"Trifecta" in Partial Nephrectomy

Andrew J. Hung, Jie Cai, Matthew N. Simmons and Inderbir S. Gill*,†

From the Hillard and Roclyn Herzog Center for Robotic Surgery, University of Southern California Institute of Urology, Keck School of Medicine, University of Southern California, Los Angeles, California, and Center for Urologic Oncology, Glickman Urological and Kidney Institute, Cleveland Clinic (MNS), Cleveland, Ohio

Abbreviations and Acronyms

AKI = acute kidney injury

eGFR = estimated glomerular filtration rate

LPN = laparoscopic PN

MDRD = Modification of Diet in Renal Disease

PN = partial nephrectomy

RPN = robot-assisted PN

WIT = warm ischemia time

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* Correspondence: University of Southern California Institute of Urology, 1441 Eastlake Ave., Suite 7416, Los Angeles, California 90089 (telephone: 323-865-3700; FAX: 323-865-0120; e-mail: gillindy@gmail.com).

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Purpose: We introduce the concept of trifecta outcomes during robotic/laparoscopic partial nephrectomy, in which the 3 key outcomes of negative cancer margin, minimal renal functional decrease and no urological complications are simultaneously realized. We report serial trifecta outcomes in patients treated with robotic/laparoscopic partial nephrectomy for tumor in a 12-year period.

Materials and Methods: A total of 534 patients had complete data available and were retrospectively divided into 4 chronologic eras, including the discovery era—139 from September 1999 to December 2003, conventional hilar clamping era—213 from January 2004 to December 2006, early unclamping era—104 from January 2007 to November 2008 and anatomical zero ischemia era—78 from March 2010 to October 2011. Renal functional decrease was defined as a greater than 10% reduction in the actual vs volume predicted postoperative estimated glomerular filtration rate.

Results: Across the 4 eras tumors trended toward larger size (2.9, 2.8, 3.1 and 3.3 cm, $p = 0.08$) and yet the estimated percent of kidney preserved was similar (89%, 90%, 90% and 88%, respectively, $p = 0.3$). Recent eras had increasingly complex tumors that were more often 4 cm or greater ($p = 0.03$), centrally located ($p < 0.009$) or hilar ($p < 0.0001$). Nevertheless, with significant technical refinement warm ischemia time decreased serially (36, 32, 15 and 0 minutes, respectively, $p < 0.0001$). Renal functional outcomes were superior in recent eras with fewer patients experiencing a decrease ($p < 0.0001$). Uniquely, actual estimated glomerular filtration rate outcomes exceeded volume predicted estimated glomerular filtration rate outcomes only in the zero ischemia cohort in regard to other eras (–9.5%, –11%, –0.9% and 4.2%, respectively, $p < 0.001$). Positive cancer margins were uniformly low at less than 1%. Urological complications trended lower in recent eras ($p = 0.01$). Trifecta outcomes occurred more commonly in recent eras (45%, 44%, 62% and 68%, respectively, $p = 0.0002$).

Conclusions: Trifecta should be a routine goal during partial nephrectomy. Despite increasing tumor complexity, trifecta outcomes of robotic/laparoscopic partial nephrectomy improved significantly in the last decade.

Key Words: kidney; carcinoma, renal cell; nephrectomy; laparoscopy; robotics

SMALL renal masses are diagnosed more frequently due to the prevalent use of abdominal imaging.[1] PN is the preferred surgical treatment since it provides equivalent oncological and superior functional outcomes compared to radical nephrectomy.[2] Even for anatomically favorable tumors up to 7 cm

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with a normal contralateral kidney elective PN yields oncological outcomes equivalent to those of radical nephrectomy.[3]

In the last 10 years minimally invasive PN has increasingly become a desired approach for nephron sparing surgery. LPN/RPN closely follows the open surgical technique while decreasing patient morbidity. Initial experiences with LPN were associated with somewhat increased urological complications and longer WIT compared to open surgery.[4] With experience the outcomes of LPN have improved significantly despite increasing tumor complexity.[5] This improvement is in part due to the development of techniques that have significantly decreased WIT, such as early unclamping PN.[6] More recent efforts have focused on novel anatomical approaches to PN that may further decrease or even eliminate global ischemia to the renal remnant even for complex tumors.[7,8]

PN has the triple goals of negative surgical margins, functional preservation and complication-free recovery. Simultaneous achievement of all 3 goals in an individual may be deemed a trifecta outcome. Although described during radical prostatectomy (continence, potency and cancer cure), to our knowledge trifecta outcomes have not been described after PN to date.

We propose the concept of trifecta outcomes during PN. Presented are serial trifecta outcomes in patients with mostly T1a tumors treated with RPN/LPN in a 12-year period, encompassing progressively decreasing ischemia time by evolving techniques.

MATERIALS AND METHODS

All data were prospectively collected in institutional review board approved databases and analyzed retrospectively. Between September 1999 and October 2011, 534 of 900 consecutive evaluable patients treated with RPN/LPN by a single surgeon (ISG) had a complete data set available for review and were included in study. Of the patients 366 were excluded due to missing data on the percent of kidney preserved after PN (284), a solitary kidney (55), multiple metachronous or simultaneous tumors (26) and multiple tumors in a solitary kidney (1). Patients undergoing RPN/LPN between November 2008 and March 2010 were not included in study because during this period the senior surgeon was relocating and becoming established in a new institution. As such, institutional review board approval was not available until March 2010, precluding patient enrollment in our prospective database until this point.

Patients were retrospectively divided into 4 chronological periods, including the discovery era—139 from September 1999 to December 2003, during which the LPN technique was initially discovered/developed, conventional hilar clamping era—213 from January 2004 to December 2006, during which hilar cross clamping was performed for the entire duration of PN, early unclamping era—104 from January 2007 to November 2008, during which the early unclamping technique of PN was used, as described, and anatomical zero ischemia era—78 from March 2010 to October 2011, during which the zero ischemia technique of PN was used, as described.

Our evolving minimally invasive PN techniques have been detailed previously.[6,7] During the discovery and conventional hilar clamping eras, our PN technique involved en bloc hilar clamping of the main renal artery and vein for the entire duration of tumor excision and renal reconstruction.[4] In the early unclamping era we developed the technique of clamping the hilum only during tumor excision and placement of the initial central running suture. The hilum was then unclamped early and all subsequent suturing of the PN bed to secure hemostasis and pelvicalyceal repair was performed in the perfused kidney.[6] In the most recent zero ischemia era a novel anatomical approach to PN was developed, in which vascular microdissection of targeted, tumor specific tertiary or higher order arteries was performed to achieve tumor specific devascularization.[7] Continued normal arterial perfusion to and the absence of any clinically discernible ischemia of the rest of the uninvolved kidney were objectively documented intraoperatively by 2 techniques, including 1) real-time color Doppler ultrasound showing preserved waveform and resistive indexes, and/or 2) intravenous indigo cyanine green with robotic infrared vision showing global perfusion. In the zero ischemia era hilar clamping was necessary intraoperatively in only 1 patient (1.3%).

Our RPN and LPN techniques mirror each other and, thus, they are completely interchangeable. Robot use or nonuse depended exclusively on robot availability.

All tumor specimens were extracted intact for pathological evaluation according to the 2002 American Joint Committee on Cancer TNM staging. A margin positive for cancer was defined as cancer cells present at the inked parenchymal margin.

Renal function assessment included serum creatinine and eGFR calculated by the abbreviated MDRD equation.[9] Postoperative renal function was recorded as the latest available serum creatinine value within 30 days after surgery. AKI was defined as a greater than 50% increase in postoperative serum creatinine compared to baseline.[10] The estimated percent of kidney preserved was subjectively based on renal remnant size by the surgeon and 2 assistants. Predicted postoperative eGFR was calculated by multiplying preoperative eGFR by the percent of total kidney tissue preserved after PN. For example, in a patient with 2 kidneys if 20% of the ipsilateral kidney was excised during PN, the percent of total kidney tissue preserved was deemed to be 90% since 80% of the ipsilateral kidney and 100% of the contralateral kidney were preserved. Given a baseline eGFR of 100 ml/minute/1.73 m^2, the predicted postoperative eGFR would be 90 ml/minute/1.73 m^2 (100 $\times$ 90%). Renal functional decrease was defined as a 10% or greater reduction in actual postoperative eGFR compared to predicted postoperative eGFR.

Complications were classified as intraoperative or postoperative and urological or nonurological (nonexclusive definitions). Urological complications included renal hemorrhage (bleeding from the kidney requiring reoperative