Weill Cornell Medicine NewYork-Presbyterian

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Patient Information

Vasovasostomy and Vasoepididymostomy

Thank you for your inquiry regarding microsurgical reconstruction for vasectomy reversal or repair of blockages from other causes. Attached you will find articles from peer-reviewed journals which should answer many of your questions about reconstruction and sperm retrieval.

Although success rates for microsurgical reconstruction correlate somewhat with the length of time since the original obstruction (such as vasectomy), we have had successful reconstructions more than twenty years after obstruction. If good sperm are found above the obstruction site at the time of surgery, success can be expected, regardless of the length of time since the obstruction. Longer periods of time between the original obstruction and the reconstruction attempt, however, may necessitate a more extensive operation called a vasoepididymostomy to restore fertility. The determination is made at the time of the actual surgery. The attached information provides more details regarding the predictors of success after this type of surgery.

Our success rate for men who have had failed previous reconstructive surgery is almost as good as those undergoing reconstruction for the first time. Because of scarring from previous surgery, however, second operations may require more extensive surgery and may take longer to perform.

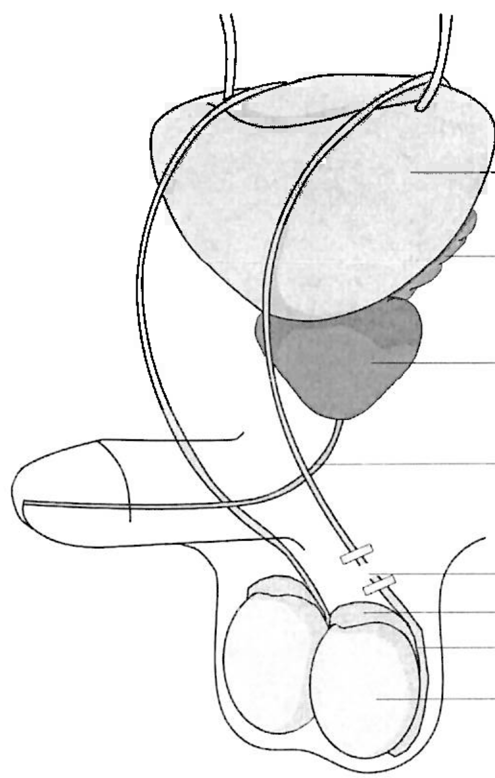
Definitions:

An **obstruction** is the blockage within the male reproductive tract where sperm is being stopped from exiting the body. This can be caused by vasectomy, injury from a prior surgery such as hernia repair or hydrocelectomy, infections such as epididymitis or can be congenital.

A **reconstruction** is the surgical procedure which attempts to reconnect, or unobstruct, the male reproductive tract. This usually requires one of two procedures: microsurgical vasovasostomy, or microsurgical vasoepididymostomy.

A microsurgical **vasovasostomy** (also known as a vasectomy reversal) is the reconnection of the two cut ends of the vas deferens. The vas deferens is the tube through which sperm travel from the testicle to the urethra.

A microsurgical **vasoepididymostomy** is the connection of the end of the vas deferens to the epididymis. This is a more difficult and time-consuming procedure, and is performed when there is a blockage of the epididymis.



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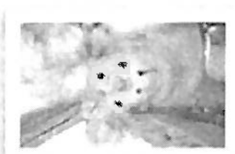
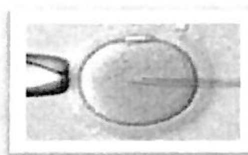
Sperm Retrieval

Sperm aspiration involves the extraction of sperm from either the ducts (epididymis or vas deferens) leading out from the testicle, or from the testicle itself. **Sperm obtained by aspiration can only be used for in-vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI).** This is because aspirated sperm in men who are blocked do not swim well, and will not fertilize the egg unless the sperm is injected directly into the egg using ICSI. **For men undergoing microsurgical vasovasostomy on at least one side, we usually do not recommend aspiration of sperm at the time of the surgery because our success rate for return of sperm in the semen after vasovasostomy is 99.5%.** If a vasoepididymostomy is necessary on both sides, however, the success rates drop to 80% for return of sperm. Therefore, in all men undergoing only vasoepididymostomy, we recommend the aspiration and freezing of sperm in the operating room at the time of surgery. This will allow sperm to be available for future IVF in the event that the surgery to repair the blockage is not successful.

Vasectomy Reversal or Sperm Retrieval?



- Female partner < 35 years old
- < 15 years since vasectomy
- Desire for several children
- Presence of sperm granuloma at vasectomy site regardless of time since vasectomy
- Availability of skilled urologic microsurgeon
- Post-vasectomy pain syndrome



- Female partner > 37 years old
- > 15 years since vasectomy
- Want only one child
- Skilled reversal surgeon not available
- Female factors requiring IVF present
- Male factor infertility in addition to vasectomy
- Availability of skillful IVF/ICSI unit

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Microsurgical management of male infertility

Marc Goldstein* and Cigdem Tanrikut

SUMMARY

The introduction of microsurgical techniques has revolutionized the treatment of male infertility. As a result of technical advances and innovation over the past 10–15 years, previously infertile couples are now able to conceive naturally or to parent their own biological children with the aid of assisted reproductive technologies. This article reviews the indications, techniques, and outcomes of the various microsurgical procedures currently used to optimize male fertility. The most up-to-date methods of microsurgical vasal and epididymal reconstruction, sperm retrieval, and varicocele repair are discussed.

KEYWORDS male infertility, microsurgery, varicocele, vasoepididymostomy, vasovasostomy

REVIEW CRITERIA
Information presented in this review is based on the authors' extensive collection of research papers, textbooks, and Marc Goldstein's vast personal experience in the field of male infertility.

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INTRODUCTION

According to the Centers for Disease Control and Prevention 2003 Assisted Reproductive Technology (ART) Report, male factors play a significant role in 30–40% of couples dealing with infertility.[1] The more common causes of infertility in men include obstruction of the reproductive tract, which can be congenital, acquired or iatrogenic, and impairment of sperm production associated with karyotypic or Y-chromosomal abnormalities, testicular pathology or the presence of varicocele. Most causes of male infertility are treatable, and many treatments restore the ability to conceive naturally.

The dramatic recent improvements in the management of male infertility are largely attributable to improved microsurgical techniques for the repair of obstruction, microsurgical varicocelectomy for enhancement of spermatogenesis, new options for sperm retrieval, and refined microsurgical intracytoplasmic sperm injection (ICSI). These factors have made male infertility one of the fastest growing subspecialties of urology.[2–11]

VASAL AND EPIDIDYMAL OBSTRUCTION

The most common causes of vasal and epididymal obstructions are vasectomy and iatrogenic vasal injury (7% of cases) from previous scrotal/inguinal surgeries, particularly those performed in childhood.[12,13] Microsurgical reconstruction remains the safest and most cost-effective treatment option for these patients,[14–16] and also allows natural conception, which is preferred by couples.

The lumina of the vas deferens and epididymal tubule are only about 0.3 mm and 0.2 mm in diameter, respectively, and, therefore, a precise microsurgical technique is the most important factor in the success of reconstruction (as defined by return of sperm to the ejaculate). With recent improvements in microsurgical techniques, the success rate for vasovasostomy is between 70% and 99%,[2,3,17,18] and success rates between 40% and 90% have

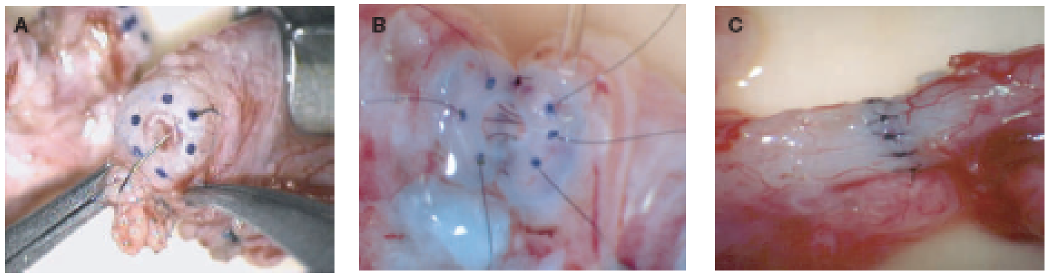

Figure 1 Microsurgical vasovasostomy with multilayer microdot method (×25). (**A**) Placement of 10-0 nylon suture inside the vasal lumen and through the microdot target. (**B**) The first three (of six) sutures of the anastomosis have been placed and tied down. The final three sutures have been placed and are ready to be tied. (**C**) Completed anastomosis. Reproduced with permission from reference 23 © (2002) Elsevier Inc.

been reported for microsurgical vasoepididymostomy.[2,6,19,20] Many patient-related factors, such as time interval from vasectomy, sperm granuloma at the site of anastomosis,[21] antisperm antibodies[22] and gross appearance of the vasal fluid,[23] can influence the outcome of the reconstruction. The age of the female partner should also be taken into account.[24] In addition, the surgeon's skill, reconstructive technique and experience all have a significant impact on surgical outcome.

MICROSURGICAL VASECTOMY REVERSAL

Vasectomy is the most common urologic operation in North America, where between 500,000 and 1 million men undergo the procedure each year. Before undergoing vasectomy, the patient should receive counseling regarding the permanency of the procedure and be offered the option of sperm banking. Despite preoperative counseling, surveys suggest that 2–6% of vasectomized men will ultimately seek vasectomy reversal because of unforeseen changes in lifestyle.[25]

Vasovasostomy

The microdot technique was developed at Cornell University as a means of improving the vasovasostomy procedure. It ensures precise suture placement by the exact mapping of each planned suture. When sperm are found in the fluid emanating from the testicular end of the vas, the patency rate of this technique for return of sperm to the ejaculate is 99.5%, and the 1-year cumulative pregnancy rate for partners of patients undergoing this procedure is 70%.[3] The microdot method separates the planning of suture position from the physical act of suture placement. Much as an architect prepares blueprints before the builder constructs the house, the perioperative planning of suture placement is critical to a successful surgical outcome. This painstaking planning allows the surgeon to focus on one task at the time of suture placement, 'hitting the bulls eye'. In addition, the discrepancy in diameter between the proximal (obstructed) vasal lumen and the distal (nonobstructed) vasal lumen is typically 2:1 to 3:1, sometimes more; careful, even spacing of the sutures minimizes luminal discrepancy and limits 'dogears' and leaks, thus decreasing the risk of postoperative stricture, granuloma formation, and reconstructive failure. The microdot method results in substantially improved accuracy of suture placement and minimizes the discrepancy between luminal diameters of the proximal and distal vasal ends, allowing for a watertight anastomosis.

A microtip skin-marking pen is used to map out planned needle exit points. Exactly six monofilament 10-0 double-arm nylon mucosal sutures (first layer) are used for every anastomosis, because they are easy to map out and always result in a leak-proof closure, even when the lumen diameters are markedly discrepant. After completion of the mucosal layer, six 9-0 deep muscularis sutures are placed exactly in between each mucosal suture, just above, but not penetrating, the mucosa (second layer). Six additional 9-0 nylon interrupted sutures are then placed between each muscular suture (third layer). These sutures only involve the adventitial layer that covers the underlying mucosal suture. The anastomosis is finished by approximating the vasal sheath with six interrupted sutures of 7-0 PDS, completely covering the anastomosis and relieving it of all tension (fourth layer). All anastomoses consist of four layers of

Table 1 Surgical recommendations based on gross appearance of vasal fluid and microscopic findings.

Appearance of vasal fluid	Most common findings on microscopic examination	Surgical procedure recommended
Copious, crystal clear, watery	No sperm	Vasovasostomy
Copious, cloudy thin, water soluble	Sperm with tails	Vasovasostomy
Copious, creamy yellow, water insoluble	Many sperm heads, occasional sperm with short tails	Vasovasostomy
Copious, thick white toothpaste-like, water insoluble	No sperm	Vasoepididymostomy
Scant white thin fluid	No sperm	Vasoepididymostomy
Scant fluid, no granuloma at vasectomy site	No sperm	Vasoepididymostomy
Scant fluid, granuloma present at vasectomy site	Barbotage fluid reveals sperm	Vasovasostomy

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six sutures, for a total of 24 sutures (Figure 1). The dartos layer is approximated with interrupted 4-0 absorbable sutures and the skin with subcuticular sutures of 5-0 Monocryl® (Johnson and Johnson, New Brunswick, NJ).

Vasoepididymostomy

Microsurgical vasoepididymostomy

Microsurgical vasoepididymostomy is considered the most technically challenging type of surgery for the male reproductive system. In virtually no other operation are results so dependent upon the surgeon's technical expertise. Surgeons who perform vasoepididymostomy, therefore, must have extensive experience in microsurgical techniques and carry out the procedure frequently. The indications for performing vasoepididymostomy at the time of vasectomy reversal, based on gross appearance of the vasal fluid,[23] are reviewed in Table 1. Although occasional discrepancies exist between gross and microscopic findings, they correlate approximately 80% of the time. It is, however, essential to view the vasal fluid under the microscope, in order to determine whether to proceed with vasovasostomy or with vasoepididymostomy. For obstructive azoospermia that is not due to vasectomy or absence of the vas deferens, vasoepididymostomy is indicated when the testis biopsy reveals complete spermatogenesis and scrotal exploration reveals the absence of sperm in the vasal lumen.

Microsurgical end-to-side two-suture intussusception vasoepididymostomy

The intussusception technique, originally known as the three-suture triangulation technique, was developed by Berger.[26] Marmar described a modified technique that consists of two sutures with transverse double-needle placement within the epididymal tubule.[27] At Cornell University, a longitudinal two-suture intussusception vasoepididymostomy approach (Figure 2A) was developed in order to further improve the procedure.[7] With this method, four microdots are marked on the cut surface of the vas deferens and two parallel double-arm sutures are placed in the distended epididymal tubule; however, the needles are not pulled through. After the epididymal fluid is tested for sperm and aspirated into micropipettes for cryopreservation, the two needles within the epididymal tubule are pulled through, and all four

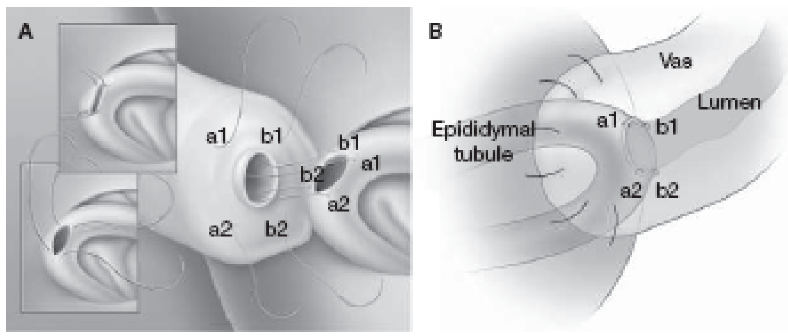

Figure 2 Microsurgical end-to-side two-suture intussusception vasoepididymostomy. (**A**) Two parallel sutures are placed in the selected epididymal tubule, oriented longitudinally, then the tubule is incised between the two needles (top inset). Once the epididymal tubule has been incised, the sutures are pulled through (bottom inset). The double-arm needles are placed in-to-out through the vasal lumen. The suture points are labeled to indicate where they run (a1 to a1, etc.). (**B**) Completed anastomosis. The suture points at the completed anastomosis are indicated by a1, a2, b1 and b2. Reproduced with permission from reference 7 © (2003) Elsevier Inc.

Table 2 Advantages and disadvantages of surgical techniques for sperm retrieval.

	Advantages	Disadvantages
Microsurgical epididymal sperm aspiration	Low complication rate if performed microsurgically Epididymal sperm have better motility than testicular sperm Large number of sperm can be harvested for cryopreservation of multiple vials in a single procedure	General anesthesia preferred Requires microsurgical skills Not indicated for nonobstructive azoospermia
Percutaneous epididymal sperm aspiration	No microsurgical skill required Local rather than general anesthesia Epididymal sperm have better motility than testicular sperm	Variable success in obtaining sperm Smaller quantity of sperm obtained than with microsurgical epididymal sperm aspiration Not indicated for nonobstructive azoospermia Complications include hematoma, pain and vascular injury to testes and epididymis
Testicular sperm aspiration	No microsurgical skill required Local rather than general anesthesia Can be used for obstructive azoospermia	Immature or immotile sperm Small quantity of sperm obtained Poor results in nonobstructive azoospermia Complications include hematoma, pain and vascular injury to testes and epididymis
Testicular sperm extraction	Low complication rate if performed microsurgically Preferred technique for nonobstructive azoospermia	Requires general anesthesia and microsurgical skills

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needles are placed through the vas lumen at the marked locations. Tying down the sutures allows the epididymal tubule to be intussuscepted into the vasal lumen, completing the anastomosis (Figure 2B). The patency rate with the longitudinal intussusception vasoepididymostomy approach was over 90% in a recent clinical series, and intussusception is the preferred method for all vasoepididymostomies.[6]

All successful vasovasostomy and vasoepididymostomy techniques rely on adherence to surgical principles that are universally applicable to anastomoses of all tubular structures: an accurate mucosa-to-mucosa approximation; leakproof anastomosis; tension-free anastomosis; good blood supply; healthy mucosa and muscularis; and atraumatic anastomotic technique.

EPIDIDYMAL SPERM ASPIRATION

When to perform sperm extraction

Although most postvasectomy patients are candidates for microsurgical reconstruction, not all obstructive-azoospermic men can be managed surgically. In order that these men can become biological fathers, various sperm-retrieval techniques have been developed for use in conjunction with *in vitro* fertilization (IVF). Before the introduction of ICSI, sperm retrieval was performed with IVF and limited forms of micromanipulation, such as partial zona dissection. ICSI has now replaced all other types of assisted reproduction.

Congenital bilateral absence of the vas deferens (CBAVD) is an abnormality related to cystic fibrosis. In patients with mutations in the cystic fibrosis transmembrane conductance regulator (CFTR) gene, segments of the excurrent ductal system anywhere from the midportion of the epididymis to the seminal vesicles are missing.[28] Only a minority of patients with a CFTR gene mutation have enough healthy tissue for reconstruction to be feasible.[29] The majority of patients with CBAVD, therefore, will need epididymal sperm aspiration for IVF via ICSI.[30–32] Before IVF is performed, it should be determined whether both partners are carriers of the CFTR gene mutation.

There are various surgical techniques for sperm retrieval; their advantages and disadvantages are summarized in Table 2. These techniques are also useful for intraoperative retrieval of sperm during reconstructive procedures such as vasoepididymostomy, which have failure rates high enough that intraoperative cryopreservation of sperm for a future IVF cycle should be considered, in the event that the reconstructive surgery is unsuccessful.

Sperm obtained from patients with chronically obstructed reproductive systems usually have poor motility and decreased fertilization capacity. The use of ICSI is essential to achieve optimal results in most cases. One notable exception is chronic obstruction secondary to previous vasectomy. Female partners of men who underwent vasovasostomy more than 15 years after their initial vasectomy still achieved a natural pregnancy rate of 44%.[20] The sperm of patients with chronic epididymal obstruction in this setting will take longer to regain motility; however, even if natural conception does not occur, ejaculated sperm could be used for intrauterine insemination or ICSI.

Open epididymal tubule sperm retrieval technique

Microsurgical epididymal sperm aspiration can be employed either for intraoperative sperm retrieval at the time of vasoepididymostomy or as an isolated procedure in men with congenital absence of the vas deferens or unreconstructable obstructions.[33] Under the operating microscope, the epididymal tunic is incised and a dilated epididymal tubule is selected, isolated and incised with a 15° microknife (Figure 3A). The fluid is touched to a slide, a drop of saline or Ringer's solution is added, a cover slip is placed over the slide, and the fluid is immediately examined under a bench microscope. As soon as motile sperm are found, a dry micropipette is placed adjacent to the effluxing epididymal tubule (Figure 3B). A standard hematocrit pipette is less satisfactory, but can be used if a micropipette is not available. Sperm are drawn into the micropipette by simple capillary action. Negative pressure, as is generated by the action of an in-line syringe, should not be applied during sperm retrieval as this can disrupt the delicate epididymal mucosa. Two micropipettes can be employed simultaneously in order to increase the speed of sperm retrieval. The highest rate of flow is observed immediately following incision of the tubule. Progressively better-quality sperm are often found following the initial washout. Gentle compression of the testis and epididymis enhances flow from the incised tubule. With patience, 25–50 μl of highly concentrated epididymal fluid, containing approximately 75 million sperm, can be recovered. This is diluted in multiple aliquots of 2–3 ml of human tubal-fluid medium, so that there are 5–10 million sperm per ml. Those specimens not used immediately for ART are cryopreserved for possible future use. If no sperm are obtained, the epididymal tubule and tunic are closed with 10-0 and 9-0 monofilament nylon sutures, respectively, and an incision is made more proximally in the epididymis, or even at the level of the efferent ductules, until motile sperm are obtained.

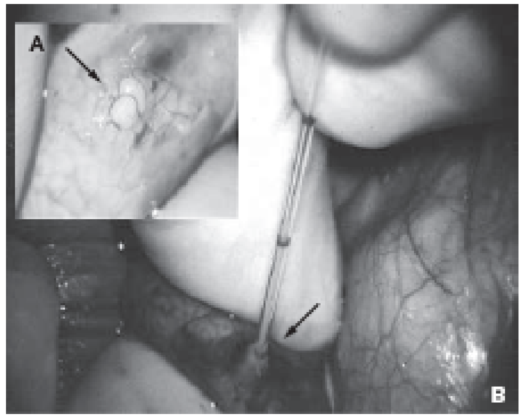

Figure 3 Microsurgical epididymal sperm aspiration **(A)** Selection and isolation of dilated tubule (×10). **(B)** Aspiration of sperm into micropipette by capillary action (×15). Reproduced with permission from reference 23 © (2002) Elsevier Inc.

Box 1 Causes of nonobstructive azoospermia.

Congenital and developmental

Genetic
- Karyotypic abnormalities
- Y-chromosomal microdeletions

Testicular
- Cryptorchidism
- Torsion
- Bilateral anorchia

Endocrinologic
- Deficiencies of gonadotropin-releasing hormone agonist, luteinizing hormone, and follicle-stimulating hormone
- Excess of androgen, estrogen, prolactin, glucocorticoid
- Thyroid abnormalities
- Receptor abnormalities

Varicocele

Acquired

Environmental hazards
- Radiation
- Heat or thermal injury

Iatrogenic
- Ischemic atrophy
- Radiotherapy
- Chemotherapy

Diseases
- Neoplastic diseases
- Infections or inflammatory causes
- Systemic illness

Drugs or gonadotoxins

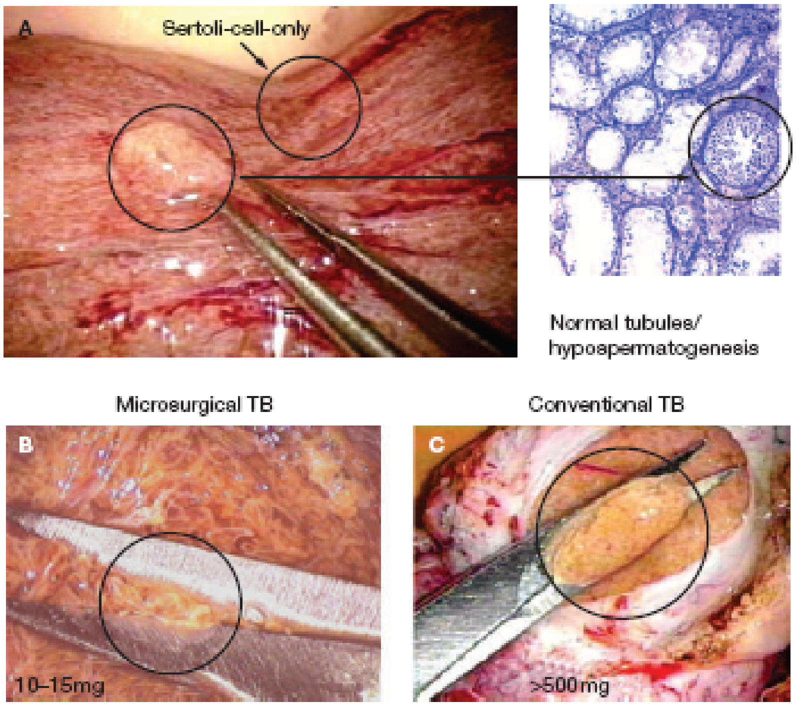

Figure 4 Microdissection testicular sperm extraction. (**A**) Comparison of full, white sperm-containing tubules (to left) with stringy-appearing, yellowish Sertoli-cell-only tubules (right) (×25). An example is provided of what a sample might look like under microscopic histologic examination. (**B**) Excision of full tubules under microscopic assistance (×25). (**C**) Conventional testis biopsy. Abbreviation: TB, testis biopsy. Reproduced with permission from reference 23 © (2002) Elsevier Inc.

Success of sperm extraction techniques

Sperm retrieval from the epididymides of men with obstructive azoospermia is possible in over 99% of patients when performed by experienced microsurgeons.[34,35] Success rates such as these are possible even if multiple prior procedures have been performed and extensive scarring is present in the scrotum. If the epididymis is obliterated because of previous procedures or infection, the most proximal efferent ductules of the testis can be exposed by reflection of the caput epididymis to uncover the 7 to 11 dilated tubules. One should be able to aspirate sperm from at least one of these tubules.

In a study of 76 attempts at sperm retrieval using MESA and ICSI in men with obstructive azoospermia, clinical pregnancies were detected by a fetal heartbeat after 75% of attempts, with ongoing pregnancy or delivery achieved for 64% of attempts.[36] For men with CBAVD, the success rate is even higher.[37] Optimal fertilization and pregnancy rates are obtained with a technique of agressive immobilization of spermatozoa prior to ICSI. It is possible that aggressive immobilization acts by enhancing sperm membrane permeability to improve the ability of immature spermatozoa to fertilize oocytes.[38] The teamwork and collaborative effort of reproductive endocrinologists, embryologists, and male reproductive surgeons is of paramount importance for successful results.

NONOBSTRUCTIVE AZOOSPERMIA

Nonobstructive azoospermia (NOA), or testicular failure, is the most challenging type of male-factor infertility to manage. Various conditions that can lead to NOA have been identified (Box 1). While some of the underlying causes of NOA might be reversible to a degree, advanced ART techniques are needed for the majority of patients with this condition. With the advent of ART, particularly ICSI in conjunction with sperm obtained via testicular sperm extraction (TESE), many of these men are now able to father their own biological children. However, there remain subgroups of 20–40% of patients with NOA who, despite the advent of ICSI and advances in microsurgical sperm extraction techniques, are not able to have sperm retrieved for assisted reproduction.[39] In these cases, the couples should consider donor-sperm fertilization or adoption as alternatives.

Testicular-sperm extraction

Testicular sperm can be found within the testicular tissue of many men with NOA. The optimal technique of sperm extraction would be minimally invasive and avoid destruction of testicular function, without compromising the chance of retrieving enough spermatozoa with which to perform ICSI.

Microdissection testicular sperm extraction

Microdissection TESE is an advanced version of TESE that applies microsurgical techniques to the retrieval of sperm from the seminiferous tubules. Although microdissection TESE is not a minimally invasive technique, it results in the removal of a minimal amount of testicular tissue with maximal sperm yield, and minimizes the negative impact on testicular function. This method was developed by Schlegel,[40] and is an effective method for the retrieval of sperm from men with NOA, for use in ICSI. The seminiferous tubules from different areas of the testis are often associated with different states of maturation of spermatogenesis. In other words, in some areas of the testis, the Sertoli-cell-only pattern might be present, whereas other areas might show maturation arrest, hypospermatogenesis, or even normal spermatogenesis. Under the operating microscope (×25), an experienced surgeon can usually distinguish between 'more active' and 'less active' seminiferous tubules by their appearance; tubules that appear full, opaque, and are larger in comparison to other tubules are more likely to contain sperm (Figures 4A and 4B).

The conventional TESE technique requires multiple, blind testis biopsies with excision of large volumes (>500 mg) of testicular tissue, which can result in permanent damage to the testis (Figure 4C). The microdissection TESE technique of sequential excision of microdissected seminiferous tubules (10–15 mg, or 2 mm in length, of seminiferous tubule) has been shown to be more successful, compared with the results achieved by conventional TESE, or random biopsies of testicular tissue. In a sequential series of TESE attempts, Schlegel showed that sperm-retrieval rates improved from 45% (10 out of 22 patients) with conventional TESE to 63% (17 out of 27 patients) with microdissection TESE. Microdissection samples yielded an average of 160,000 spermatozoa per 9.4 mg sample, whereas only 64,000 spermatozoa were found in an average 720 mg conventional biopsy sample (P<0.05 for all comparisons).[41]

Outcomes of testicular sperm extraction

By using microdissection TESE in men with NOA, a sufficient number of spermatozoa can be retrieved with a minimal amount of testicular tissue being excised. In addition, optical magnification allows for the minimal disturbance of the testicular blood supply.[42] Microdissection TESE is a more efficient technique for sperm retrieval in men with NOA than conventional TESE, and results in less postoperative intratesticular scarring.[43]

The likelihood of sperm retrieval in patients with nonobstructive azoospermia can be estimated on the basis of the most advanced pattern of spermatogenesis (not the most predominant pattern) seen on histopathology, if a previous testis biopsy has been performed.[44] In men with at least one area of hypospermatogenesis, microdissection TESE resulted in successful sperm retrieval in 81% of patients. In men where the most advanced form of spermatogenesis was maturation arrest, the retrieval rate was 44%. Even those who exhibited a Sertoli-cell-only pattern had sperm retrieved in 41% of cases.[43]

In an extension of the 1999 study by Palermo *et al.*,[45] the team at Cornell University made 684 attempts at sperm retrieval, using microdissection TESE for men with NOA, with encouraging results. Sperm were retrieved from 59% of the men. The fertilization rate from subsequent ICSI procedures using the extracted sperm was 59% per injected oocyte, and clinical pregnancy, as defined by detection of a fetal heartbeat, was achieved in 48% of the cycles in which sperm were retrieved (PN Schlegel, unpublished data).

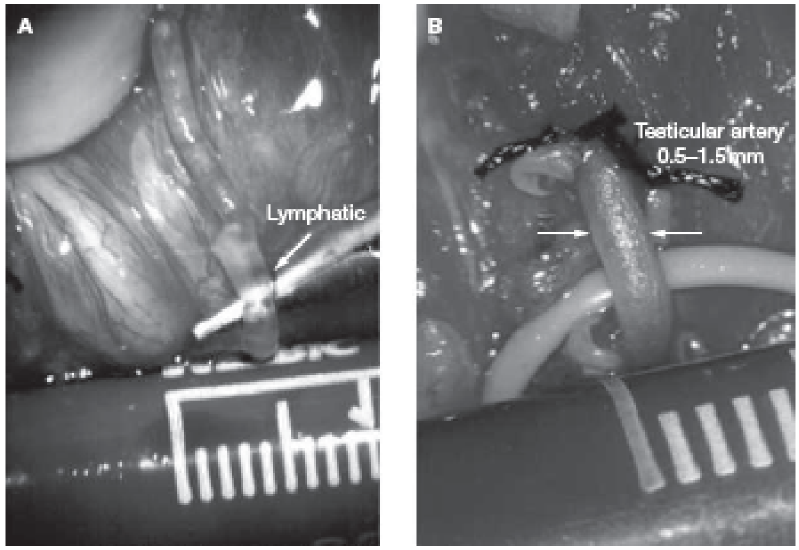

Figure 5 Microsurgical varicocelectomy (×25). (**A**) Lymphatic vessel. (**B**) Testicular artery. Reproduced with permission from reference 23 © (2002) Elsevier Inc.

Varicocelectomy

Varicocelectomy is the most common procedure for male infertility. Varicoceles are found in approximately 10–15% of unmarried, male military recruits,[46] in 35% of infertile men who have never fathered a child, and in 81% of men who were once fertile, as proven by previous conception, but who are now infertile (secondary infertility).[47] Repair of varicocele for treatment of male infertility is controversial;[48] however, any studies that have not shown an improved pregnancy rate after varicocele repair were small, were not stratified by grade of varicocele, and did not control for type of repair technique.[49]

Table 3 Techniques of varicocelectomy and potential complications.

Technique	Artery preserved	Incidence of hydrocele (%)	Failure rate (%)	Potential for serious morbidity
Microscopic inguinal	Yes	<1	<1	No
Conventional inguinal	No	3–30	5–15	No
Retroperitoneal	No	7	15–25	No
Laparoscopic	Yes	12	5–15	Yes

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It is possible that varicocelectomy can halt further damage to testicular function and improve spermatogenesis, as well as enhancing Leydig-cell function (as reflected by an increase in postoperative serum testosterone levels in infertile men).[50] Urologists might, therefore, have a valuable role in preventing future infertility and androgen deficiency[51,52] in aging men, and this underscores the importance of using a varicocelectomy technique that minimizes the risk of complications and varicocele recurrence.

Preferred approaches: microsurgical inguinal and subinguinal operations

The advantages of microsurgical techniques over other approaches to varicocele repair (e.g. open surgical, laparoscopic, and percutaneous techniques) are the reliable identification and preservation of the testicular artery or arteries, cremasteric artery or arteries, and lymphatic channels, as well as the reliable identification of all internal spermatic veins and gubernacular veins. Delivery of the testis through the subinguinal incision allows inspection of the gubernacular veins, assuring direct visual access to all possible routes of venous return, including external spermatic, cremasteric, and gubernacular veins.[53] Postoperatively, venous return is via the deferential (vasal) veins, which drain into the internal pudendal veins and usually have competent valves.

The application of microsurgical techniques[53,54] to varicocelectomy has resulted in a substantial reduction in the incidence of hydrocele formation. This is because the lymphatic vessels can be more easily identified and preserved (Figure 5A). Furthermore, the use of magnification enhances the surgeon's ability to identify and preserve the 0.5–1.5 mm testicular artery[55] (Figure 5B), thus avoiding the complications of atrophy or azoospermia.

Varicocelectomy outcomes

The goals of varicocele repair are to relieve pain in symptomatic cases and to improve semen parameters, testicular function, and pregnancy rates in couples with male-factor infertility associated with varicocele. Studies have shown that varicocele repair can improve all three of these in infertile men,[46,56] with a significant improvement in semen analysis seen in 60–80% of men.[57] Varicocele repair in young men might be able to prevent infertility and androgen deficiency later in life.[50]

The clinical outcomes of varicocelectomy are also related to the size of the varicocele. Repair of large varicoceles results in a significantly greater improvement in semen quality than repair of small varicoceles.[58,59] In addition, large varicoceles are associated with greater preoperative impairment in semen quality than small varicoceles; consequently, overall pregnancy rates are similar regardless of varicocele size. In the presence of small (grade I) varicoceles along with larger (grade II and III), contralateral varicoceles, greater improvement in semen parameters can be expected if repair is performed bilaterally, rather than only the larger side being repaired.[60] Some evidence suggests that the younger the patient is at the time of varicocele repair, the greater the improvement after repair and the more likely the testis is to recover from varicocele-induced injury.[61–63] Testicular artery ligation and post-varicocelectomy hydrocele formation may be associated with poor postoperative results.

In a controlled trial of varicocele repair in infertile men that compared surgery with no surgery, the surgery group had a pregnancy rate of 44% at 1 year, compared with 10% in the no-surgery group. Using the microsurgical technique in 1,500 men who underwent varicocelectomy, the pregnancy rate in couples was

43% after 1 year and 69% after 2 years, compared to 16% in couples with men who declined surgery and instead had hormone treatment or used ART. There have been only 14 recurrences (1%), no reports of hydrocele or testicular atrophy,[53] and only a 1% incidence of inadvertent unilateral testicular artery ligation.[64]

The most common complications of varicocelectomy are hydrocele formation, varicocele recurrence, and testicular artery injury (Table 3). Use of the operating microscope allows for reliable identification of spermatic cord lymphatics, internal spermatic veins and venous collaterals, and the testicular artery or arteries; the incidence of such complications can, therefore, be significantly reduced. Delivery of the testis through a small subinguinal incision provides direct visual access to all possible avenues of testicular drainage to ensure complete ligation. Failure to deliver the testis might result in varicocele recurrence in 7% of patients because of scrotal collaterals.[65] Additional benefits of delivery of the testis include the identification of otherwise-undetected small testicular tumors and previously undiagnosed epididymal or vasal obstructions (M Goldstein, unpublished data).

Advocates of nonmicrosurgical techniques contend that the deferential (vasal) artery and, if preserved, the cremasteric artery, will ensure blood supply to the testes that is adequate to prevent atrophy.[66,67] Anatomic studies, however, have shown that the diameter of the testicular artery is greater than the diameter of the deferential artery and cremasteric artery combined.[55] The testicular artery is the main blood supply to the testes. At the very least, it is inarguable that ligation of the testicular artery is unlikely to enhance testicular function. Microsurgical varicocelectomy is a safe and effective approach to varicocele repair, and preserves testicular function, improves semen quality and pregnancy rates in a significant number of couples. Ultimately, the ideal intervention for varicoceles can only be determined by a large, prospective, randomized and controlled study using a microsurgical, artery and lymphatic-sparing technique.

CONCLUSION

Very few medical fields have changed as dramatically over the past decade as reproductive medicine, particularly in terms of the diagnostic and treatment strategies for male infertility. These advances include ICSI, refined microsurgical reconstructive techniques (vasovasostomy and vasoepididymostomy), microsurgical techniques for surgical sperm retrieval from the epididymis and testis, and microsurgical varicocele repair. These techniques remain the safest and most cost-effective ways of treating infertile men, and, perhaps more importantly for the couples involved, many of these techniques enable couples to conceive naturally.

KEY POINTS

- Successful vasovasostomy is predicated on the basic surgical principles of a tension-free, watertight anastomosis with mucosa-to-mucosa apposition.
- Performing vasovasostomy or vasoepididymostomy is more cost-effective for achieving pregnancy than assisted reproductive technologies that use sperm aspiration
- Vasoepididymostomy is the most technically difficult of all microsurgical procedures, and should only be performed by experienced microsurgeons
- Varicocele is a risk factor for impaired spermatogenesis and Leydig-cell function, and varicocele repair can improve testicular function
- Ligation of the testicular artery during varicocele repair is not likely to improve testicular function
- Preservation of lymphatic drainage during varicocele repair decreases the risk of postoperative hydrocele

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MICROSURGICAL VASOVASOSTOMY: THE MICRODOT TECHNIQUE OF PRECISION SUTURE PLACEMENT

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ABSTRACT

Purpose: A technique of vasovasostomy that facilitates precision suture placement is presented.

Materials and Methods: The technique involves mapping of the planned suture exit points with "microdots" placed on the cut ends of the vas deferens with a microtip marking pen.† Microdots are placed at 12, 3, 6 and 9 o'clock positions. Four additional dots are placed between each of the previous 4 dots. Exactly 8 mucosal sutures (double armed 10-zero monofilament sutures‡) are used for each anastomosis. The anastomosis is completed with 8 muscularis sutures (9-zero monofilament) and 6 to 8 sutures (6-zero monofilament) approximating the vasal sheath.

Results: In a series of 194 consecutive vasovasostomy procedures using this technique a patency rate of 99.5% was achieved. Pregnancy rates of 54% (crude) and 64% (excluding female factor infertility) were observed for the first 100 subjects of this cohort.

Conclusions: The microdot technique ensures precision suture placement and facilitates the anastomosis of lumens of discrepant diameters by exact mapping of each planned suture. The microdot method separates the planning from the placement. Patency rates using the microdot technique approach 100%.

KEY WORDS: vas deferens, vasovasostomy, surgery

The Vasovasostomy Study Group reporting on a cohort of more than 1,200 vasectomy reversal procedures observed a mean interval of obstruction before surgery of 7 years.[1] The physiological effect of prolonged obstruction on the testicular end of the vas deferens in the absence of a more proximal pressure vent is dilatation of the lumen up to or greater than a diameter of 1 mm. The unobstructed abdominal end of the vas deferens retains its normal dimensions with a luminal diameter of 0.3 mm. Therefore, vasectomy reversal following an interval of obstruction requires an anastomosis of lumina of widely discrepant diameters. Suture placement must be accurate to approximate the testicular and abdominal ends of the vas deferens precisely without gaps or dog-ears and to ensure a leak-proof anastomosis. Failure to achieve a technically sound anastomosis may have a negative impact on patency and subsequent fertility. We present a method of vasectomy reversal that addresses these issues, and ensures precise and accurate suture placement.

TECHNIQUE

Setup. Surgeon and assistant should be comfortably seated on well padded stools to stabilize the lower body. A simple rolling stool supplemented by a round bean bag or thick foam cushioning provides a comfortable and stable platform. Two arm boards placed on either side of the surgeon and assistant provide excellent support, and improve arm stability and microsurgical accuracy. The arm boards may be bolstered with folded towels to provide the appropriate elevation for patients of any body habitus. This setup is flexible and maneuverable, and can be had at a fraction of the cost of more cumbersome microsurgery chairs. A right-handed surgeon should sit on the right side of the patient so the forehand stitch will always be on the smaller and more difficult abdominal side lumen.

Anastomosis. The microdot technique of vasovasostomy can accommodate lumina of markedly discrepant diameters in either the straight or convoluted vas deferens. If the mucosa is not sharply defined, the cut surface of the vas may be highlighted with indigo carmine (fig. 1). Microdot placement is facilitated by drying the cut surface of the vas with a Weck cell and a microtip marking pen is used to map out planned needle exit points. Microdots are placed at the 3 and 9 o'clock positions. Lines are extended from these 2 dots as reference points. Then dots are placed at the 12 and 6 o'clock positions. Four more dots are placed between the previous 4 dots. Microdots are placed midway between the mucosa and serosal margins. The abdominal and testicular ends of the vas deferens are identically marked (fig. 2). Mapping planned suture exit points eliminates dog-ears and leaks when anastomosing lumens of discrepant diameters.

Double-armed 10-zero monofilament sutures are used. The double-armed sutures reduce tissue trauma by eliminating any need for mucosal dilation and manipulation. A double-armed suture, using an inside out technique of suture placement, further reduces the risk of iatrogenic obstruction ("back walling") possible with an outside in technique. If the mucosal edges of the small abdominal side lumen are not clearly visualized even with indigo carmine staining, momentary and gentle dilatation with a microvessel dilator just before suture placement may be used.

The anastomosis is begun with the placement of 4, 10-zero mucosal sutures (fig. 3). Sutures are exited precisely through the center of each microdot (fig. 4, *A*). Include exactly the same amount of tissue on each side (fig. 4, *B*). After the first 4 mucosal sutures are tied, 3, 9-zero polypropylene sutures are placed between the 4 mucosal sutures in the muscularis above but not through the mucosa. This suture eliminates any gap between mucosal sutures.

The vas is then rotated 180 degrees (fig. 5, *A*) and 4 additional 10-zero sutures are placed to complete the mucosal anastomosis (fig. 5, *B*). Exactly 8 mucosal sutures are used

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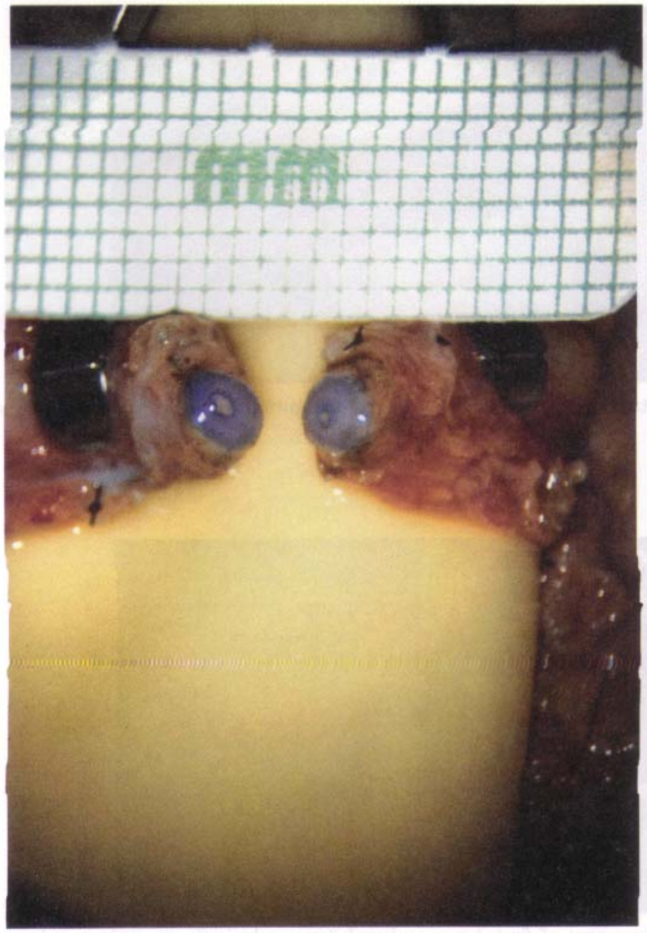

FIG. 1. View from left side of patient. Indigo carmine improves visualization of mucosal margins. On left side is transected testicular remnant (note comparatively larger diameter) and abdominal end is at right. Ruler above uses millimeter scale.

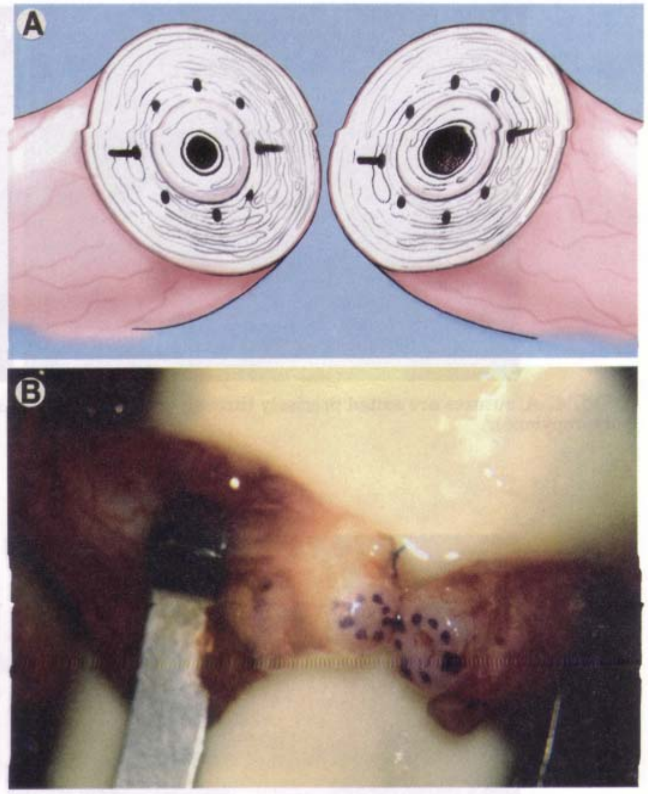

FIG. 2. *A*, schematic representation of microdot placement. *B*, intraoperative view of completed microdot placement.

for each anastomosis. Just before tying the last 2 mucosal sutures, the lumen is gently irrigated with heparinized Ringer's lactate solution to reduce the risk of clot formation. The muscularis layer is completed with the placement of 5 additional 9-zero sutures as previously described. A watertight anastomosis is achieved. The anastomosis is completed by approximation of the vasal sheath with 6 to 8 interrupted sutures of 6-zero monofilament. The third layer covers the anastomosis and relieves tension.

RESULTS

The 194 consecutive vasovasostomy procedures performed by a single surgeon (M. G.) using the microdot technique were reviewed. Only men with sperm in the testicular end of at least 1 vas deferens were enrolled in the study. Unilateral (18 cases) and bilateral (176) vasovasostomy procedures were considered. Men undergoing unilateral vasovasostomy with contralateral vasoepididymostomy were excluded from review. The initial postoperative semen analysis is obtained 1 month after surgery and subsequent analyses are obtained at 3 months and then every 3 months for the first post-reversal year, at 6-month intervals in postoperative year 2 and annually thereafter. All men not contributing to pregnancy were followed for a minimum of 1 year. Patency (complete sperm with tails present) was observed in 193 of the 194 men (99.5%).[2,3] For the first 100 men with a mean duration of 17 months of followup 54 (54%) have contributed to pregnancies with their partners. Excluding those couples with associated female factor infertility, a 64% pregnancy rate was observed.

DISCUSSION

Following obstruction the testicular end of the vas deferens is subjected to increased storage pressures resulting in marked dilatation of its lumen in contrast to the unobstructed and essentially normal caliber abdominal end of the vas deferens. Vasovasostomy following vasectomy and an interval of obstruction necessitates an anastomosis between lumina of widely discrepant diameters. Precise end-to-end vasal anastomosis requires that the arc of circumference covered between adjacent sutures be equal for the testicular and abdominal ends. For lumina of unequal diameters this anastomosis necessitates that distances between sutures on the obstructed testicular end are greater than those on the abdominal vas. Unequal distribution of sutures along the circumference of the testicular and abdominal ends of the vas deferens may result in large gaps and/or dog-ear deformities. An anastomosis in which sutures are unevenly distributed is

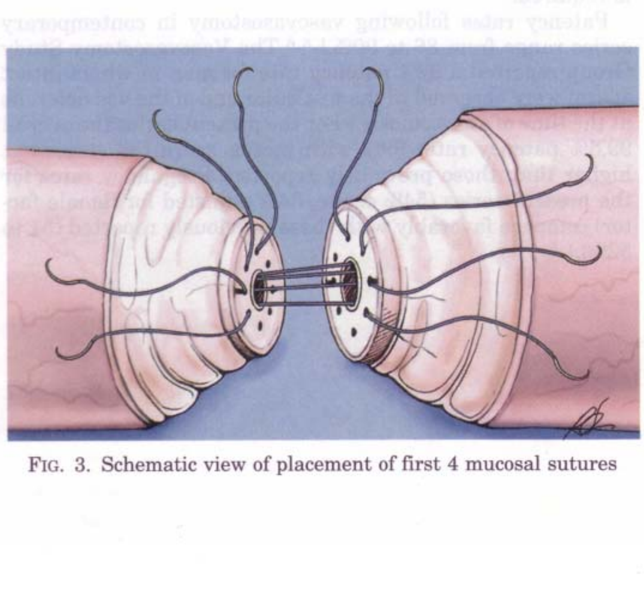

FIG. 3. Schematic view of placement of first 4 mucosal sutures

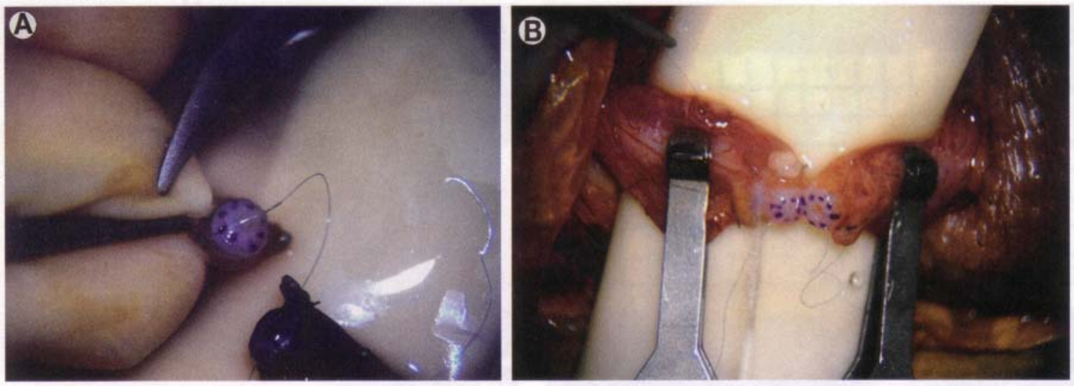

FIG. 4. *A*, sutures are exited precisely through each microdot. *B*, intraoperative view after placement of initial 3 mucosal sutures (10-zero polypropylene).

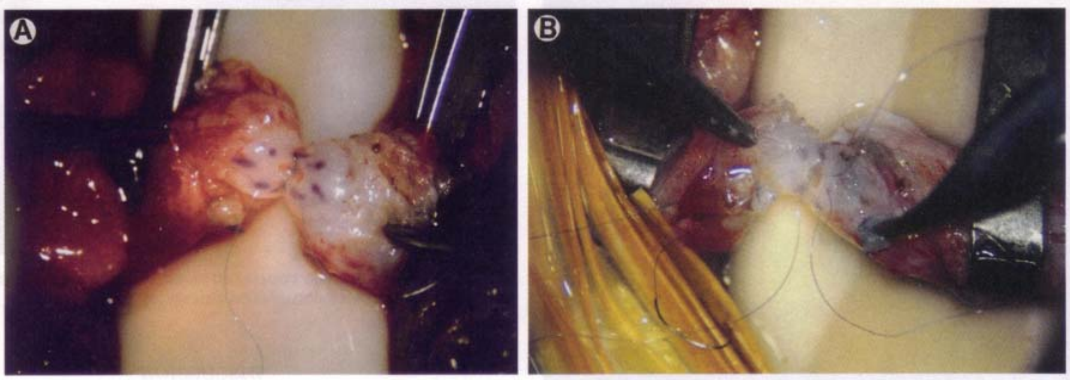

FIG. 5. *A*, vas deferens has been rotated 180 degrees following placement of first 4 mucosal and 3 muscularis (9-zero polypropylene) sutures. *B*, mucosal anastomosis is completed.

more likely to leak, resulting in sperm granuloma formation and increased risk of failure.[4]

The microdot technique of vasovasostomy ensures precise placement of sutures. The anastomosis of lumens of discrepant diameters is facilitated by the exact mapping of each planned suture. The microdot method separates suture planning from suture placement. This technique is performed without the need for or expense of additional microsurgical tools or instruments. Microdot vasovasostomy requires no additional surgical skills to adopt successfully and may be of benefit in improving technique among less experienced microsurgeons. In our experience no additional operative time is required.

Patency rates following vasovasostomy in contemporary series range from 86 to 90%.[1,5,6] The Vasovasostomy Study Group reported a 92% patency rate for men in whom intact sperm were observed in the testicular end of the vas deferens at the time of anastomosis.[1] For the present series the overall 99.5% patency rate (99% with motile sperm) is somewhat higher than those previously reported. Pregnancy rates for the present series (54% crude, 64% adjusted for female factor) compare favorably with those previously reported (51 to 52%).[1,5]

In summary, the microdot method of vasovasostomy promotes accuracy and precision in anastomotic technique. For the current series patency rates using this technique approach 100%.

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Vasoepididymostomy

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Introduction

Vasoepididymostomy is considered to be the most challenging microsurgical procedure in male reproduction. It is the reconstructive means to anastomose the vas deferens to an epididymal tubule. This technique is used in obstructive azoospermia, where obstruction occurs at the level of the epididymis. The earliest forms of vasoepididymostomy described in 1903, involved opening several epididymal tubules and the vas deferens, and hoping the lumena would fistulize. In 1918, Lespinasse attempted the first deliberate anastomosis of the epididymal and vas deferens (Chan et al., 2005). Due to the microscopic size of the vas deferens lumen (300–500 μm) and the epididymal tubule (150–250 μm), success was limited until the introduction of optical magnification for the procedure by Silber (1978). Since, several variations in technique have been trialed. We will discuss the most contemporary and successful techniques in this article.

Diagnosing Epididymal Obstructive Azoospermia

Etiology

Epididymal obstruction may be congenital or acquired. Congenital forms of epididymal obstruction include hypoplasia associated with cystic fibrosis transmembrane regulatory protein (CFTR) and unilateral or bilateral absence of the vas deferens (CBAVD). Acquired causes of epididymal obstruction include: infectious etiologies, that is, epididymitis, scrotal, or pelvic trauma, vasal obstruction with epididymal blowout, or direct epididymal injury (Wosnitzer et al., 2014). The latter two etiologies are often iatrogenic. The most common being hydrocelectomy, spermatocelectomy, inguina hernia repair, vasectomy, percutaneous epididymal sperm aspiration (PESA), microsurgical epididymal sperm aspiration (MESA) (Fuchs and Burt, 2002).

History and Physical Exam

A thorough history and physical examination are crucial for identification and localization of epididymal or vasal obstruction. A focused reproductive history of both the male and their partner is essential. The clinician should determine if this is primary or secondary infertility, and if either partner has contributed to a pregnancy or been surprised in the absence of a pregnancy with unprotected intercourse. Features on history which may suggest epididymal obstruction include: sexually transmitted infection or epididymitis, scrotal surgery, that is, vasectomy and number of years since vasectomy, orchidopexy, spermatocelectomy, hydrocelectomy, previous attempts at epididymal or vasal reconstruction, inguinal surgery, that is, inguinal hernia repair (especially with mesh), varicocelectomy, excision of lipoma. Furthermore, one should enquire about scrotal or pelvic trauma, or additional pelvic surgeries which may compromise the intraabdominal portion of the vas deferens such as radical prostatectomy, or renal transplant.

On physical examination, the clinician should perform a full reproductive exam including degree of virulization, midline defects, abdominal, and genital assessment. Special attention should be drawn to identifying surgical scars to the abdomen, inguinal region, and scrotum. With a warm, relaxed scrotum, testicles should be palpated for size, firmness, and asymmetries. Epididymal fullness or induration is often present with obstructive azoospermia. Cord structures should be assessed for presence of the vas deferens, vasal defects, and sperm granuloma if previous vasectomy, varicocele, spermatocele, lipoma, and inguinal hernia.

Investigations

Among men with two azoospermic semen analyses, obstructive etiology may be identified by history and physical exam. Low volume semen analyses or ejaculates with a pH of <7.2 should lead one to suspect congenital absence of the vas deferens, or in the presence of palpable vasa, partial absence or ejaculatory duct obstruction (EDO) and a transrectal ultrasound should be performed for diagnosis. EDO is discussed at further depth elsewhere in this text.

Investigations beyond the semen analysis serve to determine if the man has active spermatogenesis. Hormone profiles may identify men with low testosterone, which could be due to hypogonadotrophic hypogonadism (low T, FSH, and LH), or hypergonadotrphic hypogonadism (low T, high FSH >7.6 mIU/mL, and LH). Serum FSH and testicular size are important predictors for differentiating OA from NOA; in one study, a FSH of <7.6 mIu/mL and testicular long axis of >4.6 cm predicts OA in 96% of cases (Schoor et al., 2002). Genetic evaluation for the patient with azoospermia and primary infertility includes a karyotype, y-microdeletion, and CFTR gene assessment if one or both vas deferens are nonpalpable, or ejaculatory duct obstruction is suspected. In patients with primary infertility, spermatogenesis must be confirmed prior to reconstruction of the excurrent ductal system. A serum anti-sperm antibody assay may be ordered including IgG, IgA, and IgM to assess for active spermatogenesis. The area under the curve (AUC) for ROC curves were 0.92, 0.85, and 0.67 respectively. This translates to a sensitivity and specificity of 85% and 97% respectively for IgG, while the specificity, positive predictive value and positive likelihood ratio for IgA were 99%, 99%, and 70% respectively (Lee et al., 2009). If there are no antisperm antibodies, or if the FSH is abnormally high >7.6 mIU/ml, then confirmation of

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obstruction is warranted prior to reconstruction. This may be performed in advance of a planned surgical procedure, or, it may be performed at the beginning of a case with intraoperative microscopic inspection of the epididymis. If markedly dilated tubules are seen, obstruction is confirmed. If the epididymal tubules are flat, a testis biopsy is necessary, with intraoperative microscopic examination of the testicular tissue for presence of sperm. In this case, the patient must be counseled and consented for the different potential procedures depending on the findings. For instance, microscopic testicular extraction of sperm is required if there is abnormal sperm production on the diagnostic biopsy, or reconstruction is required if obstruction is confirmed. Men with secondary infertility due to vasectomy, and proven fecundity, do not need additional confirmation of spermatogenesis if physical exam reveals normal testis volume and consistency and a hormone profile reveals normal serum FSH. A positive serum antisperm antibody assay also suffices to confirm obstruction.

Localizing the Obstruction

Once OA is diagnosed, identifying the level of obstruction requires assessment of history, physical exam, and semen analyses as discussed earlier. EDO is suspected with low semen volume, pH <7.2 and absence of fructose in the semen. TRUS should be performed to assess for seminal vesicle dilation and midline cysts. In the absence of EDO, the level of obstruction is limited to the vas deferens or epididymis. Features on history may identify seminal vesicle side vasal obstruction associated with inguinal surgeries such as hernia repairs, or pelvic surgery such as renal transplant or prostatectomy. Definitive determination of the level of obstruction is imperative to ensure optimal result. This must be determined intraoperatively. First, the surgeon should visualize the epididymis for signs of dilated epididymal tubules and a transition of dilated to nondilated tubules. The transition signifies epididymal obstruction is probable. Next, the surgeon performs a vasotomy and samples fluid from the testicular side of the vas. Presence of abundant sperm or sperm parts confirms patency of the epididymis. Next, a vasogram toward the seminal vesicle side and testicular vasal fluid sampling. The vasogram initially consists of injecting normal saline or lactated ringer's solution through a 24-gauge angiocatheter. Lack of resistance and absence of reflux suggest patency. If resistance or reflux is met, the surgeon may place a 2–0 monofilament suture tail in the vasal lumen on the seminal vesicle side to determine where the suspected obstruction is present. This is diagnostic if it stops in the middle of the hernia scar. A formal vasogram with radio-opaque contrast and intraoperative X-ray may be performed if there is uncertainty regarding the location of the distal obstruction. The surgeon must also sample fluid from the testicular lumen to determine if sperm are present at the level of the vasotomy, indicating lack of epididymal obstruction. Visual appearance of the fluid provides insight to the presence of patency or obstruction; however, microscopic analysis is most definitive. Clear copious fluid suggests an unobstructed epididymis, while thick, toothpaste-like fluid, devoid of sperm, is suggestive of obstruction. Creamy yellow fluid may possess sperm parts and suggest epididymal patency. The fluid is then placed on a glass microscope slide and examined under $400\times$ magnification using bright-field microscopy intraoperatively. The presence of sperm or sperm parts indicates epididymal patency. If no sperm or only rare sperm heads are present, the surgeon must sequentially sample fluid from the epididymis in a stepwise fashion, using a 10–0 needle until sperm or abundant sperm parts are identified. In our experience, we sample every 3-5 mm to identify the most distal site of vasal or epididymal patency, since more distal reconstructions portend to better postoperative patency rates.

Managing Epididymal Obstruction

Once epididymal obstruction has been identified, two management options exist: sperm retrieval for assisted reproductive techniques (ART) or reconstruction in the form of vasoepididymostomy (VE). The former may occur percutaneously via percutaneous epididymal sperm aspiration (PESA) or microsurgical epididymal sperm aspiration (MESA), Fig. 1. Here, couples must be counseled and be willing to undergo ART to obtain pregnancy. PESA may be performed under local anesthetic, using a 21–26-gauge needle inserted percutaneously into the epididymis while withdrawing on the syringe and thus, aspirating sperm. A small volume of fluid (~ 0.1 mL) is retrieved, and yields thousands to millions of sperm among 61%–96% of men. MESA requires a general anesthetic. Here, the testis is delivered, and under $20\text{–}25\times$ magnification with use of an operating microscope, the caput of the epididymis is reflected from the testis, exposing the 7–11 efferent ducts; an efferent duct is selected and punctured. A micropipette is then used to collect the epididymal fluid through capillary action. Sperm is successfully retrieved in 96%–100% of cases yielding 15–95 million sperm. Reconstructive options for epididymal obstruction is a viable option for a skilled microsurgeon and consists of a VE.

Cost-Effectiveness

Men with epididymal obstruction have the choice of sperm retrieval and subsequent in vitro fertilization/intracytoplasmic sperm injection (IVF/ICSI) or VE. The latter appears to be more cost-effective with an estimated cost per live delivery, in 1997 dollars, of $31,099 based upon an 85% VE patency rate and 36% live birth rate. Meanwhile, sperm retrieval via MESA and subsequent IVF/ICSI had a cost per live delivery rate of $51,024. This particular study considered both direct and indirect costs to the associated procedures (Kolettis and Thomas, 1997). Several other studies have supported vasal reconstruction for men with previous vasectomies as being more cost effective compared to sperm retrieval and IVF/ICSI; however, these series include vasovasostomies which characteristically have higher patency rates compared to VE's.

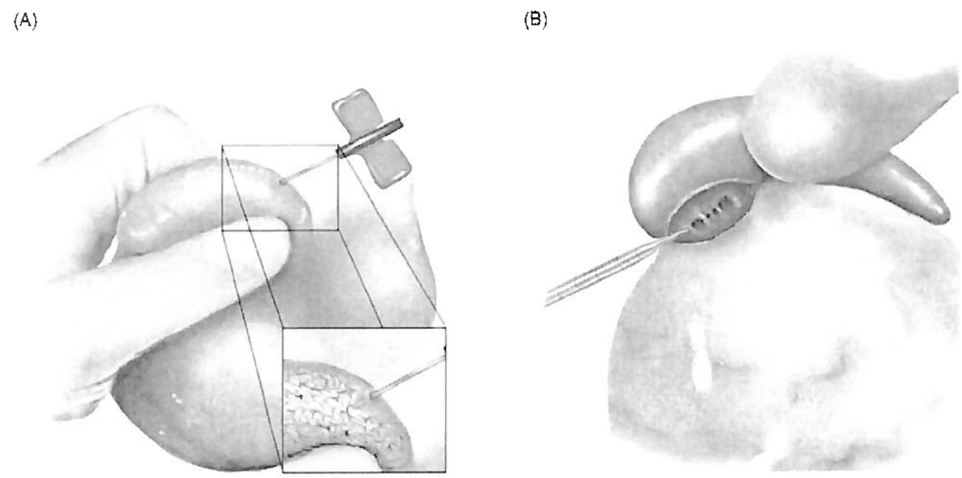


Fig. 1 (A) Percutaneous epididymal sperm aspiration (PESA). Under local anesthetic (skin and cord block), a 21–26 gauge needle is inserted to the epididymis, and epididymal fluid is aspirated for the presence of sperm. (B) Microsurgical epididymal sperm aspiration (MESA). Under general anesthetic, the testis is delivered and the tunica vaginalis is opened exposing the epididymis. The caput of the epididymis is reflected gently by incising the tunica albuginea at the junction of the testis and caput. The efferent ducts are visualized, and one is punctured. A micropipette is used to aspirate the sperm containing fluid by capillary action.

Vaso-Epididymostomy Surgical Principles

Surgical Incision and Mobilization

Vertical hemiscrotal incisions should be made in the mid to upper scrotum, this affords the ability to extend the incision cranially if additional dissection of the abdominal vas deferens if necessary. The testis is delivered with the tunica vaginalis intact. The vas deferens is then identified and separated from the rest of the spermatic cord with a Penrose drain at the site of previous vasectomy or at the junction of the straight and convoluted vas if the patient has not previously undergone vasectomy. The operating microscope is then used to carefully dissect the peri-vasal vessels off of the vasal surface at the site of planned vasotomy.

Identifying the Site of Obstruction

A hemivasotomy is performed and the vasal fluid is assessed visually, and smeared onto a glass slide and examined under 400 × bright-field microscope for the presence of spermatozoa. Table 1 provides an overview of vasal fluid findings and procedure necessary. If thick white toothpaste-like fluid with no sperm is found in the case of a previous vasectomy, then a VE is indicated. Here, the epididymal tubules must be carefully evaluated starting at caudal end of the epididymis. A tubule is then punctured and the fluid is examined under the bright-field microscope. This is repeated moving 2–3 mm proximally until sperm is identified. If the line of demarcation is clearly seen with dilated tubules above and collapses below, one can go straight to set up for a vasoepididymostomy.

Preparing for the Anastomosis

Once a dilated tubule above the obstruction is identified, the site of anastomosis is prepared by excising a 2.5 mm ellipse of tunica overlying the favorable, dilated tubules. The abdominal vas deferens must have adequate length for a tension free anastomosis. The posterior vasal sheath is then sutured to the cranial portion of the tunical window to prevent tension during the anastomosis.

Table 1 Intraoperative testicular end vasal fluid is sampled at the time of vasal reconstruction for OA

Vasal fluid	*Microscopic findings*	*Surgical procedure indicated*
Copious clear fluid	No sperm	Vasovasostomy
Cloudy fluid	Intact sperm	Vasovasostomy
Creamy yellow fluid	Sperm heads	Vasovasostomy
Thick white toothpaste-like fluid	No sperm	Vasoepididymostomy
Dry vas with no granuloma	No sperm	Vasoepididymostomy
Dry vas with granuloma at vasectomy site	Barbotage fluid reveals sperm	Vasovasostomy

The decision to proceed with vasovasostomy compared to vasoepididymostomy is made by examining the appearance of the vasal fluid and the microscopic findings.

Unique Considerations

Obstruction of Both Epididymis and Abdominal Vas Deferens

In this scenario, the vasal fluid from the hemi-vasotomy demonstrates an absence of spermatozoa and injection of normal saline is met with resistance to the abdominal vas deferens. The tail of a 2–0 monofilament suture may be used to cannulate the abdominal vas and locate the site of obstruction; if localization is unclear, a formal vasogram should be performed to determine the site of obstruction. If the obstruction is at the level of the inguinal canal, we recommend sperm retrieval if the couple is willing to undergo IVF/ICSI, closing the hemi-vasotomy, and abandoning the VE. If the hemi-vasotomy is small and vessels preserved, then inguinal vasovasostomy may be considered during the initial procedure with plans for a delayed scrotal VE in 6 months. This period of time will allow the inguinal vasovasostomy site to heal and reconstitute vascularization to the intervening vas deferens. Performing both a scrotal VE and an inguinal VV would result in devascularization of the intervening segment of vas deferens. In a second scenario, with the site of distal obstruction localizing to the ejaculatory ducts, we recommend management of the EDO first, and if successful, subsequent VE.

Crossed Vasoepididymostomy

Men that have a clear asymmetry in testis quality, that is, atrophic or absent unilateral testis, accompanied with a contralateral vasal obstruction, that is, inguinal hernia repair, renal transplant, then a crossed vasal reconstruction may be considered. Here, the better quality testis is confirmed to be obstructed, while the poor quality testis has a patent abdominal end of the vas deferens as confirmed intraoperatively. The optimal procedure to facilitate sperm returning to the ejaculate is to anastomose the testicular end of the vas deferens or epididymis (based upon microscopic analysis of vasal fluid results) of the best quality testis to the patent vas deferens from the side of the atrophic testis. Here, the testicular vas deferens is tunneled through a copious opening in the scrotal septum for a tension free anastomosis; if vasal length for is a concern, the better testis can be transposed to the contralateral side.

Varicocele and Vasoepididymostomy

In the event that a patient presents with both epididymal obstruction and a varicocele, it is recommended to treat the epididymal obstruction first. By correcting the obstruction, the patient has the opportunity to develop sperm in the ejaculate and obtain paternity without requiring a varicocele repair (VR). However, if pregnancy is still not achieved due to presumed implications from the varicocele, we recommend waiting 6 months to perform the VR. We advocate against performing simultaneous VE and VR due to the venous congestion at the site of anastomosis. This congestion is unlikely to aid in healing the delicate anastomosis.

Vasoepididymostomy Surgical Techniques

Several techniques for VE are discussed in this section. End-to-end and end-to-side techniques were among the first described. More contemporary techniques include intussuscepting the epididymal tubule into the vasal lumen using two or three sutures. In a randomized controlled trial using an animal model, Chan and colleagues determined the highest patency rate among the longitudinal intussuscepted vasoepididymostomy (LIVE) two suture technique. Regardless of technique, the microsurgeon must practice strong principles of surgery for optimal results. These include, tension free and water-tight anastomosis, atraumatic tissue handling, precision of needle placement, square knots, a bloodless operating field, and preservation of anatomy while optimizing necessary exposure.

End-to-End Technique

An end-to-end (EE) anastomosis to a specific tubule is the original technique for VE as described by Silber (1978). The epididymis is cut in cross-section starting caudal and moving toward the caput systematically. Bipolar cautery is used to control bleeding vessels, and the epididymal fluid is assessed under a microscope for the presence of sperm. If no sperm is identified, a more proximal section is made. If sperm is found, the epididymis is milked until only one tubule continues to ooze clear fluid, this fluid is sampled once more to ensure sperm is present prior to the anastomosis. The epididymal tubule is then anastomosed to the vasal lumen with four to six, 9–0 or 10–0 sutures placed inside-out on the epididymal tubule to the corresponding location on the vas deferens, Fig. 2. A second, muscular layer anastomosis is performed to achieve a watertight anastomosis.

End-to-Side Technique

Most contemporary techniques beyond the conventional end-to-side (ES) use this approach. However, in the conventional ES technique, no intussusception is performed. Here, an epdidymal tubule with sperm is identified as mentioned in section "Identifying the Site of Obstruction." The selected epididymal tubule is then puncture with a microknife or microscissors and the fluid is tested again to confirm sperm. Methylene blue may be used to differentiate the out and inner surface of the epididymal tubule. Three to six double-armed 10–0 sutures are then place inside-out in the epididymal tubule, then to the corresponding location in an inside-out fashion, Fig. 3. A second anastomotic layer is performed with 9–0 sutures from the muscularis of the vas deferens to the cut tunical edge on the epididymis.

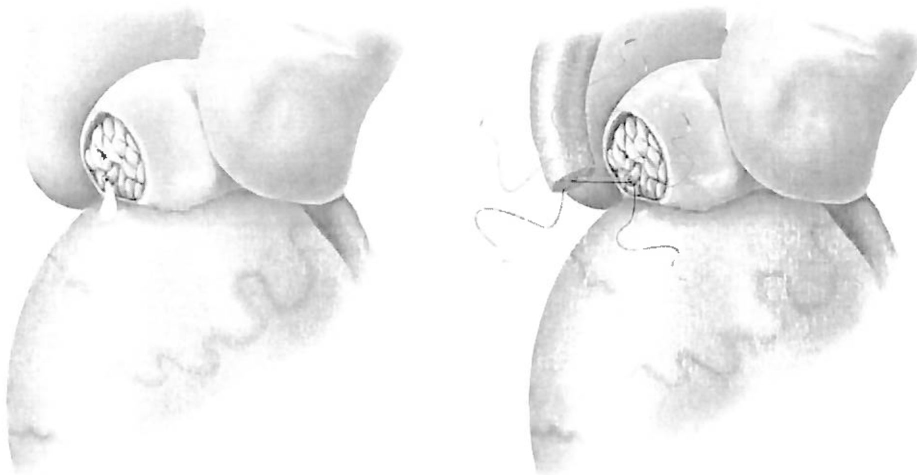


Fig. 2 End-to-end vasoepididymostomy. Here, the epididymal tubule that contains to leak fluid is likely the patent tubule containing sperm. This fluid may be tested under a microscope for presence of sperm. Four to six 9–0 or 10–0 sutures have been used for this anastomosis. A second layer of 9–0 sutures are then placed peripherally.

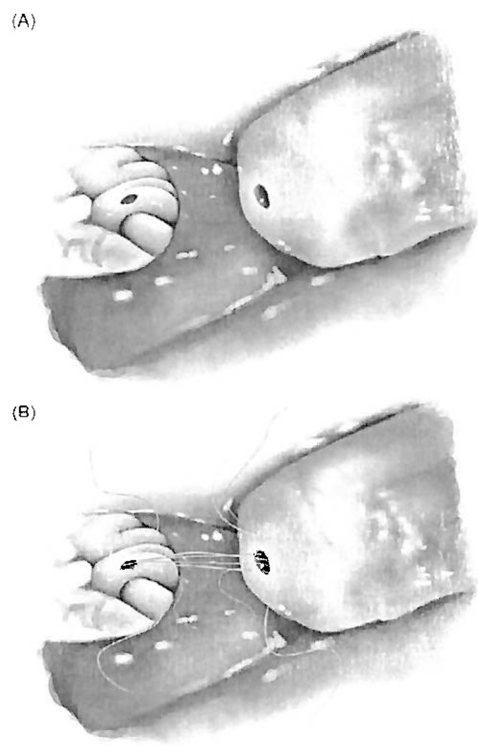
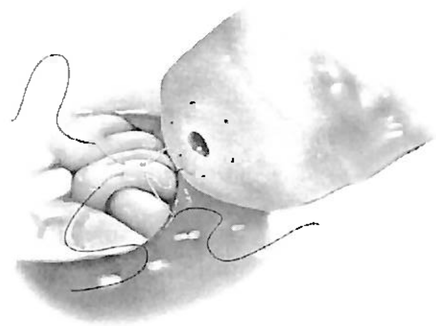


Fig. 3 End-to-side vasoepididymostomy. Here, the epididymal tubule that is dilated and contains sperm is opened with a 15° microknife or microscissors (A). Three to six 9–0 or 10–0 sutures are then used for the lumen anastomosis (B). A second layer of 9–0 sutures are then placed peripherally.

(A)



(B)

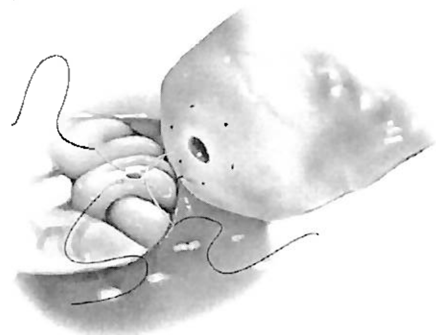


Fig. 4 Intussuscepted three-suture triangulation. Here, the dilated epididymal tubule containing sperm is isolated. Three double-armed 10–0 sutures are placed and partially pulled through the tubule in a triangulating orientation. A 15° microknife is then used to incise the lumen between the sutures. The needles are then pulled through and placed to the corresponding locations of the vas deferens inside to out. Upon tying these sutures, the epididymal tubule is intussuscepted into the vasal lumen. A second layer of 9–0 sutures are then place from the outer edge of the vas deferens to the tunica of the epididymis circumferentially.

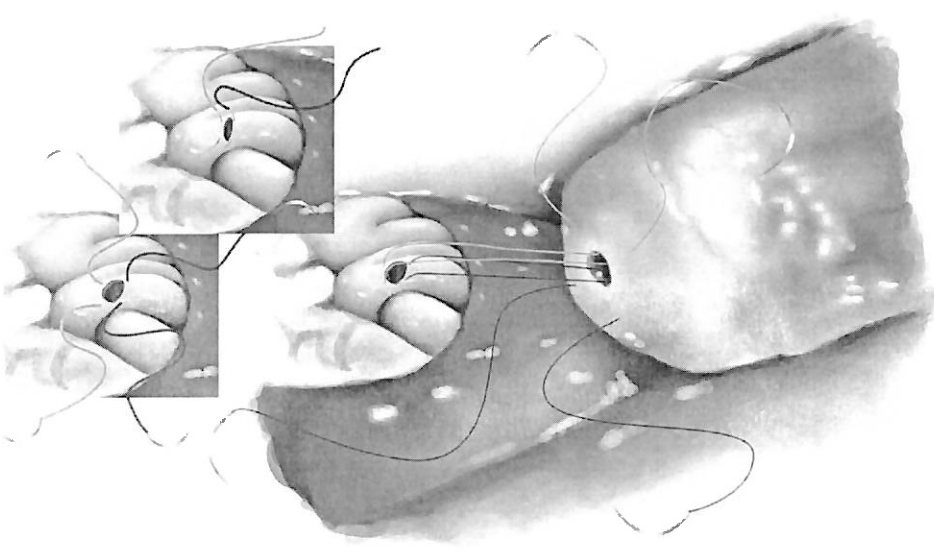


Fig. 5 Intussuscepted two-suture transverse technique. Here, the dilated epididymal tubule containing sperm is isolated. Two double-armed 10–0 sutures are placed and partially pulled through the tubule in a transverse orientation. A 15° microknife is then used to incise the lumen between the sutures. The needles are then pulled through and placed to the corresponding locations of the vas deferens inside to out. A 9–0 suture is then placed opposite to the original approximating 9–0 suture and tied. This opposes the vasal lumen and the epididymal opening, allowing for avoidance of tension to the epididymal anastomosis. Upon tying these sutures, the epididymal tubule is intussuscepted into the vasal lumen. A second layer of 9–0 sutures are then place from the outer edge of the vas deferens to the tunica of the epididymis circumferentially.

Intussuscepted Three-Suture Triangulation Technique

The intussuscepted three-suture technique was the first technique to utilize intussusception and was first described by Berger (1998). This technique uses the same approach to isolate the epididymal tubule of choice as the above ES technique. This anastomosis however, differs from the conventional ES technique. Here, three double-armed 10–0 suture needles are placed partially through the epididymal tubule in a triangular fashion, prior to incising the tubule. Since the needles are larger diameter than the suture connected to the needle, leaving the needle in the tubule allows the tubule to maintain fullness for more precise placement of the 2nd and 3rd sutures, Fig. 4. Following placement of all three sutures, the tubule is incised with a 15° microknife, and the sutures are then placed inside-out to the vasal lumen, intussuscepting the opening of the tubule into the vasal lumen. The sutures are gentle placed on traction until the tail of the suture begins to move, and are then tied. A second layer of 9–0 sutures are placed from the muscularis of the vas deferens to the tunical edge for a watertight closure.

Intussuscepted Two-Suture Transverse Technique

Marmar first described the two-suture transverse intussusception technique (Marmar, 2000). This technique involves the same preparation as the three-suture intussusception technique; however, two doubled-armed 10–0 sutures are placed perpendicular to the length of the epididymal tubule, and kept only partially drawn through, Fig. 5. A 15° microknife is then used to make a transverse incision between the two needles. The ends of the 10–0 sutures are then placed inside out to the corresponding locations in the vas

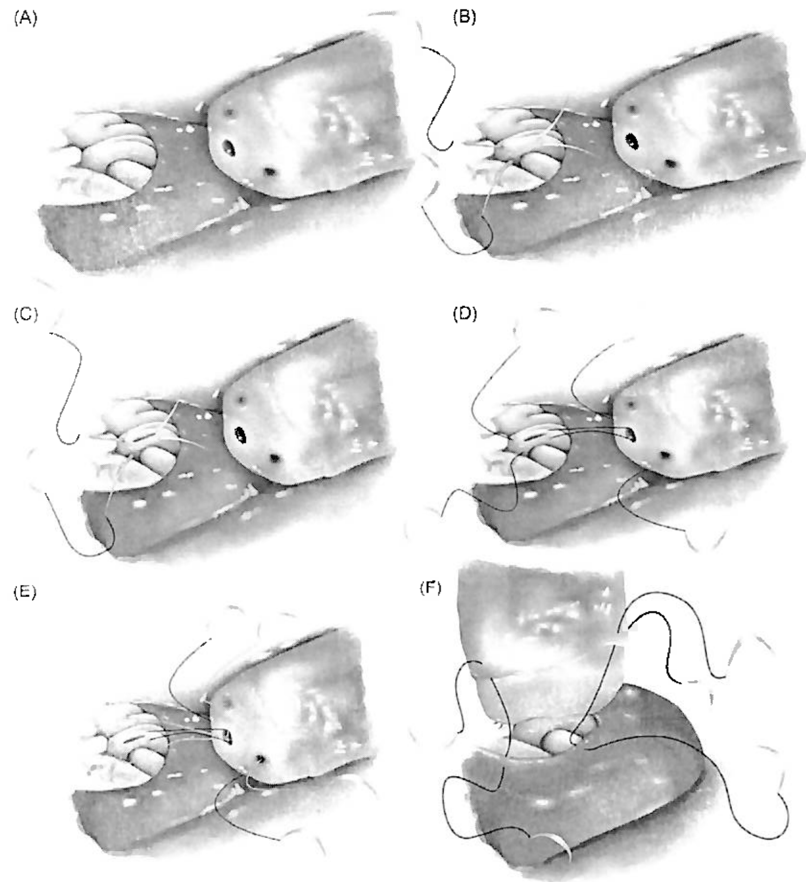


Fig. 6 Longitudinal intussuscepted vasoepididymostomy (LIVE). Here, the dilated epididymal tubule containing sperm is isolated. A 9–0 suture is placed on the posterior side of the vas deferens and tied to the corresponding side of the epdidymal tunica to bring the vas in close approximation and avoid any tension. Four microdots are placed at the junction of the mucosa to muscularis of the vas deferens to plan the vasal stitches. Two double-armed 10–0 sutures are placed and partially pulled through the tubule in a longitudinal orientation. A 15° microknife is then used to incise the lumen between the sutures. The needles are then pulled through and placed to the corresponding locations of the vas deferens inside to out. A 9–0 suture is then placed opposite to the original approximating 9–0 suture and tied. This opposes the vasal lumen and the epididymal opening, allowing for avoidance of tension to the epididymal anastomosis. Upon tying these sutures, the epididymal tubule is intussuscepted into the vasal lumen. A second layer of 9–0 sutures are then place from the outer edge of the vas deferens to the tunica of the epididymis circumferentially.

Fig. 7 Single arm suture longitudinal intussuscepted vasoepididymostomy (LIVE). Here, the dilated epididymal tubule containing sperm is isolated. A 9–0 suture is placed on the posterior side of the vas deferens and tied to the corresponding side of the epdidymal tunica to bring the vas in close approximation and avoid any tension. Four microdots are placed at the junction of the mucosa to muscularis of the vas deferens to plan the vasal stitches. Two single arm sutures are placed outside-in from the microdots out through the lumen. The needles are then placed in a direction back toward the vas deferens in the epididymal tubule in a longitudinal fashion and partially pulled through the tubule. A 15° microknife is then used to incise the lumen between the sutures. The needles are then pulled through and placed to the corresponding locations of the vas deferens inside to out. A 9–0 suture is then placed opposite to the original approximating 9–0 suture and tied. This opposes the vasal lumen and the epididymal opening, allowing for avoidance of tension to the epididymal anastomosis. Upon tying these sutures, the epididymal tubule is intussuscepted into the vasal lumen. A second layer of 9–0 sutures are then place from the outer edge of the vas deferens to the tunica of the epididymis circumferentially.

deferens. A second layer of interrupted 9–0 sutures are placed from the muscularis of the vas deferens to the tunical edge as with the three suture technique.

Intussuscepted Two-Suture Longitudinal Technique

Preferred technique, Chan, Li, and Goldstein described the double-armed longitudinal intussuscepted vasoepididymostomy (LIVE) technique and is the authors preferred technique (Chan et al., 2003). It involves the same preparation as the above two and three suture techniques. At our institution, we emphasize the importance of a consistent setup. Using a microtip surgical marker, we place four microdots at the transition of mucosa to muscularis of the vas deferens to separate planning form execution of needle placement. In the LIVE technique, use of double-armed and single-armed sutures has been described. In the standard double-arm technique, two double-armed 10–0 sutures are placed longitudinally in the epididymal tubule, but not pulled through (Fig. 6). The needle is 70 μm in diameter, but the suture is only 17 μm, so if the needles are pulled through before both are placed, and the tubules incised, sperm will leak from the suture holes and the tubule will collapse, obviating a major benefit of the intussusception technique. A longitudinal incision between the sutures is then made with a 15-blade microknife and the suture ends are carefully pulled through the epididymal tubule and placed in the respective positions in the vas deferens inside-to-out through the microdots. However, in the single-arm technique, the 10–0 suture must first be place outside-to-in, through the microdot, and out of the lumen, Fig. 6. The needles are then placed longitudinally in the epididymal tubule, and partially withdrawn. The tubule is opened as in the double-arm technique, then the single arm sutures are placed to the corresponding locations on the vas deferens inside-to-out. The single arm technique may be used where double-armed sutures are not available, Fig. 7. Prior to tying the 10–0 sutures, one end is pulled until the other end begins to move; at this point, it may be assumed that the slack has been removed and an appropriately intussuscepted anastomosis has been created. The second layer of 9–0's are then placed in an interrupted fashion as above to prevent leakage and subsequent sperm granuloma which may cause a late failure. We prefer the LIVE technique to the two-suture transverse technique since there is less risk of inadvertently transecting the epididymal tubule. Furthermore, Chan et al. performed a randomized trial in an animal model that demonstrated best patency rate among the LIVE technique (Chan et al., 2003).

Outcomes and Complications

For the LIVE technique, patency results have varied (48%–84%), but the highest reported rate was 84% at Weill Cornell, with a paternity rate of 40%, 31% of which required in vitro fertilization or intracytoplasmic sperm injection using fresh ejaculated sperm (Chan et al., 2005). Semen analyses may be ordered at 1 month postoperatively then every 3 months thereafter. Up to 60% of men will have sperm return to the ejaculate within 1-month post operatively. Mean sperm counts following LIVE are 12.8 (0.01–80) million with 21% motility (0%–30%) (Chan et al., 2005). Patients may develop a late failure where motile sperm was initially present, and they later become azoospermic. This has been estimated to occur at a rate of 8%–30% (Schiff et al., 2005). Thus, it is important to consider cryopreservation of ejaculated motile sperm postoperatively at first presentation in the event of an unfortunate late failure. Other potential complications include: scrotal hematoma, failure of anastomosis, wound infection, epididymorchitis, orchalgia or more rarely testicular atrophy or fibrosis of the epididymis. These complications are not common but should always be discussed with the patient prior to surgery at the time of informed consent. Diligent surgical technique can mitigate many of these complications, and never hesitate to place a Penrose for 24–48 h to prevent scrotal hematoma. Other important considerations are to maintain patient body temperature throughout the case and ensure the patient is well padded and positioned to avoid a position injury. These may occur with the arms outstretched for a long period of time, as such anesthesia should massage the arms and shoulders or safely reposition the arms between sides for a short break during the case.

Summary

Vasoepididymostomy is both cost effective compared to immediate in vitro fertilization and an effective surgical procedure to relieve epididymal obstruction in men wishing to achieve paternity. The LIVE technique has been well adopted internationally, with success using both single and double-armed sutures. A high regard for surgical principles are necessary for optimal results when performing vasoepididymostomies.

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THE IMPACT OF OBSTRUCTIVE INTERVAL AND SPERM GRANULOMA ON OUTCOME OF VASECTOMY REVERSAL

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ABSTRACT

Purpose: We studied the impact of the interval from vasectomy to reversal and presence of sperm granuloma on outcomes of reversal.

Materials and Methods: A total of 213 microsurgical vasectomy reversals performed by a single surgeon were stratified according to obstructive intervals of less than 5 years, 5 to 10 years, 10 to 15 years and greater than 15 years. The effects of obstructive interval on patency and pregnancy rates were assessed using multivariate logistical regression. The impact of sperm granuloma on patency and pregnancy was assessed using the chi-square test.

Results: Patency did not change with increasing obstructive intervals as can be seen with 91% patency at less than 5 years, 88% at 5 to 10 years, 91% at 10 to 15 and 89% at greater than 15 years. There was no difference in pregnancy rates (89%, 82% or 86%) at obstructive intervals of 0 to 5, 5 to 10 or 10 to 15 years, respectively. Pregnancy rates were significantly lower (44%, $p < 0.05$) with obstructive intervals greater than 15 years. Men with at least unilateral sperm granuloma had patency of 95% vs 78% without granulomas, a trend which did not quite reach statistical significance ($p = 0.07$). There was no difference in pregnancy rates with or without granulomas.

Conclusions: Vasectomy reversal patency rates are high regardless of time since vasectomy. Pregnancy rates are lower more than 15 years after vasectomy. Sperm granuloma had a favorable impact on patency. Our data indicate that for obstructive intervals less than 15 years vasectomy reversal yields much higher pregnancy rates than in vitro fertilization and intracytoplasmic sperm injection, and that even for intervals greater than 15 years reversal outcomes equal or exceed those of in vitro fertilization and intracytoplasmic sperm injection.

KEY WORDS: vasectomy, vavovavostomy, pregnancy rate, granuloma

The number of vasectomies performed each year in the United States is about 500,000, and it is estimated that between 2% and 6% of these men will ultimately seek reversal.[1] With the advent of in vitro fertilization and intracytoplasmic sperm injection (IVF/ICSI), which currently results in clinical pregnancy rates of 20% to 45% per initiated cycle,[2] the therapeutic options for couples with male factor infertility have increased. Thus, to provide couples with information to make decisions regarding infertility treatment, particularly in an era of increased cost consciousness, the need exists to establish the success rate of vasectomy reversals as well as to determine potential preoperative predictors for reversal success.

One parameter which has been evaluated for its impact on post-reversal pregnancy rates is the obstructive interval, defined as the length of time from vasectomy to reversal. Although previous studies have agreed that the obstructive interval is inversely related to reversal success, there has been considerable controversy regarding the specific impact of interval on postoperative outcome.[3–5]

A second potential predictor of outcome after vasectomy reversal is the presence of a sperm granuloma at the vasectomy site. The presence of sperm granuloma is associated with better quality intraoperative vasal fluid but has not been consistently associated with improved postoperative patency or pregnancy rates.[4–6] We studied the impact of the obstructive interval and the presence of sperm granuloma on the outcome of vasectomy reversal on a series of reversals performed by a single surgeon in a tertiary care university setting.

MATERIALS AND METHODS

Patients. We retrospectively reviewed randomly selected vasectomy reversals performed by a single surgeon from 1984 through 2001. Demographic data, patient history and followup were obtained from chart review. Enrollment criteria for the study included first time vasectomy reversals, whereas men who presented for repeat reconstruction were excluded. Only men undergoing bilateral reconstruction were considered. Female factor infertility was excluded from study in all cases. Beginning in alphabetical order from the reversal chart rack, the first 213 couples who met these criteria were selected for study.

Groups. Patients were stratified by obstructive interval (defined as the time from vasectomy to reversal, rounded off to the nearest complete year) into those less than 5 years, 5 to 10 years, 10 to 15 years and greater than 15 years. The presence or absence of a sperm granuloma at the vasectomy site was determined by preoperative physical examination and confirmed by histological evaluation of the surgical specimen.

Surgery. Vasovasostomy (VV) and vasoepididymostomy (VE) were performed using a multilayer microsurgical approach previously described.[1] The entire vasectomy site including sperm granuloma, if present, was always excised. Suspected sperm granuloma were sent for histological evaluation by a surgical pathologist.

Postoperative evaluation. Postoperative evaluation included serial semen analyses beginning at 6 weeks and con-

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tinuing until a pregnancy was achieved or patients were lost to followup. For those men whose partner has yet to conceive, the minimum followup was 6 months. Only naturally conceived pregnancies were included in the calculations, and none of the female partners used assisted reproduction techniques to achieve pregnancy. Only clinical pregnancies with documented heartbeats were included in the study. Pregnancy rates were calculated for the cohort of patients within each obstructive interval. We defined patency as the presence of any sperm (motile or nonmotile) with tails in the ejaculate.

Statistical analysis. The effect of obstructive interval on vasal patency and postoperative pregnancy rates was assessed using multivariate logistical regression. The impact of sperm granuloma on patency and pregnancy was assessed using the chi-square test. Statistical analysis was performed using SAS 8.2 software (SAS Institute, Inc., Cary, North Carolina).

RESULTS

The characteristics of the patient population according to obstructive interval are shown in table 1. Neither the mean age of the men nor of the female partners differed among the intervals. There was no significant difference in the type of reconstruction performed within the groups; that is, the percentage of men in each interval who underwent at least a unilateral VE was equivalent.

Patency and pregnancy rates were determined according to obstructive interval (table 2). Vasal patency did not change with increasing obstructive interval: 91% at less than 5 years, 88% at 5 to 10 years, 91% at 10 to 15 years and 89% for more than 15 yrs. There was also no difference in pregnancy rate at obstructive intervals of 0 to 5, 5 to 10 or 10 to 15 years. However, pregnancy rates were significantly lower (44%, $p < 0.05$) for patients with obstructive intervals greater than 15 years. The pregnancy rate for the entire cohort was 81%. Mean followup was 25 months.

A total of 54 patients (25% of total population studied) underwent at least a unilateral VE during reconstruction, and 18 patients underwent VV/VE, while 36 patients underwent a bilateral VE. Patients who underwent bilateral VV had a significantly higher patency rate (95%) than patients who had unilateral VV and VE (83%) and patients who had bilateral VE (83%, $p < 0.05$), as shown in table 3. However, pregnancy rates did not differ significantly among the procedures performed.

A total of 28% (76) patients had evidence of at least a unilateral sperm granuloma on physical examination before treatment (all of which were subsequently confirmed histologically). Of these 76 men, 65 underwent a bilateral VV, while 5 had a VV/VE and 6 men a bilateral VE. After reversal patients with a palpable sperm granuloma had a patency of 95% vs 78% for patients without a sperm granuloma, a trend which did not quite reach statistical significance ($p = 0.07$). There was no significant difference in pregnancy rates with or without sperm granuloma (83% vs 78%).

DISCUSSION

The patency rate after vasectomy did not significantly change with increasing obstructive interval even at intervals greater than 15 years. This finding conflicts with previous vasectomy reversal studies which consistently reported an inverse relationship between patency and obstructive interval.[3–5] These results may reflect our policy of routinely performing VE in the face of intravasal azoospermia (except when copious clear fluid is present) as well as the use of newer VE techniques with higher reported patency rates.[1,7–11]

The difference in patency rates between the VV and VE procedures is similar to that reported previously from our institution.[12,13] In the present study the frequency of VE procedures was similar (approximately 25%) among obstructive intervals, thus our outcomes cannot be attributed solely to differences inherent in the reconstructive approach.

The pregnancy rate after vasectomy reversal at our institution remained constant (at 82% to 89%) for obstructive intervals less than 15 years. This absence of an inverse relation between pregnancy rate and obstructive interval up to 15 years, as well as the high pregnancy rate during the interval, differs from prior reversal studies.[3–5] Pregnancy rates were significantly lower (44%) in our series for patients with obstructive intervals greater than 15 years, which concurs with results from previous studies.[3–5]

A discrepancy between patency and pregnancy rates after reconstruction was noted across all obstructed intervals in our series. This disparity widened with increasing interval, from 2% for obstructed intervals less than 5 years to 45% for intervals greater than 15 years. The difference between patency and pregnancy rates which has been noted in previous studies may be the result of female factors, antisperm antibodies,[14] a time dependent post-vasectomy germ cell damage[15,16] or post-vasectomy epididymal dysfunction.

The frequency of palpable sperm granulomas in our series (28%) was in accord with prior reports.[17] Previous studies have demonstrated an association between the presence of sperm granuloma and the intraoperative finding of better quality vasal fluid.[6,17] This beneficial effect of sperm granuloma is thought to be due to a "pop off valve," pressure releasing effect of the granuloma on the proximal duct system.[18] That is, the increase in intratubular pressure which occurs after vasectomy may induce rupture of the epididymis and subsequent epididymal obstruction.[19,20] Formation of a granuloma at the vasectomy site, reflecting leakage of sperm and a subsequent decrease of intratubular pressure, may thus prevent epididymal obstruction. This potential protection of the epididymis may be reflected by our experience in that the subset of patients with a sperm granuloma had a lower incidence of unilateral or bilateral VE (11 of 76 or 14%) than patients without a sperm granuloma (43 of 137 or 31%).

In spite of the presumed benefit of sperm granuloma, previous studies have failed to demonstrate an improvement in patency or pregnancy rates in the presence of a granuloma.[4,5] Likewise, although our study demonstrated a trend toward increased patency associated with sperm granuloma, this

TABLE 1. *Patient characteristics by obstructive interval*

Obstructive Interval (yrs)	No. Pts	Mean Age		% Pts With 1 or More VE
		Males	Female Partners	
Less than 5	45	39	34	18
5–10	85	41	33	29
10–15	56	44	32	25
Greater than 15	27	49	34	26

TABLE 2. *Impact of obstructive interval on postoperative outcomes*

Obstructed Interval (yrs)	No. Pts	No. With Vasal Patency (%)	No. Clinical Pregnancies (%)
Less than 5	45	41 (91)	40 (89)
5–10	85	75 (88)	70 (82)
10–15	56	51 (91)	48 (86)
Greater than 15	27	24 (89)	12 (44)

TABLE 3. *Outcome according to procedure performed*

Reconstruction Type	No. Performed	No. Vasal Patency Rate (%)	No. Pregnancies Achieved (%)
VV/VV	159	151 (95)	132 (83)
VV/VE	18	15 (83)	13 (72)
VE/VE	36	30 (83)	29 (81)

association did not reach statistical significance ($p = 0.07$). Moreover, there was no difference in pregnancy rates with or without sperm granuloma.

CONCLUSIONS

The results of our study may be useful in counseling patients seeking post-vasectomy fertility. The information here concerning the chance for successful vasectomy reversal is particularly relevant when considering the current alternative to reversal, IVF/ICSI, using aspirated sperm. Our data indicate that for obstructive intervals less than 15 years vasectomy reversal yields much higher pregnancy rates than IVF/ICSI, and that even for intervals greater than 15 years reversal outcomes equal or exceed those of IVF/ICSI. Reversal is a more cost-effective option regardless of the interval since vasectomy, especially for couples seeking more than 1 child post-vasectomy.

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Reassessing Reconstruction in the Management of Obstructive Azoospermia: Reconstruction or Sperm Acquisition?

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Infertility currently affects approximately 15% of all couples, with an increase anticipated over the next 20 years [1,2]. Approximately 50% of cases of infertility may be attributed to male factors. Male reproductive medicine has undergone significant changes in recent years, and the advent of assisted reproductive technology (ART) has substantially improved our ability to successfully manage male factor infertility. Specifically, improved techniques in microsurgical reconstruction and refinement in techniques for sperm retrieval combined with in vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI) have materially altered our ability to treat obstructive azoospermia.

Selecting the optimal therapy for couples with obstructive azoospermia can be challenging. In this article, we limit our discussion to patients with reconstructable obstruction, such as the common situation of men desiring fertility after vasectomy. Sperm retrieval with IVF/ICSI offers the allure of early achievement of a relatively high live delivery rate, although its use consigns the female partner to the greater costs and complications of an IVF cycle and potential health problems in the resulting offspring. In contrast, surgical reconstruction does not require treatment of the female partner, and pregnancy usually occurs naturally after sexual intercourse. However, reconstruction may not always be successful, and the time to achieve a pregnancy is longer, especially in patients who have endured long durations of obstruction. We examine the various therapeutic options available for surgical reconstruction and sperm retrieval, specifically their rates of success and attendant costs in an effort to define the optimal treatment for couples with obstructive azoospermia.

Methods of surgical reconstruction

Vasovasostomy

The first-line method for surgical reconstruction of obstructive azoospermia secondary to vasectomy consists of vasovasostomy, in which the obstructed length of vas deferens is excised and the cut ends are reanastomosed [3,4]. Microsurgical reconstruction seems to be superior to macrosurgical reconstruction and currently represents the standard of care. Variations of the microsurgical technique exist, including multilayer vasovasostomy versus a modified single-layer adaptation.

Vasoepididymostomy

Some patients with obstructive azoospermia require a vasoepididymostomy instead of

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a vasovasostomy if their epididymis is found to be obstructed. Vasoepididymostomy consists of anastomosing a patent epididymal tubule directly to the vas deferens, thus bypassing any obstruction in the epididymis distal to the tubule. Multiple techniques have been described, although three variations are currently used: direct end-to-end, direct end-to-side, and end-to-side intussusception [5]. Epididymal obstruction and the need for vasoepididymostomy seem to be related to the duration of deferential obstruction [6–8]. Fuchs and Burt [6], for example, reported that 62% of patients who had undergone vasectomy at least 15 years before reversal required vasoepididymostomy. Significantly lower patency and pregnancy rates have been reported after vasoepididymostomy compared with vasovasosotomy [5].

Methods of sperm acquisition

One should note that all methods of sperm acquisition consign the female partner to IVF/ICSI for successful fertilization and delivery.

Microsurgical epididymal sperm aspiration

Microsurgical epididymal sperm aspiration (MESA) was introduced in the 1980s by Temple-Smith and colleagues and Silber and colleagues [9,10] originally to enable sperm retrieval in the setting of congenital bilateral absence of the vas deferens. It consists of microsurgically exposing the epididymis, incising the epididymal tunic, and then aspirating sperm-filled epididymal fluid. MESA enables the collection of large quantities of motile sperm for cryopreservation.

Percutaneous epididymal sperm aspiration

Percutaneous epididymal sperm aspiration (PESA) was introduced in 1994 by Craft and Shrivastav [11,12] as a simpler, less invasive alternative to MESA for patients with obstructive azoospermia who were unable to undergo or who decided against surgical reconstruction. A needle is introduced through the skin into the epididymis and is then aspirated. Three pregnancies (43%) were obtained in seven couples, and one set of twins was delivered in the original description [12]. Criticisms of this technique include frequently unreliable sperm retrieval [5]. Our data analysis focuses on the more reliable microsurgical approach.

Some surgeons prefer MESA or PESA as the source of sperm in obstructive azoospermia, because epididymal sperm tend to be more mature and are obtainable in higher, bankable numbers relative to that obtained from the testis [13]. In 1998, Sheynkin and colleagues [14] compared percutaneous and microsurgical sperm retrieval in men with obstructive azoospermia. Nine men underwent simultaneous MESA, testicular fine needle aspiration, and PercBiopsy. As expected, the mean number of sperm retrieved via MESA (15×10^6) was higher than that retrieved percutaneously (testicular fine needle aspiration = 0.014×10^6 and PercBiopsy = 0.116×10^6). Overall, testicular sperm aspiration pregnancy rates have been reported to be as high as 31%, with a calculated live delivery rate of 27% if one assumes a miscarriage rate of 11.6% rate after ICSI [15,16]. Similarly, PESA pregnancy rates have been reported to be as high as 43%, with a calculated live delivery rate of 38% if one makes a similar assumption regarding ICSI miscarriage rate [12,16,17].

Open testis biopsy

The original description of sperm retrieval for assisted reproduction by open testicular biopsy was proposed by Silber and colleagues [18] in 1995. Multiple pieces of testicular tissue from the same incision are taken for use in IVF/ICSI.

Microsurgical testicular sperm extraction

Microsurgical testicular sperm extraction (TESE), as described by Schlegel and colleagues [19] in 1999, uses the operating microscope to identify larger caliber, sperm-containing seminiferous tubules. Microsurgical TESE is traditionally used in the setting of nonobstructive azoospermia and offers the advantages of less bleeding and greater sperm extraction per gram of testicular tissue extracted. It plays little role in the setting of obstructive azoospermia.

Percutaneous testicular sperm extraction

Like PESA, percutaneous TESE offers a less costly and invasive alternative to its microsurgical counterpart. A needle is introduced percutaneously into the testis and is then aspirated; the tissue obtained is then processed for use in IVF. Percutaneous TESE also represents a less invasive choice compared with open testis biopsy, although less tissue is generally obtained with the percutaneous technique. Belker and colleagues [15] described a 100% sperm retrieval rate when used in obstructed patients. Fine-needle mapping as described by Turek and colleagues [20] is designed for use in nonobstructive azoospermia and plays little role in this particular analysis.

Outcome metrics

This article focuses on three main metrics to assess outcomes: (1) cost, (2) effectiveness, and (3) various analytic methods to combine the information embodied in cost and effectiveness data.

Costs

Costs may be broken down into two main components: direct and indirect [21–23]. Direct costs encompass expenditures for medical products or services, including office examination fees, surgeon fees for microsurgical reconstruction or sperm retrieval, associated anesthesia and operating room or facility fees, recovery room fees, the cost of diagnostic imaging tests, the cost of blood tests, the cost of gonadotropins if IVF/ICSI is used, and finally the cost of the IVF cycle, including all technical and professional fees if sperm retrieval is chosen. Indirect costs represent the economic impact that occurs from morbidity, mortality, or loss of livelihood secondary to a procedure. In this analysis, indirect costs would represent the economic impact of procedure-associated complications, lost productivity because of time away from work, and the impact from multiple gestation pregnancies that may ensue.

This analysis uses complication and multiple gestation rate data that have appeared in the peer-reviewed literature. Male infertility procedure-related complications include bleeding, infection, and testicular atrophy and occur at a rate of 0.3% to 2% [5,24,25]. Maternal complications caused by IVF are estimated to occur in 3% to 6% of all cases and include ovarian hyperstimulation syndrome, pelvic hemorrhage, infection, stroke, myocardial infarction, and possibly ovarian cancer [26–29]. The impact of multiple gestation pregnancies has been well studied. Such pregnancies are associated with higher rates of neonatal complications and longer intensive care unit stays compared with singleton infants [27,30]. Much of the increase in costs associated with higher order gestations can be traced to greater neonatal lengths of stay in addition to greater direct use of medical resources.

It is important to note that the true cost of care is best represented by the amount resources consumed in providing that care. Because the true economic burden of providing services is usually difficult to measure, charges are instead used as a proxy [31]. Charges are set by the marketplace and may not accurately reflect the true burden of providing care, although they do represent the best available metric for cost-effectiveness evaluations.

Effectiveness

Multiple definitions of success are possible when treating obstructive azoospermia. Patency, as signified by the return of sperm to the ejaculate, may be used as one measure of success with surgical reconstruction. Successful fertilization and pregnancy after reconstruction or sperm retrieval may constitute a separate metric. Finally, delivery of at least one or more live children after either treatment may represent yet another measure of success. It is the opinion of the authors that live delivery represents the most relevant and appropriate metric to consider: the outcome of most value to couples is the delivery of at least one live child. All other markers of success are of secondary value.

Analysis and evaluation methods

Economic analyses weave the dual components of cost and effectiveness into a rational framework for decision making. Because choices must be made between alternative uses of scarce or limited health care resources, economic analyses are able to consider cost and outcome to arrive at an optimal allocation decision [21–23]. Different types of economic analyses include cost-identification analysis, cost-effectiveness analysis, and cost-benefit analysis [31,32].

Cost-identification analysis consists of ascertaining the economic resources involved in providing a product or service or that involved in disease burden. Cost-identification studies do not consider the benefits derived from the expenditure of economic resources. In contrast, cost-effectiveness analysis considers the cost of providing a service in addition to the benefit or outcome that arises from that service; the metric given in this type of analysis usually refers to cost per unit of outcome. This evaluation allows a comparison of the relative value of different treatment approaches. Cost-benefit analyses attempt to determine if a given outcome is worth its requisite cost to an individual. Clinical outcomes are translated into monetary terms via willingness-to-pay approaches and the outcomes compared with the benefits on a direct monetary basis.

Like most infertility-related peer-reviewed literature, this article focuses primarily on cost-effectiveness analysis as a method of identifying optimal treatment for obstructive azoospermia. First, the effectiveness and then more importantly the cost effectiveness of IVF treatments in general are examined because they constitute a major component of treatment by sperm retrieval. The analysis then focuses on examining male factor infertility treatments for obstructive azoospermia in similar fashion.

In vitro fertilization studies

Effectiveness of in vitro fertilization for male factor infertility

The most complete set of data regarding the effectiveness of IVF for male factor infertility is found within the Society of Assisted Reproductive Technology (SART) database, published by the Centers for Disease Control and Prevention under the 1992 Fertility Clinic Success Rate and Certification Act [33]. A summary of SART data from 1995, the first available year, to 2004, the latest available year, is shown in Table 1. Although the number of total IVF cycles has risen from approximately 46,000 to 89,500 cycles over the intervening years, the percentage of cycles undertaken for male factor infertility alone has declined from a peak of 32% to the current level of 17%. Similarly, the percentage of total ICSI cases used for male infertility cases has declined from 57.8% in 2001 to 51.4% in 2004. The live delivery rate for male factor infertility IVF cases in contrast has improved from 21% to 33% over the same time period.

One should note that although the SART summary data offer an impression of the effectiveness of IVF-driven treatments for male factor infertility, they do not offer fine enough resolution to distinguish IVF treatments undertaken for obstructive versus nonobstructive azoospermia cases. SART data reflect a mixture of the two. Theoretically, however, IVF treatments undertaken solely for obstructive azoospermia should be even more effective than the outcomes reported by SART, as the nonobstructive azoospermia cases reported by SART would be expected to generally yield lower live delivery rates compared with their obstructive counterparts.

Cost effectiveness

Neumann and colleagues [27] were the first to study the cost of a successful live delivery with an IVF pregnancy. Direct and indirect costs were considered in this analysis. The cost per live delivery ranged from $66,667 in 1992 dollars with one cycle of IVF to $114,286 by the sixth cycle in the study. A subgroup analysis that examined couples with advanced maternal age (ie, $>$ 40 years) and male-factor subfertility (ie, sperm concentration $<$ 20 million/mL or motility

Table 1
Summary SART statistics for 1995 to 2004 for couples undergoing assisted reproductive technology treatment

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total cycles (fresh embryo, nondonor eggs)	45,906	49,584	55,002	61,650	63,303	71,556	77,102	81,888	86,753	89,533
% cycles for male factor infertility by diagnosis	32.0	23.0	16.0	24.0	18.0	17.0	17.0	17.0	17.0	17.0
Pregnancies per cycle (%)	29.7	27.5	29.4	30.5	31.6	31.8	34.0	35.5	35.7	35.2
Live deliveries per cycle (%)	25.3	22.6	24.0	24.9	26.1	26.5	28.1	29.5	29.5	28.9
Live delivery rate for male factor infertility (%)	21.0	24.3	25.5	27.1	28.9	29.3	32.0	33.6	33.8	33.3
Multiple gestation live births										
single (%)	63.0	52.0	50.1	62.0	63.4	65.0	64.2	64.6	65.8	67.5
twin (%)	31.1	39.3	41.4	32.0	31.7	30.7	32.0	31.6	31.0	29.9
triplet or more (%)	5.9	8.7	8.5	6.0	4.9	4.3	3.8	3.8	3.2	2.6

< 40%) was conducted. The cost per live delivery increased to $160,000 for the first cycle to $800,000 by the sixth cycle.

Since the study conducted by Neumann and colleagues, various other groups have examined the costs of IVF. Chambers and colleagues [34] performed a population-based costing study of resources consumed during ART in Australia using a decision analytic model that drew upon data from the Australian and New Zealand Assisted Reproduction Database. Direct costs were queried from various fertility centers and rebates through the Medicare or Pharmaceutical Benefit Scheme. The cost per live delivery was calculated to be $32,903 in 2005 Australian dollars, although this cost increased to $182,794 for women older than 42 years. The most complete survey of IVF costs was perhaps undertaken in a review by Collins [35] in 2002. The use of IVF was studied in 48 countries, where direct and some indirect costs were considered. The mean cost per live delivery in the United States was estimated to be $58,394 in 2002 dollars per live birth, compared with $22,048 in non-US countries. As in previous studies, multiple gestation pregnancies were shown to pose a significant economic burden, costing 36% more than regular IVF singleton pregnancies. Price elasticity estimates indicate that a 10% decrease in IVF/ICSI costs would result in a 30% increase in overall ART use. Of note, the study emphasized that most IVF-related economic studies in the peer-reviewed literature possessed no outcomes assessment or comparison with alternative policies.

The costs of multiple gestation pregnancies have been well studied. The landmark study by Callahan and colleagues [30] demonstrated that predicted charges for an IVF singleton pregnancy were $9845 in 1991 dollars, compared with $37,947 for twins and $107,965 for triplets. Low birthweight and gestational age were found to represent the major contributors to the increased use of health care resources with IVF-related multiple gestation pregnancies [36]. Subsequent studies have confirmed the major contribution of multiple gestation pregnancies toward overall IVF cost. Lukassen and colleagues [37] retrospectively compared the relative cost of twin versus singleton IVF pregnancies in a single institutional study in the Netherlands from 1995 to 2001. They calculated the cost of twin pregnancies to be €13,469 in 2002 euros, more than five times higher than the €2,550 of a singleton pregnancy, because of longer maternal and neonatal admissions. Ledger and colleagues [38] modeled the cost impact to the British National Health System of IVF-related multiple births and concluded that multiple gestation pregnancies represented 56% of the cost of all IVF pregnancies, although they represented less than one third of the total number of maternities in the United Kingdom. Singletons cost £3313 in £ year 2002 sterling, whereas twins cost £9122, and triplets cost £32,354. Wølner-Hanssen and Rydhstroem [39] modeled the use of single-embryo transfer, compared with actual standard two-embryo transfer protocols, and concluded that although more cycles would be needed to achieve a single live delivery with single-embryo transfer, the strategy would still be more cost efficient than the standard two-embryo transfer protocol because of the lower rate of twin pregnancies.

The highest quality studies to examine the cost effectiveness of IVF consist of three randomized controlled trials (Table 2). As the earliest, the Ontario trial compared one stimulated treatment cycle without embryo freezing versus a 6-month period of untreated observation or elective conventional therapy, including ovulation induction and intrauterine insemination (IUI), in the 1980s [40]. The live delivery rate was 10% in the former group versus 6% in the latter. The marginal cost of live delivery was calculated as $89,427 in 1992 Canadian dollars. A major

Table 2
Summary of randomized controlled trials for in vitro fertilization cost effectiveness

Trial	Reference	Intervention	Marginal cost of delivery (in trial year currency)
Ontario	Soliman et al [40]	IVF cycle versus 6 mo of observation or IUI with ovulation induction	$89,427
Illinois	Karande et al [41]	IVF cycle versus 6 mo of clomiphene and gonadotropin cycles	$21,627
The Netherlands	Goverde et al [42]	IVF versus IUI versus IUI/ovarian hyperstimulation	26,779 NLG

weakness of the trials was that it occurred in the 1980s; ostensibly, the effectiveness of ART treatments has since improved considerably. A second trial in Illinois compared 46 couples undergoing IVF to 50 couples randomized to 6 months of standard therapy that consisted of three clomiphene cycles and three gonadotropin cycles followed by four IVF cycles [41]. The former group achieved a 35% pregnancy rate, whereas the latter group achieved a 56% pregnancy rate. As with the Ontario trial, only direct costs were considered. The marginal cost of an additional live delivery was calculated to be −$21,627 in 1999 dollars (ie, IVF was deemed to be not only more expensive but also to offer less benefit). The final trial occurred in the Netherlands [42]. Eighty-six couples with idiopathic subfertility or male subfertility were assigned to six cycles of IUI alone, 85 to six cycles of IUI with ovarian hyperstimulation, and 87 to six cycles of IVF. After 3.5 years, the live birth rates were 7.4%, 8.7%, and 12.2%, respectively. Couples in the IVF arm were more likely to discontinue treatment before the maximum of six attempts. IUI (10,406 NLG per live delivery for male subfertility in 1995 NLG) and IUI with ovarian hyperstimulation (15,448 NLG per live delivery) were found to be more cost effective than IVF (37,185 NLG per live delivery), even at higher maternal ages, when the effectiveness of IUI declines. Questions regarding the generalizability of the Netherlands trial arise because few couples undergo more than three IVF cycles, whereas the trial tested up to six cycles. Overall, these three trials differed in terms of patient population, treatments offered, and country-specific health economic systems, thus potentially accounting for the differences in results seen. It was unclear whether these studies included patients with obstructive azoospermia undergoing sperm acquisition and IVF.

On a broader basis, one should note that the improved live delivery rates and decreased multiple gestation rates with IVF reported by more recent SART data might materially affect the outcomes of the cost-effectiveness analyses mentioned. Direct comparison of the IVF studies is also limited by the heterogeneity in the definition of costs used. Some studies examined only direct costs, whereas others included direct and indirect costs. Finally, some studies assumed costs to be equal to charges, whereas others considered the two to be separate. Several well-written reviews regarding the cost impact and cost effectiveness of IVF treatments have been published [31,32,35,43,44].

Male factor infertility studies

Effectiveness of surgical techniques

The peer-reviewed literature was queried for articles pertaining to microsurgical vasectomy reversal and sperm retrieval; specifically, a Medline search using the terms "vasectomy reversal," "vasovasostomy," "vasoepididymostomy," "sperm retrieval," "sperm aspiration," "sperm extraction," "TESE," "TESA [testicular sperm aspiration]," "PESA," "MESA," and "testis biopsy" was conducted. All relevant studies were identified, and only articles that presented original primary data sufficient to calculate patency, when relevant, and live delivery rates were included for analysis. All data from the studies were pooled and are presented in Tables 3–5.

The overall patency rate for vasectomy reversal is approximately 86% in the peer-reviewed literature (see Table 3). The corresponding live delivery rate in these studies is 58%. One should note that the results of one study were substantially different from the remainder of published literature; the rationale for this difference and the generalizability of the study could not be determined [45]. In this study, the overall reported patency rate was 90% for the 3378 (86.5%) patients with data available. Live delivery rates were 84% for the 1738 (44.5%) patients with data available. If data from this particular study were separated from the others, the overall patency rate for microsurgical vasectomy reversal would decrease to 81%, and the live delivery rate would decrease to 44%.

More than the rate of successful sperm retrieval, the live delivery rate with sperm retrieval techniques represents the critical metric of success if a couple chooses retrieval as treatment for obstructive azoospermia. According to the peer-reviewed literature, the overall live delivery rate for couples undergoing MESA is 44%. One should note that Tables 3 and 4 present all vasectomy reversal and MESA studies identified by Medline and contain multiple studies from same clinical groups. Some of these studies may represent subgroup analyses of an identical larger patient population. Because improvements in surgical technique may have occurred over time, however, all studies have been presented *in toto*.

Data were gathered for the 1999 and 2005 years for TESE procedures from the SART

Table 3
Patency and live delivery rates for peer-reviewed literature studying vasectomy reversal

Vasectomy reversal studies	Patency rate (%)	Live delivery rate (%)
Belker AM, Thomas AJ Jr, Fuchs EF, et al. Results of 1,469 microsurgical vasectomy reversals by the Vasovasostomy Study Group. J Urol 1991;145(3):505–11	1231/1469 (84)	664/1469 (45)
Boorjian S, Lipkin M, Goldstein M. The impact of obstructive interval and sperm granuloma on outcome of vasectomy reversal. J Urol 2004;171:304–6	196/213 (92)	168/213 (79)
Chan PT, Goldstein M. Superior outcomes of microsurgical vasectomy reversal in men with the same female partners. Fertil Steril 2004;81(5):1371–4	22/27 (82)	22/27 (82)
Deck AJ, Berger RE. Should vasectomy reversal be performed in men with older female partners? J Urol 2000;163:105–6	NA/29 (NA)	NA/29 (NA)
Fuchs EF, Burt R. Vasectomy reversal performed 15 years or more after vasectomy: correlation of pregnancy outcome with partner age and with pregnancy results of in vitro fertilization with intracytoplasmic sperm injection. Fertil Steril 2002;77:516–9	147/173 (85)	66/173 (38)
Heidenreich A, Altmann P, Engelmann UH. Microsurgical vasovasostomy versus microsurgical epididymal sperm aspiration/testicular extraction of sperm combined with intracytoplasmic sperm injection. Eur Urol 2000;37:609–14	120/156 (77)	81/156 (52)
Kolettis PN, Sabanegh ES, D'amico AM, et al. Outcomes for vasectomy reversal performed after obstructive intervals of at least 10 years. Urology 2002;60(5):885–8	57/74 (77)	26/74 (35)
Kolettis PN, Sabanegh ES, Nalesnik JG, D'Amico AM, Box LC, Burns JR. Pregnancy outcomes after vasectomy reversal for female partners 35 years old or older. J Urol 2003;169(6):2250–2	37/46 (81)	15/46 (33)
Kolettis PN, Thomas AJ Jr. Vasoepididymostomy for vasectomy reversal: a critical assessment in the era of intracytoplasmic sperm injection. J Urol 1997;158:467–70	49/58 (85)	21/58 (36)
Kolettis PN, Woo L, Sandlow JI. Outcomes of vasectomy reversal performed for men with the same female partners. Urology 2003;61:1221–3	30/32 (93)	18/32 (56)
Matthews GJ, Schlegel PN, Goldstein M. Patency following microsurgical vaso-epididymostomy and vasovasostomy: temporal considerations. J Urol 1995;154:2070–3	164/200 (82)	65/200 (32)
Nalesnik JG, Sabanegh ES Jr. Vasovasostomy: multiple children and long-term pregnancy rates. Curr Surg 2003;60:348	44/73 (60)	21/73 (28)
Schlegel PN, Goldstein M. Microsurgical vasoepididymostomy: refinements and results. J Urol 1993;150:1165–8	77/110 (70)	43/110 (39)
Silber SJ. Results of microsurgical vasoepididymostomy: role of epididymis in sperm maturation. Hum Reprod 1989;4:298–303	NA/190 (NA)	81/190 (42)
Silber SJ, Grotjan HE. Microscopic vasectomy reversal 30 years later: a summary of 4010 cases by the same surgeon. J Androl 2004;25:845–9	3040/3378 (90)	1460/1738 (84)
Thomas AJ. Vasoepididymostomy. Urol Clin North Am 1987;14:527–38	172/228 (75)	59/228 (26)
Total	5386/6266 (86)	2808/4816 (58)

Table 4
Live delivery rates for peer-reviewed literature studying microsurgical epididymal sperm aspiration

MESA studies	Live delivery rate (%)
Anger JT, Wang GJ, Boorjian SA, et al. Sperm cryopreservation and in vitro fertilization/intracytoplasmic sperm injection in men with congenital bilateral absence of the vas deferens: a success story. Fertil Steril 2004;82(5):1452–4	21/30 (70)
Devroey P, Silber S, Nagy Z, et al. Ongoing pregnancies and birth after intracytoplasmic sperm injection with frozen-thawed epididymal spermatozoa. Hum Reprod 1995;10:903–6	3/7 (40)
Heidenreich A, Altmann P, Engelmann UH. Microsurgical vasovasostomy versus microsurgical epididymal sperm aspiration/testicular extraction of sperm combined with intracytoplasmic sperm injection. Eur Urol 2000;37:609–14	19/69 (28)
Janzen N, Goldstein M, Schlegel PN, et al. Use of electively cryopreserved microsurgically aspirated epididymal sperm with IVF and intracytoplasmic sperm injection for obstructive azoospermia. Fertil Steril 2000;74:696–701	82/141 (58)
Oates RD, Lobel SM, Harris DH, et al. Efficacy of intracytoplasmic sperm injection using intentionally cryopreserved epididymal spermatozoa. Hum Reprod 1996;11:133–8	8/31 (26)
Schlegel PN, Palermo GD, Alikani M, et al. Micropuncture retrieval of epididymal sperm with in vitro fertilization: importance of in vitro micromanipulation techniques. Urology 1995;46:238–41	13/27 (48)
Schroeder-Printzen I, Zumbe J, Bispink L, et al. Microsurgical epididymal sperm aspiration: aspirate analysis and straws available after cryopreservation in patients with non-reconstructable obstructive azoospermia: MESA/TESE Group Giessen. Hum Reprod 2000;15(12):2531–5	35/93 (38)
Sharma RK, Padron OF, Thomas AJ Jr, et al. Factors associated with the quality before freezing and after thawing of sperm obtained by microsurgical epididymal aspiration. Fertil Steril 1997;68(4):626–31	64/131 (49)
Shibahara H, Hamada Y, Hasegawa A, et al. Correlation between the motility of frozen-thawed epididymal spermatozoa and the outcome of intracytoplasmic sperm injection. Int J Androl 1999;22(5):324–8	5/18 (30)
Silber SJ, Nagy ZP, Liu J, et al. Conventional in vitro fertilization versus intracytoplasmic sperm injection for patients requiring microsurgical sperm aspiration. Hum Reprod 1994;9:1705–9	20/48 (42)
Tournaye H, Devroey P, Liu J, et al. Microsurgical epididymal sperm aspiration and intracytoplasmic sperm injection: a new effective approach to infertility as a result of congenital bilateral absence of the vas deferens. Fertil Steril 1994;61:1045–51	3/14 (21)
Tournaye H, Merdad T, Silber S, et al. No differences in outcome after intracytoplasmic sperm injection with fresh or with frozen-thawed epididymal spermatozoa. Hum Reprod 1999;14(1):90–5	48/176 (27)
Zenke U, Jalalian L, Shen S, et al. The difficult MESA: findings from tubuli recti sperm aspiration. J Assist Reprod Genet 2004;21(2):31–5	4/10 (44)
Total	372/843 (44)

database, the former representing the earliest year for which complete data were readily available and the latter the latest year for which robust SART data existed for TESE (see Table 5). Only 1.6% of cycles undergone for male factor infertility used TESE with IVF/ICSI to treat male factor infertility in 1999 (1029 cycles); this percentage remained unchanged for 2005 (1425 cycles). The live delivery rate for TESE cycles increased from 28.3% to 33.6% ($P = .042$) in couples in whom sperm was successfully retrieved. Although the multiple gestation pregnancy rate decreased from 37% to 31.9% for all IVF cycles, it did not do so for TESE cycles (29.6% to 28.0%, $P = .737$). The percentage of cycles resulting in triplet or more infants in the latter group did decline from 5.8% to 2.1%, however ($P = .008$). One should note that the "TESE" designation within the SART database does not differentiate between sperm obtained via percutaneous TESE versus microsurgical TESE versus open testicular biopsy, nor does the database distinguish between

Table 5
Society of Assisted Reproductive Technology live delivery rates for testicular sperm extraction patients for 1999 to 2005

	1999	2005
Total number of cycles	62,991	88,422
% cycles for male factor infertility with TESE/ICSI	1.6	1.6
% cycles for male factor infertility with TESE/ICSI resulting in live births	28.3	33.6
% male factor infertility TESE+ICSI live births with multiple infants	29.6	28.0
% male factor infertility TESE+ICSI live births with singleton	70.4	72.0
% male factor infertility TESE+ICSI live births with twins	23.7	25.9
% male factor infertility TESE+ICSI live births with triplets or more	5.8	2.1

Cycles in this table refer to those using use fresh, autologous eggs with cervical transfer.

obstructive versus nonobstructive azoospermia for "male factor infertility." The live delivery rates cited by the database likely underestimate the success rates that would be obtained by patients with obstructive azoospermia.

Cost effectiveness: vasectomy reversal versus sperm retrieval studies

Prior groups have compared different treatments for obstructive azoospermia. Pavlovich and Schlegel [25] studied the use of vasectomy reversal via vasovasostomy or vasoepididymostomy versus sperm retrieval via MESA and percutaneous and testicular sperm retrieval with ICSI in men with postvasectomy infertility and female partners 39 years old or younger. Direct costs for all procedures were considered and surveyed from multiple US centers reporting results for ICSI and vasectomy reversal, as were the indirect costs of complications, lost productivity, and multiple gestation pregnancies. Vasectomy reversal was calculated to cost $25,475 per live delivery (95% confidence interval: $19,609–$31,339) in 1994 dollars. Sperm retrieval and IVF, in contrast, were calculated to cost $72,521 per live delivery (95% confidence interval: $63,357–$81,685). The main driver responsible for the spread in costs in the sperm retrieval arm consisted of IVF-associated and higher order gestation costs. They concluded that the most cost-effective approach to postvasectomy infertility lay with microsurgical vasectomy reversal; microsurgical vasectomy reversal was also the most effective method with which to produce a live delivery with only one intervention.

Kolettis and Thomas [46] next compared the cost effectiveness of MESA to vasoepididymostomy in the Cleveland Clinic experience. Fifty-five men undergoing vasoepididymostomy for vasectomy reversal were studied. A patency rate of 85% was achieved at 6 months, with an accompanying live delivery rate of 36%. The cost of MESA was calculated to be $51,024 per live delivery in 1997 dollars versus $31,099 for vasoepididymostomy. These figures also considered the impact of direct and indirect costs. Donovan and colleagues [47] compared MESA versus repeat surgical reconstruction in postvasectomy patients in the University of Iowa experience. A patency rate of 78% was achieved in the latter group. Only direct costs were considered. The cost per live delivery for MESA was calculated to be $35,570 in 1998 dollars compared with $14,892 for repeat vasectomy reversal.

Deck and Berger [48] described the University of Washington experience with vasectomy reversal compared with IVF/ICSI. The clinical course of 29 patients undergoing vasectomy reversal with ovulating partners older than 37 years was retrospectively studied. With a patency rate of 75%, the live birth rate achieved was 17%. The cost per live delivery was calculated to be $28,530 in 2000 dollars, compared with $103,940 for testicular sperm aspiration /IVF/ICSI. These figures only accounted for direct procedural costs and did not consider the impact of indirect costs.

Meng and colleagues [49] also examined the issue of vasectomy reversal through either microsurgical vasovasostomy or vasoepididymostomy versus sperm retrieval via unspecified means by use of a decision analytic model. In contrast to the Pavlovich and Schlegel analysis, although direct procedural costs were considered, the impact of indirect costs was not; all costing data came from a single institution. The results of the analysis by Meng and colleagues favored vasectomy reversal as the more cost-effective treatment for postvasectomy related obstructive azoospermia, as long as postreconstruction patency rates could be maintained more than 79%. Their analysis calculated that the cost per live delivery for vasectomy reversal in the base case scenario was $38,983 in 2004 dollars, whereas that for sperm retrieval/ICSI was $39,506. Although their sensitivity analysis suggested that the cost effectiveness of vasectomy reversal depends on male—not female—fertility factors, it is important to note that the effects of age on maternal fecundity were not considered. It was also suggested that sperm retrieval/ICSI would be more cost effective in situations where the need for uni- or bilateral vasoepididymostomy arose (ie, where the expected patency rate of reconstruction would be lower).

Lee and colleagues (unpublished data) most recently compared vasectomy reversal versus MESA versus percutaneous TESE for the treatment of obstructive azoospermia via use of a decision analytic model that accounts for direct and indirect costs. Costing and IVF outcomes were taken from population-based databases for maximum generalizability of results. The cost-effectiveness performance of all three therapies was also examined over time. In this study, the cost per live delivery for vasectomy reversal was $20,019 in 1999, compared with $43,886 for percutaneous TESE and $46,133 for MESA. In 2005, vasectomy reversal ($21,304) remained the most cost-effective treatment over TESE ($53,356) and MESA ($55,317). The cost effectiveness of all treatments during this time period improved over projections by inflation. Unlike the analysis by Meng and colleagues, however, sensitivity analysis suggested that cost effectiveness of vasectomy reversal was superior to MESA and TESE under all conditions, implying that the additional cost per pregnancy generated by the lower patency rates in patients requiring uni- or bilateral vasoepididymostomy is still outweighed by the cost of IVF in MESA and TESE. The duration of obstruction becomes an insignificant factor in deciding which therapy to recommend. Conversely, the improved cost effectiveness from an enhanced ability to achieve successful delivery with IVF is still outweighed by the indirect costs of the therapy. The magnitude of IVF-related indirect costs seemed to significantly alter the outcome of this decision model compared with prior studies. For instance, the probability- and inflation-adjusted cost of multiple gestation pregnancies alone ($31,637 in 1999 and $35,105 in 2005) outweighed the procedural cost of an IVF cycle in the base ($9765) and latter ($12,507) years of the study.

It should be emphasized that all cost-effectiveness studies reflect locoregional costs, which can vary dramatically. As mentioned elsewhere in the surgical literature, the results of the most experienced or successful surgeons form the basis of this analysis, which creates further bias in the results.

Summary

A detailed examination of the data regarding surgical reconstruction versus sperm retrieval with IVF/ICSI for the treatment of obstructive azoospermia reveals several key points. First, multiple techniques for surgical reconstruction and sperm retrieval exist. Vasovasostomy represents the first-line modality for surgical reconstruction and is clearly preferable to vasoepididymostomy. MESA is more effective than PESA in terms of quantity and quality of sperm retrieved with consequent impact on live delivery rates. Excellent sperm retrieval and pregnancy rates can be achieved with epdididymal or testicular sperm obtained by each of these techniques. All modalities of sperm retrieval consign the female partner of a couple to undergo the greater costs and complications of an IVF cycle and expose the resulting offspring to potential health problems. It seems that reconstructive procedures should be offered as a first-line therapy to couples who seek conception after vasectomy. The treatment eventually chosen by an individual couple, however, should be an informed one based on the data available.

Cost-effectiveness analysis reveals multiple implications. First, although the direct cost of undergoing IVF can be tremendous and may vary greatly between countries, the indirect costs are even more significant, most specifically because of the impact of multiple gestation pregnancies. Randomized controlled trials have failed to consistently demonstrate the cost effectiveness of IVF over conventional, less invasive fertility treatments, such as IUI. When these data are taken into consideration for sperm retrieval in the treatment of obstructive azoospermia, it is clear why multiple studies have demonstrated the superior cost effectiveness of surgical reconstruction over sperm retrieval in linear and decision analytic models: the cost of the IVF that must be coupled to sperm retrieval is so great that it becomes a less cost-effective therapy compared with surgical reconstruction.

Limitations

It is important to note that limitations exist with cost-effectiveness analysis. Cost-effectiveness analysis by its nature involves implicit assumptions and judgments. First, such analysis operates on the premise of maximizing health care benefits across a target population given a limited amount of economic resources (ie, it encompasses a societal perspective). Individual outcomes to specific patients are not considered, because the analysis instead considers net gains and benefits to all individuals in the population equally. Issues such as equity in individual access to health care services, the internal validity and comparability of cost-effectiveness studies, and the external validity of applying generalized cost-effectiveness models to specific locoregional conditions all remain unanswered.

Many of the studies assumed costs to be equal to charges to best evaluate the overall impact of ART on society. The impact on individual patients and individual patient willingness to undergo ART varies depending on the extent of specific health insurance coverage. None of the studies considered the downstream costs of raising children conceived by ART; higher rates of chromosomal anomalies, prematurity, and low birthweight are found in ART children, which would lead to greater downstream costs in children born via sperm retrieval IVF [50–52]. Petrou and colleagues, for example, studied the cumulative cost impact of preterm birth infants and found longer duration of hospital admissions, significantly greater inpatient service costs, and a persistent cost difference of £11,958 in £ 1998 sterling up to £14,614 over the first 5 years of life depending on gestational age. Few studies also considered the issue of maternal age impact on fecundity. For example, vasectomy reversal would represent a suboptimal therapy with greater maternal age; couples would be more likely to choose sperm retrieval in the interests of expediting the time to pregnancy and delivery, yet few of the studies considered this trend. How would the decision process be altered if a couple desired more than one child? Finally, some of the broader effects of ART were also not considered. The economic impact of multiple births, for instance, on downstream social welfare and public health programs may become significant in the future. What proportion of public resources should optimally be used to help pay for ART versus other potentially life-saving or extending technologies? What is the most efficient allocation of these resources, and how does one determine who should be the recipients? These are critical and possibly the most important questions that remain unanswered in the limited scope of cost-effectiveness analysis.

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A SIMPLIFIED METHOD OF EPIDIDYMAL SPERM ASPIRATION

GERALD J. MATTHEWS, AND MARC GOLDSTEIN

ABSTRACT

We present a simple technique of epididymal sperm aspiration that uses inexpensive and readily available materials. Men undergoing epididymal reconstruction with vasoepididymostomy or autogenous sperm reservoir had sperm aspiration for cryopreservation. Mean total and total motile sperm per aspirate recovered from 25 men have been $25.1 \pm 4.8 \times 10^6$ and $4.0 \pm 1.4 \times 10^6$, respectively. Two ongoing pregnancies have been achieved with intracytoplasmic sperm injection using thawed epididymal sperm. Sperm aspiration and cryopreservation maximize a couple's fertility potential with a single procedure and provide a viable fertility alternative to a second surgical procedure in the event of a primary reconstructive failure. UROLOGY® **47:** 123–125, 1996.

Men undergoing a microsurgical vasoepididymostomy (VE) or an autogenous sperm reservoir (ASR) procedure face a significant possibility of reconstructive failure. We have previously reported that the likelihood of a durable response, as measured by the recovery of motile sperm either in the ejaculate following a VE or from a percutaneous aspiration of an ASR is 52% and 47%, respectively.[1,2] For men who fail initial reconstructive attempts, the only alternative available for those desiring a pregnancy is a repeat surgical procedure. However, if sperm were recovered and cryopreserved at the time of the initial surgery, an alternative to a second surgical procedure can be considered.

We have attempted to maximize ultimate success in a single procedure by using a simple and atraumatic method of sperm recovery at the time of epididymal reconstruction. This method uses inexpensive materials, readily available in most operating theaters. We currently offer all men with epididymal obstruction the option for simultaneous epididymal sperm aspiration and cryopreservation.

TECHNIQUE

Our technique for the construction of an ASR and for microsurgical VE has previously been reported.[2,3] Prior to reconstruction and epididymal sperm recovery, communication with the sperm bank or in vitro fertilization (IVF) laboratory is made to ensure the timely processing and cryopreservation of the aspirate. Using an operating microscope, epididymal tubule dissection and aspiration are performed using ×15 to ×32 magnification. The epididymal tubule and tunic are prepared for either VE or an ASR. Meticulous hemostasis is obtained with micro-bipolar forceps prior to aspiration, as the presence of erythrocytes and leukocytes has been demonstrated to diminish sperm function.[4,5]

The most distal tubule containing clear or opalescent fluid should be selected. Tubules containing yellow inspissated material should be avoided. A 0.5- to 1.5-mm buttonhole is made in the epididymal tubule with fine blunt-tipped microscissors. Alternatively, the epididymal tubule may be sharply incised with a microknife. After opening the epididymal tubule, a 5-μL micropipette with a 0.5-mm internal diameter, 0.9-mm outer diameter, and scored at 1-μL intervals (Drummond Scientific Co., Broomall, Pa) is placed adjacent to the effluxing epididymal tubule. A standard hematocrit pipette is also satisfactory and readily available.

Sperm are drawn into the micropipette by simple capillary action. Negative pressure, as is generated by action of an in-line syringe, should not be applied during sperm recovery, as this may damage the delicate epididymal mucosa. For this reason, we do not recommend a syringe and angiocatheter technique. The micropipette/capillary action technique provides a direct visual confirmation and quantification of epididymal fluid recovery (Fig. 1). Air drawn into a syringe during the negative pressure aspiration of epididymal fluid results in less precise volume quantification and a more difficult transfer into buffer. Multiple micropipettes may be used simultaneously to increase speed of recovery. With patience, 10 to 20 μL of epididymal fluid is easily recovered in no more than 5 to 10 minutes.

The highest rate of flow is observed immediately following incision of the tubule; however, progressively better quality sperm are found following the

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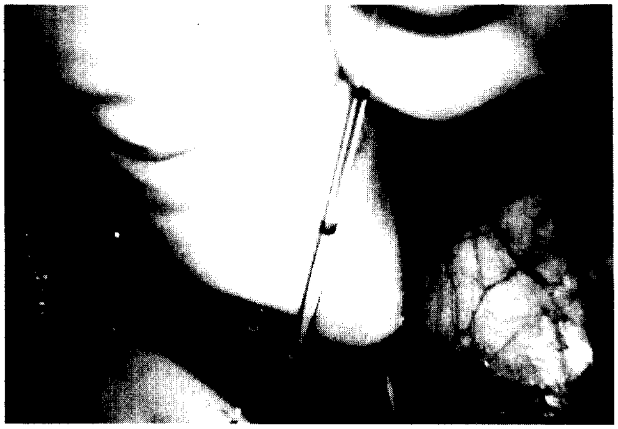

FIGURE 1. *The technique of atraumatic sperm recovery by simple capillary action.*

initial washout. Gentle compression of the testis and epididymis enhances flow from the incised tubule. During fluid recovery, a drop is examined under the microscope to confirm the presence of sperm. Since processing techniques, including pentoxifylline incubation, stimulate sperm motility, we aspirate in the presence of both motile and nonmotile sperm. If intact sperm are not encountered, then a more proximal epididymotomy is performed.

The micropipette is connected to a short (3 to 5 cm) segment of medical grade silicone tubing (American Scientific Products, McGaw Park, Ill) (Fig. 2). Alternatively, the tubing attached to a butterfly needle may be used. A 20-gauge needle fitted to a Luer-tip syringe is then placed in line (Fig. 2). The fluid is flushed into a sterile container of buffer solution (0.5 to 1.0 mL) obtained from the sperm-processing laboratory. Once a micropipette has been used, it is discarded. Residual fluid in the pipette will disrupt capillary action. A typical procedure requires 4 to 8 micropipettes.

The sperm bank is instructed to cyropreserve the aspirate in multiple straws (aliquots), so that several IVF cycles may be used if required. At our institution, epididymal aspirates are diluted in an equal volume of glycerol cryoprotectant. Aliquots are then slowly cooled to 4°C, transferred to a sequential freezer for refrigeration to –90°C prior to immersion in liquid nitrogen (–196°C).

RESULTS

The results of atraumatic epididymal sperm aspirations are presented for the last 25 men undergoing either a VE procedure (n = 15) or the creation of an ASR (n = 10) (Table I). In each case, epididymal fluid was rapidly recovered with no more than 10 minutes of added surgical time. Motile sperm were recovered from the epididymides and cryopreserved in 21 of 25 (84%) men. As the epididymal aspirate was immediately diluted in a buffer solution, aspirate volume and sperm density recorded by the processing laboratory do not accurately represent the initial aspirate parameters. Semen parameters reported are limited to percent motility, total sperm per aspirate, and total motile sperm per aspirate.

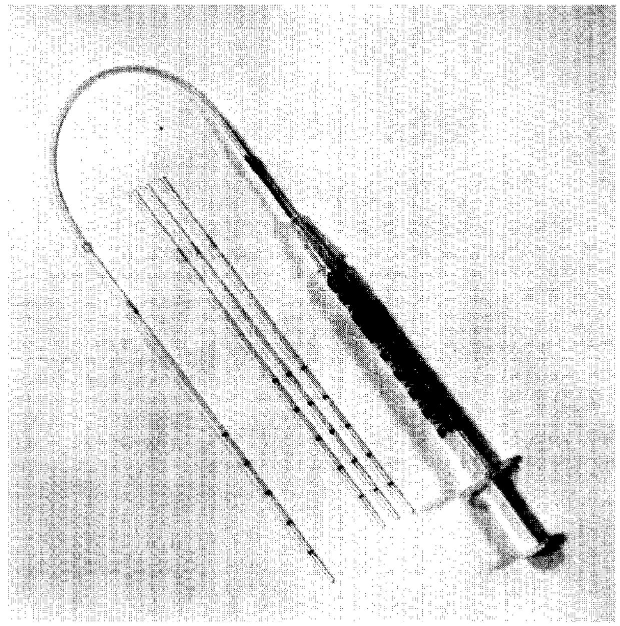

FIGURE 2. *Materials (micropipettes, silicone tubing) used for atraumatic sperm recovery.*

Two couples, the male partners with congenital absence of the vas deferens and having undergone the microsurgical creation of an ASR, elected to undergo an IVF cycle with aspirated cryopreserved sperm prior to an evaluation of reservoir status. Two ongoing pregnancies have been established for these couples using IVF with intracytoplasmic sperm injection (ICSI).

COMMENT

In reviewing treatment outcomes following 100 consecutive VE procedures, we observed the return of motile sperm in only 52 men.[1] Subsequently, 21% (11 of 52), after initial demonstration of patency with motile sperm, have experienced a late anastomotic failure.[1] Similarly, motile sperm have been recovered by percutaneous aspiration from only 47% of men undergoing an ASR procedure.[2] For the majority who fail epididymal reconstruction, fertility treatment options necessitate additional surgical procedures.

The technique of atraumatic epididymal sperm aspiration presented provides couples with an alternative to surgery following reconstructive failure. The method of sperm recovery presented should not be confused with the technique of epididymal micropuncture with sperm aspiration (MESA).[6] Epididymal micropuncture requires highly modified micropipettes used to puncture into the lumen of an individual epididymal tubule. These micropipettes are not commercially available and must be hand-manufactured from commercial stock. The

TABLE I. ***Aspirate parameters are summarized for the entire cohort and for men undergoing either a vasoepididymostomy procedure or the creation of an autogenous sperm reservoir****

	Motility	Total Sperm/Aspirate	Total Motile Sperm/Aspirate
Cohort (n = 25)	15.2 ± 3.7	$25.1 \pm 4.8 \times 10^6$	$4.0 \pm 1.4 \times 10^6$
Range:	0–66%	$1.6–106 \times 10^6$	$0–26.5 \times 10^6$
ASR (n = 10)	20.2 ± 6.9	$32.1 \pm 9.6 \times 10^6$	$5.6 \pm 2.6 \times 10^6$
Range:	0–66%	$4.9–106 \times 10^6$	$0–26.5 \times 10^6$
VE (n = 15)	11.8 ± 4.0	$20.4 \pm 4.6 \times 10^6$	$3.0 \pm 1.6 \times 10^6$
Range:	0–56%	$1.6–60 \times 10^6$	$0–23 \times 10^6$

**No difference in sperm motility was observed for men undergoing either a vasoepididymostomy (VE) or autogenous sperm reservoir (ASR) procedure (P = NS).*

equipment used for the modification of micropipettes for epididymal micropuncture is not available at many institutions and requires technical skill to fashion a micropipette suitable for epididymal micropuncture. The technique we present has a minimal learning curve and requires no specialized equipment. On the contrary, we have successfully recovered motile sperm using standard hematocrit pipettes attached to butterfly-needle tubing.

Additionally, for men with reconstructible tracts, a simultaneous epididymal micropuncture may compromise surgical results. MESA typically uses epididymal micropunctures at multiple points along the length of the epididymis. VE, performed in conjunction with MESA, thus requires an anastomosis proximal to the highest level of epididymal micropuncture. This results in a sacrifice of potentially viable epididymal length. We have previously reported that no man undergoing a simultaneous ASR with epididymal micropuncture has had sperm recovered from his ASR.[2] The technique of atraumatic aspiration of epididymal sperm with cryopreservation offers the clinician a simple and inexpensive method of sperm collection and the couple the opportunity to maximize their chances for fertility with a single procedure without compromise of the primary reconstructive efforts. For men with congenital absence of the vas deferens in whom a simultaneous IVF/ICSI cycle is to be undertaken with epididymal sperm, epididymal sperm quality should be maximized. This may necessitate multiple epididymal micropunctures.

We do not recommend sperm aspiration and cryopreservation at the time of vasovasostomy (VV). As motile sperm are observed in the ejaculate of 98% of men following VV in our hands, we believe that postoperative sperm collection is more economic and practical for men undergoing a VV.[1] We also recommend postoperative sperm banking for all men with motile sperm in the ejaculate following a VE procedure.

The pregnancies established with cryopreserved sperm recovered with this technique from patients undergoing a simultaneous reconstructive procedure reinforces the concept of maximizing a couple's reproductive options. Pregnancy with cryopreserved sperm requires IVF. Chances for pregnancy will be maximized by IVF with ICSI. At our institution, pregnancy (ongoing) rates of 38.5% per cycle are achieved with IVF/ICSI.[7] Current per cycle costs for IVF/ICSI average $12,000. Couples should be informed of the risks, benefits, and costs for IVF and IVF/ICSI prior to surgery and sperm aspiration. Those unwilling to accept IVF should not be offered sperm cryopreservation.

In our experience, the recovery of epididymal sperm is accomplished quickly with little added operating time. In 21 of 25 cases, motile sperm, in sufficient numbers for multiple cycles of IVF, were cryopreserved by the sperm bank.

CONCLUSIONS

It is incumbent on the clinician treating the infertile couple to maximize their options and therefore their chances for a pregnancy with a single surgical procedure. The simultaneous atraumatic recovery of epididymal sperm is advantageous and practical for men in whom epididymal reconstruction is being considered. This technique is rapid, inexpensive, and requires no special or modified instruments.

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ORIGINAL ARTICLE

Although vasectomy remains a popular method of contraception, the number of men requesting reversal has risen dramatically. The microsurgical techniques described in this article have yielded excellent results.

Vasectomy Reversal

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INTRODUCTION

Approximately 500,000 vasectomies are performed each year in the United States. It is estimated that 2% to 6% of vasectomized men ultimately seek reversal. Divorce with subsequent remarriage is by far the most common reason given for requesting reversal. In developing countries, the death of a child is the most common reason. In Bangladesh, for example, 5% of all couples who choose sterilization experience the death of a child within 1 year after the operation.

Although this article focuses on vasectomy reversal, or vasovasostomy, the same technique can be used to repair vasal obstructions of other etiologies. Iatrogenic injuries to the vas deferens are, unfortunately, quite common. It is estimated that injury to the vas deferens occurs in 0.3% of adult inguinal hernia repairs[1] and up to 2% of pediatric inguinal surgeries.[2]

Before the refinement of microsurgical techniques, the results of vasovasostomy were relatively poor. The lumen of the vas deferens is only about 0.3 mm in diameter. As one might imagine, creating an accurate, leakproof anastomosis of a structure this small is a formidable challenge. Microsurgical techniques of vasectomy reversal now result in return of sperm to the ejaculate in over 90% of men and yield naturally conceived pregnancy rates over 50%.[3]

PREOPERATIVE EVALUATION

History. In men presenting for vasectomy reversal, the prevasectomy fertility status should be ascertained. If a man had trouble conceiving prior to the vasectomy, this may certainly be the case again even if the operation is technically successful. The time since vasectomy is also an important factor influencing outcome. There is no length of time beyond which vasectomy reversal uniformly fails. However, it is clear that success rates are lower

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with longer obstructive intervals. This is due to the increased rate of secondary epididymal obstruction as the obstructive interval lengthens.

A history of complications following the vasectomy, such as a scrotal hematoma or epididymitis, may also affect the results of reversal. Any scrotal or inguinal surgeries performed subsequent to the vasectomy should alert the urologist to the possibility of a second site of vasal obstruction.

Finally, the reproductive health of the female partner should be assessed before embarking on reconstructive surgery for the male. A young, healthy woman with no previous pelvic surgery and with normal menstrual cycles does not require a formal gynecologic work-up. However, older female partners without proven fertility should undergo gynecologic evaluation.

Physical Examination. A complete physical examination should be performed with particular attention to the male genitalia. The spermatogenic component of the testis, called the seminiferous tubules, makes up 80% of the testicular volume. Therefore, small or soft testicles suggest impaired sperm production and predict a poorer outcome. An indurated epididymis suggests secondary epididymal obstruction that may require a more complex procedure, called a vasoepididymostomy, for repair.

Sometimes men who have undergone vasectomy will leak sperm from the end of the vas deferens on the testicular side. This leaking sperm incites an inflammatory response that leads to formation of a sperm granuloma. Palpable as a nodule at the testicular end of the vas, these sperm granulomas are actually a good prognostic sign. The leaking sperm vents the high pressure away from the epididymis, thus protecting the epididymis from pressure-induced damage. Men with palpable sperm granulomas have an improved prognosis regardless of the time interval since vasectomy.

Careful palpation of the relaxed scrotum in a warm examining room reveals the size and location of the vasal gap. Some urologists remove or cauterize a large segment of vas deferens when performing the vasectomy. These destructive vasectomies may require a more extensive dissection when performing the reversal in order to achieve a tension-free anastomosis. In addition, some physicians perform the vasectomy high in the scrotum near the external ring; others perform the procedure lower down, closer to the testicle. These findings also may affect the complexity of the reversal procedure.

Varicoceles are very common in the male population and are frequently detected in men seeking vasectomy reversal. Although varicoceles are the most common surgically correctable cause of male infertility, they do not all need to be repaired. Therefore, we recommend performing the vasovasostomy first, followed by the varicocelectomy several months later if semen analysis parameters remain suboptimal. Performing the procedures concurrently presents technical problems that could jeopardize the success of both operations.

Finally, it is important to note any operative scars in the inguinal or scrotal region that may suggest a possible vasal obstruction at a site remote to the vasectomy. Performing 2 vasovasostomies simultaneously in the same vas is not recommended because devascularization of the intervening segment with subsequent fibrosis and failure of the reversal is likely to result.

Laboratory Tests. The majority of men who have undergone a vasectomy are azoospermic (ie, have no sperm in the ejaculate). Indeed, this is the purpose of the vasectomy in the first place. However, we have observed that 10% of all men presenting for reversal will have a few nonmotile sperm detected in their centrifuged semen specimen.[4] This is due to the spontaneous formation of microscopic channels and not from "reconnection" of the vas deferens. As one might expect, finding rare sperm in the prereversal semen specimen is an excellent prognostic sign. Under these circumstances, sperm are certain to be found in the vas deferens on at least 1 side, improving the likelihood of restored fertility.

A serum follicle-stimulating hormone (FSH) should be measured in any man with small and/or soft testes. Elevated FSH levels suggest impaired spermatogenesis and a poorer prognosis. Antisperm antibodies can be detected in the blood of most men who have undergone vasectomy. The unique surface characteristics of sperm, as well as the delay in their appearance until puberty, make them potential targets for recognition as foreign by the immune system.

The tight junctions between Sertoli cells of the seminiferous tubules create a "blood-testis barrier" that effectively shields sperm and their surface antigens from the systemic circulation. The integrity of this barrier is maintained from the testis to the urethra by an unbroken epithelial lining. When this barrier is violated by surgery, such as vasectomy, or any other injury that allows sperm leakage outside the barrier, antibodies to sperm antigens can form in the blood. Although preoperative antibody levels in serum or seminal fluid do not predict the ultimate outcome of vasovasostomy, the presence of sperm-bound antibodies postoperatively does appear to predict a lower pregnancy rate.[5]

SURGICAL TECHNIQUE

Microsurgical vasectomy reversal is an extremely difficult operation, preferably done under general or regional anesthesia, and takes 2 to 4 hours to perform. The operation is best reserved for urologists with extensive microsurgical training who perform the procedure frequently. The keys to a successful anastomosis are summarized in Table 1.

Bilateral high vertical scrotal incisions are made (Figure 1). Once the scarred ends of the vasa are identified, the vas is transected and patency of the abdominal side is confirmed by injection of saline. If large segments of the vas were removed or destroyed during the vasectomy, extension of the incision into the groin may be necessary. The obstructed portion of the vas deferens is dissected out and serial transections of both ends of the vas are performed until a patent lumen with healthy, well-vascularized mucosa and muscularis are found.

Fluid emanating from the testicular end of the vas should be sampled and examined microscopically. If sperm are observed, a vasovasostomy is performed. The absence of sperm indicates epididymal obstruction, necessitating a more difficult operation (vasoepididymostomy) connecting the vas deferens to the epididymis at a point closer to the testis where it remains patent.

Our multilayer microdot technique for vasovasostomy has been described in detail elsewhere.[6] Briefly, a microtip marking pen is used to map out planned needle exit points (Figure 2). This helps to accurately approximate lumina that frequently have markedly discrepant diameters. Very fine (10-0 nylon) nonabsorbable sutures with needles at both ends are placed inside-out through the dots (Figure 2).

After these sutures are tied, the anastomosis is flipped over to complete the mucosal layer (Figure 3). Another layer of sutures is placed through the muscularis exactly between each of the previously placed mucosal stitches (Figure 4). This creates a water-tight anastomosis that prevents sperm from leaking postoperatively. As mentioned previously, leaking sperm creates an intense inflammatory reaction (sperm granuloma) that compromises the chances of achieving a patent anastomosis. A final layer of suture is placed through the vasal sheath to provide added strength and remove all tension from the anastomosis (Figure 5). An identical procedure is carried out on the opposite side and a multilayer skin closure is accomplished. The patient can be discharged on the day of surgery, and normal activities, including intercourse, may be resumed after 4 weeks.

TABLE 1

Keys to a Successful Anastomosis

- Accurate mucosa-to-mucosa approximation
- Leakproof anastomosis
- Tension-free anastomosis
- Good blood supply to anastomosis
- Healthy vasal mucosa and muscularis
- Precise atraumatic technique

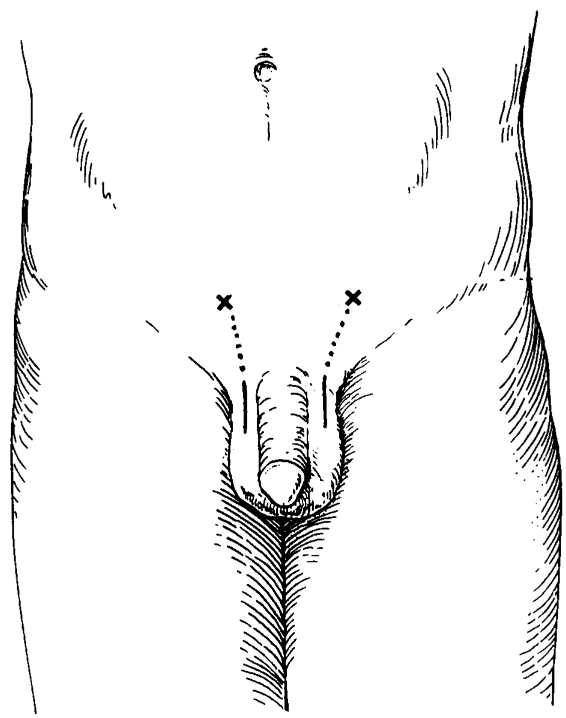

Figure 1.—Preferred incisions for vasectomy reversal. Dotted line indicates extention of incision if needed for gaining extra vasal length. The "x" marks the external inguinal ring. (Reprinted, with permission, from Goldstein M. Vasovasostomy. In: Goldstein M, ed. *Surgery of Male Infertility.* Philadelphia: WB Saunders Co.; 1995:47.)

RESULTS

Using the vasovasostomy technique outlined above, we have observed a patency rate of 99% and a pregnancy rate of 64% (excluding couples with female-factor infertility).[3] The results for vasoepididymostomy are lower (65% and 41%, respectively). The major factors affecting the chances of successful vasectomy reversal are summarized in Table 2. Some patients who are initially patent will develop stenosis and closure of the anastomosis 2–5 years postoperatively. The late failure rates are 12% for vasovasostomy and 21%

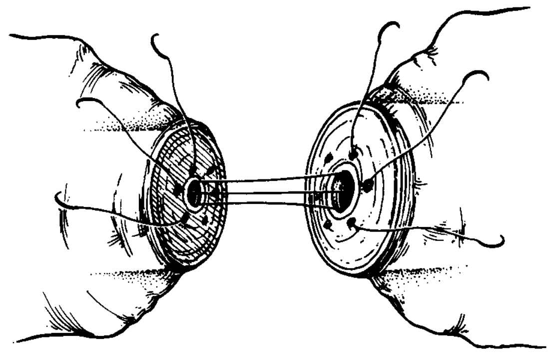

Figure 2.—Three mucosal sutures have been placed inside-out using double-armed needles. The microdots aid precision suture placement. (Reprinted, with permission, from Goldstein M. Vasovasostomy. In: Goldstein M, ed. *Surgery of Male Infertility.* Philadelphia: WB Saunders Co.; 1995:54.)

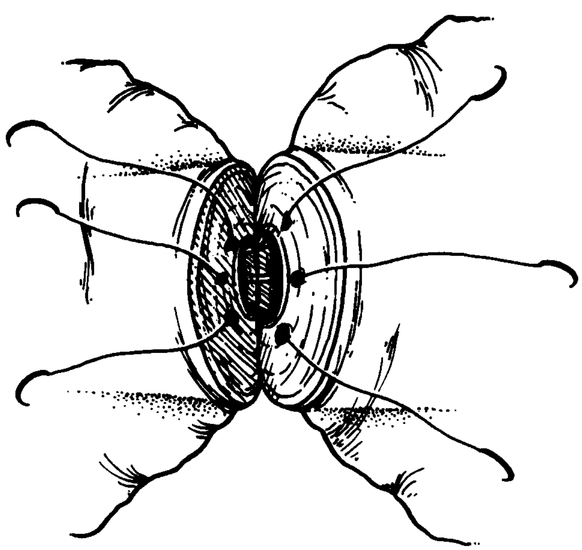

Figure 3.—The vas deferens is turned 180° for placement of the remaining mucosal sutures. (Reprinted, with permission, from Goldstein M. Vasovasostomy. In: Goldstein M, ed. *Surgery of Male Infertility.* Philadelphia: WB Saunders Co.; 1995:56.)

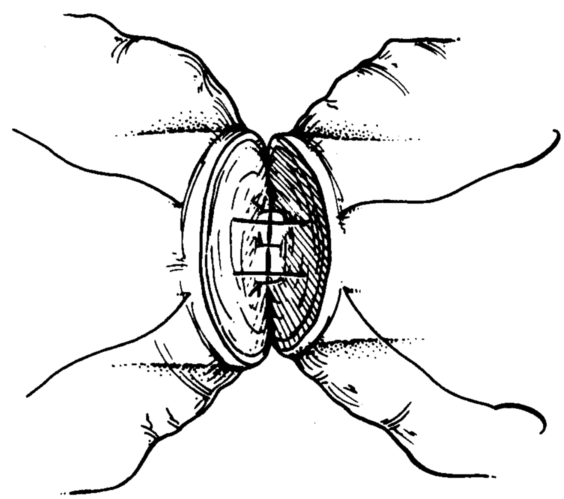

Figure 4.—Deep muscularis sutures are placed exactly between the mucosal sutures to ensure a water-tight anastomosis. (Reprinted, with permission, from Goldstein M. Vasovasostomy. In: Goldstein M, ed. *Surgery of Male Infertility.* Philadelphia: WB Saunders Co.; 1995:55).

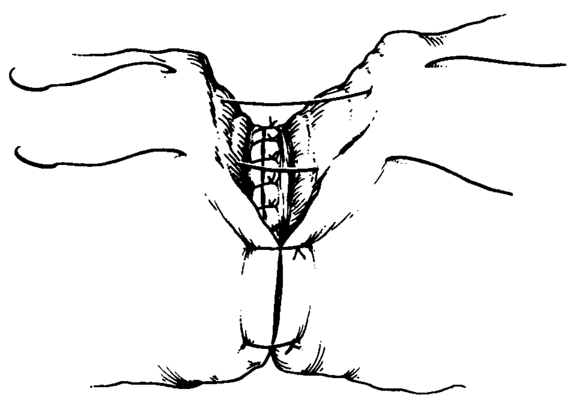

Figure 5.—Superficial adventitial sutures are placed to strengthen the anastomosis and relieve all tension. (Reprinted, with permission, from Goldstein M. Vasovasostomy. In: Goldstein M, ed. *Surgery of Male Infertility.* Philadelphia: WB Saunders Co.; 1995:58).

following vasoepididymostomy.[6] For this reason, we encourage men who have undergone vasectomy reversal to cryopreserve sperm for future use should it be needed. Because men requiring vasoepididymostomy have a lower patency rate, we will also obtain sperm for cryopreservation at the time of their reversal procedure.

The widespread availability of advanced assisted reproduction techniques such as in vitro fertilization and intracytoplasmic sperm injection (IVF-ICSI) has given men who wish to have their own biologic offspring following vasectomy an additional option. Instead of undergoing vasectomy reversal, they may now choose to have sperm aspiration from the testis or epididymis for use with IVF-ICSI.

Although seemingly simple, this approach has distinct disadvantages. First, it subjects an otherwise healthy female partner to the risks of ovarian stimulation and procedural intervention for egg retrieval. Second, it could make future attempts at reconstruction difficult or impossible should the couple opt for reversal following a failed attempt at IVF-ICSI. Third, it is dramatically more expensive. A recent cost-effectiveness analysis was performed compar-

TABLE 2

Factors Influencing the Success Rate of Reversal Surgery

Factor	Comment
Time interval since vasectomy	Longer obstructive intervals are associated with lower success rates
Sperm granuloma	Sperm granulomas at the vasectomy site are a favorable prognostic sign
Antisperm antibodies	Postoperative sperm-bound antibodies result in lower pregnancy rates
Quality of vasal fluid	Vasoepididymostomy is required when sperm are absent in the vasal fluid
Microsurgical technique	Technique, judgment, and experience are important factors for success
Comorbid conditions	Any condition that impairs spermatogenesis (eg, varicocele) may lower postoperative pregnancy rates

ing vasectomy reversal with IVF-ICSI.[7] The analysis assessed cost per delivery, taking the following factors into account: success rates and costs of the 2 treatments, cost of treating complications, cost of delivery, and the costs attributable to multiple gestations that are very common with assisted reproduction. This analysis revealed an average cost per delivery of $25,500 for vasectomy reversal and $72,500 for sperm retrieval and IVF-ICSI.

Finally, the greatest advantage of vasectomy reversal is, perhaps, the most obvious: It allows natural conception, an option preferable to most couples when possible. Therefore, we believe vasectomy reversal is the best option except in cases where female infertility factors exist (such as advanced age) that make natural conception unlikely.

Depending on the clinical situation, men who fail vasectomy reversal may have the procedure repeated or proceed directly to IVF-ICSI. "Redo" vasectomy reversals carry a lower success rate than first-time procedures, primarily because a vasoepididymostomy frequently will be required on at least 1 side. Nevertheless, we have obtained good results in this situation, with patency rates of 67% and pregnancy rates of 30%.[8]

CONCLUSION

Microsurgical technique and intraoperative judgment are the most important factors in determining the success of vasectomy reversal. Hundreds of hours of laboratory practice are necessary to acquire the requisite skills. Although vasectomy is usually considered a permanent form of sterilization, the procedure can be reliably reversed with excellent patency and pregnancy rates. Vasectomy reversal has several advantages over proceeding directly to IVF-ICSI, not the least of which is superior cost effectiveness. **CT**

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Vasectomy Myth Debunked: NewYork-Presbyterian/Weill Cornell Study Finds Vasectomy Reversal Highly Effective, Even After 15 Years

New York, NY (February 19, 2004) -- Debunking a popular myth about vasectomy, a new ıdy by physician-scientists at NewYork-Presbyterian Hospital/Weill Cornell Medical Center finds ǝt vasectomy reversal is highly effective, even 15 years or more after the s deferens, the tube that carries sperm, is blocked. The study, published in the January *Journal Urology*, documents the highest pregnancy rates following vasectomy of any study to date.

Whether a man had a vasectomy this year or 15 years ago, there was no difference in the egnancy rate achieved following a vasectomy reversal, with an average 84-percent likelihood of egnancy over two years, the study finds. (Comparatively, healthy men without vasectomy can :pect a pregnancy rate of 90 percent.) Previous studies have demonstrated pregnancy rates llowing vasectomy reversal of only 50–60 percent, a difference that can be attributed to lvances in vasectomy-reversal techniques. The study also finds that at intervals of greater than ; years, the pregnancy rate dropped to 44 percent.

"Vasectomy is not a permanent condition. For men who had a vasectomy less than 15 :ars ago, a reversal will result in a much higher pregnancy rate than sperm aspiration and vitro fertilization (IVF) with intracytoplasmic sperm injection (ICSI). Even at intervals greater an 15 years, reversal outcomes will equal or exceed those of IVF with ICSI," says Dr. Marc ɔldstein, the study's lead author, Professor of Reproductive Medicine and Urology at Weill ɔrnell Medical College, and Surgeon-in-Chief of Male Reproductive Medicine and Microsurgery at ǝwYork-Presbyterian Hospital/Weill Cornell Medical Center. IVF with ICSI results in pregnancy

(MORE)

rates of up to 50 percent per attempt at the best centers, and may take two or three tries to achieve one pregnancy.

"Additionally, vasectomy reversal is a more cost-effective option, especially for couples seeking more than one child," adds Dr. Goldstein. "IVF with ICSI typically costs approximately two to three times more than vasectomy reversal. And, unlike IVF with ICSI, a reversal is covered by health insurance in certain states, including New York."

Men seek to reverse a vasectomy for two main reasons: they either remarried or they lost a child, says Dr. Goldstein. Approximately half a million vasectomies are performed each year in the U.S., and it is estimated that between two percent and six percent of the men will ultimately seek reversal.

The study involved a retrospective analysis of 213 vasectomy reversals performed at NewYork-Presbyterian Hospital/Weill Cornell Medical Center between 1984 and 2001. Outcomes data were stratified according to obstructive interval: less-than 5 years, 5–10 years, 10–15 years, and greater than 15 years. Only men with fertile female partners were studied.

The study also found that the level of patency (or lack of obstruction) in the vas deferens remained high up to 15 years, averaging at 90 percent, and holding at this rate no matter when the vasectomy was performed. This finding contradicts other study results; this may be explained by the recent introduction of improved surgical techniques for vasectomy reversal. One such technique, the microdot method for precision suture placement, was pioneered by Dr. Goldstein in 1998.

Another vasectomy myth holds that the presence of granulomas -- knots that form in the vas deferens when a vasectomy is too tight -- result in a higher patency and pregnancy rate. The current study finds that granulomas, which occurred in 28 percent of vasectomies, did not increase patency to a statistically significant level and had no impact on pregnancy.

The study represents the first analysis of pregnancy and patency following two different types of vasectomy reversal -- vasovasostomy (VV) and vasoepididymostomy (VE) -- finding that patients who underwent a bilateral VV had a significantly greater patency rate (95%) than patients who had unilateral VV and VE (83%) and bilateral VE (83%). However, pregnancy rates were consistent.

Vasovasostomy (VV) involves a reconnection of the vas deferens to the vas deferens. Vasoepididymostomy (VE) connects the vas deferens to the epididymis, a duct that carries sperm to the vas deferens. In general, if sperm is present in the vas fluid, VV is performed. If sperm is not present in the vas fluid, VE is performed. Both outpatient procedures take less than three hours.

For men unable to achieve pregnancy following VV or VE, the next step is assisted reproductive techniques such as intra-uterine *insemination (IUI) or IVF with ICSI, says Dr.* Goldstein.

The study's co-authors are Dr. Stephen Boorjian, a urology resident at NewYork-Presbyterian Hospital/Weill Cornell and Michael Lipkin, a medical student.

Recognized as leaders in the field male reproductive surgery, Dr. Goldstein and his colleagues at the Center for Male Reproductive Medicine and Microsurgery at NewYork-Presbyterian Hospital/Weill Cornell Medical Center have received honors for their instructional videos. In 2003, they received the American Urological Association's "Audio-Visual Award" (first prize) for "Ultra-Precise Multilayer Microsurgical Vasovasostomy: Trick of the Trade." And in 2002, they received the American Society for Reproductive Medicine's "Best Video Award" for "Three Techniques of Microsurgical Intussusception Vasoepididymostomy: Cost-Effective Options for Obstructive Azoospermia."

# # #

THE COUPLE'S GUIDE TO FERTILITY

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Unblocking Ducts

Blocked ducts in a man's reproductive tract contribute to another 10 percent of male infertility. Half of these men are born with abnormal or missing ducts, such as an absent vas deferens or an abnormal epididymis. The other half have acquired blockages, most commonly due to scarring from infections with gonorrhea or chlamydia. If the epididymis becomes infected on both testicles, or if a man has only one healthy, functioning testicle and its epididymis becomes infected, this tiny tube may become blocked and the man may become completely sterile.

New microsurgical techniques have dramatically improved the results in repairing a blocked epididymis. In Dr. Goldstein's latest studies, sperm reappear in the ejaculate in 83 percent of men, and 40 percent will father a child naturally. Those who don't father a child naturally can be helped with assisted reproductive technologies. Lower fertility rates have to do with how the epididymis functions. When sperm first enter the epididymis, they can't swim and won't penetrate an egg. As the sperm come out the other end of the epididymis, they can swim and penetrate an egg. If the epididymis is damaged and repaired microsurgically, it may still not allow sperm to mature fully and develop their full swimming and fertilizing abilities. IVF with injection of sperm directly into the egg (intracytoplasmic sperm injection, or ICSI) can now help these men impregnate their wives.

Another cause of blocked ducts includes injury to the vas deferens from a hernia repair. From 5 to 17 percent of males who have a hernia repaired suffer a blocked vas. Fortunately, the blockage is usually on only one side. But if hernias are repaired on both sides, or a hernia on the side of the only functioning testicle is repaired, it could damage the vas deferens and cause infertility. These blocked tubes can be repaired microsurgically, and more than half of these men's wives become pregnant.

Vasectomy Reversal

"I thought I never wanted any more kids," recalls Roy, age forty-six, who had a vasectomy at thirty after fathering three children. Then he divorced his first wife and married Dawn, age thirty-seven, and after "spending a lot of time talking about having a child together, we decided to give it a try." A little apprehensive about the vasectomy reversal, Roy had the delicate surgery with no major trouble. He was in the hospital on a Wednesday, rested at home for a few days, and went back to his job at the phone company the next Monday.

Although Roy's reversal operation was a technical success—his tubes were open and healthy—his sperm count remained low a year later. "The doctor told me I had one strike against me since it had been so long since my vasectomy," he says. He and Dawn kept trying anyway, and she got pregnant about a year later, but lost the baby to a miscarriage. "I thought that was our one and only shot," says Dawn. Six months later, Roy was started on hormone treatments. His sperm count rose sharply, and within four months, Dawn was pregnant. Their son, Andy, is now seven and a half years old.

"I'm experiencing more with Andy than when I watched my first three kids grow up," says Roy. "I can enjoy him more. I'm looking forward to being a Little League coach again."

A vasectomy causes sterility by blocking the vas deferens. Each year, about half a million American men choose vasectomy as their primary form of birth control. It can be safely performed as an outpatient procedure with minimal discomfort using local anesthesia. The doctor removes about a one-inch segment of the vas deferens and seals the cut ends of the vas with stitches, heat, or clips.

Inevitably some of the men who had vasectomies have reconsidered and regret their earlier decision. Most men who have had vasectomies and want them reversed are in their late thirties or early forties. These men had children, then divorced, and have now remarried, usually to younger women who do not have children of their own.

Another group of men who regret having undergone vasectomy are those in their early thirties who put off marriage and having children. Now these socially conscious men have married and they want children.

Still others want their fertility restored in response to improved financial status, allowing the couple to afford more children, or the improved health of either the man or the woman.

Urologic microsurgeons can perform the delicate sterilization reversal surgery. Before the introduction of microsurgery, less than 25 percent of the approximately three thousand men who had vasectomy reversals were able to impregnate their wives. Microsurgical repair of the vas has more than doubled the success rate. With recent publicity about greater successes, more of the nearly 17 million men who have had vasectomies are seeking reversals.

The length of time since the vasectomy has some effect on the success of a reversal operation. The more years that have passed since vasectomy, the lower the natural pregnancy rates after microsurgery. If the reversal is performed within a decade of vasectomy by an expert reproductive microsurgeon, more than 90 percent of men have sperm return to their ejaculate. In the more than 1,250 vasectomy reversals he has performed, Dr. Goldstein's overall return of sperm rate is 96 percent and the pregnancy rate is 63 percent for all men who have fertile wives. This includes men who have blockages of the epididymis. For those who had the sterilization procedure less than five years ago, the pregnancy rate is 73 percent. A man who had a vasectomy more than ten years ago should know that his odds of success are good but lower.

A new technique for vasectomy reversal developed by Dr. Goldstein increases the chances for fertility. The Microdot technique facilitates more accurate placement of sutures, which, in turn, helps to secure a leak-proof reconnection of the vas deferens. Like an architect making a blueprint before building a building, Dr. Goldstein makes a blueprint before performing the microsurgery. Using an operating microscope that magnifies this tiny duct thirty times and a microscopic marking pen, he places six dots at 1, 3, 5, 7, 9, and 11 o'clock positions. Then he reattaches the vas deferens by lining up the dots with six sutures for each of four separate layers.

The challenge faced by microsurgeons for a vasectomy reversal is to reattach two widely discrepant sides of the vas deferens without gaps in order to prevent sperm leakage. The Microdot technique facilitates this process. As a result, Dr. Goldstein's overall success rate for return of sperm to the semen after vasectomy reversal has increased to 99.5 percent using the Microdot technique for men who have sperm found in at least one vas at the time of the surgery.

Dr. Goldstein also has imported a Chinese technique to do a quicker, less painful vasectomy without a scalpel that also is highly reversible. He makes a tiny puncture in the scrotum, pulls the vas deferens out, cuts it and seals both ends with heat, then slips the tube back in. There are no stitches and little blood. The no-scalpel vasectomy takes ten minutes or less and the man can return to work the same day.

In contrast, a crudely performed vasectomy can damage the nerve supply of the vas deferens and possibly compromise its function, making a vasectomy reversal less successful. Also, if too much of the vas has been removed, a reversal is more difficult.

In addition to blocking the vas deferens, a vasectomy may also later result in a block of the epididymis. Between 30 and 50 percent of vasectomies ultimately result in ruptures of the epididymis and a secondary obstruction in that tiny tube. In order to repair the obstruction, the urologic microsurgeon must open up the epididymis to allow a free flow of fluid and sperm through it and reconnect it to the vas deferens. This is a much more difficult procedure than the standard microsurgical vasectomy reversal because the epididymis is considerably thinner and more delicate than the muscular vas deferens. Nevertheless, in the hands of a skilled microsurgeon using newer microsurgical techniques, the damaged epididymis can be repaired with more than 80 percent return of sperm to semen. Pregnancy rates, however, are in the 40 to 50 percent range, lower than that of men who have a vasectomy reversal and no epididymis obstruction.

In some men after vasectomy, sperm leak from the vas, provoking an inflammatory reaction. The immune system responds by forming a nodule, called a sperm granuloma, at the vasectomy site. The end of the vas forms a network of pockets and channels that trap the sperm. This small knot of tissue, from pea to grape size, relieves the pressure on the epididymis and protects that delicate tube. Men with a sperm granuloma have a better chance of pregnancy after a reversal.

Vasectomy may also lead to the production of antisperm antibodies, which play a significant role in those men who have reasonably good sperm counts after reversal surgery, yet can't get their wives pregnant. Up to two thirds of vasectomized men develop antibodies that can interfere with sperm motility and fertilizing capability. This problem can sometimes be overcome by treatment with steroid medications to reduce antibody production and with sperm washing and separation procedures, followed by artificial insemination into the uterus. If this doesn't work, then ICSI is a very successful treatment for sperm antibodies.

Marc Goldstein, M.D., F.A.C.S.

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(April 13, 2022) **Marc Goldstein, MD, DSc (hon), FACS** is the Matthew P. Hardy Distinguished Professor of Reproductive Medicine, and Urology at Weill Cornell Medical College of Cornell University; Surgeon-in-Chief, Male Reproductive Medicine and Surgery; and Director of the Center for Male Reproductive Medicine and Microsurgery at the New York Presbyterian Hospital Weill Cornell Medical Center. He is Adjunct Senior Scientist with the Population Council's Center for Biomedical Research, located on the campus of Rockefeller University.

Dr. Goldstein is the only male infertility specialist cited in the American Health Magazine special issue on ***The Best Doctors in America*** and is listed in the *New York Times Magazine* ***Super Doctors*** (2015-2018). He is listed in the books ***Best Doctors in America*** (2017), The Castle Connolly Guide ***America's Top Doctors*** (2018 for fourteen consecutive years), ***How to Find the Best Doctors***, New York Metro Area (2017), as well as ***America's Top Surgeons*** (2017). He is a board certified urologic surgeon and member of a dozen national and international medical societies dealing with male infertility and reproduction. He is Past-President of the Society for Male Reproduction and Urology of the American Society for Reproductive Medicine, and recipient of the 1997 ***Master Teacher in Urology Award*** and the 2002 ***Distinguished Alumni Achievement Award*** from his alma mater. He has been honored by RESOLVE and the American Infertility Association for his "***Outstanding Dedication and Commitment to Family Building,"*** and was the recipient of the 2007 ***Lifetime Achievement Award*** of The American Fertility Association. He received an ***honorary Doctor of Science*** in 2008 from the State University of New York, Downstate Medical Center. In 2009, he received the ***John Coleman, M.D. Teaching Award*** from the Department of Urology at Weill Cornell Medical College. On the occasion of SUNY Downstate's 150th anniversary in 2010, he was named one of the 150 most distinguished graduates in the history of the Medical College. He is the recipient of the 2016 ***Distinguished Surgeon Award*** from the Society of Reproductive Surgeons, the **2017 Kavoussi Family Outstanding Teacher Award** of the American Society of Reproductive Medicine and the recipient of the **2018 Distinguished Reproductive Urology Award** from the Society for the Study of Male Reproduction. Dr. Goldstein presented the **2021 American Urological Association Bruce Stewart Memorial Lecture at the Annual Meeting of the American Society of Reproductive Medicine**.

Dr. Goldstein is internationally renowned for his pioneering work in vasectomy reversals and microsurgical repair of varicoceles and blockages. He has performed over 1,000 microsurgical vaso-vasostomies and vaso-epididymostomies, yielding the highest peer-reviewed journal reported sperm return and pregnancy rates. He developed a microsurgical technique of varicocelectomy in 1984 and has performed over 4,500 cases with the lowest reported failure and complication rates. He was the first American surgeon to be trained in, and perform, the Chinese method of No-Scalpel Vasectomy. He has introduced the microsurgically assisted inguinal hernia repair which significantly reduces complications and failures.

Dr. Goldstein has authored or co-authored over 330 journal articles, book chapters and books. He is the author of ***Surgery of Male Infertility,*** the first textbook on the subject. He is co-author of **The Couple's Guide to Fertility** (Broadway/Random House 2001, 3rd edition), **The Vasectomy Book** (Houghton Mifflin), **Reproductive Medicine Secrets** (Hanley & Belfus, 2004), **A Baby at Last** (Simon & Schuster 2010), and, with Peter Schlegel, **Male Infertility** (Cambridge University Press, 2013). He is on the editorial board of the medical journals ***Microsurgery*** and ***Fertility and Sterility***. He has also been featured in interviews on numerous major media outlets including NBC's ***The Today Show***, ABC's ***Good Morning America***, ABC's ***Eyewitness News, Newsweek***, ***The Wall Street Journal*** and ***The New York Times.***

A ***summa cum laude*** graduate of the College of Medicine, State University of New York – Downstate Medical, Dr. Goldstein was an intern and resident in general surgery at Columbia Presbyterian Medical Center in New York. After three years overseas in the U.S. Air Force, attaining the rank of Major and flying in F4 Phantom aircraft as a Flight Surgeon, Dr. Goldstein was trained in urology at Downstate Medical Center. He continued his post-graduate training in reproductive physiology as an AUA scholar at the Population Council, Center for Biomedical Research, located on the campus of Rockefeller University, and at the Rockefeller University Hospital.

Drawing on his Air Force experience, Dr. Goldstein was one of the first surgeons to routinely employ checklists in the operating room to reduce errors and complications.

Dr. Goldstein is an admirer of the late, great physician, Sir William Osler, whose motto was, **"Do the kind thing, and do it first,"** and said, **"The secret of good patient care is caring for the patient."**

Dr. Goldstein is a long distance runner and triathlete who races regularly and has completed over 20 triathlons and duathlons, and 20 New York City Marathons.

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