Computer-assisted robotic renal surgery

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Abstract: Computer-assisted robotic renal surgery (CARRS) is a minimally invasive surgical treatment option for renal tumors. We review the literature regarding techniques and outcomes and the potential advantages of CARRS. We retrospectively reviewed the literature regarding techniques and outcomes of CARRS, with specific analysis on robotic radical nephrectomy (RRN) and robotic partial nephrectomy (RPN). Multiple papers on RRN and RPN were found where the techniques were performed with either a transperitoneal or a retroperitoneal approach. Preliminary outcomes with RRN and RPN were at least comparable to those of a laparoscopic approach, with some parameters of RPN improved over the laparoscopic approach (warm ischemia time, length of hospital stay and estimated blood loss). CARRS is an emerging field with preliminary outcomes at least comparable to the laparoscopic approach. Large prospective, randomized trials are needed to assess the benefit of CARRS compared with current methods.

Keywords: minimally invasive, robotic radical and partial nephrectomies, robotics, surgery

Introduction

Computer-assisted robotic renal surgery (CARRS) is a minimally invasive treatment option that is being used increasingly frequently for kidney tumors. Conventional laparoscopic renal surgery can be technically challenging, particularly with intracorporeal suturing under the time constraints of warm ischemia. The development of the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA) allows surgeons to perform complex minimally invasive procedures more easily than with conventional laparoscopic approach. The benefits of CARRS include a three-dimensional magnified stereoscopic view, a tremor-free platform, wristed articulating instruments, and the absence of a fulcrum effect.

The newer da Vinci Surgical systems (S, Si, etc) offer several advantages compared with the older system, including smaller robotic arms for more efficient docking, the ability to display imaging results and real-time ultrasound findings on the surgeon's console, and a high-definition display.

We review the literature regarding the techniques and outcomes of CARRS, with a particular focus on robotic radical nephrectomy (RRN) and robotic partial nephrectomy (RPN).

Patient positioning, operative setup, and equipment

Following induction of anesthesia and placement of a Foley catheter and orogastric tube, the patient is placed in flank position with the kidney over the table break. Mild table flexion may be used to help increase space for ports if needed. All pressure points are carefully padded and the patient is well secured to the operating table. The anesthesiology team is at the patient's head and the surgical console and console surgeon are to the side of the room. Monitors are set up for the bedside assistant. The bedside assistant is positioned on the abdominal side of the patient next to the surgical technician. The robot is docked over the back of the patient at a slight angle over the shoulder.

A variety of robotic instruments and other equipment can be used during CARRS. Robotic instruments for the dominant hand include monopolar curved scissors and the monopolar hook. Robotic instruments for the nondominant hand include Maryland bipolar forceps, fenestrated bipolar forceps, and Prograsp forceps. Robotic needle drivers are used for intracorporeal suturing. The surgeon may keep forceps in the nondominant hand as a needle driver as per personal preference. Robotic instruments that may be used for the fourth robotic arm (optional)

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include the dual blade retractor and the double fenestrated retractor.

The robotic hook may be useful for blunt dissection of renal vessels. The curved monopolar scissors can also be used for dissection of the renal hilum and may be more cost effective during RPN as they are also utilized for tumor excision. The fine-tipped Maryland bipolar forceps may be used for precise cauterization of small vessels, while the blunt-tipped fenestrated bipolar and Prograsp forceps allow for spreading and isolation of tissues, and can be used later in the case as a needle driver.

Standard laparoscopic instruments are used by the bedside assistant, which may include a 5 mm laparoscopic grasper, 5 mm laparoscopic needle driver, 5 mm laparoscopic scissors, laparoscopic bulldog clamp applicator and/or Satinsky clamp (RPN), 5 mm and 10 mm Weck clip applicator, suction tip, and irrigator.

Surgical approaches

CARRS has been described with both transperitoneal and retroperitoneal approaches.

Transperitoneal approach

Proper port placement is important for success in CARRS. Different port strategies have been described based on the position of the robotic camera, which can be placed either medially [Benway *et al.* 2009; Rogers *et al.* 2008b] or laterally [Badani *et al.* 2008; Kaul *et al.* 2007]. With a medial camera position, the robotic ports are triangulated towards the renal hilum in a wide V configuration. The medial camera placement provides a global view similar to that of conventional laparoscopy. With a lateral camera position, the camera is placed lateral to the robotic arms, reducing arm collisions and providing more room for the assistant and fourth robotic arm. However, the camera is closer to the kidney, resulting in a less global view. The camera can also be placed in an intermediate position, combining the advantages of both the medial and lateral camera positions.

The use of fourth robotic arm during CARRS has been described [Benway *et al.* 2009; Rogers *et al.* 2009]. The fourth robotic arm can be used to retract and position the kidney independent of the assistant. The robotic instrument can be placed under the ureter and lifted to place the kidney on stretch, allowing two-handed

dissection of the renal vessels. However, use of the fourth arm can result in more arm collisions and may be difficult to use in a patient with a wide hips.

Retroperitoneal approach

Potential advantages of a retroperitoneal approach include shorter time to renal hilar control, avoidance of the peritoneum, and improved access to posterior renal tumors.

The patient is positioned in full flank position with table flexion. Retroperitoneal access is obtained laparoscopically as described previously [Gill and Rassweiler, 1999; Gaur, 1992]. An incision is made between the 12th rib and the iliac crest to access the retroperitoneum. A PDB balloon dissector is used to dilate the retroperitoneal space. A 12 mm balloon trocar is placed for the robotic camera. Two robotic instrument ports and a lateral 12 mm assistant port are placed, maximizing the distance between ports. The robot is docked over the head of the patient. The kidney is retracted anteriorly and dissection proceeds along the psoas muscle with robotic assistance until pulsations in the retroperitoneal fat are identified, denoting the underlying renal vessels. The renal hilum is dissected and the renal procedure is completed.

The feasibility of CARRS has been described by Patel and colleagues using a retroperitoneal approach in 10 patients with a mean age of 56 years, (range 36–72 years) [Patel *et al.* 2009]. Mean console time was 166 (120–300) min. Mean blood loss was 82 (50–100) ml and average hospital stay was 2.6 (1–5) days. One patient who underwent nephrectomy with xanthogranulomatous pyelonephritis required open conversion for failure to progress due to dense adhesions.

The authors concluded that a retroperitoneal approach is a safe and feasible alternative to a transperitoneal approach for robotic renal surgery, particularly for patients undergoing partial nephrectomy for posterior renal tumors, or for patients with extensive prior abdominal surgery [Patel *et al.* 2009].

Robotic nephrectomy

Open radical nephrectomy is the gold standard of treatment for large renal tumors and has demonstrated good long-term oncologic outcomes. Since the first laparoscopic nephrectomy in 1991

[Clayman *et al.* 1991], the use of a minimally invasive approach has become the preferred treatment modality for most nephrectomy cases. The safety and efficacy of RRN have been described by several groups [Hemal and Kumar, 2009; Rogers *et al.* 2008a; Nazemi *et al.* 2006; Klingler *et al.* 2005].

The control of renal vessels during RRN can be achieved by using suture ligation, hemolock clips, or an endovascular stapler. Hemolock clips can be placed by the assistant or by the console surgeon using a robotic hemolock clip applicator. Robotic suture ligation of the renal hilum is performed using a 0-silk suture and robotic needle drivers. The nephrectomy specimen can be extracted by extending the peri-umbilical assistant port or through a lateral muscle splitting incision incorporating robotic trocars.

Klingler and colleagues initially described the feasibility of RRN for a small cohort of five patients [Klingler *et al.* 2005]. In another study, this same group compared RRN in six patients with laparoscopic ($n=33$) and open ($n=18$) approaches [Nazemi *et al.* 2006]. The robotic surgery group had a lower estimated blood loss (EBL) but longer operative time than the other groups (345 *versus* 265 min). There was no statistically significant difference in hospital cost or operative parameters between robotic or laparoscopic approaches. The complication rate with RRN was 18%. The longer operative time for a robotic approach was attributed to the learning curve for robotic techniques as well as port placement and robot dock time. These studies did not specify differences between operative console time and total operative time.

Rogers and colleagues studied 42 patients who underwent robotic nephrectomy (RRN 35, simple 7) using a transperitoneal ($n=39$) or retroperitoneal ($n=3$) approach [Rogers *et al.* 2008a]. Mean operative console time was 158 min, mean EBL was 223 ml, mean tumor size was 5.1 cm, and mean hospital stay was 2.4 days. Renal hilar vessels were controlled using robotic suture ligation ($n=25$), robotic hemolock clips ($n=12$), or laparoscopic staplers ($n=5$). No patients required open conversion. One morbidly obese patient developed a wound dehiscence (complication rate 2.6%). All surgical margins were negative for malignancy with no evidence of tumor recurrence at mean follow up of 15.7 months (range 1–51 months). The

authors concluded that robotic nephrectomy is a safe and feasible option for minimally invasive nephrectomy using either a transperitoneal or a retroperitoneal approach.

Robotic assistance may not be practical or necessary for all nephrectomy cases. However, robotic assistance may offer benefits in select situations. For example, the fourth robotic arm can be used to provide upward retraction on the kidney, placing the renal hilum on stretch to facilitate two-handed, precise dissection of the renal hilar vessels. With robotic assistance, suture ligation of the renal vessels can be performed, similar to an open approach. Hemolock clips can be placed robotically under the control of the console surgeon for precise ligation of renal hilar or collateral vessels that are difficult to reach with a conventional laparoscopic hemolock clip applicator. Most importantly, RRN may serve as a useful training platform for RPN, in which robotic assistance may facilitate tumor excision and renal reconstruction [Rogers *et al.* 2008b].

Robotic partial nephrectomy

For renal masses smaller than 4 cm, nephron-sparing surgery is preferred to preserve renal function and minimize the long-term complications associated with renal insufficiency [Go *et al.* 2004]. Laparoscopic partial nephrectomy (LPN) has emerged as a viable alternative to open partial nephrectomy demonstrating favorable long-term oncologic outcomes [Permpongkosol *et al.* 2005; Portis *et al.* 2002] comparable to open partial nephrectomy [Colombo *et al.* 2008; Mattar and Finelli, 2007; Chan *et al.* 2001; Dunn *et al.* 2000], but with the convalescence benefits of a minimally invasive approach [Porpiglia *et al.* 2008; Gill *et al.* 2001]. However, LPN is a technically challenging procedure, particularly performing intracorporeal sutured renal reconstruction under the time constraints of warm ischemia. RPN may aid in these technical challenges of LPN.

Most of early RPN series report a hybrid procedure, with initial bowel mobilization and kidney exposure performed laparoscopically and the robot docked later for tumor excision and renal reconstruction [Aron *et al.* 2008; Deane *et al.* 2008; Caruso *et al.* 2006; Gettman *et al.* 2004]. However, more recent descriptions by Bhayani, Kaul and colleagues, and others report success with an entirely robotic procedure [Bhayani, 2008; Kaul *et al.* 2007].

Following exposure of the kidney and dissection of the renal hilum, intraoperative ultrasound is useful to locate the tumor and delineate tumor margins prior to resection. The TilePro feature of the da Vinci S/Si system allows the surgeon to view live intraoperative ultrasound footage and preoperative radiographic images as a picture-on-picture display on the console screen, guiding tumor localization without the need to leave the console to view external images [Rogers *et al.* 2009; Bhayani and Snow, 2008]. Image sources are connected to the console and TilePro is activated by tapping the camera pedal to turn the images on or off.

Hilar occlusion is performed by using either bulldog clamps or a Satinsky clamp. In both cases, clamps are placed by the assistant through an accessory port. When using bulldog clamps, the renal artery is occluded prior to the renal vein and the venous clamp is the first to be removed when the procedure is completed. For small or exophytic tumors, the renal artery alone may be clamped. A Satinsky clamp offers the advantage of en-block clamping of the renal hilum without the need for complete dissection. However, the kidney is less mobile and a dedicated port is required. Also, care must be taken to avoid external collision of the robotic arms with the Satinsky clamp which could cause avulsion injury to renal vessels. There are several different pharmaceutical agents that have been used during hilar clamping to help protect the kidney against ischemic injury. The most commonly used agent is intravenous mannitol prior to hilar clamping. Excision and reconstruction may be attempted without hilar clamping for small or exophytic tumors, however predissection of the renal hilum is recommended to allow for vascular control if needed.

For renal reconstruction, the curved scissors in the right hand are replaced with a robotic needle driver. The Prograsp or fenestrated bipolar forceps may be switched to a needle driver, or kept in the left hand and used as a needle driver as per surgeon preference. Sutured renal reconstruction may be performed to achieve hemostasis and repair any entry into the collecting system. The sliding hemolock clip renorrhaphy technique may be used to secure intraparenchymal stitches without the need for knot tying [Bhayani and Figenschau, 2008]. Hemolock clips can be slid down the suture by the console surgeon to reapproximate capsular edges under tension [Bhayani

and Figenschau, 2008]. For wedge resections performed on smaller tumors, the capsule often closes completely. Bolsters and hemostatic agents may not be needed, but can be used as per surgeon preference.

The largest series to date comparing RPN with LPN found perioperative outcomes at least equivalent to those of LPN, with significant reduction of intraoperative blood loss (155 *versus* 196 ml), hospital stay (2.4 *versus* 2.7 days), and warm ischemia times (19.7 *versus* 28.4 min) for RPN [Benway *et al.* 2009]. There was no increase in overall operative times for RPN with increasing tumor complexity, but increasing tumor complexity resulted in increased operative times for LPN.

Conclusion

Despite the advantages of nephron-sparing surgery in treating patients with small renal tumors, more than 90% of these patients undergo radical nephrectomy [Miller *et al.* 2006]. The incorporation of CARRS may allow more surgeons to offer patients a minimally invasive partial nephrectomy.

Potential limitations associated with CARRS include a learning curve for new techniques, reliance upon an experienced bedside surgical assistant, and potential increased costs. Limitations of the majority of studies of CARRS include their small sample size and nonrandomized, retrospective nature, which are subject to bias.

CARRS is an emerging field with early results at least comparable to a laparoscopic approach and some parameters even appearing better than with a laparoscopic approach. Large prospective, randomized trials are needed to further assess the benefit of CARRS compared with current methods, particularly in regards to cost effectiveness and long-term outcomes.

Conflict of interest statement

The authors have no conflict of interest to declare in connection with this study.

References

- Aron, M., Koenig, P., Kaouk, J.H., Nguyen, M.M., Desai, M.M. and Gill, I.S. (2008) Robotic and laparoscopic partial nephrectomy: a matched-pair comparison from a high-volume centre. *BJU Int* 102: 86–92.

- Badani, K.K., Muhletaler, F., Fumo, M., Kaul, S., Peabody, J.O., Bhandari, M. *et al.* (2008) Optimizing robotic renal surgery: the lateral camera port placement technique and current results. *J Endourol* 22: 507–510.
- Benway, B.M., Bhayani, S.B., Rogers, C.G., Dulabon, L.M., Patel, M.N., Lipkin, M. *et al.* (2009) Robot assisted partial nephrectomy versus laparoscopic partial nephrectomy for renal tumors: a multi-institutional analysis of perioperative outcomes. *J Urol* 182: 866–872.
- Bhayani, S.B. (2008) da Vinci robotic partial nephrectomy for renal cell carcinoma: an atlas of the four-arm technique. *J Robotic Surg* 1: 279–289.
- Bhayani, S.B. and Figenschau, R.S. (2008) The Washington University Renorrhaphy for robotic partial nephrectomy: a detailed description of the technique displayed at the 2008 World Robotic Urologic Symposium. *J Robotic Surg* 2: 139–140.
- Bhayani, S.B. and Snow, D. (2008) Novel dynamic information integration during da Vinci robotic partial nephrectomy and radical nephrectomy. *J Robotic Surg* 2: 67–69.
- Caruso, R.P., Phillips, C.K., Kau, E., Taneja, S.S. and Stifelman, M.D. (2006) Robot assisted laparoscopic partial nephrectomy: initial experience. *J Urol* 176: 36–39.
- Chan, D.Y., Cadeddu, J.A., Jarrett, T.W., Marshall, F.F. and Kavoussi, L.R. (2001) Laparoscopic radical nephrectomy: cancer control for renal cell carcinoma. *J Urol* 166: 2095–2099, discussion 2099–2100.
- Clayman, R.V., Kavoussi, L.R., Soper, N.J., Dierks, S.M., Meretyk, S., Darcy, M.D. *et al.* (1991) Laparoscopic nephrectomy: initial case report. *J Urol* 146: 278–282.
- Colombo Jr, J.R., Haber, G.P., Jelovsek, J.E., Lane, B., Novick, A.C. and Gill, I.S. (2008) Seven years after laparoscopic radical nephrectomy: oncologic and renal functional outcomes. *Urology* 71: 1149–1154.
- Deane, L.A., Lee, H.J., Box, G.N., Melamud, O., Yee, D.S., Abraham, J.B. *et al.* (2008) Robotic versus standard laparoscopic partial/wedge nephrectomy: a comparison of intraoperative and perioperative results from a single institution. *J Endourol* 22: 947–952.
- Dunn, M.D., Portis, A.J., Shalhav, A.L., Elbahnasy, A.M., Heidorn, C., McDougall, E.M. *et al.* (2000) Laparoscopic versus open radical nephrectomy: a 9-year experience. *J Urol* 164: 1153–1159.
- Gaur, D.D. (1992) Laparoscopic operative retroperitoneoscopy: use of a new device. *J Urol* 148: 1137–1139.
- Gettman, M.T., Blute, M.L., Chow, G.K., Neururer, R., Bartsch, G. and Peschel, R. (2004) Robotic-assisted laparoscopic partial nephrectomy: technique and initial clinical experience with DaVinci robotic system. *Urology* 64: 914–918.
- Gill, I.S., Meraney, A.M., Schweizer, D.K., Savage, S.S., Hobart, M.G., Sung, G.T. *et al.* (2001) Laparoscopic radical nephrectomy in 100 patients: a single center experience from the United States. *Cancer* 92: 1843–1855.
- Gill, I.S. and Rassweiler, J.J. (1999) Retroperitoneoscopic renal surgery: our approach. *Urology* 54: 734–738.
- Go, A.S., Chertow, G.M., Fan, D., McCulloch, C.E. and Hsu, C.Y. (2004) Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. *N Engl J Med* 351: 1296–1305.
- Hemal, A.K. and Kumar, A. (2009) A prospective comparison of laparoscopic and robotic radical nephrectomy for T1-2N0M0 renal cell carcinoma. *World J Urol* 27: 89–94.
- Kaul, S., Laungani, R., Sarle, R., Stricker, H., Peabody, J., Littleton, R. *et al.* (2007) Da Vinci-assisted robotic partial nephrectomy: technique and results at a mean of 15 months of follow-up. *Eur Urol* 51: 186–192.
- Klingler, D.W., Hemstreet, G.P. and Balaji, K.C. (2005) Feasibility of robotic radical nephrectomy—initial results of single-institution pilot study. *Urology* 65: 1086–1089.
- Mattar, K. and Finelli, A. (2007) Expanding the indications for laparoscopic radical nephrectomy. *Curr Opin Urol* 17: 88–92.
- Miller, D.C., Hollingsworth, J.M., Hafez, K.S., Daignault, S. and Hollenbeck, B.K. (2006) Partial nephrectomy for small renal masses: an emerging quality of care concern? *J Urol* 175: 853–857, discussion 858.
- Nazemi, T., Galich, A., Sterrett, S., Klingler, D., Smith, L. and Balaji, K.C. (2006) Radical nephrectomy performed by open, laparoscopy with or without hand-assistance or robotic methods by the same surgeon produces comparable perioperative results. *Int Braz J Urol* 32: 15–22.
- Patel, M.N., Kaul, S.A., Laungani, R., Eun, D., Bhandari, M., Menon, M. *et al.* (2009) Retroperitoneal robotic renal surgery: technique and early results. *J Robotic Surg* 3: 1–5.
- Permpongkosol, S., Chan, D.Y., Link, R.E., Sroka, M., Allaf, M., Varkarakis, I. *et al.* (2005) Long-term survival analysis after laparoscopic radical nephrectomy. *J Urol* 174: 1222–1225.
- Porpiglia, F., Volpe, A., Billia, M. and Scarpa, R.M. (2008) Laparoscopic versus open partial nephrectomy: analysis of the current literature. *Eur Urol* 53: 732–742, discussion 742–733.
- Portis, A.J., Yan, Y., Landman, J., Chen, C., Barrett, P.H., Fentie, D.D. *et al.* (2002) Long-term followup after laparoscopic radical nephrectomy. *J Urol* 167: 1257–1262.
- Rogers, C., Laungani, R., Krane, L.S., Bhandari, A., Bhandari, M. and Menon, M. (2008a) Robotic

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nephrectomy for the treatment of benign and malignant disease. *Br J Urol Int* 102: 1660–1665.

Rogers, C.G., Laungani, R., Bhandari, A., Krane, L.S., Eun, D., Patel, M.N. *et al.* (2009) Maximizing console surgeon independence during robot-assisted renal surgery by using

the fourth arm and TilePro™. *J Endourol* 23: 115–122.

Rogers, C.G., Singh, A., Blatt, A.M., Linehan, W.M. and Pinto, P.A. (2008b) Robotic partial nephrectomy for complex renal tumors: surgical technique. *Eur Urol* 53: 514–523.