During the past decade, microsurgery has become a urologic subspecialty. Historically, vascular and vasal anastomosis have formed the foundation of genitourinary microsurgery. With the advent of improved instrumentation and the interest of devoted urologic microsurgeons, a multitude of new applications of microsurgery in urology have developed. In this paper, we discuss some of the new directions in male reproductive microsurgery.

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NEW DIRECTIONS IN MALE REPRODUCTIVE MICROSURGERY

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A multitude of microsurgical procedures have evolved since Silber[1] and Owen[2] reintroduced microsurgical techniques to urologists over 10 years ago. Since that time, a new breed of urologist has emerged, utilizing microsurgical methodology for routine urologic procedures, with markedly superior results. Advances in this field can be directly attributed to the development of superior instrumentation and microsutures.[3] Improvements in optical magnification, illumination, and microsurgical instrumentation have allowed clear visualization and precise alignment of lumens as small as 200 μm. Intensive practice in the microsurgical laboratory is the most important factor in the development of skilled urologic microsurgeons.[4]

Microsurgical techniques have now been applied to the treatment of a wide range of genitourinary disorders. In addition to reproductive urology, microsurgery has been used for renovascular repair,[5,6] ureteroureterostomy,[7] hypospadias repair,[8] and the treatment of cryptorchidism and testis autotransplantation.[9-11] These procedures were intensively studied in the animal laboratory prior to their successful use in humans.

In this paper, we focus on recent advances in male reproductive microsurgery. We highlight applications of microsurgery to male factor infertility and preservation of testis function.

MICROSURGICAL VARICOCELECTOMY

The incidence of varicocele is greater than 30% among infertile males.[12,13] This is more than two times the incidence of varicocele in the general male population.[14] Improvements in both semen analysis and pregnancy rates have been documented with varicocelectomy.[15]

Reported complications of varicocelectomy have included hydrocele in 3-5% of cases and recurrence in 5-15%. Testicular atrophy, the most devastating complication of varicocelectomy, is rarely reported, making its incidence difficult to quantitate.

Efforts to reduce the incidence of complications by exploiting microsurgical techniques for ligation of the internal spermatic veins have been gaining in popularity.[16] We have used the following method in more than 400 varicocelectomies. There are several advantages of microsurgical varicocelectomy. With a microsurgical approach, the testicular artery is identified and preserved in more than 98% of patients. Thus testicular atrophy is avoided. Also, lymphatics traveling with the cord are easily visualized and preserved, preventing hydrocele formation, the most common previously reported complication. The recurrence rate with this method has been extremely low. In the 350 consecutive cases followed for over 1 year, only two recurrent varicoceles have been detected.

The procedure is depicted in Figure 1A-D. Briefly, after isolation of the cord structures through a 3-cm inguinal incision, the testis is delivered, and all external spermatic and gubernacula veins are ligated (Fig. 1A). Under ×8 magnification, the external and internal spermatic facias are opened (Fig. 1B), and the testicular artery is identified, surrounded with a 0-silk marker, and preserved (Fig. 1c). All internal spermatic veins are then ligated with silk sutures (Fig. 1D). The procedure takes no longer than standard macrosurgical methods and yields excellent results. No hydroceles or testicular atrophy have resulted from this approach.

MICROSURGICAL VASOVASOSTOMY

The objective in vasectomy reversals is to attain a leakproof and accurate mucosal approximation despite the discrepancy in lumenal diameters (Fig. 2A). This size difference occurs from chronic pressure buildup on the testicular

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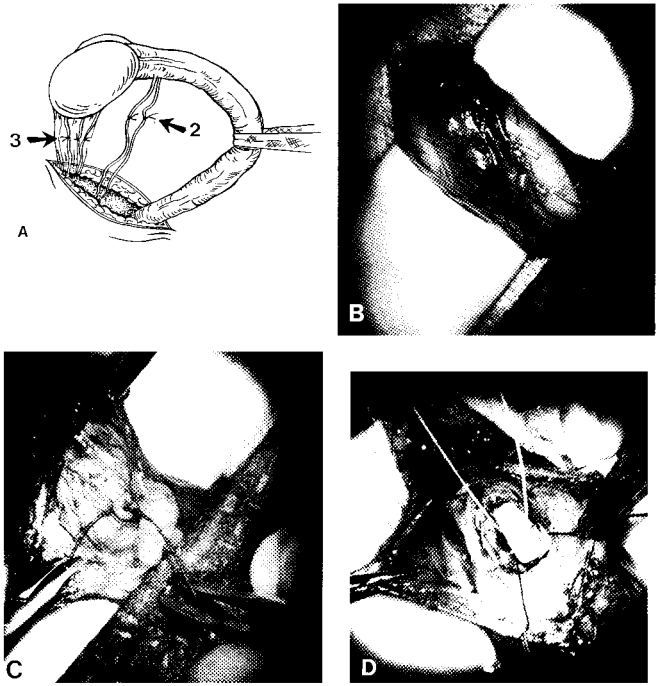

Figure 1. ***A:*** *The spermatic cord is placed on traction by a Penrose drain. The cremasteric (2) and gubernacular (3) vessels are ligated with 3-0 silk ligatures.* ***B:*** *The spermatic cord is shown with both external spermatic and internal spermatic facia intact. The cord is supported by a platform made of a Penrose-covered tongue depressor. ×8.* ***C:*** *The testicular artery is easily isolated, as shown here identified by a 0 silk. ×8.* ***D:*** *The internal spermatic veins are tied with 3-0 silk ties. Lymphatic vessels are easily seen and avoided. ×8. 3-0 silk ties.*

side of the obstructed vas deferens. We have modified the two-layer closure first described by Owen[2] and Silber[17,18] by utilizing atraumatic, 75-μm, double-armed sutures of 10-0 monofilament nylon for the inside-out atraumatic placement of the mucosal layer (Fig. 2A,B). Their use minimizes handling of the mucosa and virtually eliminates the possibility of back-walling the mucosa. A seromuscular layer of 9-0 sutures (Fig. 2C), an adventitial layer of 9-0 sutures (Fig.

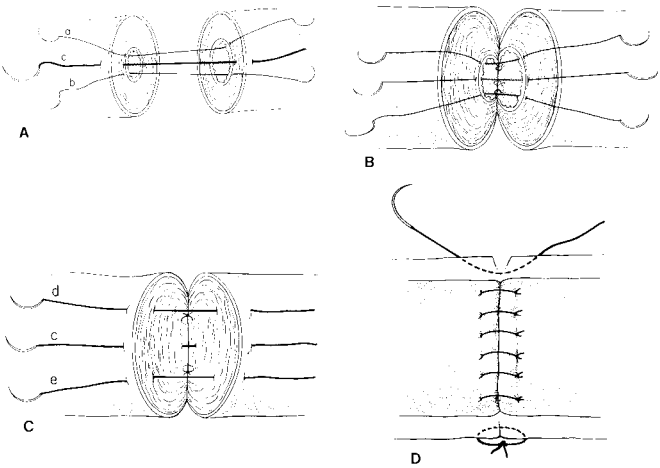

Figure 2. **A:** *The testicular vasal lumen is dilated secondary to the obstruction produced by chronic obstruction. Accurate mucosal alignment is provided by 10-0 monofilament sutures (a, b). A second layer (c) of 9-0 monofilament suture material is placed afterwards.* **B:** *After placement of mucosal, seromuscular, and adventitial layers on the anterior aspect of the vas, it is turned 180° while being held by the vas approximator, and posterior layers are then placed.* **C:** *Shown here are the seromuscular (c) sutures, which are placed between the mucosal layer of sutures and the adventitial sutures (d, e) placed between mucosal sutures.* **D:** *The anastomosis is completed by placement of a layer of 6-0 PDS sutures to approximate the loose periadventitial tissues.*

2C), and a periadventitial layer of 6-0 PDS (Fig. 2D) complete the anastomosis. Because of the large discrepancy in vas lumen diameters often found at the time of vasovasostomy, we believe that this atraumatic multilayer vasovasostomy provides a more accurate approximation of the mucosal margins as well as a watertight anastomosis. In 211 men operated upon with this method, the patency rate is 96% and the pregnancy rate is 61% two years postoperatively.

As was mentioned above, the development of improved microsurgical instruments designed for specific applications has been an important factor in facilitating microsurgical procedures. We have found two instruments particularly useful. The use of a Microspike approximator (Accurate Surgical and Scientific Instruments Corporation, Westbury, NY) provides excellent stabilization of both ends of the vas. When needed, versions of this clamp are available for end-to-end or end-to-side vasal epididymostomosus. This clamp provides a motion-free stage for precise suture placement. In addition, the use of a 4-cm-long 10-0 monofilament nylon double arms with 75-μm diameter fish hook-shaped atraumatic needles (Fig. 3; Sharpoint Inc., Reading, PA) has facilitated precise mucosal alignment.

MALE FACTOR INFERTILITY AND IN VITRO FERTILIZATION (IVF)

A new and exciting application of in vitro fertilization is being used for the treatment of male factor infertility. Patients considered for this new approach have either obstructive azoospermia, congenital absence of the vas, or severe asthenospermia. All have previously failed more conventional therapy.

Figure 3. A 10-0 monofilament nylon swedged to an atraumatic fish-hook needle is shown with a 9-0 monofilament nylon swedged to a cutting needle (Sharpoint Inc., Reading, PA).

Since 1984, patients with azoospermia secondary to obstruction have had sperm operatively retrieved from both the vas as well as the epididymis for the purpose of in vitro fertilization. In some of these patients, an artificial sperm reservoir was implanted at the initial procedure for future retrieval purposes. Although the experience with this technique is limited, the results appear to be encouraging. Pryor et al.[19] report on a patient in whom 0.15 ml of vasal fluid was retrieved containing 17.7 million sperm with 70% motility. Unfortunately, a spontaneous abortion occurred at 9 weeks. Pryor's group also anastomosed a "Port-a-cath" drug delivery system at the time of the operation in an attempt to avoid the need for future operative sperm retrievals. Temple-Smith et al.[20] reported a patient with obstructive azoospermia in whom epididymal fluid was collected by microaspiration. At insemination, 61% of the sperm were found to be motile. One of five eggs was fertilized, which resulted in a 30-week gestation at the time of the report.

Silber and colleagues[21] reported that sperm obtained from any portion of the epididymis are capable of fertilization with in vitro techniques. This apparently can occur even with sperm having poor motility (1–20%). In a recent abstract by Silber and colleagues[22] 9 of 17 patients (53%) with congenital absence of the vas and 2 of 4 patients with previous failed vasoepididymostomy produced cleaving embryos. In addition, caput sperm fertilized in 9 of 10 cases and corpus sperm fertilized in two of five cases.

When IVF fails to produce a pregnancy in male factor infertility, micromanipulatory sperm injection has been attempted. In this technique, penetration of the zona pellucida by a 5–7μm-diameter injection pipet was performed. Sperm are then deposited in the perivitelline space, so damage of the egg cytoplasm is avoided. No pregnancies were achieved by Meta et al.[23] using this method; however, fertilization and early cleavage have been documented.

A variation of this micromanipulatory technique termed zona drilling is also being investigated. In this technique, a solvent is applied to the zona pellucida prior to sperm admixture. Fertilization, cleavage, and pregnancy have now been achieved with this technique.[24]

ALLOPLASTIC SPERMATOCELES

The use of a sperm reservoir is not new. Kelami et al.[25] have shown in animals that it is possible to recover sperm directly from artificial spermatoceles and achieve pregnancies. Its use in humans has been less encouraging. Schoysman[26] has proposed creation of an artificial spermatocele formed by a saphenous vein graft. Unfortunately, this method rarely yielded a sufficient number of motile spermatozoa. Obliteration and fibrosis of the graft uniformly resulted. Wagenknecht et al.[27] developed an implantable device, which was tested in rats and bulls. They found that sperm aspirated from these alloplastic spermatoceles were capable of impregnation. Marmar et al.[28] have reported implantation of an expanded polytetrafluoroethylene spermatocele. Although spermatozoa were retrieved, they were not motile. In 1985, Brindley et al.[29] reported 12 patients in whom implantable sperm reservoirs were used. Seven of these patients were azoospermic secondary to obstruction of the abdominal part of the vas. Five patients were paraplegic with ejaculatory failure. Eight patients (67%) in this group had motile sperm recovered. Two pregnancies were achieved, with subsequent live births by artificial insemination (AIH). Infection necessitated the removal of two of the 12 reservoirs (17%). The use of in vitro fertilization in combination with these techniques promises improved results.

CRYPTORCHIDISM AND TESTICULAR AUTOTRANSPLANTATION

At birth, 3–4% of full-term infants have undescended testis. Most of these descend during the first year of life, with only 0.8% remaining undescended.[30] Greater than 80% of these undescended testis are in the inguinal canal, less than 20% are intraabdominal. About 5% cannot be brought into the scrotum by conventional orchidopexy. The limiting factor in these situations is usually the short length of the internal spermatic artery and vein. A risk of testicular ischemia with subsequent atrophy exists if these vessels are ligated, since the other two vascular supplies to the testis—the deferential vessels and cremasteric vessels—are usually compromised by the dissection of the spermatic cord during orchidopexy.

In 10% of patients, the testes are bilaterally undescended. In addition, approximately 5% of individuals in whom a testis is not palpable in the inguinal canal or scrotum actually are anorchid. Thus an attempt at identification of the intraabdominal testis is made with various imaging modalities and/or provocative hormonal tests. Although many reasons for operative intervention have been given, a major objective in performing an orchidopexy is to preserve fertility potential.[31] There appears to be an age-dependent decrease

in testicular viability. This begins after the first year of life. Certainly by 5 years of age irreversible histologic changes can be found. Thus several operative techniques have been developed to place these high intraabdominal testis into their orthotopic scrotal position. These methods usually involve microvascular anastomosis of the testicular vein to the superficial inferior epigastric vein and the testicular artery to the deep inferior epigastric artery.

Microsurgical techniques have been used to develop animal models in which autotransplantation or selective microsurgical vascular occlusion was carried out. Goldstein et al.[32] developed a microsurgical method for creating vascularized testicular isografts. In this model, preservation of Leydig and Sertoli cell structure and function provided a unique model for studies of the hypothalamic-pituitary-testis axis. Young et al.[33] produced a model of Sertoli-cell-only syndrome in the rat by microscopically selectively occluding the testicular blood supply and subjecting the ischemic testis to cold.

CONCLUSIONS

Microsurgical techniques will continue to play an increasingly important role in the treatment of male factor infertility. As more urologists become dedicated microsurgeons the frontiers of male reproductive microsurgery will continue to expand.

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