18 Robotic Microsurgery for Male Infertility and Chronic Orchialgia

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Key Points

- Robotic assistance during microsurgery provides microsurgeons with many advantages: improved operative efficiency, elimination of tremor, scaling of motion, and enhanced imaging.
- Improved clinical efficiency appears likely with robotic assistance, and preliminary studies appear to support this concept.
- Novel treatment options for men with chronic testicular or groin pain are now available with this technology.
- Structured evidence-based platforms for the scientific development of this technology are necessary to protect patient safety. Groups such as RAMSES may provide guidance.

18.1 Introduction

Since the use of the operating microscope for microsurgery in 1975 [1], there has been a steady increase in the use of such technology in the operative management of male infertility and chronic testicular or groin pain [1–11]. Added to the reports relating to greater patency rates and fertility rates of vasovasostomy performed with the operating microscope [12], the concepts of magnification have been successfully applied to vasoepididymostomy and varicocele ligation. More recently, microscopic spermatic cord neurolysis has demonstrated applicability to the treatment of groin and testicular discomfort [13, 14]. These techniques require varying degrees of microsurgical skills and an array of supporting technology, neither of which may be part of many urologists' personal or technical armamentarium. The melding of improved visualization with magnification to an ergonomic platform that can be operated remotely has a significant application to testicular and reproductive surgery. Robotic assistance during surgical procedures has been utilized in a wide array of surgical fields with the abovementioned benefits [15–19]. This chapter covers the latest developments in the robotic microsurgical platform, robotic microsurgical tools, and current evaluations of various robotic microsurgical applications for male infertility and patients with chronic testicular or groin pain.

18.2 Novel Equipment

With any new field, the development of novel tools or instruments that can enable surgeons to create new solutions for existing clinical needs is of paramount importance. Below are some new products that enhance the ability to perform robotic-assisted microsurgery.

18.3 New Robotic Surgical Platform

Intuitive Surgical (Sunnyvale, CA) now offers an enhanced four-arm da Vinci-type Si robotic system with high-definition digital visual magnification that allows for greater magnification than the standard robotic system (up to 10–15×). The enhanced magnification capability allows the surgeon to position the camera 6–7 cm away from the operative field to avoid any local tissue effects from the heat emitted from the camera lighting (this was a problem with the older system, where the camera had to be placed within 2–3 cm of the operative field for microsurgery). This new system allows greater range of motion and better microsurgical instrument handling. The additional fourth arm has improved range of motion and positioning capabilities to provide the microsurgeon with one additional tool during procedures. The robot is positioned from the right side of the patient for microsurgical cases as illustrated in Fig. 18.1.

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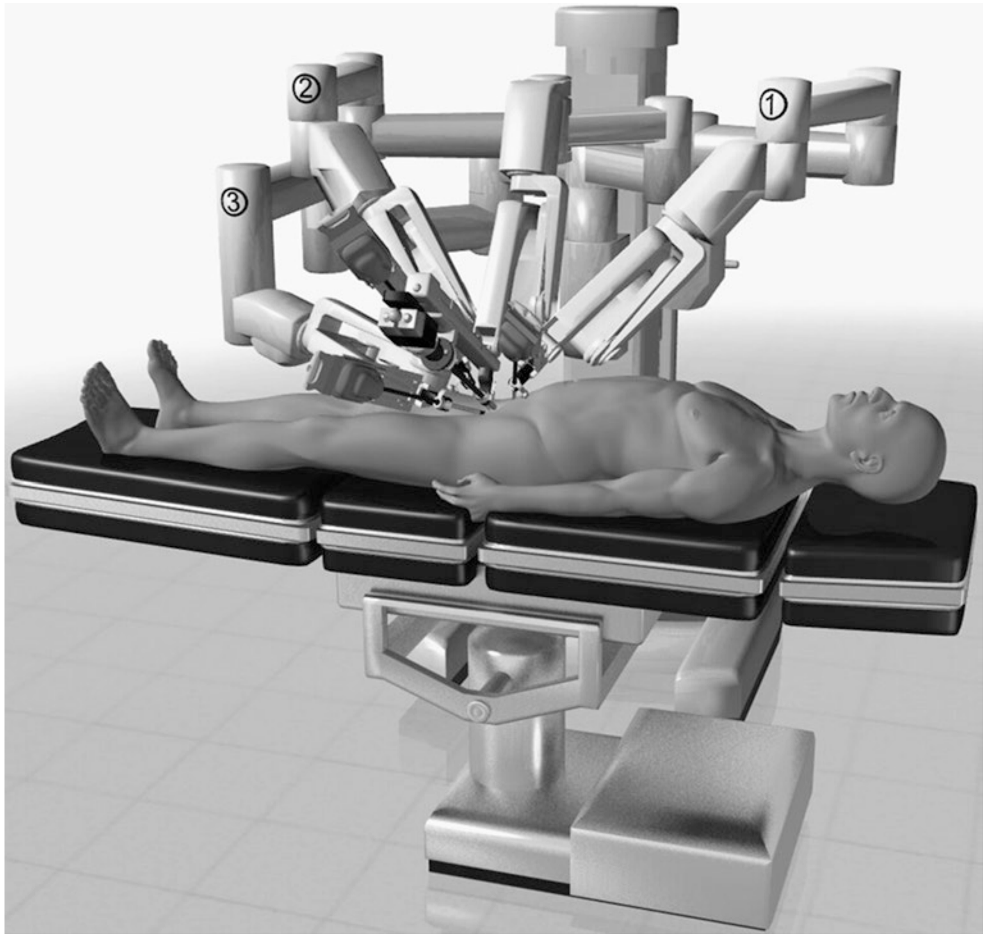

Fig. 18.1 Robotic platform positioning for microsurgical cases

18.4 Refined Robotic Doppler Flow Probe

Cocuzza et al. [20] have shown that the systematic use of intraoperative vascular Doppler ultrasound during microsurgical subinguinal varicocelectomy improves precise identification and preservation of testicular blood supply. During robotic microsurgical cases, the standard Doppler probe has to be held by a surgical assistant and cannot be manipulated readily with the robotic graspers. A new revised micro-Doppler flow probe (MDP) has been developed by Vascular Technology Inc. (Nashua, NH) that is designed specifically for use with the robotic platform (Fig. 18.2). This new probe allows for easy manipulation of the probe with the fourth arm and allows the surgeon to perform real-time Doppler monitoring of the testicular artery during cases such as robotic-assisted microscopic varicocelectomy (RAVx) and robotic-assisted microscopic denervation of the spermatic cord (RMDSC). This allows the surgeon to hear the testicular artery flow while dissecting out the veins and nerves with the other two robotic arms.

A recent prospective randomized controlled trial of the MDP was performed in 273 robotic microsurgical cases from July 2009 to September 2010: 67 robotic subinguinal varicocelectomies (RVx) and 206 robotic spermatic cord denervation procedures (RMDSC). The use of the MDP was randomized to 5 RVx and 20 RMDSC procedures. The primary endpoint was operative time, and secondary endpoint was surgeon ease in testicular artery localization and robotic grasper maneuverability. Operative duration was not affected

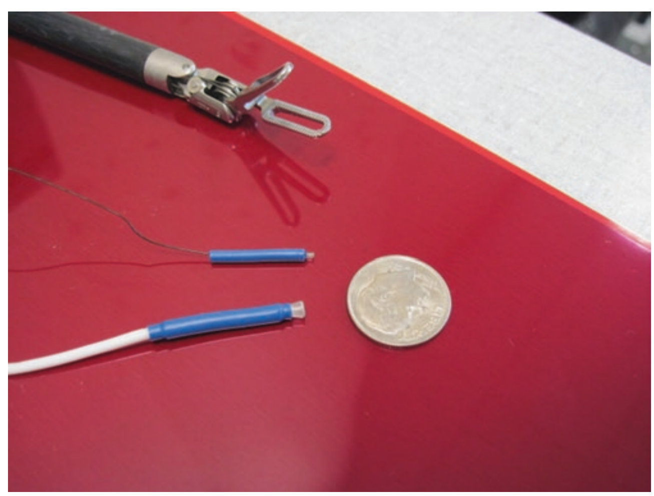

Fig. 18.2 Robotic micro-Doppler probe

by utilization of the MPD ($p = 0.5$). The MDP was effective in identifying all testicular arteries within the spermatic cord in all cases. Due to the compact size of the MDP, maneuverability using the robotic grasper was significantly improved over the standard handheld Doppler probe. MDP allowed for full range of motion of the robotic arms allowing the surgeon to easily scan vessels from a wide range of angles. No complications from use of the MDP occurred. The new micro-Doppler probe for robotic microsurgical procedures appears to have performed effectively in this study.

Vascular Technology Inc. (Nashua, NH) has recently developed an even smaller microprobe that can detect flow through vessels at about 0.5-mm diameter (Fig. 18.2). This just expands further potential applications for this technology.

18.5 Enhanced Digital Visual Magnification

The miniaturization and development of advanced digital microscopic cameras (100–250×) allow even greater magnification than the standard robotic (10–15×) and microscopic (10–20×) magnification in use at this time. Our group is currently involved in clinical trials of a 100× digital camera (Digital Inc., China) that can be utilized via the TilePro™ da Vinci Si robotic system (Intuitive Surgical, Sunnyvale, CA) to allow the surgeon to toggle or use simultaneous 100× and 10–15× visualization. This provides the surgeon with unparalleled visual acuity for complex microsurgical procedures.

Karl Storz (El Segundo, CA) also offers a robotic arm platform to hold an optical mini-scope that offers 16–20× magnification that can then be used during the da Vinci robotic cases to provide an additional enhanced magnification view (routed through the da Vinci console).

18.6 Robotic Microsurgical Procedures

18.6.1 Robotic-Assisted Microscopic Vasectomy Reversal

A number of groups have developed robotic-assisted techniques to perform robotic-assisted microscopic vasectomy reversal (RAVV) in animal and ex vivo human models [21–25]. Some studies suggest that robotic-assisted reversal may have advantages over microsurgical reversal in terms of ease of performing the procedure and improved patency rates [23, 24]. A few groups have performed human robotic-assisted vasovasostomies using the initial da Vinci robotic system [26] (Intuitive Surgical, Sunnyvale, CA).

These efforts have been confirmed in human RAVV cases performed using the new da Vinci Si system [27, 28]. Our group performed a prospective control study comparing RAVV and robotic-assisted vasoepididymostomy (RAVE) to standard microsurgical vasovasostomy (MVV) and vasoepididymostomy (MVE) [29, 30]. Between August 2007 and February 2012, 155 vasectomy reversal cases were performed by a single fellowship-trained microsurgeon. The primary endpoint was operative duration. The secondary endpoint was total motile sperm count at 2, 5, 9, and 12 months postoperatively [30]. Case breakdown was as follows: 110 with robotic assistance, 45 pure microsurgical, 66 bilateral RAVV, 44 RAVE on at least one side, 28 bilateral MVV, and 17 MVE on at least one side. Selection of approach (robotic vs. pure microscopic) was based on patient choice. Preoperative patient characteristics were similar in both groups. The same suture materials and suturing techniques (two-layer 10-0 and 9-0 nylon anastomosis for RAVV; 10-0 nylon double-armed longitudinal intussusception technique for RAVE) were used in both approaches.

Ninety-six percent patency was achieved in the RAVV cases and 80% in MVV (>1 million sperm/ejaculate). There was a statistically significant difference in patency rates between the two groups ($p = 0.02$). Pregnancy rates (within 1 year post-op) did not differ significantly for the two groups: 65% for the RAVV and 55% for the MVV. Operative duration (skin to skin) started at 150–180 min initially for the first 10 cases for RAVV, but median operative duration was significantly decreased in RAVV at 97 min (40–180) compared to MVV at 120 min (60–180), $p = 0.0003$. RAVE at 120 min (60–180) was significantly faster than MVE at 150 min (120–240), $p = 0.0008$. Suture breakage and needle bending reduced significantly after the first 10 RAVV cases. Mean postoperative total motile sperm counts were not significantly higher in RAVV/RAVE versus MVV/MVE, but the rate of postoperative sperm count recovery was significantly greater in RAVV/RAVE. Similar outcomes have been reported by other groups as well [31, 32].

Further evaluation and longer follow-up are needed to assess its clinical potential and the true cost–benefit ratio.

18.6.2 Robotic-Assisted Microscopic Varicocelectomy

Although reports of robotic-assisted laparoscopic intra-abdominal varicocelectomy have been published [33], there are a number of publications that suggest that microscopic subinguinal varicocelectomy (MVx) may provide superior outcomes compared to intra-abdominal varicocelectomy [34–37]. Shu et al. were the first to publish on robotic-assisted microsurgical subinguinal varicocelectomy (RAVx) [38]. They compared standard microsurgical to robotic-assisted varicocelectomy and found that the robotic approach provided advantages in terms of slightly decreasing operative duration and complete elimination of surgeon tremor.

To further explore these findings, we performed a prospective randomized controlled trial of MVx to RAVx in a canine varicocele model by a fellowship-trained microsurgeon. The surgeon performed cord dissection and ligation of three veins with 3-0 silk ties. Twelve canine varicocelectomies were randomized into two arms of six: MVV versus RAVx. Procedure duration, vessel injury, and knot failures were recorded. The RAVx mean duration (9.5 min) was significantly faster than MVV (12 min), $p = 0.04$. The duration for robot setup and microscope setup was not significantly different. There were no vessel injuries or knot failures in either group.

A review of our prospective clinical database of 97 RAVx cases from June 2008 to September 2010 (median follow-up of 11 months: range 1–27) is as follows. The median duration per side was 30 min (10–80). Indications for the procedure were the presence of a grade 2 or 3 varicocele and the following conditions: 10 with azoospermia, 42 with oligozoospermia, and 49 with testicular pain (with or without oligozoospermia, and failed all other conservative treatment options). Three-month follow-up was available for 81 patients: 75% with oligozoospermia had a significant improvement in sperm count or motility; one with azoospermia was converted to oligospermia. For testicular pain, 92% had complete resolution of pain (targeted neurolysis of the spermatic cord had been performed in addition to varicocelectomy). One recurrence or persistence of a varicocele occurred (by physical and ultrasound exam), one patient developed a small postoperative hydrocele, and two patients had small postoperative scrotal hematomas (treated conservatively). The fourth robotic arm allowed the surgeon to control one additional instrument during the cases decreasing reliance on the microsurgical assistant. The fourth arm also enabled the surgeon to perform real-time intraoperative Doppler mapping of the testicular arteries while dissecting the veins with the other arms if needed.

McCullough et al. [39] recently published at large series review of 258 cases with similar outcomes to the pure microsurgical technique. Robotic-assisted microsurgical subinguinal varicocelectomy appears to be safe, feasible, and efficient. The preliminary human results appear promising. Further evaluation and comparative effectiveness studies are warranted.

18.6.3 Robotic-Assisted Microscopic Denervation of the Spermatic Cord

Recent studies by Levine [13] and Oliveira et al. [14] have shown that microscopic denervation of the spermatic cord is an effective treatment option for men with chronic testicular pain. Our group has been developing a robotic-assisted microsurgical approach for the denervation of the spermatic cord (RMDSC) to assess if there may be any potential benefit over the standard microscopic technique.

Our group recently published a retrospective review of 872 cases (772 patients) who underwent RMDSC from October 2007 to July 2016 [40]. Selection criteria were as follows: chronic testicular pain (>3 months), failed conservative treatments, negative neurologic and urologic workup, and temporary resolution of pain with local anesthetic spermatic cord block. RMDSC was performed. Pain was assessed preoperatively and postoperatively using the subjective visual analog scale (VAS) and objectively with the standardized validated pain score (PIQ-6 by RAND). Follow-up data was available in 860 cases. Over a median follow-up of 24 months (1–70), 83% (718 cases) had a significant reduction in pain and 17% (142 cases) had no change in pain by subjective VAS scoring. Within the patients who had significant reduction in pain, 49% (426 cases) had complete resolution and 34% (292 cases) had a ≥50% reduction in pain. Objective PIQ-6 analysis showed a significant reduction in pain: 67% at 6 months, 68% at 1 year, 77% at 2 years, 86% at 3 years, and 83% at 4 years post-op.

RMDSC is an effective, minimally invasive approach with potential long-term durability for patients with refractory chronic orchialgia.

18.7 Single Port and Abdominal Robotic Microsurgical Neurolysis

Chronic groin pain can be debilitating for patients. Microsurgical subinguinal denervation of the spermatic cord (MDSC) is a treatment option for this pain. However, there are limited further options for patients who fail this treatment or who have phantom pain after orchiectomy. Our goal was to develop a single port and abdominal robotic microsurgical neurolysis technique to ligate the genitofemoral and inferior hypogastric nerve fibers within the abdomen above the internal inguinal ring.

We performed a prospective study of patients with chronic groin pain who either had failed previous MDSC or had phantom pain after orchiectomy. Primary endpoint was impact of pain on quality of life (PIQ-6 pain impact questionnaire from RAND) and secondary endpoint was operative robotic duration. PIQ-6 scores were collected pre-op and at 1, 3, 6, and 12 months post-op.

We completed 30 cases (five single ports) from June 2009 to September 2010. Elimination of pain occurred in 60% (18 cases), and a greater than 50% reduction in pain occurred in an additional 13% (4 cases) within 1 month post-op. Two of the failures were patients that had pain elimination for 6 months, but then pain returned thereafter. Median OR duration was 10 min (5–30). There were three complications: (i) one post-op scrotal hematoma that resolved with conservative measures, (ii) one patient had pain at one of the port sites, and (iii) one patient had pain that shifted from the groin to the leg. Single port and abdominal robotic microsurgical neurolysis appears to be an option for treatment in this difficult patient population. Further follow-up and evaluation are warranted.

18.8 Conclusion

The use of robotic assistance during microsurgical procedures is expanding. The application of this technology in other microsurgery fields apart from urology is also expanding, such as ophthalmology, hand surgery, and plastic and reconstructive microsurgery. The advantages of a stable microsurgical platform, ergonomic surgeon instrument controls, elimination of tremor, and magnified immersive 3D vision are all intuitively apparent. Further comparative effectiveness studies are ongoing and will be forthcoming on the true applicability of this new surgical platform. However, the preliminary results so far are quite impressive.

18.9 Review Criteria

A search of studies on robotic-assisted microsurgery in andrology was performed using search engines such as ScienceDirect, OVID, Google Scholar, PubMed, and MEDLINE. The overall strategy for study identification and data extraction was based on the following keywords: “robotic vasectomy reversal,” “robotic varicocelectomy,” “robotic denervation,” “infertile men,” “varicocelectomy,” “vasectomy reversal,” and “infertility.” Articles published in languages other than English were also considered. Data that were solely published in conference or meeting proceedings, websites, or books were not included.

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