medical, Inc.
Ex. 1094, p. 10
Aviation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

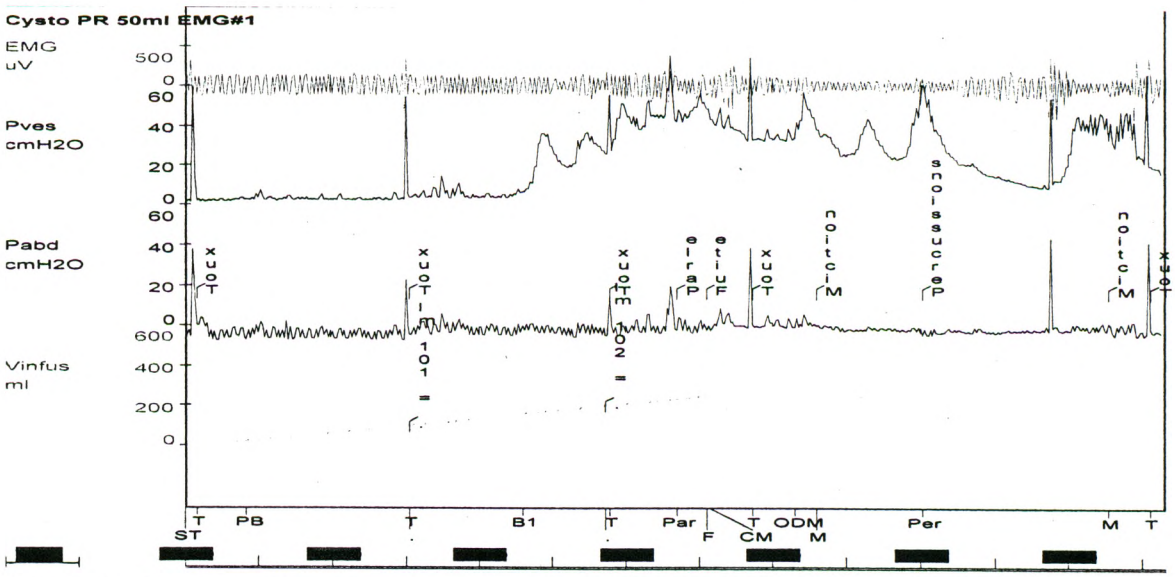

FIG. 3. Standard cystometry in 42-year-old patient with multiple sclerosis presenting with urge incontinence, frequency and urgency shows overactive bladder with noninhibited detrusor contraction.

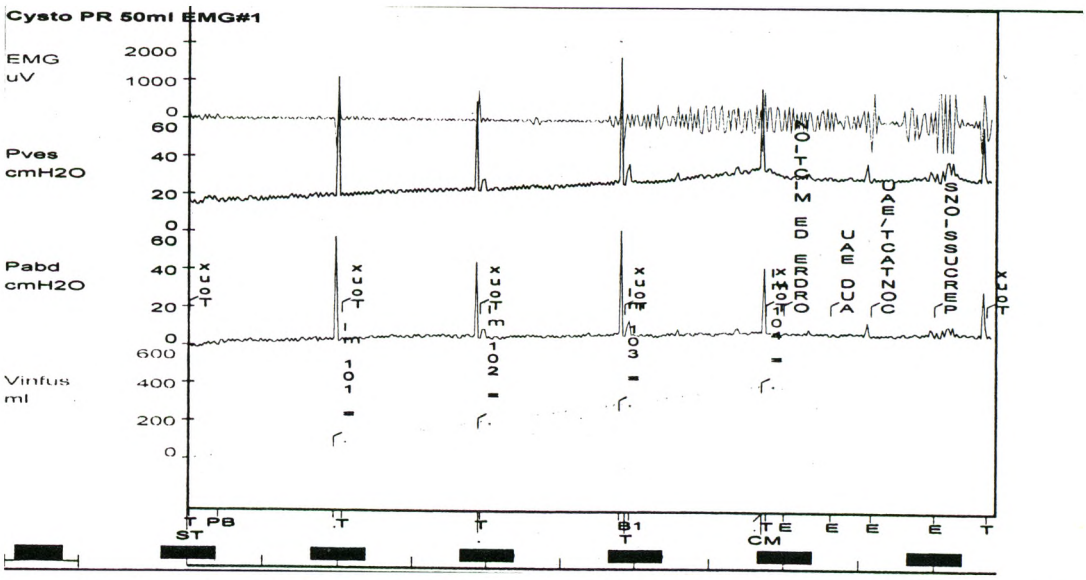

FIG. 4. Cystometry following surface stimulation with 10 Hz. of posterior tibial nerve at ankle demonstrates improvement in urodynamic parameters with suppression of involuntary detrusor contractions.

the 44 cases (figs. 3 and 4). Regarding the increase of more than 100 ml. in first involuntary detrusor contraction volume during stimulation, the test was positive in 13 cases. Regarding the improvement of more than 50% of maximum cystometric capacity during posterior tibial nerve stimulation, the test was positive in 15 cases. Regarding improvement of more than 100 ml. of first involuntary detrusor contraction volume during stimulation, the test was positive in 11 cases. Globally with 1 at least of the 4 previous criteria the test was considered positive in 22 cases (50%). Only 1 patient had improved maximum cystometric capacity without an increase in first involuntary detrusor contraction volume of more than 100 ml. or 50%.

DISCUSSION

Patients with irritative symptoms such as frequency, urgency and urge incontinence secondary to detrusor instability or hyperreflexia are habitually treated with anticholinergic drugs. However, in some patients anticholinergic drugs may have no efficacy for urinary symptoms immediately or after months of treatment. Moreover, these drugs may have side effects (dry mouth, constipation, blurring eyes, hesitancy or urinary retention), which can lead to the cessation of treatment despite its efficacy. Finally detrusor overactivity may persist despite treatment with a high risk of reflux or renal complications in neurologic cases. In all of these cases alternative therapeutic solutions have been proposed before bladder augmentation, such as bladder training and perineal electrical stimulation. Recently local drug treatments have been tested, including intravesical instillation of capsaicin or resiniferatoxin and and botulinum-A toxin injections into the detrusor. Meanwhile, these treatments are actually only proposed in neurological cases, especially spinal cord injury with intractable overactivity, which can lead to ureteral reflux and kidney damage. Moreover, these treatments are only available for pharmaceutical trials and need invasive protocols.

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 11
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

The use of electrostimulation to improve bladder storage capacity has a long history. Various types of neurostimulation have been tried for urge incontinence treatment, frequency and urgency but also for stress urinary incontinence. Sacral anterior root stimulation and S3 neuromodulation[11] have been well evaluated with real benefits of these devices for bladder overactivity control. These techniques are safe and effective but they require surgical implantation and a test period, which can limit their use. Pudendal nerve stimulation, anal or vaginal stimulation and more generally surface stimulation on the perineal area have been evaluated for various conditions, such as stress urinary incontinence and irritative symptoms. Many clinical studies have demonstrated their efficacy to decrease incontinence episodes, urinary frequency and urge sensation, and increase bladder capacity[4,6,7,12–14] using quality of life instruments, and frequency and volume charts.

On the other hand, urodynamic studies of the effects of chronic electrostimulation are less frequent (table 2).[6,8,12–15] Various sites of stimulation have been tested (perianal skin, sphincter stimulation, dorsal penile or clitoris nerve, quadriceps and hamstring muscles) and different types of patients have been studied with idiopathic detrusor instability or detrusor hyperreflexia, especially concerning spinal cord injury. Thus, transcutaneous electrical stimulation applied to the perianal skin has been demonstrated to be efficacious for abolishing detrusor instability and increasing mean volume at first bladder sensation and mean total bladder capacity.[6,14,15] Meanwhile, other studies have not shown significant changes in cystometric findings after chronic electrostimulation (volume at first involuntary detrusor contraction, duration of phasic contractions or bladder capacity).[8,12,13] However, clinical improvements were noted in these studies, including increased functional capacity, decreased daily number of voids and improved quality of life measures.[8,13]

The urodynamic effects of acute electrical stimulation on detrusor activity is also less reported (table 3).[5,6,16–20] Detrusor hyperreflexia in patients with chronic suprasacral spinal cord injury has especially been studied.[5,16,19,20] Significant differences in bladder capacity were found during electrostimulation of the dorsal penile or clitoris nerve via surface electrodes[5] and during percutaneous sacral nerve neurostimulation.[19] Bladder volume at first uninhibited contraction was also increased and maximum detrusor pressure during uninhibited contractions decreased during sacral root stimulation.[19] Noninvasive third sacral nerve (S3) stimulation and its acute effect on urodynamic parameters were also tested.[16] Transcutaneous electrical stimulation was applied on the skin overlying S3 dermatomes (junction of the buttock and upper thigh) and a statistically significant increase in bladder storage capacity without a corresponding decrease in detrusor pressure was observed in the 74 neurostimulated patients.[16] Electrical current was also delivered to the suprapubic region and third sacral foramen via a transcutaneous electrical nerve stimulator. A decreased mean maximum amplitude of detrusor contraction was noted.[17]

McGuire et al were the first to report the efficacy of direct electrical stimulation of the posterior tibial nerve in patients with urge incontinence.[4] More recently several studies have been done to evaluate intermittent percutaneous posterior tibial nerve stimulation as a treatment in patients who presented with symptoms of bladder overactivity (urgency and frequency syndrome, and/or urge incontinence).[9,10] A statistically significant decrease was observed in leakage episodes, the number of pads used, voiding frequency and nocturia, and an equal increase in the mean and smallest volumes voided. Two-thirds of the cases were classified as treatment

TABLE 2. *Literature on chronic effect of electrostimulation*

References	No. Pts.	Electrostimulation Modality	Disease (No. pts.)	% Overactivity Suppression	Increase (No. pts.)	
					Max. Capacity	First Uninhibited Contraction
Nakamura et al[6]	21	Perianal skin	Detrusor instability	62	—	—
Petersen et al[13]	13	Sphincter stimulation 12 days, 30 mins. twice daily	Detrusor hyperreflexia	0	0	0
Okada et al[15]	19	Quadriceps + hamstring muscles, 20 mins./day, 14 days	Detrusor instability (5) Detrusor hyperreflexia (14)	—	Greater than 50% (11/19)	
Previnaire et al[12]	6	Dorsal penile or clitoris nerve	Detrusor hyperreflexia	0	0	0
Klingler et al[14]	15	Stoller afferent nerve stimulator 4–15 mos.	Detrusor instability	76.9	197 to 252 Ml. (15/15)	
Soomro et al[8]	43	Perianal region	Detrusor instability	0	0	0

TABLE 3. *Literature on acute effect of electrostimulation*

References	Electrostimulation Site	No. Pts.	Disease	Main Results
Nakamura et al[7]	Perianal skin	25	Frequency, urgency or incontinence	Inhibition of detrusor instability in 4/8 pts. + increased max. cystometric capacity in 5/25
Previnaire et al[5]	Dorsal penile or clitoris nerve surface electrodes	10	Spinal cord injury	Significant increase in bladder capacity vs. baseline (318.5 vs. 155.5 ml., $p < 0.007$)
Bower et al[17]	Suprapubic region + third sacral foramina			Decreased mean max. detrusor contraction wt.
Yamanishi et al[18]	Vaginal electrode or surface electrode on dorsal part of penis	33	Detrusor overactivity	Bladder capacity at first desire to void + max. cystometric capacity increased significantly during stimulation ($p = 0.0015 + 0.0229$, respectively)
Chartier-Kastler et al[19]	Sacral neurostimulation (S3)	14	Spinal cord injury	Statistically significant differences in max. bladder capacity (206.8 ml.), bladder vol. at first uninhibited contraction (151.5 ml.) + max. detrusor pressure during uninhibited contractions (−23.4 cm. H_2O)
Walsh et al[16]	Transcutaneous electrical stimulation of third sacral nerve (skin overlying S3 dermatomes, junction of buttock and upper thigh)	74	Idiopathic instability, multiple sclerosis + spinal cord injury	Max. cystometric capacity increased significantly during stimulation ($p = 0.0002$)
Lee and Creasey[20]	Dorsal nerve of penis	1	Incomplete spinal cord injury	Suppressive effect of electric stimulation on hyperreflexic contractions

Petitioner - Avation Medical, Inc.
Ex. 1094, p. 12
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

successes. In these studies stimulation was delivered using a 34 gauge stainless steel needle inserted about 3 finger breadths cephalad to the medial malleolus, between the posterior margin of the tibia and soleus muscle. We chose another technique that is less invasive using disposable, self-adhesive contact electrodes. This technique is cheap, noninvasive and free of pharmaceutical side-effects. Moreover, stimulation outside of the anogenital region has higher acceptance by patients.

In our series a significant statistical difference was noted between the 2 groups but there were many failures. Comparisons in specific groups (hyperreflexia versus instability, multiple sclerosis versus spinal cord injury, male versus female and so forth, failed to reveal significance. This finding was probably due to poor patients homogeneity, including neuropathic and nonneuropathic groups. The second reason is that many patients had severe detrusor overactivity with low detrusor capacity. This severe detrusor overactivity may be less sensitive to posterior tibial nerve stimulation. In the methodology we chose the limit of 400 ml. maximum filling to standardize the procedure and avoid difficult interpretation of bladder overactivity at high capacities. Another remark concerns the possible effect of habituation due to repeat cystometry on the recorded increase in urodynamic volume parameters. This effect is possible and other studies are necessary to determine its interference.

Posterior tibial nerve stimulation inhibits bladder activity by depolarizing somatic sacral and lumbar afferent fibers.[2] Afferent stimulation provides central inhibition of the preganglionic bladder motor neurons through a direct route in the sacral cord.[1] Meanwhile, the neuromodulation of the micturition reflex allowed by posterior tibial nerve stimulation remains unclear. Modification of perineal spasticity may be one of the different mechanisms involved in neurological cases. Indeed, the effect of afferent cutaneous electrical stimulation on the spasticity of leg muscles is well known. Transcutaneous electrical nerve stimulation at the usual intensity only stimulates sensory fibers. This technique is widely used for pain management and many commercial devices are available. Transcutaneous electrical nerve stimulation applied to the sural nerve may induce short-term post-stimulation inhibitory effects on abnormally enhanced stretch reflex activity in patients with spasticity of cerebral origin. Likewise, transcutaneous electrical nerve stimulation applied in those with spastic hemiparesis caused an immediate increase in soleus H reflex latencies that was evident for up to 60 minutes after stimulation in more than 75%. The short-term effects of transcutaneous electrical nerve stimulation on the H reflex and spinal spasticity was evaluated in spinal cord injured subjects. Although statistical analyses failed to reveal significant effects of transcutaneous electrical nerve stimulation on H reflex amplitude, there was a significant decrease in scores for the Achilles tendon reflex and the modified Ashworth test. In spastic cases the mean peak-to-peak amplitude of H reflexes, F waves, H/M and F/M ratios were significantly decreased and the mean latencies of H reflexes and F waves were significantly increased after the application of transcutaneous electrical nerve stimulation. Other studies have suggested an indirect action of transcutaneous electrical nerve stimulation on the central nervous system, especially a modification on the dorsal column-medial lemniscal pathway. When transcutaneous electrical nerve stimulation was applied to the palm distal to the median nerve stimulation used for somatosensory evoked potentials, cortical N20/P25 amplification disappeared, evidence that transcutaneous electrical nerve stimulation suppresses the central amplification phenomenon, most probably at the level of the cuneate nucleus. A modification of somatovisceral reflexes can be discussed, as previously described for gastric electrical activity modified by transcutaneous electrical nerve stimulation and evaluated by gastric myoelectric activity measured by electrogastrography.

CONCLUSIONS

Posterior tibial nerve stimulation is a minimally invasive technique that can suppress detrusor instability or hyperreflexia. Improved bladder capacity is an encouraging finding that further supports its use as a noninvasive treatment modality in clinical practice. However, there is no argument in this study suggesting that posterior tibial nerve stimulation may predict S3 neuromodulation failure. Thus, S3 neuromodulation remains indicated in patients in whom posterior tibial nerve stimulation has failed. Furthermore, posterior tibial nerve stimulation may be proposed as a test to select candidates for definitive S3 neuromodulation, which is simpler than the several days of clinical evaluation following an S3 stimulation test. However, further studies are required to test this hypothesis.

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Ex. 1094, p. 13
Avation Medical, Inc. v. EMKinetics, Inc., IPR2024-01378

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