Received: 29 March 2018 | Accepted: 22 April 2018

DOI: 10.1002/rmb2.12207

REVIEW ARTICLE

WILEY Reproductive Medicine and Biology

Vasovasostomy and vasoepididymostomy: Review of the procedures, outcomes, and predictors of patency and pregnancy over the last decade

Takeshi Namekawa | Takashi Imamoto | Mayuko Kato | Akira Komiya | Tomohiko Ichikawa

Department of Urology, Graduate School of Medicine, Chiba University, Chiba, Japan

Correspondence
Takeshi Namekawa, Department of Urology, Graduate School of Medicine, Chiba University, Chiba, Japan.
Email: takeshi.namekawa@gmail.com

Abstract

Background: In the era of improving assisted reproductive technology (ART), patients with obstructive azoospermia (OA) have 2 options: vasal repair or testicular sperm extraction with intracytoplasmic sperm injection. Vasal repair, including vasovasostomy (VV) and vasoepididymostomy (VE), is the only option that leads to natural conception.

Methods: This article reviews the surgical techniques, outcomes, and predictors of postoperative patency and pregnancy, with a focus on articles that have reported over the last 10 years, using PubMed database searches.

Main findings: The reported mean patency rate was 87% and the mean pregnancy rate was 49% for a patient following microscopic VV and/or VE for vasectomy reversal. Recently, robot-assisted techniques were introduced and have achieved a high rate of success. The predictors and predictive models of postoperative patency and pregnancy also have been reported. The obstructive interval, presence of a granuloma, and intraoperative sperm findings predict postoperative patency. These factors also predict postoperative fertility. In addition, the female partner's age and the same female partner correlate with pregnancy after surgery.

Conclusion: In the era of ART, the physician should present and discuss with both the patient with OA and his partner the most appropriate procedure to conceive by using these predictors.

KEYWORDS

male infertility, obstructive azoospermia, vasectomy reversal, vasoepididymostomy, vasovasostomy

1 | INTRODUCTION

In the era of improving assisted reproductive technology (ART), patients with obstructive azoospermia (OA) have 2 options, vasal repair or testicular sperm extraction (TESE) with intracytoplasmic sperm injection (ICSI), to achieve fertility.[1] Vasal repair, including vasovasostomy (VV) and vasoepididymostomy (VE), is the only option that leads to natural conception. In the USA, it is estimated that 175 000-354 000 men undergo a vasectomy each year.[2] However, ≤6% of patients who undergo a vasectomy request a reversal procedure.[3]

Therefore, the vasectomy is the most common cause of OA in the USA. Similarly in Japan, vasectomy reversal (VR) accounts for the largest portion of the reasons for seminal tract reanastomosis.[4,5] Childhood inguinal herniorrhaphy is also a common cause of seminal tract obstruction. Secondary epididymal obstruction, which is caused by a relatively long-term vasal obstruction, is a common cause of lower patency, compared with VV due to a vasectomy in adults.[6]

In 1902, the first human vasal repair was conducted by performing a VE on a patient with obstruction secondary to epididymitis.[7] Later, the first successful VV was reported in 1919.[8] In 1977, others independently reported the success of the microscopic VV (MVV)[9,10] and also that the microscopic approach improved the patency rate and the natural pregnancy rate.[11] After their reports, the MVV became common and further modified techniques were reported.[12] The Vasovasostomy Study Group published a landmark multicenter study on the outcomes of 1469 patients who underwent a VR in 1991.[13] It showed that the rates of patency and pregnancy reached 86% and 53%, respectively, following a microscopic VR. In recent years, robot-assisted VV (RAVV) was reported as a newer procedure[14] and it might contribute to improved outcomes. With a marked improvement in reproductive techniques, the number of treatment options for couples who are challenged with male infertility has increased. Determining the predictors of patency and pregnancy is important for patients with a prior vasectomy or obstructive azoospermia when they are seeking surgical reversal.

This article reviews the surgical techniques, outcomes, and predictors of postoperative patency and pregnancy, with a focus on articles reported over the last 10 years.

2 | INDICATIONS

The indications for VV and VE include the treatment of OA due to traumatic or iatrogenic vasal injury (such as during a hernia repair, orchidopexy, or hydrocelectomy), the hope to have more children by vasectomized men (remarriage or after the death of a child), or treatment of postvasectomy pain. When these patients wish for a child, they have alternative choices, including TESE or microsurgical epididymal sperm aspiration with ICSI. Some reports suggest that the most cost-effective approach to the treatment of postvasectomy infertility is microsurgical VR (MVR). This treatment also has the highest chance of resulting in the delivery of a child for a single intervention.[15,16] Female fertility factors, especially age, also are correlated with the pregnancy rate after vasal reanastomosis.[13] Therefore, the physician should present and discuss with both the patient and his partner the choice between vasal reanastomosis and ART, according to whether the couple plans to have one or more children, as well as the comparative costs of the 2 options.[17] Although a VR appeared to be beneficial for relieving pain in the majority of select patients with postvasectomy pain syndrome, physicians should offer counseling or more conservative methods of pain management before proceeding with a VR.[18,19] In the patients following a vasectomy, the indication of a VV or VE is decided according to the intraoperative findings. The criteria are discussed in detail later in this review. In contrast, in the patient with OA that is caused by the epididymis or an unknown etiology, the VE may be selected as the first choice.

3 | PREOPERATIVE EVALUATION

A complete history should be performed prior to proceeding with surgical intervention. Attention should be paid to the duration of time since the vasectomy, any prior inguinal (hernia repair) or scrotal surgery, any postvasectomy complication, the age of the female partner, and any potential female factor that is contributing to infertility.[20,21] Along with routine preoperative tests, a careful genital examination should be performed. The physical examination includes the size of the testicles, a palpable vasal defect, the presence of a sperm granuloma, and if possible, the length of the testicular vasal segment. In addition, determining the presence of a varicocele is important because a varicocelectomy can be performed alongside the VR in selected cases.[22] Formal vasography rarely is necessary. In laboratory investigations, the measurement of the gonadotropin and testosterone levels should be considered for patients with small testes, a history of abnormal semen analysis, or impaired sexual function. As will be described later, the importance of antisperm antibody is still controversial for predicting postoperative outcomes.

4 | ANESTHESIA

Although a VV or VE may be performed by using local, regional, or general anesthesia, general anesthesia is chosen in many cases.[21] One study recommended that local anesthesia alone is a suboptimal anesthetic choice for the patient who meets the following conditions: a short interval to reversal, easily palpable vasal ends, and cooperative and free of anxiety.

5 | PLACEMENT OF THE INCISION

The patients are placed in the supine position on the operating table. A VR is usually performed through high bilateral vertical scrotal incisions on each side. Generally, the incision is made ~1 cm lateral to the base of the penis. An extension of this incision toward the external ring can be undertaken easily as needed. This incision easily provides the delivery of the testis in cases of VE. When the level of obstruction is within the inguinal vas, as in patients with prior orchidopexy or herniorrhaphy, it could be necessary to extend the scrotal incisions upward into the lower inguinal region or to use an infrapubic incision.[23] When choosing these incisions, the surgeon must pay attention to the amount of tension that will be placed on the anastomosis when the exposed portions are returned to their natural anatomic position.

6 | PREPARATION OF THE VAS DEFERENS

Once the incision is made, the first step is to prepare the vas deferens and gain an adequate vasal length to avoid tension on the anastomosis. The vasal ends then should be cut at a 90° angle to allow for a precise anastomosis. To assess the patency of the abdominal vasal end, the surgeon intubates the abdominal end and secures a watertight seal with a 24 gauge angiocatheter on a 1 mL syringe filled with saline. The saline is injected gently; if there is no resistance and the fluid does not return, then patency can be assured. The testicular end of the vas deferens then should be evaluated for the presence of sperm. The vasal fluid from the testicular end should be collected on a glass slide. The macroscopic examination includes fluid opacity and viscosity and the microscopic examination looks for the quantity and quality of the sperm, including motility, sperm parts, and any deformity. When there is no sperm on the intraoperative semen analysis and reanastomosis is abandoned, surgeons may choose other options, such as TESE and sperm cryopreservation. They should mention and discuss the possibility with the patient before the operation.

7 | CHOICE OF THE VASOVASOSTOMY OR VASOEPIDIDYMOSTOMY

The quality of the sperm that is observed in the vasal fluid is important in order to decide on the procedure. The sperm quality generally is categorized according to the Silber scale, as follows[9]: Grade 1: mainly normal motile sperm; Grade 2: mainly normal non-motile sperm; Grade 3: mainly sperm heads; Grade 4: only sperm heads; and Grade 5: no sperm. Patency rates of 94%, 91%, 96%, 75%, and 60% have been reported among men with Silber scores of Grade 1, Grade 2, Grade 3, Grade 4, and Grade 5, respectively. Therefore, the VV is performed when sperm of grades 1-3 are identified in the fluid that has been obtained from the testicular end of the vas deferens. Whether the VV is indicated for the patient with Grade 4 sperm is still controversial. It was shown that the presence of sperm parts, compared to whole sperm, does not adversely affect the patency rates after a VV. It was argued that the VV should be performed if any sperm part is identified in the intravasal fluid.[24] In contrast, another study suggested that, if only an occasional sperm head is noted in the vasal fluid, then the surgeon should consider the VE.[25]

8 | PREOPERATIVE PREDICTORS ASSOCIATED WITH THE NEED FOR A VASOEPIDIDYMOSTOMY

As the VE is a more technically challenging procedure than the VV, the VE should be performed by a urologist with experience in microsurgical techniques. For that reason, some urologists use certain general screening guidelines to preoperatively identify those patients who might need a referral to an experienced VE surgeon. Previous studies have determined the predictors for performing a VE. Table 1 summarizes these factors that have been reported over the last 10 years.[26-29]

As the obstructive interval increases, the likelihood of needing a VE increases in several studies.[26,28,29] One study evaluated 1229 patients to define how the prevalence of an epididymal blowout and the need for a VE at reversal changes over a broad spectrum of vasectomy time intervals.[28] The rate of unilateral (VV or VE) or bilateral VE increased linearly with vasectomy intervals of 1-22 years at 3% per year, but plateaued at 72% with vasectomy intervals of 24-38 years. In addition, the sperm counts were maintained with increasing time after the vasectomy, but the motile sperm counts decreased significantly. The hypothesis was that sperm production is impaired by prolonged obstruction and that protective mechanisms ameliorate epididymal "blowout." Another study reported other factors that predict the need for a VE, including the patient's age (odds ratio: 1.11) and repeat VRs (odds ratio: 5.78).[29] An increased epididymal T1 signal intensity on the preoperative magnetic resonance imaging suggests vassal or epididymal tubular occlusion and the need for a VE rather than a VV.[27]

In 2005, Parekattil, Kuang, Agarwal, and Thomas first devised a model to predict the need for a VE by using the obstructive interval and patient's age.[30] The equation for the model is: VE prediction score = (age × 0.31) + (obstructive interval × 0.94). If the prediction score is >20, then a VE (one or both sides) is predicted.

TABLE 1 Preoperative predictors that are associated with the need for a vasoepididymostomy

First author	Year	Patient number	VE rate (%)	Predictor	*P*-value
Fenig[26]	2012	271	33	Obstructive interval	<.001
				Presence of granuloma	—
McCammack[27]	2014	24	—	MRI findings	.010
Mui[28]	2014	1229	33	Obstructive interval	.010
Fuchs[29]	2016	2697	26	Patient's age	<.001
				Obstructive interval	<.001
				Repeat vasectomy revearsal	<.001
				Procedure number	.010

MRI, magnetic resonance imaging; VE, vasoepididymostomy.

However, this model was validated externally by a different study and was not a reliable predictor in that patient population.[31] To better predict the need for a VE, one study created a nomogram that was based on preoperative patient characteristics, including the obstructive interval and the presence of sperm granuloma.[26]

9 | ANASTOMOSIS METHODS

For a VV anastomosis, the procedures include a modified 1-layer and multilayer technique. In the modified 1-layer anastomosis, four to eight 9-0 nylon sutures are placed through all layers of the vas deferens to bring the 2 ends together and an additional layer of interrupted seromuscular 9-0 nylon sutures are placed in between the full-thickness sutures.[32] During the 2-layer technique, 5-8 interrupted 10-0 nylon sutures first are placed in the inner mucosal edges of the ends of the vas deferens, incorporating a small portion of the inner muscular layer, and then 7-10 additional interrupted 9-0 nylon sutures are placed in the seromuscular layer.[9] One study reported that there was no difference between the modified 1-layer and double-layer techniques in the percentage of patients postoperatively who obtained a normal sperm count and pregnancy.[33] In addition, another study showed that the modified 1-layer VV resulted in shorter operative times and lower costs than the double-layer technique.[34]

The VE is performed most commonly by using an end-to-side anastomosis.[35] Surgeons initially should deliver the testis into the field and locate the area of obstruction, which typically lies in the cauda epididymis. Once the area is identified, a dilated tubule that is proximal to the obstruction is identified. When the surgeon makes an incision of the epididymal tube and collects sperm, sperm cryopreservation should be considered. The vas mucosa is approximated to the opened edges of the epididymal tubule with 4-6 interrupted 10-0 nylon sutures and the outer muscular layer of the vas deferens is approximated to the incised edges of the epididymal tunic with 7-10 interrupted 9-0 nylon sutures. To simplify the procedure, an alternative technique, "longitudinal intussusception VE," was developed.[36] In the tubular intussusception technique, 4 microdots are placed on the vasal ends to mark the placement of the sutures on the vas deferens. After securing the vas deferens with 9-0 nylon sutures to the edge of the tunica epididymis, 2 double-armed 10-0 nylon sutures are placed in parallel in the epididymal tubule. After the tubulotomy, the needles are pulled through and placed through the 4 microdots on the vasal ends in an inside-out fashion. Then, the outer layer of 9-0 nylon sutures completes the anastomosis. One study proved the benefit of the intussusception VE technique. The late failure rate is lower with the use of the intussusception technique (4%), compared with the non-intussusception technique (37%).[37]

10 | POSTOPERATIVE MANAGEMENT

Surgeons should advise their patients to use a scrotal supporter for 6 weeks and to avoid heavy physical activity for ~3-4 weeks, as well as to avoid sexual activity for at least 4 weeks after surgery. Postoperative pain generally can be controlled adequately with oral analgesics. Semen analyses are performed at 2, 4, and 6 months postoperatively. For the patients who have the risk of reobstruction, such as VE cases, sperm cryopreservation should be performed at the same time of the postoperative semen analysis. If azoospermia persists at 6 months, a revision of the VV should be considered.

11 | OUTCOMES

The outcomes of the VV and VE that have been reported over the last 10 years are summarized in Table 2.[6,28,34,38-46] The number of patients ranged from 25 to 1303. The mean age was 40 years, the mean obstructive interval was 8.5 years, the mean operative time was 114 minutes, the mean patency rate was 87% (range: 80%-98%), and the mean pregnancy rate was 49% (range: 22%-68%) in the patients who underwent a MVV and/or microscopic vasoepididymostomy (MVE) for a VR. The high patency rates after a VV and VE have been reported by experienced surgeons using microsurgical techniques in patients with OA following a vasectomy over the past decade.

Owing to long-term obstruction and a difficulty in finding the vas deferens, the patency and pregnancy rates are relatively low in patients with OA following childhood herniorrhaphy. A study reported that the postoperative patency rate was 56.5% and the natural pregnancy rate was 25.8% in patients with OA following an inguinal hernia repair.[6] Another study improved the success rate in these patients by using laparoscopic techniques.[46] If the vas deferens was not detected in the inguinal region, a laparoscopy was used to mobilize the remnant of the intra-abdominal vas deferens and deliver it to the inguinal region for a VV. In this study, the overall patency and natural pregnancy rates were 87.5% and 42.5%, respectively. With an improvement in the operative procedure for infantile inguinal hernia, the number of patients with OA following a herniorrhaphy will decrease. Actually, the ratio of patients with OA that was caused by an inguinal herniorrhaphy decreased significantly in 2013 (9%), compared to 2000 (25%), in Japan.[4]

12 | NEW INVENTIONS IN MICROSCOPIC VASOVASOSTOMY AND VASOEPIDIDYMOSTOMY

12.1 | Mini-incision microscopic vasovasostomy

In order to reduce the morbidity of the VR, one study introduced techniques to perform a MVR through a mini-incision in the scrotum.[47] A no-scalpel vasectomy technique was applied to the mini-incision MVV.[48,49] The vas deferens was grasped through the skin with the no-scalpel vasectomy ring forceps and a 1 cm incision was made through the skin and dartos directly on top of the elevated vas deferens. This procedure enabled the surgeons to exteriorize the vas deferens from the small incision. The same group evaluated

TABLE 2 Operative outcomes of the vasovasostomy and the vasoepididymostomy

First Author	Year	Patient number	Mean patient's age (years)	Mean obstructive interval (years)	Surgical procedure	Anastomosis method	Operative time (min)	Patency rate (%)	Pregnancy rate (%)
Bolduc[38]	2007	747	37	6.8	MVV	1 layer	–	86	33
Patel[39]	2008	106	40	8.2	MVV	1 layer/2 layer	–	98	–
Jee[40]	2010	25	39	7.1	MVV	1 layer	106	96	40
		25	39	6.9	LAVV	1 layer	78	72	28
Peng[41,a]	2011	73	31	–	MVE	LIVE	–	72	33
Parekattil[42]	2012	28	–	–	MVV	2 layer	97	80	–
Schwarzer[43]	2012	1303	41	8.2	MVV/MVE	3 layer	110	89	59
Li[44]	2013	34	39	9.2	MVV/MVE	2 layer	120	94	68
Mui[28]	2014	1229	41	10.0	MVV/MVE	1 layer/2 layer	–	84	–
Chen[6,a]	2014	62	31	–	MVV/MVE	2 layer	–	57	29
Kavoussi[45]	2015	27	–	–	MVV/MVE	1 layer/2 layer	141	89	22
Nyame[34]	2016	86	40	8.0	MVV	2 layer	165	89	–
		20	43	9.5	MVV	1 layer	120	93	–
Wang[46,a]	2017	56	28	24.1	MVV	2 layer	–	88	43

LAVV, loupe-assisted vasovasostomy; LIVE, longitudinal intussusception vasoepididymostomy; MVE, microscopic vasoepididymostomy; MVV, microscopic vasovasostomy.
[a]Report for only the patients with obstructive azoospermia following childhood herniorrhaphy.

the efficacy and postoperative morbidity of a mini-incision MVV, compared with traditional incisional approaches.[50] The patency rate was 96% and 91% for the mini-incision MVV and bilateral traditional incision, respectively. The level of pain severity during the first 48 h after surgery was significantly less ($P = .05$) for those patients who had undergone the bilateral mini-incision MVV than for the patients who had undergone the traditional incision. Another study introduced a less invasive approach for the MVE.[51] A 1.0-2.0 cm incision was made on the scrotal skin directly over the palpable defect at the vasectomy site and a no-scalpel vasectomy ring clamp was used to grasp the vas deferens. Then, the testis was pushed under the incision and the tunica was opened, providing access to the epididymis. A Babcock clamp was placed carefully around the distal portion of the epididymis to elevate and fix the epididymis in place just outside the skin incision. With these original approaches, mini-incision MVV was performed.

12.2 | Robot-assisted vasovasostomy and vasoepididymostomy

Robot-assisted procedures continue to expand in the urological field, including robot-assisted laparoscopic radical prostatectomy (RALP), robot-assisted laparoscopic partial nephrectomy, and robot-assisted laparoscopic radical cystectomy.[52-54] In Japan, the RALP was approved in 2012 and it now has become part of the standard armamentarium in the management of prostate cancer.[55,56] Additionally, studies that have examined the potential of robot-assisted microsurgical approaches have even been performed for ocular surgery, cardiovascular surgery, and plastic surgery for performing microvascular anastomoses.[57-59] In 2004, in vivo RAVV on 2 patients was first reported.[14] Another group reported the details of the RAVV operation on a 34 year old man by using the da Vinci robotic system for a VR.[60] They reported that the vasovasal anastomosis was performed by using a 1-layer technique with a single-armed 8-0 Prolene suture. The operating time was 120 minutes and the semen analysis after 3 months showed 120×10^6 viable spermatozoa per mL. As these initial cases were reported, some institutes also reported the operative outcomes of RAVV and robot-assisted vasoepididymostomy (RAVE).[42,45,61,62]

For a VR, the patients are placed in the supine position on the operating table. Paramedian incisions are made bilaterally and the vasal defects are identified and exposed. The vasal fluid is aspirated and analyzed for the presence of sperm. To confirm vasal patency, the lumen is cannulated by using a small angiocatheter and sterile saline is injected. The da Vinci robot (Intuitive Surgical, Sunnyvale, CA, USA) is docked alongside the operating table. A zero-degree lens is used and 2 black diamond forceps are attached as needle drivers. Some surgeons performed a 1-layer anastomosis.[45,61,62] The vasal anastomosis was completed by using 9-0 nylon sutures incorporating both the mucosal and serosal layers. One study reported the 2-layer anastomosis method, in which 9-0 nylon sutures are used for the muscularis layer of the vas deferens and double-armed 10-0 nylon sutures are placed to anastomose the mucosal lumen.[42]

TABLE 3 Operative outcomes of robot-assisted vasovasostomy and vasoepididymostomy

First Author	Year	Patient number	Mean patient's age (years)	Mean obstructive interval (years)	Surgical procedure	Anastomosis method	Operative time (min)	Patency rate (%)	Pregnancy rate (%)
Santomauro[61]	2012	20	33	5.5	RAVV	1 layer/2 layer	184	92	—
Parekattil[42]	2012	66	—	—	RAVV	2 layer	120	96	—
Kavoussi[45]	2015	25	—	—	RAVV/RAVE	1 layer/2 layer	150	92	28
Marshall[62]	2017	60	35	5.7	RAVV	1 layer	192	88	—

RAVE, robot-assisted vasoepididymostomy; RAVV, robot-assisted vasovasostomy.

The RAVV has a short history as an operative method for vasal reanastomosis; thus, there are only a few reports with a small number of patients. Table 3 shows the outcomes of the RAVV and RAVE.[42,45,61,62] The number of patients ranged from 20 to 65 years in these studies. The mean operative time was 157 minutes (range: 120-191 minutes) and the mean patency rate was 92% (range: 88%-96%). A study compared the operative outcomes between the RAVV and MVV.[42] The median operative time was significantly decreased by using the RAVV, at 97 minutes, compared with the MVV, at 120 minutes ($P < .05$). Additionally, the patency rate was 96% for the RAVV and 80% for the MVV cases; there was a significant difference between the 2 groups ($P < .05$). It was suggested that the RAVV might have a potential benefit over the MVV with regards to decreasing the operative time and improving the patency rate. It was considered that robot assistance has potential advantages, including ergonomic surgeon instrument control, the elimination of tremor, and magnified immersive 3-dimensional vision. These features might provide surgeons with an advantage in performing complex microsurgical anastomoses. One group also validated robot-assisted vasectomy reversal (RAVR), including RAVV and RAVE.[45] In the report, there was no significant difference in the operative duration between the RAVR group (150 minutes) and the MVR group (141 minutes) ($P = .3$). Additionally, there was no difference between the 2 groups in postoperative patency. However, it was argued that the principles of microsurgery were being applied to robot-assisted microsurgery and what is learned of tissue handling microsurgically is easily translated to robotic microsurgery. Therefore, it was considered that a surgeon who is trained in both RAVV and MVV is best suited for vasal anastomosis in order to shorten the operative time and improve the patency rate. Additionally, the learning curve for robotic surgery seems to be shorter than for microsurgery and previous experience in microsurgery does not affect the curve.[63,64] This advantage is a boon to urologists who lack opportunities for microsurgery.

For the treatment of bilateral vasal obstruction that occurs following bilateral inguinal hernia repairs, Trost, Parekattil, Wang, and Hellstrom first performed intracorporeal RAVV.[65] The patients were placed in the dorsolithotomy position on the operating table and robotic trocars were placed in a manner similar to robot-assisted prostatectomy. Each vas deferens was identified and dissected intra-abdominally from the level of the internal inguinal ring to the obturator nerves. Then, each vas deferens was transected at the most distal extent of the internal ring. The external proximal vasal segments were passed into the peritoneal cavity through the new cavity. To limit motion, 5-0 polypropylene sutures were placed in the adventitial layer of the proximal and distal vasa and the pelvic side wall and a 2-layer anastomosis was performed intracorporeally using 10-0 or 9-0 sutures. The total operative time was 278 minutes and there was no intraoperative complication. Eight weeks after the operation, the patient was evaluated and the semen analysis demonstrated a volume of 5.4 mL, 8.4 million sperm per mL, and a total sperm count of 45.4 million. An inguinal obstruction after a herniorrhaphy represents a challenging clinical scenario for traditional open microscopic techniques. Laparoscopic-assisted techniques were described to harvest and extracorporealize the intra-abdominal vas deferens and improved results were reported. However, the laparoscopic approach has limitations, particularly in cases of an inadequate intra-abdominal vasal length. The RAVV maintains the advantages of the laparoscopic approach and it gives the surgeon flexibility to adapt the procedure, based on patient characteristics.

One of the potential problems of robot-assisted microsurgery is the formidable cost of the da Vinci robotic system itself and its annual maintenance fee. One study reported that the group tried to come to an understanding with its community-based hospital to use the robot in slots when there was less use, such as early morning and late afternoon. It was argued that the average per-case added cost was reduced when more patients underwent robotic surgery.[66]

As the RAVV and RAVE are relatively new methods, there are few reports with a limited number of patients. Further large-scale, prospective, randomized, controlled trials of robot-assisted surgery would give better data to confirm their superiority over traditional microsurgery.

13 | PREDICTORS OF POSTOPERATIVE PATENCY AND PREGNANCY

In 1991, the Vasovasostomy Study Group published a landmark multicenter study on the outcomes of 1469 patients who underwent a VR.[13] It reported that a longer obstructive interval, an absence of a sperm granuloma on physical examination, and the presence of sperm or sperm parts at the time of reversal were associated with the success of a VR. The predictors of postoperative patency and pregnancy that have been reported in recent years are summarized in Table 4.[38,41,67-75] With marked improvement in reproductive techniques, including microscopic epididymal sperm aspiration and TESE in combination with ICSI, the number of treatment options for couples who are challenged with male infertility has increased. Additionally, the most cost-effective approaches to the treatment of postvasectomy infertility are the VV and VE.[15] Therefore, determining the predictors of patency and pregnancy is important for patients with a prior vasectomy or obstructive azoospermia when they are seeking surgical reversal.

13.1 | Predictors of the postoperative patency rate

Some reports show that the intraoperative sperm status, including the gross fluid quality and microscopic characteristics, are strong predictors of postoperative patency.[38,41,67,74] During the operation, the surgeon's decision to proceed with a VV rather than with a VE depends on the gross fluid quality that is expressed from the testicular end of the vas deferens and the microscopic examination of the fluid. In a systematic review and meta-analysis of the reports on the association between the presence of sperm in the intraoperative vasal fluid and patency, it was reported that the odds ratio of postoperative patency was 4.1-fold higher in the presence of intravasal sperm or sperm parts than in their absence.[76] Another study

TABLE 4 Predictors for postoperative patency and pregnancy

First author	Year	Patient number	Surgical procedure	Patency rate (%)	Predictor	*P*-value	Pregnancy rate (%)	Predictor	*P*-value
Bolduc[38]	2007	747	MVV	86	Type of ligature at the vasectomy	.006	53	Identification of intraoperative motile sperm	.004
					Presence of a granuloma	.004		Obstructive interval	.003
					Identification of intraoperative motile sperm	<.001		Same female partner	.002
					Obstructive interval	.005		Previous pregnancy	.020
					—	—		Postoperative semen α-glucosidase	<.040
Gerrard[67]	2007	294	VV/VE	89	Obstructive interval	.019	54	Obstructive interval	.025
					Presence of intraoperative sperm	.001		Presence of intraoperative sperm	0.033
Hinz[68]	2008	212	VV/VE	93	—	—	72	Partner's age	.014
								Silber score	.028
Hinz[69]	2009	351	VV/VE	93	Presence of a granuloma	.029	62	Silber score	.018
Magheli[70]	2009	334	VV/VE	97	—	—	63	Partner's age	.018
Hinz[71]	2010	315	VV/VE	93	—	—	61	Partner's age	.045
								Preoperative serum LH	.030
Hsiao[72]	2011	206	—	—	—	—	25	Preoperative serum FSH	.010
Peng[41]	2012	53	MVE	72	Epididymal fullness	<.001	32	—	—
					Bilateral anastomosis	.024			
					Corpus anastomosis	.004			
					Motile sperm with flowing epididymal fluid	.022			
Ostrowski[73]	2014	3315	VV/VE	—	—	—	60	Same female partner	<.001
Ramasamy[74]	2015	1331	MVV	98	Identification of intraoperative motile sperm	<.001	—	—	—
					Clear gross fluid	.01			
					Surgeon's experience	.014			
Majzoub[75]	2017	139	MVV/MVE	—	—	—	50	Bilateral MVV	.001
								Presence of intraoperative sperm	.001

FSH, follicle-stimulating hormone; LH, luteinizing hormone; MVE, microscopic vasoepididymostomy; MVV, microscopic vasovasostomy; VE, vasoepididymostomy; VV, vasovasostomy.

confirmed the association between the presence of intravasal spermatozoa during a VV and having a successful patency outcome in a large series from 2 experienced surgeons (n = 1331).[74] It also showed that the odds of postoperative patency were ~14-fold higher in the presence of intravasal whole spermatozoa than by having merely sperm fragments or azoospermia. Although these data suggested that the gross fluid quality might be associated with the outcome, in the multivariable analysis, the gross fluid quality became insignificant. Therefore, microscopic visualization of the intravasal spermatozoa might be a more suitable intraoperative examination than a gross quality check to decide to proceed with a VV rather than a VE. However, because microscopic examination of the vasal fluid is not universally performed, certainly some of the failures with a VV might have occurred in patients who actually required a VE because of epididymal obstruction. Of course, performing a VE rather than a VV is an intraoperative decision and it remains difficult to determine before surgery which patients will have epididymal obstruction and will require a VE.[76]

The presence of a sperm granuloma is a classic predictor of postoperative patency.[38,69,77] One study reported that postoperative patency was significantly higher in those patients with a sperm granuloma (93%) than in those without a granuloma (84%) (P = .004).[38] Previous studies demonstrated an association between the presence of a sperm granuloma and the intraoperative finding of better-quality vasal fluid.[78,79] The formation of a sperm granuloma at the vasectomy site reflects a leakage of sperm and a subsequent decrease of intratubular pressure.[80] The pressure-releasing effect of the granuloma as a "pop-off valve" on the proximal duct system could contribute to the potential protection of the epididymis.[81,82]

The obstructive interval has been listed as a predictor of the patency rate since the beginning of VR studies.[13,79,83] The vasectomy has time-dependent adverse effects on the testis, epididymis, and vas deferens.[79,82,84] A study showed a 100% increase in the thickness of the seminiferous tubular walls, a 50% increase in the mean cross-sectional tubular area, and a significant reduction in the mean number of Sertoli cells and spermatids per tubular cross-section in the postvasectomy group, compared with the control group. It was concluded that significant morphologic changes occur in the human testis after a vasectomy.[84] Another study compared the patency rate following a VV with different obstructive intervals by using Kaplan-Meier curve analysis.[38] There was a significant decrease in the patency rate with longer obstructive intervals (P = .005). In this analysis, the patency rate decreased linearly, even among obstructive intervals of <10 years. However, some studies reported that the patency rate after a vasectomy did not change significantly with an increasing obstructive interval, even at intervals that were >10-15 years.[77,85-87] For example, one study reported patency rates of 91% and 89% among men with obstructive intervals of 10-15 years and >15 years, respectively.[77] Similarly, in a series of 535 men who underwent a VR, the study reported patency rates of 95%, 87%, 94%, and 92% among men with obstructive intervals of <10 years, 10-15 years, 15-20 years, and >20 years, respectively.[85] It was argued that, although the obstructive interval has a significant effect on the operative procedure, provided a surgeon is proficient with both the VV and VE, favorable semen parameters and a good patency rate can be achieved in men with an obstructive interval of >10 years.

Surgeons' experience also affects the patency rate as a predictor in relation to the VV and VE.[13] The odds ratio of postoperative patency was 3.8-fold higher in those patients who were operated on by an experienced surgeon (number of operations: 1250 cases) than in those patients who were operated on by an inexperienced surgeon (number of operations: 57 cases).[74]

One group reported a prospective study to evaluate the variables that are associated with a successful outcome of only the VE.[41] It was found that the anastomosis site affected the postoperative patency. The patency rates for anastomoses on the caput, corpus, and caudal were 38.5%, 78.5%, and 100%, respectively. It was considered that the luminal diameters of the epididymal tubules are significantly smaller in the caput epididymis than in the corpus and caudal epididymis. Thus, reconstructive surgery is easier on the corpus or caudal epididymis than on the caput epididymis.

In order to accurately counsel men on the chance of patency after a VV or VE, Hsiao, Goldstein, Rosoff et al were the first to create a nomogram.[88] They incorporated significant preoperative and intraoperative factors into nomograms to predict postoperative patency. The preoperative nomogram was constructed by using the clinical predictors of the obstructive interval, presence of sperm granuloma, testicular volume, history of a previously attempted VR, type of reconstruction performed, and age at surgery. The postoperative nomogram included all of the factors from the preoperative model and also included the gross characteristics of the vasal fluid and the presence of sperm on microscopy at the time of reconstruction. The factors with the greatest effect on patency were the average testicular volume and the obstructive interval. The factor with the least effect was the presence of a sperm granuloma. They performed bootstrapping to validate their nomogram.[89,90] The concordance indices of the nomograms were estimated to be 0.64 and 0.66 for the preoperative and postoperative nomograms, respectively. Among the advantages of using nomograms is the ability to integrate multiple variables, as well as to provide quantification of individual patency outcomes. Their preoperative nomogram might better inform men about their chance of patency when deciding between a VR and sperm retrieval, coupled with in vitro fertilization (IVF).

13.2 | Predictors of the postoperative pregnancy rate

The predictors of the postoperative pregnancy rate have some factors in common with the predictors of patency, as might be expected. They include the intraoperative sperm status and obstructive interval. In addition to these factors, the characteristics of the female partner contribute largely to the postoperative pregnancy rate.

The female partner's age is a strong predictive factor of postoperative pregnancy.[67,68] One study reported that the postoperative

pregnancy rates were 67%, 52%, 57%, 54%, and 14% for patients with a female partner who was aged 20-24 years, 25-29 years, 30-34 years, 35-39 years, and >40 years, respectively.[67] Also performed was a multivariate analysis comparing the 2 groups: patients with a female partner who was aged <40 years old and patients with a female partner who was aged ≥40 years old. The pregnancy rate for the couples with a female partner who was aged ≥40 years (14%) was significantly lower than for those with a female partner who was aged <40 years (56%) ($P = .049$). Previous studies showed a similar tendency. One study reported that the pregnancy rate was 22% and the live birth rate was 17% for patients with a female partner who was aged >37 years.[91] Another study demonstrated decreases in pregnancy and delivery rates with advancing female age, particularly after the age of 35 years.[92] For the female partner who was aged <30 years, 30-35 years, 36-40 years, and >40 years, the pregnancy rates were 64%, 49%, 32%, and 28%, respectively. Similarly, yet another study reported that the pregnancy and ongoing and delivery rates, respectively, were 46% and 46% for a female partner who was aged 35-39 years old and 14% and 7%, respectively, for a female partner who was aged >40 years.[93] The chance of success is similar to that of a single cycle of IVF with ICSI when the female partner is aged ≥35 years old. It also was concluded that these couples should not be eliminated from consideration for reversal simply because the female partner is aged ≥35 years old. It is clear that the pregnancy rates decrease with an increasing female age around the forties. In a retrospective analysis using prospectively collected data for all IVF and ICSI cycles, the delivery rate decreased from 33.3% among women who were aged 30-35 years to 14.8% among women who were aged 40-44 years ($P < .001$).[94] This decrease in the success rate is related to the gonadotropin response and the number of oocytes retrieved, both of which decrease with advancing age.[67,95,96]

It is also important for postoperative infertility to determine whether the patient has the same female partner. The outcomes of clinical pregnancy and live birth rates are higher in men who undergo a VR with the same female partner.[73,97,98] In a large series, 524 of 3135 (17%) patients who underwent a VR had the same female partner as before surgery.[73] The reason for the reversal was the desire for more children in 89% of the couples and the death of a child in 11% of them. All the couples had previous proven fertility. The clinical pregnancy rate in the patients with the same female partner (83%) was higher than in the general VR population (60%) ($P < .0001$). These results could be related to previous proven fecundity as a couple, a shorter time interval since the vasectomy, and emotional dedication.[97,98]

The serum levels of gonadotropins, follicle-stimulating hormone (FSH), and luteinizing hormone (LH) before surgery affect the pregnancy rate after a VV or VE. One study evaluated the preoperative FSH as a predictor of the reproductive outcome in men with suspected subfertility who underwent a VR.[72] The patients were divided into 2 groups, according to a FSH level of <10 U/L or not. On the postoperative semen analysis, there was a higher percentage of sperm with normal forms in the high-FSH group. The natural clinical pregnancy rate was lower in the high-FSH group (14.9%) than in the normal-FSH group (33.6%) ($P = .01$). Additionally, the high-FSH group showed a much higher use of any ART (78.4% vs 54.8%; $P = .0028$). Follicle-stimulating hormone, which is produced in the anterior pituitary gland in response to gonadotropin-releasing hormone, is essential for complete spermatogenesis. Impaired spermatogenesis that is associated with an elevated serum FSH concentration suggests primary damage to the seminiferous tubules.[99] A high FSH level and differential FSH receptor expression in the testicular tissue of patients with idiopathic azoospermia could be associated with the degree of spermatogenesis.[100]

Men with impaired spermatogenesis have a lower fertility rate, even with adequate anastomotic patency and thus they show a higher rate of using ART.[72] The level of preoperative LH is also a potential predictor of pregnancy after a VV or VE.[71] An elevated serum LH concentration suggests primary damage to the Leydig cells.[99] The LH levels increase significantly after a vasectomy, which might prevent normal fertility after men undergo successful rejoining of the cut ends of the vas deferens.[101]

Increased α-glucosidase (AG) in the postoperative semen predicts improved patency and pregnancy outcomes. A study noted a significant association between lower levels of postoperative AG and oligospermia ($P < .02$) and higher levels of AG were significantly correlated with the success rate of pregnancy ($P < .04$).[38] The AG was severely decreased in the semen from vasectomized men and from those with complete obstruction of the genital tract.[102-104] It was considered that a postoperative low AG level reflected residual obstruction.

Antisperm antibodies remain controversial as a predictor of postoperative fertility. They have been considered as a possible causative factor in infertility.[105,106] One study noted a correlation between antisperm antibodies and fertility after a VV.[107] Another study also indicated that the presence of high titers of antisperm antibodies in the semen decreased the probability of achieving a pregnancy.[38] However, some authors argued that there are antisperm antibodies that are not correlated with infertility after a VV and VE.[71,108]

14 | CONCLUSION

The VV and VE are complex microsurgical procedures that have evolved significantly over the past century. High patency and pregnancy rates are reported by experienced surgeons using microsurgical techniques over the past decade. Recently, robot-assisted techniques have been introduced and they also achieve a high rate of success. Some reports have shown the factors that predict the need for a VE. As the VE is a more technically challenging procedure than the VV, patients who need a VE should be referred to an experienced VE surgeon. The predictors and predictive models for postoperative patency and pregnancy have been reported. In the era of ART, the physician should present and discuss with both the patient with OA and his partner the most appropriate procedure to conceive by using these predictors.

DISCLOSURES

Conflict of interest: The authors declare no conflict of interest. *Human rights statement and informed consent:* All the procedures that were followed were in accordance with the ethical standards of the responsible committees on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and its later amendments. *Animal studies:* This article does not contain any study with animal participants that were performed by any of the authors.

ORCID

Takeshi Namekawa http://orcid.org/0000-0002-0054-0985

REFERENCES

1. Palermo GD, Neri QV, Takeuchi T, Rosenwaks Z. ICSI: where we have been and where we are going. *Semin Reprod Med*. 2009;27:191-201.
2. Eisenberg ML, Lipshultz LI. Estimating the number of vasectomies performed annually in the United States: data from the national survey of family growth. *J Urol*. 2010;184:2068-2072.
3. Sandlow JI, Nagler HM. Vasectomy and vasectomy reversal: important issues. [Preface.] *Urol Clin North Am*. 2009;36:xiii-xiv.
4. Taniguchi H, Iwamoto T, Ichikawa T, et al. Contemporary outcomes of seminal tract re-anastomoses for obstructive azoospermia: a nationwide Japanese survey. *Int J Urol*. 2015;22:213-218.
5. Yumura Y, Tsujimura A, Imamoto T, et al. Nationwide survey of urological specialists regarding male infertility: results from a 2015 questionnaire in Japan. *Reprod Med Biol*. 2017;17:44-51.
6. Chen XF, Wang HX, Liu YD, et al. Clinical features and therapeutic strategies of obstructive azoospermia in patients treated by bilateral inguinal hernia repair in childhood. *Asian J Androl*. 2014;16:745-748.
7. Martin E, Carnett JB, Levi JV, Pennington ME. The surgical treatment of sterility due to obstruction at the epididymis; together with a study of the morphology of human spermatozoa. *Univ Pa Med Bull*. 1902;15:2-15.
8. O'Conor VJ. Anastomosis of the vas deferens after purposeful division for sterility. *J Urol*. 1948;59:229-233.
9. Silber SJ. Microscopic vasectomy reversal. *Fertil Steril*. 1977;28:1191-1202.
10. Owen ER. Microsurgical vasovasostomy: a reliable vasectomy reversal. *Aust N Z J Surg*. 1977;47:305-309.
11. Silber SJ. Perfect anatomical reconstruction of vas deferens with a new microscopic surgical technique. *Fertil Steril*. 1977;28:72-77.
12. Dickey RM, Pastuszak AW, Hakky TS, Chandrashekar A, Ramasamy R, Lipshultz LI. The evolution of vasectomy reversal. *Curr Urol Rep*. 2015;16:40.
13. Belker AM, Thomas AJ Jr, Fuchs EF, Konnak JW, Sharlip ID. Results of 1,469 microsurgical vasectomy reversals by the vasovasostomy study group. *J Urol*. 1991;145:505-511.
14. Fleming C. Robot-assisted vasovasostomy. *Urol Clin North Am*. 2004;31:769-772.
15. Pavlovich CP, Schlegel PN. Fertility options after vasectomy: a cost-effectiveness analysis. *Fertil Steril*. 1997;67:133-141.
16. Kolettis PN, Thomas AJ Jr. Vasoepididymostomy for vasectomy reversal: a critical assessment in the era of intracytoplasmic sperm injection. *J Urol*. 1997;158:467-470.
17. Shridharani A, Sandlow JI. Vasectomy reversal versus IVF with sperm retrieval: which is better? *Curr Opin Urol*. 2010;20:503-509.
18. Nangia AK, Myles JL, Thomas AJ. Vasectomy reversal for the post-vasectomy pain syndrome: a clinical and histological evaluation. *J Urol*. 2000;164:1939-1942.
19. Horovitz D, Tjong V, Domes T, Lo K, Grober ED, Jarvi K. Vasectomy reversal provides long-term pain relief for men with the post-vasectomy pain syndrome. *J Urol*. 2012;187:613-617.
20. Patel AP, Smith RP. Vasectomy reversal: a clinical update. *Asian J Androl*. 2016;18:365-371.
21. Herrel L, Hsiao W. Microsurgical vasovasostomy. *Asian J Androl*. 2013;15:44-48.
22. Loughlin KR. Microsurgical vasectomy reversal and varicocele ligation. *Urology*. 1999;53:239-240.
23. Belker AM. Infrapubic incision for specific vasectomy reversal situations. *Urology*. 1988;32:413-415.
24. Sigman M. The relationship between intravasal sperm quality and patency rates after vasovasostomy. *J Urol*. 2004;171:307-309.
25. Kolettis PN, Burns JR, Nangia AK, Sandlow JI. Outcomes for vasovasostomy performed when only sperm parts are present in the vasal fluid. *J Androl*. 2006;27:565-567.
26. Fenig DM, Kattan MW, Mills JN, Gisbert M, Yu C, Lipshultz LI. Nomogram to preoperatively predict the probability of requiring epididymovasostomy during vasectomy reversal. *J Urol*. 2012;187:215-218.
27. McCammack KC, Aganovic L, Hsieh TC, et al. MRI of the epididymis: can the outcome of vasectomy reversal be predicted preoperatively? *Am J Roentgenol*. 2014;203:91-98.
28. Mui P, Perkins A, Burrows PJ, Marks SF, Turek PJ. The need for epididymovasostomy at vasectomy reversal plateaus in older vasectomies: a study of 1229 cases. *Andrology*. 2014;2:25-29.
29. Fuchs ME, Anderson RE, Ostrowski KA, Brant WO, Fuchs EF. Pre-operative risk factors associated with need for vasoepididymostomy at the time of vasectomy reversal. *Andrology*. 2016;4:160-162.
30. Parekattil SJ, Kuang W, Agarwal A, Thomas AJ. Model to predict if a vasoepididymostomy will be required for vasectomy reversal. *J Urol*. 2005;173:1681-1684.
31. Kavoussi PK, Bird ET. Validation of a vasoepididymostomy predictor model: is vasoepididymostomy truly predictable preoperatively? *Fertil Steril*. 2009;92:180-181.
32. Schmidt SS. Vas anastomosis: a return to simplicity. *Br J Urol*. 1975;47:309-314.
33. Sharlip ID. Vasovasostomy: comparison of two microsurgical techniques. *Urology*. 1981;17:347-352.
34. Nyame YA, Babbar P, Almassi N, Polackwich AS, Sabanegh E. Comparative cost-effectiveness analysis of modified 1-layer versus formal 2-layer vasovasostomy technique. *J Urol*. 2016;195:434-438.
35. Thomas AJ Jr. Vasoepididymostomy. *Urol Clin North Am*. 1987;14:527-538.
36. Chan PT. The evolution and refinement of vasoepididymostomy techniques. *Asian J Androl*. 2013;15:49-55.
37. Schiff J, Chan P, Li PS, Finkelberg S, Goldstein M. Outcome and late failures compared in 4 techniques of microsurgical vasoepididymostomy in 153 consecutive men. *J Urol*. 2005;174:651-655; quiz 801.
38. Bolduc S, Fischer MA, Deceuninck G, Thabet M. Factors predicting overall success: a review of 747 microsurgical vasovasostomies. *Can Urol Assoc J*. 2007;1:388-394.
39. Patel SR, Sigman M. Comparison of outcomes of vasovasostomy performed in the convoluted and straight vas deferens. *J Urol*. 2008;179:256-259.
40. Jee SH, Hong YK. One-layer vasovasostomy: microsurgical versus loupe-assisted. *Fertil Steril*. 2010;94:2308-2311.

41. Peng J, Yuan Y, Zhang Z, et al. Patency rates of microsurgical vasoepididymostomy for patients with idiopathic obstructive azoospermia: a prospective analysis of factors associated with patency – single-center experience. *Urology*. 2012;79:119-122.
42. Parekattil SJ, Gudeloglu A, Brahmbhatt J, Wharton J, Priola KB. Robotic assisted versus pure microsurgical vasectomy reversal: technique and prospective database control trial. *J Reconstr Microsurg*. 2012;28:435-444.
43. Schwarzer JU. Vasectomy reversal using a microsurgical three-layer technique: one surgeon's experience over 18 years with 1300 patients. *Int J Androl*. 2012;35:706-713.
44. Li B, Chen G, Wang X. Treatment of failed vasectomy reversal using a microsurgical two-layer anastomosis technique. *Transl Androl Urol*. 2013;2:94-98.
45. Kavoussi PK. Validation of robot-assisted vasectomy reversal. *Asian J Androl*. 2015;17:245-247.
46. Wang J, Liu Q, Zhang Y, et al. Treatment for vas deferens obstruction following childhood herniorrhaphy. *Urology*. 2018;112:80-84.
47. Jarvi K, Grober ED, Lo KC, Patry G. Mini-incision microsurgical vasectomy reversal using no-scalpel vasectomy principles and instruments. *Urology*. 2008;72:913-915.
48. Li SQ, Goldstein M, Zhu J, Huber D. The no-scalpel vasectomy. *J Urol*. 1991;145:341-344.
49. Weiss RS, Li PS. No-needle jet anesthetic technique for no-scalpel vasectomy. *J Urol*. 2005;173:1677-1680.
50. Grober ED, Jarvi K, Lo KC, Shin EJ. Mini-incision vasectomy reversal using no-scalpel vasectomy principles: efficacy and postoperative pain compared with traditional approaches to vasectomy reversal. *Urology*. 2011;77:602-606.
51. Werthman P. Mini-incision microsurgical vasoepididymostomy: a new surgical approach. *Urology*. 2007;70:794-796.
52. Pruthi RS, Nielsen ME, Nix J, Smith A, Schultz H, Wallen EM. Robotic radical cystectomy for bladder cancer: surgical and pathological outcomes in 100 consecutive cases. *J Urol*. 2010;183:510-514.
53. Rassweiler J, Hruza M, Teber D, Su LM. Laparoscopic and robotic assisted radical prostatectomy – critical analysis of the results. *Eur Urol*. 2006;49:612-624.
54. Caruso RP, Phillips CK, Kau E, Taneja SS, Stifelman MD. Robot assisted laparoscopic partial nephrectomy: initial experience. *J Urol*. 2006;176:36-39.
55. Yoshioka K, Hatano T, Nakagami Y, et al. Robotic-assisted laparoscopic radical prostatectomy: initial 15 cases in Japan. *J Robot Surg*. 2008;2:85-88.
56. Nishimura K. Current status of robotic surgery in Japan. *Korean J Urol*. 2015;56:170-178.
57. Tsirbas A, Mango C, Dutson E. Robotic ocular surgery. *Br J Ophthalmol*. 2007;91:18-21.
58. Bonaros N, Schachner T, Lehr E, et al. Five hundred cases of robotic totally endoscopic coronary artery bypass grafting: predictors of success and safety. *Ann Thorac Surg*. 2013;95:803-812.
59. Katz RD, Taylor JA, Rosson GD, Brown PR, Singh NK. Robotics in plastic and reconstructive surgery: use of a telemanipulator slave robot to perform microvascular anastomoses. *J Reconstr Microsurg*. 2006;22:53-57.
60. De Naeyer G, Van Migem P, Schatteman P, Carpentier P, Fonteyne E, Mottrie A. Robotic assistance in urological microsurgery: initial report of a successful in-vivo robot-assisted vasovasostomy. *J Robot Surg*. 2007;1:161-162.
61. Santomauro MG, Choe CH, L'Esperance JO, Auge BK. Robotic vasovasostomy: description of technique and review of initial results. *J Robot Surg*. 2012;6:217-221.
62. Marshall MT, Doudt AD, Berger JH, Auge BK, Christman MS, Choe CH. Robot-assisted vasovasostomy using a single layer anastomosis. *J Robot Surg*. 2017;11:299-303.
63. Karamanoukian RL, Bui T, McConnell MP, Evans GR, Karamanoukian HL. Transfer of training in robotic-assisted microvascular surgery. *Ann Plast Surg*. 2006;57:662-665.
64. Elzanaty S, Dohle G. Advances in male reproductive surgery: robotic-assisted vasovasostomy. *Curr Urol*. 2013;6:113-117.
65. Trost L, Parekattil S, Wang J, Hellstrom WJ. Intracorporeal robot-assisted microsurgical vasovasostomy for the treatment of bilateral vasal obstruction occurring following bilateral inguinal hernia repairs with mesh placement. *J Urol*. 2014;191:1120-1125.
66. Kavoussi P, Calixte N, Brahmbhatt J, Parekattil S. Robot-assisted microsurgery for chronic orchialgia. *Transl Androl Urol*. 2017;6:S6-S9.
67. Gerrard ER Jr, Sandlow JI, Oster RA, Burns JR, Box LC, Kolettis PN. Effect of female partner age on pregnancy rates after vasectomy reversal. *Fertil Steril*. 2007;87:1340-1344.
68. Hinz S, Rais-Bahrami S, Kempkensteffen C, Weiske WH, Schrader M, Magheli A. Fertility rates following vasectomy reversal: importance of age of the female partner. *Urol Int*. 2008;81:416-420.
69. Hinz S, Rais-Bahrami S, Weiske WH, et al. Prognostic value of intraoperative parameters observed during vasectomy reversal for predicting postoperative vas patency and fertility. *World J Urol*. 2009;27:781-785.
70. Magheli A, Rais-Bahrami S, Kempkensteffen C, Weiske WH, Miller K, Hinz S. Impact of obstructive interval and sperm granuloma on patency and pregnancy after vasectomy reversal. *Int J Androl*. 2010;33:730-735.
71. Hinz S, Rais-Bahrami S, Kempkensteffen C, Weiske WH, Miller K, Magheli A. Effect of obesity on sex hormone levels, antisperm antibodies, and fertility after vasectomy reversal. *Urology*. 2010;76:851-856.
72. Hsiao W, Sultan R, Lee R, Goldstein M. Increased follicle-stimulating hormone is associated with higher assisted reproduction use after vasectomy reversal. *J Urol*. 2011;185:2266-2271.
73. Ostrowski KA, Polackwich AS, Kent J, Conlin MJ, Hedges JC, Fuchs EF. Higher outcomes of vasectomy reversal in men with the same female partner as before vasectomy. *J Urol*. 2015;193:245-247.
74. Ramasamy R, Mata DA, Jain L, Perkins AR, Marks SH, Lipshultz LI. Microscopic visualization of intravasal spermatozoa is positively associated with patency after bilateral microsurgical vasovasostomy. *Andrology*. 2015;3:532-535.
75. Majzoub A, Tadros NN, Polackwich AS, Sharma R, Agarwal A, Sabanegh E Jr. Vasectomy reversal semen analysis: new reference ranges predict pregnancy. *Fertil Steril*. 2017;107:911-915.
76. Scovell JM, Mata DA, Ramasamy R, Herrel LA, Hsiao W, Lipshultz LI. Association between the presence of sperm in the vasal fluid during vasectomy reversal and postoperative patency: a systematic review and meta-analysis. *Urology*. 2015;85:809-813.
77. Boorjian S, Lipkin M, Goldstein M. The impact of obstructive interval and sperm granuloma on outcome of vasectomy reversal. *J Urol*. 2004;171:304-306.
78. Belker AM, Konnak JW, Sharlip ID, Thomas AJ Jr. Intraoperative observations during vasovasostomy in 334 patients. *J Urol*. 1983;129:524-527.
79. Silber SJ. Sperm granuloma and reversibility of vasectomy. *Lancet*. 1977;2:588-589.
80. Johnson AL, Howards SS. Intratubular hydrostatic pressure in testis and epididymis before and after vasectomy. *Am J Physiol*. 1975;228:556-564.
81. Witt MA, Heron S, Lipshultz LI. The post-vasectomy length of the testicular vasal remnant: a predictor of surgical outcome in microscopic vasectomy reversal. *J Urol*. 1994;151:892-894.
82. Silber SJ. Epididymal extravasation following vasectomy as a cause for failure of vasectomy reversal. *Fertil Steril*. 1979;31:309-315.
83. Lee HY. A 20-year experience with vasovasostomy. *J Urol*. 1986;136:413-415.

84. Jarow JP, Budin RE, Dym M, Zirkin BR, Noren S, Marshall FF. Quantitative pathologic changes in the human testis after vasectomy. A controlled study. *N Engl J Med*. 1985;313:1252-1256.
85. Grober ED, Karpman E, Fanipour M. Vasectomy reversal outcomes among patients with vasal obstructive intervals greater than 10 years. *Urology*. 2014;83:320-323.
86. Kolettis PN, Sabanegh ES, D'Amico AM, Box L, Sebesta M, Burns JR. Outcomes for vasectomy reversal performed after obstructive intervals of at least 10 years. *Urology*. 2002;60:885-888.
87. Kolettis PN, D'Amico AM, Box L, Burns JR. Outcomes for vasovasostomy with bilateral intravasal azoospermia. *J Androl*. 2003;24:22-24.
88. Hsiao W, Goldstein M, Rosoff JS, et al. Nomograms to predict patency after microsurgical vasectomy reversal. *J Urol*. 2012;187:607-612.
89. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 1982;143:29-36.
90. Kolata G. The art of learning from experience: statistician Bradley Efron tells what his field is about and how a new method, the bootstrap, exploits the power of large-scale computing. *Science*. 1984;225:156-158.
91. Deck AJ, Berger RE. Should vasectomy reversal be performed in men with older female partners? *J Urol*. 2000;163:105-106.
92. Fuchs EF, Burt RA. 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;77:516-519.
93. 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;169:2250-2252.
94. O'Brien YM, Ryan M, Martyn F, Wingfield MB. A retrospective study of the effect of increasing age on success rates of assisted reproductive technology. *Int J Gynaecol Obstet*. 2017;138:42-46.
95. Levran D, Ben-Shlomo I, Dor J, Ben-Rafael Z, Nebel L, Mashiach S. Aging of endometrium and oocytes: observations on conception and abortion rates in an egg donation model. *Fertil Steril*. 1991;56:1091-1094.
96. Sunderam S, Kissin DM, Crawford SB, et al. Assisted reproductive technology surveillance – United States, 2015. *MMWR Surveill Summ*. 2018;67:1-28.
97. Chan PT, Goldstein M. Superior outcomes of microsurgical vasectomy reversal in men with the same female partners. *Fertil Steril*. 2004;81:1371-1374.
98. Kolettis PN, Woo L, Sandlow JI. Outcomes of vasectomy reversal performed for men with the same female partners. *Urology*. 2003;61:1221-1223.
99. Snyder PJ. Endocrine evaluation of the infertile male. *Urol Clin North Am*. 1978;5:451-462.
100. Wang L, Huang H, Jin F, Zhou C, Qian Y, Chen J. High expression of follicle stimulating hormone receptor in testicular tissue of idiopathic azoospermic patients with severe spermatogenic defects. *Chin Med J (Engl)*. 2014;127:488-493.
101. Glavind K, Lauritsen NR, Klove-Mogensen M, Carl J. The effect of vasectomy on the production of plasma luteinizing hormone and follicle stimulating hormone in man. *Int Urol Nephrol*. 1990;22:553-559.
102. Tremblay RR, Chapdelaine P, Mailhot J. Alpha, 1-4-glucosidase activity in human semen: variations with number and motility of spermatozoa. *Fertil Steril*. 1979;31:592-593.
103. Tremblay RR, Paquin R, Thabet M. Nature of the residual alpha-1,4-glucosidase activity in the seminal plasma of vasectomized men. *Enzyme*. 1985;34:33-38.
104. Guerin JF, Ali HB, Rollet J, Souchier C, Czyba JC. Alpha-glucosidase as a specific epididymal enzyme marker. Its validity for the etiologic diagnosis of azoospermia. *J Androl*. 1986;7:156-162.
105. Cui D, Han G, Shang Y, et al. Antisperm antibodies in infertile men and their effect on semen parameters: a systematic review and meta-analysis. *Clin Chim Acta*. 2015;444:29-36.
106. Bates CA. Antisperm antibodies and male subfertility. *Br J Urol*. 1997;80:691-697.
107. Meinertz H, Linnet L, Fogh-Andersen P, Hjort T. Antisperm antibodies and fertility after vasovasostomy: a follow-up study of 216 men. *Fertil Steril*. 1990;54:315-321.
108. Carbone DJ Jr, Shah A, Thomas AJ Jr, Agarwal A. Partial obstruction, not antisperm antibodies, causing infertility after vasovasostomy. *J Urol*. 1998;159:827-830.

How to cite this article: Namekawa T, Imamoto T, Kato M, Komiya A, Ichikawa T. Vasovasostomy and vasoepididymostomy: Review of the procedures, outcomes, and predictors of patency and pregnancy over the last decade. *Reprod Med Biol*. 2018;17:343–355. https://doi.org/10.1002/rmb2.12207