Current Transplantation Reports (2024) 11:48–52
https://doi.org/10.1007/s40472-024-00426-8

Updated Comparison of Robotic Versus Laparoscopic Donor Nephrectomy

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Accepted: 2 February 2024 / Published online: 14 February 2024

Abstract

Purpose of review The adoption of the robotic platform for donor nephrectomies in 2002 has been the most recent advancement in operation since the laparoscopic donor nephrectomy in 1995. This article reviews recent literature regarding the use of robotic versus laparoscopic donor nephrectomies over the past 3 years.

Recent findings There have been several comparisons between the robotic and laparoscopic approach assessing operative time, learning curve, costs, and safety. Some robotic benefits are more intangible than what is available in comparisons specifically those related to ergonomics, visualization, and training of future transplant surgeons.

Summary Importantly, both techniques are safe for both the donor and recipient, and both techniques are useful tools especially in an environment where access to the robotic platform may not always be available. As with any surgical technology, it is critically important to continue to assess outcomes and other operative metrics as the use of the robotic approach becomes more widespread ensuring patient safety and an optimal patient experience.

Keywords Robotic donor nephrectomy · Laparoscopic donor nephrectomy

Introduction

The adoption of the robotic platform has been the most recent advancement in the donor nephrectomy operation since the laparoscopic donor nephrectomy (LDN) was described by Ratner et al. in 1995 [1]. The use of robotic-assisted technology for minimally invasive donor nephrectomies was first described by Horgan et al. in 2002 [2]. A 2016 study using the National Inpatient Sample estimated that robotic donor nephrectomies (RDN) only comprised 2.4% of all donor nephrectomies performed from 2008 to 2012 [3]. However, the use of the robotic platform for donor nephrectomies has likely increased over the last decade as the use of the robotic platform has ubiquitously increased across other surgical specialties. Despite this rapid expansion of robotic surgery in other specialties, evidence supporting improved clinical outcomes after robotic surgery is limited [4].

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This article reviews recent literature regarding the use of the robotic versus laparoscopic donor nephrectomies over the past 3 years. While the benefits of a minimally invasive compared to an open approach are clear, the benefits of the more expensive robotic platform over the established laparoscopic approach have been hard to prove. The main benefits of the robotic platform are surgeon ergonomics [5], 3D visualization and greater instrument articulation for difficult anatomy [6], its use as a stepping stone to the more complex robotic kidney transplant operation, and innovation of surgical technique including single incision minimally invasive surgery and natural orifice transluminal endoscopic surgery (NOTES). There may also be advantages in training opportunities with the ease of back-and-forth transitions between the surgeon and trainee. Those more skeptical of the robotic approach often denote the increased cost with equivalent patient and graft outcomes compared to the laparoscopic approach.

The popularity of the robotic donor nephrectomy is increasing with more centers publishing their experience over the past few years. Spaggiari et al. from the University of Illinois at Chicago pioneered this technique and published the largest single-center series of robotic donor nephrectomies reporting results from 1090 cases from 2000 to 2017

[7•]. Adoption of the robotic donor nephrectomy outside the United States has been described by centers in France, Switzerland, Italy, Germany, and the Netherlands (Table 1). We will also provide some insight using our institutional experience with the adoption of the robotic platform since May 2021.

Operative Time

In terms of operative time, while almost all recent studies comparing the approaches head-to-head show that the operative time for the robot is longer than the laparoscopic approach, there is some evidence that after the learning curve, the operative time may be similar. Centonze et al. compared 193 robotic donor nephrectomies performed at one center to 410 laparoscopic donor nephrectomies at a second center. The median operative time for the robotic approach was only 15 min longer compared to the laparoscopic group (210 vs 195 min) [8•]. Takagi et al. compared 103 robotic donor nephrectomies to 1365 laparoscopic donor nephrectomies and 427 hand-assisted retroperitoneal nephrectomies [9]. Their median operative time for the robotic approach was only 4 min longer than the laparoscopic approach and 15 min longer than the hand-assisted retroperitoneal approach (180 vs 184 vs 165 min). Windisch et al. found a more significant difference with a 2-h difference (127 min) between the robotic and the laparoscopic platform (287 vs 160 min) [10]. Zeuschner et al. reported no differences in their operative time (224 vs 213 min), but they note that they also waited for the recipient to be ready for the vessels to be divided, and at that time, they were also developing their robot-assisted kidney transplant program which prolonged their recipient room time [11]. Overall, Spaggiari et al.'s experience with over a thousand robotic cases showed an operative time that was even shorter than almost all the other laparoscopic series. This demonstrates that with repetition and an experienced team, equivalent or even shorter times can be achieved with RDN compared to LDN.

Pain and Length of Stay

Proponents of the robotic platform claim that the fixed pivot point of the robotic trocars at the level of the abdominal wall minimizes torque and thus decreases pain. This has not been proven in the literature, and none of the recent studies specifically sought to analyze this aspect. In terms of length of stay, there was some variation across the several series. Centonze et al. described a difference of one shorter day in the robotic group (4 vs 5 days) but attributed it to differences between the protocol of the two institutions that were being compared [8•]. Papa et al. found a shorter length of stay in the RDN group of 2.22 days vs 3.04 days in the LDN group [12]. Windisch et al. also found a shorter length of stay in the RDN group compared to the LDN group (3.9 vs 5.7 days) [10]. Olumba et al. reviewed 150 consecutive living donor

Table 1 Summary of recent studies describing robotic donor nephrectomies

Author	Dates	Cases	Operative time (min)	Warm ischemia time (sec)	Conversion	Major complications	Length of stay (days)
Spaggiari et al. [7•] Chicago, USA	2000–2017	1084 robotic	159	180	0.5%	1.7%	3
Centonze et al. [8•] Italy	2010–2021	154 robotic 358 lap	210 vs 195	230 vs 180	0% vs 0%	1.9% vs 0.3%	4 vs 5
Takagi et al. [9] Netherlands	1997–2019	103 robotic 1365 lap	180 vs 184	-	3.9% vs 4.5%	0% vs 1.3%	3 vs 3
Papa et al. [12] New York, USA	2012–2022	77 robotic 76 lap	302 vs 293	192 vs 222	0% vs 1.3%	3.9% vs 2.6%	2 vs 3
Olumba et al. [13] St Louis, USA	2017–2021	75 robotic 75 lap	182 vs 144	-	0% vs 0%	4% vs 4%	1.8 vs 2.1
Windisch et al. [10] Switzerland	2013–2019	72 robotic 104 lap	287 vs 160	221 vs 213	-	1.4% vs 1.9%	3.9 vs 5.7
Zeuschner et al. [11] Germany	2007–2020	52 robotic 205 lap	224 vs 213	147 vs 180	1.9% vs 0.5%	1.9% vs 1.5%	5 vs 5
Serni et al. [14] Italy	2012–2019	36 robotic	230	175	0%	0%	6
Garden et al. [15] New York, USA	2020–2021	7 single-port robotic	218	304			2

operations including 75 robotic donor nephrectomies and found a shorter average length of stay for the robotic group (1.8 vs 2.1 days) with 32% going home on post-operative day 1 vs 20% in the laparoscopic group [13]. Takagi et al. and Zeuschner et al. found no differences between the two groups with both groups having a median length of stay of 3 days and 5 days, respectively [9, 11]. It is likely that length of stay is influenced by institutional protocols and practices rather than real differences between the recovery from the two operative techniques. At our institution, patients follow a standardized pathway with plans for discharge on post-operative day two regardless of the operative approach. Some patients are discharged on post-operative day one, but there is not a difference based on the operative approach.

Learning Curve

The operative time correlates with the learning curve associated with the early adoption of the robotic platform. Centonze et al. showed that there was a faster decrease in surgery duration in the first 50 RDN cases compared with the first 50 LDN cases with no differences after the 100th procedure [8•]. The turning point of their operative time CUSUM curve was after about 50 cases for RDN and after about 100 cases for LDN. Olumba et al. found that the learning curve for surgeons experienced in LDN to transition to RDN to be around 30 cases [13]. Takagi et al. found the number of cases required for proficiency was similar in RDN to LDN (26 vs 23 cases) [9]. As younger surgeons with more exposure to robotic surgery in training transition to practice, this number will likely continue to decrease.

Complications

Centonze et al. did find a higher intraoperative complication rate in the robotic approach compared to the laparoscopic approach (3.9% vs 0.6%), but none required conversion to an open approach, and there was no difference in overall post-operative complications [8•]. Zeuschner et al. reported a technical defect in the stapler system in their robotic group where the stapler cut but did not staple, leading them to change to locking Hem-o-Lok clips to divide the vessels [11]. Some centers have used laparoscopic GIA staplers rather than robotic staplers to conclude the case. At our center, we have chosen to undock the robot and use a laparoscopic stapler to remove the kidney.

Cost

Traditionally, there has been a high upfront institutional cost of investing in the robot itself, which is approximately $2.5 million. Newer models for per-case charges, cost-sharing, and leasing have changed the upfront cost. Additionally, as more robotic platforms are developed and entering the market, these costs may decrease with time. The large cost difference per case is driven by consumables for the robot (Table 2). Our average cost estimate for a robotic case is $2994 compared to $2232 for a laparoscopic case. This is consistent with that reported in the literature by Tabib et al. [16]. Some institutions have been able to reduce their RDN operative supply costs by adapting the instrument trays and packs for the case. As mentioned above, our approach in undocking the robot upon completion of the dissection and using lower-cost laparoscopic staplers to divide the vessels has reduced some case costs. Using laparoscopic staplers also allows for quicker instrument exchanges during stapler reloads to minimize warm ischemia time. Undocking the robot before transection of the vessels also allows for minimization of warm ischemia time. We use a Gelport port through a Pfannenstiel incision to extract the kidney and place our robotic physician assistant (PA) assist port through the Gelport. Some institutions have opted to complete dissection but not open the peritoneum until the end of the case to further reduce costs by not using a Gelport. The cost of a bedside robotic PA is offset by billing for their time.

Table 2 Cost overview of disposables for each platform

Item	Unit cost	Units	Cost
Robotic			
Robotic arm drape	$54.60	4	$218.40
Robotic column drape	$18.90	1	$18.90
Robotic 8 mm port obturator	$26.25	1	$26.25
Robotic 8 mm optical port obturator	$31.50	1	$31.50
Robotic vessel sealer	$656.33	1	$656.33
Robotic camera port sealer	$260.00	1	$260.00
Robotic canula sealer	$40.00	2	$80.00
Robotic scissor tip	$21.00	1	$21.00
Laparoscopic			
Ligasure Maryland tip	$441.53	1	$441.53
5-mm laparoscopic ports	$17.53	2	$35.06
12-mm laparoscopic port	$26.72	1	$26.72
Both			
Laparoscopic GIA stapler handle	$112.39	1	$112.39
Vascular GIA stapler load	$140.70	2	$281.40
Hem-o-lock clips	$38.43	1	$38.43
Gelport	$700.00	1	$700.00

Surgical Technique

Across the case series, surgeons cited the benefits of the robotic platform with improved three-dimensional visualization and better dexterity for the dissection of multiple arteries. Anecdotally from our experience, the robotic platform offers several benefits. In high BMI donors, the visualization and dexterity are improved. With taller, long-abdomen donors, the robot allows for easier and safer mobilization of the spleen or liver and dissection of the upper pole. For donors with multiple vessels or other complicated anatomy, we do prefer the robotic approach. We use the robotic approach for right as well as left donor nephrectomies. For the surgeon, the robot offers a more ergonomic experience, especially compared to the hand-assisted laparoscopic approach through a Pfannenstiel incision. We also utilize a dedicated robotic PA as the bedside assistant. This does facilitate consistency and efficiency with the operation. One limitation we face at our institution that others may also encounter is the challenge in obtaining robotic block time for all donor nephrectomies, so we still perform approximately forty percent of our donor nephrectomies with a hand-assisted laparoscopic approach. Our preference is to use the robotic approach with donors with higher BMIs and those with multiple vessels or other complicated anatomy.

Teaching Trainees

The few studies describing the learning curve of robotic donor nephrectomy compared to the laparoscopic approach have mainly been with trained transplant surgeons. There have also been studies describing tools and approaches to teaching this procedure to trainees/fellows. This includes novel assessment tools that have been created to assess performance and promote operative independence in an objective fashion [17]. Three-dimensional printing and hydrogen casting to create high-fidelity robotic donor nephrectomy and recipient kidney transplant models have also been utilized in simulation [18]. In our institution, we have noted that training fellows in robotic donor nephrectomy are variable based on their robotic experience in residency and commitment to work on the simulator. We have a standardized stepwise approach to training where the fellows are first expected to complete selected modules on the simulator, do training with the PA on the bedside robotic procedures, and bedside assist cases prior to training as the operative surgeon. For those who have significant robotic experience prior to fellowship, those steps take less time than fellows new to robotic technology. A significant advantage to the robotic versus laparoscopic approach in education is the ability to change instrument controls quickly and seamlessly which allows for more gradual independence and a stepwise training approach. The robotic operations are easily recorded for future review and feedback sessions, and the fellows can log into the Intuitive app to track their progress. Due to the limited access to the robotic platform, our fellows are trained in both the robotic and laparoscopic hand assist approach.

Conclusions

In summary, the robotic donor nephrectomy is becoming a more common approach to donor nephrectomy. There have been several comparisons between the robotic and laparoscopic approach assessing operative time, learning curve, costs, and safety. Some robotic benefits are more intangible than what is available in comparisons specifically those related to ergonomics, visualization, and training of future transplant surgeons. Importantly, both techniques are safe for both the donor and recipient, and both techniques are useful tools especially in an environment where access to the robotic platform may not always be available. Transplant surgeons have been innovators seeking to improve the patient experience as exemplified by Dr. Ratner et al.'s introduction of laparoscopic donor nephrectomy almost 30 years ago. The use of robotic technology may continue to advance the field of transplantation, and robotic donor nephrectomy may be an entry port to robotic-assisted technology for transplant surgeons looking to advance their robotic practice to kidney transplant recipients and potentially even living liver donation in the future. As with any surgical technology, it is critically important to continue to assess outcomes and other operative metrics as the use of the robotic approach becomes more widespread ensuring patient safety and an optimal patient experience.

Author contributions R.T. and L.A.D. both contributed to the analysis of the data and the creation of the manuscript.

Declarations

Competing interests The authors declare no competing interests.

Conflict of Interest The authors declare no competing interests.

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