Outcomes of Robotic Surgery for Low-Volume Surgeons

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Abstract

When the outcomes are equivalent to the open technique, conventional laparoscopy is a preferred surgical approach because of its minimal invasiveness. However, outcomes following laparoscopy depend on the surgeon's expertise, and there is a significant learning curve to attain efficiency in complex reconstructing laparoscopic procedures. Robotic assistance bridges the gap between open and laparoscopic procedures and allows surgeons with limited laparoscopy experience to offer the benefits of minimally invasive surgery to their patients. While existing data do not show better outcomes with robot assistance compared with laparoscopy for most procedures, these studies are based on data from high-volume surgeons and centers. In reality, a significant number of surgeries are performed by low-volume centers and surgeons, and robotic assistance may enable them to offer benefits of minimally invasive surgery equivalent to those of higher volume centers since robotic assistance is associated with a shorter learning curve than laparoscopy. We review the data on the outcomes of robotic surgery for low-volume surgeons with a focus on centers and surgeons in Asia.

Introduction

Urology as a specialty has always been at the forefront of technological advancement and has rapidly embraced innovations in devices and techniques. Acceptance of new technology usually depends on its being better for the patient or the health care system[1]. However, being "better" is often associated with being more expensive and thus new technologies must prove themselves to not only give better outcomes but also to do so at a cost that is acceptable for the improvements in outcome at a population level. Being "better for the surgeon" is rarely considered a valid reason for accepting technology that may increase overall costs of treatment.

Among surgical approaches, laparoscopy is universally accepted as the preferred option wherever it has been shown to have outcomes equivalent to open surgery. This is because it provides better cosmesis, lower postoperative pain and earlier recovery; all outcomes that are better for the patient and the health care systems[2]. However, outcomes vary among surgeons and, depending on surgeon expertise, the possible procedures range from simple ablative to complex reconstructive ones that require intracorporeal suturing[3]. Surgical outcomes improve with increasing case load and plateau after a certain level[4]. Once expertise is achieved, outcomes are equivalent irrespective of the surgical approach. However, despite having been available over 30 years, laparoscopy remains challenging for complex reconstructive procedures and has a steep learning curve for such procedures[5].

The introduction of robotic assistance into the surgical armamentarium aimed to bridge the gap between open approaches and laparoscopy and to enable minimally invasive surgery[6]. However, despite having been available now for over 20 years, robotic surgery continues to be questioned and is often derided as a gimmick or marketing tool, primarily because of its high costs, longer operating times, and poor residency training[7,8]. These concerns

Key Words

Ergonomics, learning curve, robotic assistance, surgical outcomes, surgeon volume, urologic surgery

Competing Interests

None declared.

Article Information

Received on April 5, 2022
Accepted on May 22, 2022
This article has been peer reviewed.

Soc Int Urol J. 2022;3(5):323–330

DOI: 10.48083/PPSC8658

Abbreviations

EBL estimated blood loss
LNY lymph node yield
LPN laparoscopic partial nephrectomy
OT operative time
PSM positive surgical margin
RALP robotic-assisted laparoscopic pyeloplasty
RAPN robotic-assisted partial nephrectomy
RARC robotic-assisted radical cystectomy
RARP robotic-assisted radical prostatectomy
WIT warm ischemia time

are fuelled by a lack of studies showing the superiority of robotic assistance over laparoscopy[9]. In the absence of a difference, it is difficult to justify the use of expensive robotic assistance over pure laparoscopy.

Most of this data comes from surgeons and centers that have high volumes. It is only to be expected that once expertise has been acquired through high volumes the outcomes are likely to be similar with each technique. In the real world, most urologists do not have the high volumes of these surgeons or centers[10,11]. However, the patients they treat deserve the same outcomes as those at high-volume centers and it is pertinent to assess whether robotic assistance helps low-volume surgeons provide the benefits of minimally invasive surgery to their patients, which they may not have been able to do through pure laparoscopy.

The learning curve for robot-assisted surgery is shorter than that for conventional laparoscopy in maiden users[12]. Robot assistance allows surgeons trained in open surgery to transition easily to minimally invasive surgery without significant laparoscopy experience, and laparoscopy-naïve surgeons have rapidly gained competence in robot-assisted radical prostatectomy (RARP)[13]. As a corollary, it is plausible that robotic assistance may aid surgeons in a low-volume setting to deliver better outcomes than would be associated with laparoscopy, while providing all the advantages of minimally invasive surgery[11].

With this hypothesis, we reviewed the literature for data on outcomes of robot-assisted surgeries for low-volume surgeons for common urological surgeries such as robot-assisted radical prostatectomy (RARP), robot-assisted partial nephrectomy (RAPN), robot-assisted radical cystectomy (RARC), and robot-assisted laparoscopic pyeloplasty (RALP). This is particularly relevant for Asia since the penetration of robot-assisted surgeries in Asia trails the western world. By 2017, there were 4271 da Vinci Surgical Systems (Intuitive Surgical Inc.) installations worldwide of which 82% were in the Unites States Europe as compared with 13% in Asia but with a trend towards increasing Asian installations by 2018[14]. As per the recent data, over 5500 da Vinci Surgical Systems have been installed in 67 countries worldwide[15].

Low-Volume Robotic Surgeons and/or Hospital

What constitutes "low-volume" for surgeons and hospitals is not clearly defined. Considering RARP as the most common robotic urology surgery, in 2011, Gershman et al. found that 70% of hospitals in the United States were performing less than 50 RARP per year and the complications, hospitalizations, and transfusion rates all declined with increasing experience until around 100 RARPs were being performed per year[16]. While evaluating the impact of surgeon experience, Bravi et al. reported a decline in positive margins from 16.7% to 9.6% with increase of surgeon experience from 10 to 250 procedures[17]. Based on the evaluation of 9810 RARPs in Sweden, Godtman et al.[18] defined very low-volume (surgeon < 13 or hospital < 50 cases), low-volume (surgeon 13 to 25 or hospital 50 to 100 cases), intermediate (surgeon 25 to 50 or hospital 100 to 150 cases), high-volume (surgeon 50 to 76 or hospital 150 to 200 cases) and very high volume (surgeon ≥ 75 or hospital ≥ 200 cases) surgeons and hospitals. Based on the Swedish national guidelines for prostate cancer, Godtman et al. defined these cut-off values as a multiple of the minimum number of RARPs that should be performed by the surgeon and the center. It is expected that these numbers would differ for other procedures. This lack of consensus on the definition of low-volume surgeon would be related to the different learning curve in achieving a benchmark optimum outcome.

Methods

We searched PubMed/MEDLINE, Embase, Web of Science, and Google Scholar databases for relevant studies published in English using the following MeSH key words: (robotic urology surgery OR robotic radical prostatectomy OR RARP OR radical cystectomy OR RARC OR partial nephrectomy OR pyeloplasty) AND (low-volume surgeons OR low-volume center OR learning curve). The abstracts and full articles of systematic reviews and meta-analyses were reviewed. Case reports, letters, short communications, and articles in languages other than English language were excluded.

Radical Prostatectomy

Reviewing the outcomes of radical prostatectomies done at high-volume centers, Coelho et al. showed that RARP delivered better outcomes in terms of weighted mean PSM, continence, and potency rates compared with retropubic and laparoscopic radical prostatectomies[19]. However, with the increasing adoption of robotic system in the recent years, there has been an increase in the number of RARP being done at low-volume centers[20]. It is now estimated that between 33% and 70% of RARP in the United States are done by low-volume surgeons[10].

With conventional laparoscopic radical prostatectomy, the number needed to attain a 90% recurrence-free probability is estimated to be 750 cases[21]. In contrast, with RARP, about 80 to 120 cases are needed to attain a comparable perioperative, oncological, and functional outcomes[22]. Further, with increasing experience in RARP, the perioperative complications declined from 9.8% in low-volume surgeons to 6.7% in intermediate-volume surgeons and to 2.2% in high-volume surgeons[23]. In a retrospective analysis from India, Garg et al. showed an inverse stage migration pattern in their RARP practice. Over the time, with increasing experience in RARP, patients with more unfavorable disease characteristics underwent RARP[24].

A recent multi-national and multicenter retrospective study discussed the RARP outcomes (n = 207) of 3 fellowship-trained surgeons from low-volume regions of Gulf Cooperation Council countries[25]. This study showed trifecta outcomes comparable to those of international centers. At the 12-month follow-up, 35.8% of patients were potent, 94.6% were continent, and 9.2% had biochemical recurrence[25]. In a recent study from low-intermediate volume center, Afferi et al. retrospectively analyzed 604 men who underwent nerve-sparing RARP[26]. At a median follow-up of 28 months, the authors reported an increase in the pentafecta outcomes from 38% to 44%, with erectile dysfunction being the main limiting factor for non-achievement of pentafecta in 71% cases. However, in high-risk prostate cancers, biochemical recurrence limited the pentafecta achievement (61%)[26].

Partial Nephrectomy

The current standard of care for small renal masses is partial nephrectomy[27]. Prior reports showed equivalent oncological outcomes between open and laparoscopic approaches for partial nephrectomies[28,29]. However, laparoscopic partial nephrectomy (LPN) is a technically demanding procedure requiring intracorporeal suturing with simultaneous consideration of warm ischemia time (WIT) to prevent ischemic renal injury[30]. Considering that laparoscopic radical nephrectomy was easier to perform, it was hypothesised that partial nephrectomy was underutilized for eligible candidates[31]. After successful incorporation of robotic assistance into radical prostatectomy, robot-assisted partial nephrectomy (RAPN) was quickly and widely adopted[32]. A surgeon needs to perform fewer RAPN than LPN to attain a comparable level of competency[33]. It is estimated that about 565 cases are required to achieve the target WIT (< 20 to 25 minutes) in LPN[34], whereas it requires about 20 and 50 cases, for RAPN for equivalent WIT and operative time (OT), respectively[5]. In contrast, expert renal surgeons require < 30 cases of RAPN to achieve an equivalent proficiency.

In a low-volume center in Kuwait, a fellowship-trained robotic surgeon retrospectively assessed the perioperative, trifecta, and pentafecta outcomes following 43 RAPN cases performed over 6 years. Operative time and estimated blood loss (EBL) improved significantly after the first quartile of patients (n = 14). Trifecta and pentafecta outcomes were achieved in 93% and 81.8% cases, respectively. A higher number of complex cases with RENAL nephrometry scores of 7 to 12 were performed in the second (n = 14) and third (n = 15) quartiles[35].

In a prospective study, Dias et al. reported outcomes of RAPN by a laparoscopy trained surgeon with no prior robotic surgery experience. In 108 cases performed over 5 years, WIT ≤ 20 minutes, OT ≤ 150 minutes, and EBL < 100mL were achieved after 44, 44, and 54 cases, respectively. A trifecta outcome was achieved in 67.6% cases[36]. Motoyama et al. in a retrospective study reported the outcomes of 65 RAPN performed by a surgeon with no prior LPN experience but with extensive robotic surgery experience[37]. The learning curve was analyzed by dividing cases into 5 groups of 13 consecutive patients. Trifecta outcomes were achieved in 89.2% cases. The authors reported a WIT of ≤ 20 minutes and console time of ≤ 150 minutes could be achieved at fourth and sixth procedures, respectively[37].

In terms of complications, a multicenter study showed that a low-volume surgeon performing < 7 cases of RAPN per year had a complication rate (18.1% versus 15.9% versus 16.1%, $P = 0.81$) comparable to high-volume (15 to 30 RAPN cases/year) and very high-volume (> 30 RAPN cases/year) surgeons[38]. In a recent database study involving 124 institutions in Japan, Yokoyama et al. reported the trends and safety of RAPN done at low-volume (n = 616) and high-volume (n = 3106) institutions. After propensity score matching, the authors did not find any significant differences in anesthesia time, blood transfusions, and complication rates between low-volume and high-volume centers[39]. Similarly, data from a single-center study in Turkey confirmed that a comparable trifecta outcome (77%) can be achieved by low-volume surgeon[40].

Radical Cystectomy

Radical cystectomy with urinary diversion has one of the highest morbidity rates among urological procedures, with postoperative complication rates of up to 69%[41]. Minimally invasive surgery, both pure laparoscopy and robot-assisted, are feasible alternatives to open radical cystectomy. Data from the RAZOR trial suggest that RARC is associated with decreased blood loss, transfusion rate, and hospital stay compared with the open approach[41]. Further, RARC has been shown to be non-inferior to the open approach in terms of 3-year progression-free and overall survival[42]. The learning curve for such complex procedures is estimated to be 21 to 30 cases when using benchmarks of operating time of < 6.5 hours, lymph node yield (LNY) of 20, and < 5% positive surgical margin (PSM). The number needed to reach the target OT was 21 cases. A total of 8, 20, and 30 cases were required to attain a LNY of 12, 16, and 20, respectively. Similarly, 30 cases were required to reach competency for PSM[43].

Guru et al. divided 100 consecutive RARC procedures into 4 quartiles. The overall mean OT and EBL were 343 minutes and 598 mL, respectively. The mean OT reduced from 375 minutes in first quartile to 352 minutes in the last quartile. Similarly, the LNY increased from 14 nodes in first quartile to 23 nodes in the last quartile. While there were 4 cases of PSM in the first quartile, none of the patients in the last quartile had a positive margin. The authors reported no difference in the complication rate over time[44].

Experience in one robot-assisted procedure helps improve outcomes in other procedures. Hayn et al., using the International Robotic Cystectomy Consortium database, report that surgeons with prior experience in RARP provide better RARC outcomes with significant differences in OT, EBL, and LNY between surgeons with < 50 RARPs and those with 51 to 100 RARPs[45].

The adoption of RARC has been increasing in Asian countries in recent years. A single-center retrospective analysis from India of the initial experience of 63 RARC with extracorporeal urinary diversion reported a mean OT, EBL, and hospital stay of 348 minutes, 868 mL, and 10.4 days, respectively. The mean LNY was 12.4, ranging between 3 and 25 nodes[46]. These data are very similar to those reported from larger centers[44].

Pyeloplasty

Robotic assistance has also helped lower the steep learning curve associated with laparoscopic pyeloplasty for uretero-pelvic junction obstruction[47]. It has been documented to be of particular advantage in patients with anatomical variations like lower moiety uretero-pelvic junction obstruction, malrotated kidneys, and secondary uretero-pelvic junction obstruction[48–52].

RALP is a relatively simple procedure and has been considered as a gateway to advanced reconstructive procedures[53]. A novice can achieve an operating time within 1 standard deviation of the open pyeloplasty after 15 to 20 cases[54]. However, it takes only about 5 cases for a surgeon expert in open procedures[55]. It is not surprising that robotic assistance does not offer any benefit to experienced laparoscopic surgeons with good intracorporeal suturing skills[56]. However, a relatively faster learning curve could prompt low-volume surgeons to offer RALP to their patients to deliver comparable outcomes.

TABLE 1.

Learning curve of common robotic urological procedures

Procedure*	Number of cases required	Outcome measures
RARPa	80–120 cases[21]	Perioperative, oncological, and functional outcomes
RAPN	20 cases[5] 50 cases[5]	WIT OT
RARC	21–30 cases[41]	OT < 6.5 hours; LNY of 20; PSM < 5%
RALP	15–20 cases[52]	OT

RARP: robotic-assisted radical prostatectomy; RAPN: robotic-assisted partial nephrectomy; RARC: robotic-assisted radical cystectomy; RALP: robotic-assisted laparoscopic pyeloplasty; WIT: warm ischemia time; OT: operative time; LNY: lymph node yield and PSM: positive surgical margin

**All the data provided here are originated from surgeons trained in both open and laparoscopy except (a) Denotes the learning curve of a surgeon with no prior laparoscopic experience.*

Ergonomics

The ergonomics of the procedures for surgeons are often under-reported, and poor ergonomics affect physical, mental, and economic well-being. A greater degree of adverse ergonomic problems are expected among urologists who perform a wide range of operative procedures such as open, laparoscopic, robotic, endoscopic, and microscopic surgeries[57]. Catanzarite et al. have shown that work-related musculoskeletal disorders are prevalent in 66% to 90%, 73% to 100%, and 23% to 80% for open, laparoscopic, and robotic surgeries, respectively[58]. Surgeon fatigue after performing a conventional laparoscopic pyeloplasty may limit the number of procedures that may be performed on the same day[59]. Specifically, post-procedure fatigue affects precise intracorporeal suture placement[60]. Although robot-assisted surgery appears to be ergonomically better, it too can lead to a strain on trunk, wrist, and fingers[58]. For instance, one of the most common ergonomic issues while performing robotic surgery is abducted shoulder and not maintaining a right angle with the biceps, resulting in lifting off the elbows from the armrest. Surgeons have to use the clutch control to mitigate the abnormal posture[57].

The learning curves of common robotic urological procedures are shown in **Table 1**. These numbers should be interpreted with some caution as the data could be heterogenous as the data include different cohorts. Further, various confounders affecting the outcomes of different robotic procedures were not addressed. However, our work provides an overview of data on outcomes of common robot-assisted surgeries for low-volume surgeons.

Role of Various Robotic Training Models

Various training models have the potential to help low-volume robotic surgeons deliver a reasonable surgical outcome without compromising patient safety. In this context, expert proctorship helped trainees achieve efficiency and early performance of independent robotic procedures. With the introduction of dual-console da Vinci Si or Xi Surgical systems, the proctorship program has become more convenient for both proctor and trainee[61–63]. As the technology advances, the future looks promising for telementoring, which may facilitate remote proctorship[64]. A fellowship program has been considered the most structured robotic training model as it involves a systematic method of training[65]. The trainees perform progressive steps of the operation in succession under the guidance of an expert robotic surgeon with constant and immediate feedback[61]. Lastly, simulation-based training allows trainees to develop surgical skills without risking patient safety. It provides an objective assessment of particular surgical skills. In recent years, various robotic simulation platforms have been developed and are commercially available. In particular, the da Vinci skills simulator is closely attached to the surgeon console that would be otherwise used for robotic-assisted surgeries[66].

Conclusion

Robotic assistance has the potential to help low-volume surgeons and hospitals offer minimally invasive surgery to their patients. Robotic assistance enables surgeons to reach a higher degree of competence more quickly and easily. While the costs associated with robot assistance continue to be high, the potential benefit of minimally invasive surgery over open surgery would help mitigate concerns. Ergonomic benefits for the surgeon are unmeasured, but may also be a significant advantage of robotic-assisted surgery.

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