Published in final edited form as:

Urology. 2015 May ; 85(5): 971–975. doi:10.1016/j.urology.2014.12.059.

The History of Microsurgery in Urology

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Keywords

history of microsurgery; operating microscope; vasectomy reversal; vasovasostomy; epididymovasostomy; varicocele repair; microTESE; penile amputation; urology; microsurgery

A Brief History of Magnification in Medicine

The principle of magnification is fundamentally based on light refraction; by placing an object between one and two focal lengths from the retina, a magnifying lens can enlarge the object's appearance while maintaining resolution¹. Archimedes is credited with the invention of the "burning glass," a series of lenses used to focus the sun's rays on enemy ships, causing them to catch fire. The Roman Claudius Ptolemy described and calculated light refraction by water, while Seneca and the English philosopher Roger Bacon reported the magnification of text by looking through a water-filled sphere². Ibn al Haitham furthered the understanding of human vision with descriptions of ocular anatomy, function and visual principles in his *Opticae thesaurus*³, leading to the introduction of eyeglasses in the late 13th century by Italian monks who could grind glass³. As early as the 1500s, surgical technique began focusing on finer work. When Andreas Vesalius first described the abdominal aortic aneurysm in the Netherlands⁴ during the 16th century, European battlefield surgeons treated vascular injuries through ligation and vascular suturing, albeit rarely with success and always without magnification⁵.

The first compound microscopes are attributed to the Dutch spectacle makers Hans Jansen, Zacharia Jansen, and Hans Lippershey who around 1590 discovered that objects could be magnified using elongated telescope tubes². Soon after, Galileo studied small objects using a similarly adapted telescope. He was a member of the "Accademia dei Lincei" in Rome,

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whose members first coined the term “microscopium”². In England, Robert Hooke used a compound microscope to discover and describe the cell, while the Italian optician Giuseppe Campani examined wounds and scars^{3, 6}. In 1677 a medical student, Johann Ham, discovered spermatozoa in the ejaculate of a patient with gonorrhea. He reported his findings to the Dutch scientist Antoni van Leeuwenhoek, who performed extensive studies on seminal fluid, reporting his results in over 150 letters to the Royal Society in London⁷.

As pathology became increasingly important to surgical practice during the late 19th century, surgeons employed magnification to facilitate tissue dissection. Charles Louis Chevalier, a French optician, first constructed a loupe that could be used during surgery, magnifying objects 10-fold at a 7 cm distance. In 1886, Carl Wilhelm von Zehender, a German ophthalmologist, modified a zoological binocular and placed it on a tripod, creating a prototype surgical microscope and the forerunner of the slit-lamp². While von Zehender’s binocular was too big for use in the operating room, in 1912 the Zeiss Company introduced a lighter, binocular set of operating loupes worn like glasses². In 1923 the Leitz Company introduced a prismatic loupe which permitted beam splitting, allowing assistants to share the same view as the surgeon², facilitating teaching of surgical technique and photographic image capture. In the spring of 1921, the otorhinolaryngologist Carl Olof Nylen performed the first ear operation using a modified monocular microscope in Stockholm, solidifying his place in history as the first true microsurgeon⁸. In 1946, the American ophthalmologist Richard Perritt borrowed a binocular operative microscope from his otorhinolaryngologist colleague, G. E. Shambaugh, for use during an eye operation. Subsequently, other specialties, including neurosurgery and plastic surgery adopted microsurgical techniques during the 1960s⁵.

Microsurgery and Urology

In May 1974, Sherman Silber, an American urologist, met Earl Owen, a plastic surgeon from Melbourne, Australia, at a Royal College of Surgeons conference in Sydney⁹. Owen was a world renowned microsurgeon, having founded the International Microsurgical Society in 1969¹⁰, and by most accounts had performed the first vasovasostomy in Australia in 1971¹⁰. At the time of meeting Silber, Owen was working in organ transplantation. A pioneer in his own right, Silber had devised a microsurgical method in 1973 to facilitate his studies with rat kidney transplantation using eyeglasses with 2x magnification, mosquito forceps filed to 1 mm thickness, and 9-0 suture¹¹. Initially interested in transplantation, Silber’s meeting and subsequent partnership with Owen would radically change his career path, pushing him to specialize in urologic microsurgical techniques in male infertility where he felt there was more opportunity for discovery⁹.

The collaboration between Owen and Silber would bear fruit the following year at the University of California at San Francisco (UCSF), when Silber performed a 2-layer vasovasostomy using 9-0 and 10-0 nylon sutures and a Zeiss operating microscope, the first such procedure in the United States¹². However, controversy would arise as to whether Silber or Owen was truly the first to perform microsurgical vasovasostomy. While Owen failed to publish his approach until 1977, two years after Silber published his procedure, most believe the first vasovasostomy was indeed performed by Owen in 1971¹³. Regardless,

both men were foundational in the advent of urologic microsurgery¹⁰. Silber's microsurgical approach achieved higher success rates when compared with non-microscopic techniques - a spontaneous pregnancy rate of more than 71% was reported, compared with 40% using non-microscopic techniques^{14, 15}. Following the success and growing acceptance of the microsurgical vasovasostomy, in 1978 Silber described an end-to-end epididymovasostomy¹⁶, allowing surgeons to bypass obstruction in the 1–2mm epididymis and achieve greater success than prior approaches. The end-to-end procedure produced a patent connection between the vas deferens and the epididymis, rather than the fistulous tract that was previously obtained by grossly approximating the vas deferens to the epididymis. In 1983, L.V. Wagenknecht at the University of Hamburg introduced the end-to-side technique currently used by many urologic microsurgeons¹⁷, which would be further expounded upon in 1986 by Ingemar Fogdestam, a Swedish plastic surgeon and former fellow at St. Vincent's Hospital in Melbourne¹⁸. The epididymovasostomy would later be further developed by Larry I. Lipshultz, who used the microsurgical technique for correction of epididymal pathology not related to prior vasectomy, pushing microsurgery into more urologic areas¹⁹. Comparable advancements were made to the vasovasostomy by several others, including Joel Marmar and Anthony Thomas, who described the trans-septal crossed vasovasostomy in 1985²⁰. More recently, Richard Berger described the triangulation end-to-side vasoepididymostomy, a broadly used advancement in surgical technique²¹. Marc Goldstein would later describe the 2-stitch longitudinal intussusception technique now preferred by many microsurgeons for its simplicity and high patency rate^{22, 23}.

While microsurgery was revolutionizing vasectomy reversal techniques, it was transforming orchidopexy as well. In 1975, Silber described a microsurgical orchidopexy in a nine year-old boy in Melbourne where the spermatic artery and vein were re-anastomosed to the inferior epigastric artery and saphenous vein²⁴. This technique would be further developed by Marc Goldstein, a physician mentored by Silber for four months in 1978–79 who, after practicing vascular anastomoses on human placentas²⁵, published his work on the microsurgical transplantation of rat testes²⁶. This research, combined with Silber's work, would establish the use of microsurgery in treating testicular pathologies. Goldstein's expertise would later serve as the foundation for urologic microsurgery training in New York¹⁰.

Reimplantation of an amputated penis was also vastly aided by microsurgical technique, facilitating anastomosis of neurovascular bundles to restore penile sensation after amputation. In the summer of 1976, the Japanese orthopedic surgeon Susumu Tamai²⁷ and the American plastic surgeon Benjamin E. Cohen²⁸ independently assisted urologists in penile reimplantation procedures, using binocular magnification for the delicate vascular and neural anastomoses necessary for successful recovery of penile function. In 1981, Andrew Novick used microvascular reconstruction to manage intrarenal arterial lesions²⁹. That same year, Ira Sharlip used microsurgical technique for penile revascularization by implanting the inferior epigastric artery into the corpora cavernosa of men with vasculogenic erectile dysfunction, improving erectile function in over 40% of treated men³⁰.

The use of microsurgical technique in varicocele treatment using an inguinal approach was first presented by Marc Goldstein in 1983 at the Ferdinand C. Valentine Urology Essay

Contest of the New York Academy of Medicine¹⁰. In 1985, the subinguinal approach to microsurgical varicocelectomy was described by Joel Marmar³¹, representing another popular approach and the first published account of microsurgical varicocele repair. By allowing clear visualization of all spermatic cord vessels, selective ligation of veins with lymphatic sparing could be achieved, resulting in excellent outcomes with lower recurrence and complication rates than non-microsurgical approaches¹⁰. The results of Goldstein's work would not be published until 1992, but would facilitate acceptance of microsurgical varicocele repair as the standard³². Furthermore, this work paved the way to understanding the relationship between varicocele and testicular endocrine function^{33, 34}.

In 1993, Goldstein demonstrated motile sperm in testis biopsy specimens, whereas previously such sperm were thought to only be present in the epididymis³⁵, making possible the use of testicular biopsy to treat non-obstructive azoospermia (NOA). During that same year, the first testicular sperm extractions (TESE) were performed independently by Craft³⁶ and Schoysman³⁷ without the use of an operating microscope. The TESE, while effective, required large amounts of tissue, sometimes leading to obliteration of the testis, but was improved by Peter N. Schlegel, who performed the first microdissection TESE in 1998³⁸. Using the operating microscope to identify seminiferous tubules most likely to contain sperm, Schlegel improved sperm retrieval rates of TESE from 45% to 63% while decreasing the amount of tissue removed. This set a new standard in facilitating reproduction in NOA men, who were previously thought to be reproductive cripples³⁹.

Technological and Systematic Advances in Urologic Microsurgery

The history of microsurgery in urology is not confined to the development of surgical techniques. Indeed, many of the advances that drove acceptance of operative microscopy were unrelated to urologic practice. Robert Acland, an orthopedic and hand surgeon at the University of Louisville, was essential in convincing Swiss instrument developers Wener Spingler and Eugen Tritt, owners of S & T Microsurgical Instruments Co.⁴⁰, to develop finer suture and needles that facilitated accurate suture placement. Furthermore, Acland was instrumental in determining optimal microsurgical ergonomics⁴¹. Technical improvement of the microscope, including integration of refined fiber optics and controls usable by the surgeon while operating, are attributed to Peter Horenz⁴². Other advancements, including bipolar electrocautery, xenon lamps, finer instruments, and variable magnification microscopes have all led to further technological advancements, facilitating ease of use and contributing to better outcomes¹⁰. Indeed, instruments like the Lipshultz Pattern Scissors have been developed by urologists recognizing needs to optimize surgical tools and approaches.

The work of relatively few pioneers in microsurgery greatly advanced the field, but formal training opportunities have also proved crucial. The work of the Vasovasostomy Study Group, headed by Arnold Belker, in the 1980s is believed to have piqued interest in urologic microsurgery through reporting of the outcomes of over 1400 microsurgical vasectomy reversals⁴³. Formal fellowship training in urologic microsurgery was first introduced by Larry I. Lipshultz in 1981⁴⁴, furthering the rapid growth of the field, and cementing urologic

microsurgery as an advanced and academic discipline while simultaneously improving patient outcomes.

The Future of Microsurgery in Urology

Microsurgical practice in urology is likely to expand, particularly with the growing use of the DaVinci surgical robot, which has been applied to vasectomy reversal and management of orchalgia^{45–47}. Ureteral and urethral anastomoses, pediatric hypospadias repairs, and testicular denervation to treat chronic pain have also been suggested as possible microsurgical procedures given the manual dexterity and steady hands needed to complete these¹⁰. With respect to robotic-assisted microsurgery, better instrumentation and magnification are needed before its more widespread application. However, possible applications include vas deferens repair in the deep pelvis, ureteral repairs⁹, and as a general remedy for fine tremors¹⁰. Looking further, technological advancements may lead to wholly new procedures. For example, the use of high magnification intraoperatively may identify and facilitate harvest of germ line stem cells from the sub-basement membrane of azoospermic men, with subsequent *in vitro* culture and injection into the vasa efferentia or rete testes to repopulate the germ cell line^{9, 10}.

The use of microsurgery in humans is less than a century old, with the technology progressing from its nascence to a highly developed state during that time together with a growing list of clinical applications. In urology, microsurgical techniques are essential in the treatment of male infertility, and have been applied to a broad range of surgical problems. With the continued iterative improvement by the growing cohort of urologic microsurgeons, as well as persistent technological improvement, the future of urologic microsurgery will only broaden.

Acknowledgments

We thank Drs. Arnold Belker, Marc Goldstein, and Sherman J. Silber, for their candid and comprehensive perspectives on the history of microsurgery in urology, without which this work would not possess the depth that it does.

Financial Support: None

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The inspiration for compiling the history of microsurgery in urology arose from the authors' fascination with microsurgical technique and applications and a desire to understand how current approaches to microsurgical applications resulted from a gradual, progressive innovation process.

It is tempting to speculate about future technologies and how they may further revolutionize contemporary microsurgery. Magnified laparoscopic and robotic surgery can certainly be considered advances in "microsurgery," particularly when facilitating access to structures previously requiring a large incision followed by a precise approach requiring magnification. The future of microsurgery will likely incorporate novel technologies as adjuncts to higher magnification that enable *in situ* identification of specific tissues types, or even cell types. Software-guided tissue and cell type identification and precise isolation of cells that can later be used for autologous grafting, or even transplanted intraoperatively for improved outcomes, will help streamline operative care. One can envision the growing use of automation in surgery as well, with improved decision support software and robotic capabilities progressively improving on outcomes achievable only by humans today.

The lack of major technological leaps along the path to the current state of microsurgery pays tribute to human ingenuity, showcasing the persistence of a collaborative group of innovators who realized stepwise improvement that, over time, contributed to significant progress. Microsurgery's evolution will continue to surprise and impress even its most involved and productive innovators.