

Practice Patterns and Outcomes of Open and Minimally Invasive Partial Nephrectomy Since the Introduction of Robotic Partial Nephrectomy: Results from the Nationwide Inpatient Sample

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Purpose: We determined practice patterns and perioperative outcomes of open and minimally invasive partial nephrectomy in the United States since the introduction of a robot-assisted modifier in the Nationwide Inpatient Sample.

Materials and Methods: We identified all patients with nonmetastatic disease treated with open, laparoscopic or robotic partial nephrectomy in the Nationwide Inpatient Sample between October 2008 and December 2010. Utilization rates were assessed by year, patient and hospital characteristics. We evaluated the perioperative outcomes of open vs robotic and open vs laparoscopic partial nephrectomy using binary logistic regression models adjusted for patient and hospital covariates.

Results: In a weighted sample of 38,064 partial nephrectomies 66.9%, 23.9% and 9.2% of the procedures were open, robotic and laparoscopic operations, respectively. In 2010 the relative annual increase in open, robotic and laparoscopic partial nephrectomy was 7.9%, 45.4% and 6.1%, respectively. Compared to open partial nephrectomy patients treated with minimally invasive partial nephrectomy were less likely to receive blood transfusion (robotic vs laparoscopic OR 0.56, $p < 0.001$ vs OR 0.68, $p = 0.016$), postoperative complication (OR 0.63, $p < 0.001$ vs OR 0.78, $p < 0.009$) or prolonged length of stay (OR 0.27 vs OR 0.41, each $p < 0.001$). Only patients who underwent the robotic procedure were less likely to experience an intraoperative complication (robotic vs laparoscopic OR 0.69, $p = 0.014$ vs OR 0.67, $p = 0.069$). Excess hospital charges were higher after robotic surgery (OR 1.35, $p < 0.001$).

Conclusions: The dissemination of robotic surgery for partial nephrectomy in the United States has been rapid and safe. Compared to open partial nephrectomy the robotic procedure had lower odds than laparoscopic partial nephrectomy for most study outcomes except hospital charges. Robotic partial nephrectomy has now supplanted laparoscopic partial nephrectomy as the most common minimally invasive approach for partial nephrectomy.

Key Words: kidney, nephrectomy, robotics, laparoscopy, complications

Abbreviations and Acronyms

CCI = Charlson comorbidity index
 LOS = length of stay
 LPN = laparoscopic PN
 NIS = Nationwide Inpatient Sample
 OPN = open PN
 pLOS = prolonged LOS
 PN = partial nephrectomy
 RARP = robot-assisted radical prostatectomy
 RM = robot-assisted modifier
 RPN = robotic PN

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CURRENT American Urological Association and European Association of Urology guidelines recommend PN as

the standard of care for renal masses less than 4 and less than 7 cm.^{1,2} While OPN is the traditional standard, the

last decade has seen significant advances in minimally invasive PN.³ LPN is equivalent oncologically to OPN with lower blood loss and LOS after LPN at some centers.⁴ More recently, the adoption of robot-assisted surgery has popularized RPN.⁵ Although recent population level studies assessed PN compared to RN,^{6,7} studies evaluating the different approaches to PN have been mostly limited to institutional series^{8,9} with few population level studies.^{10,11} A reason was the difficulty of discriminating RPN from LPN in administrative data sets.

As of October 1, 2008, Food and Drug Administration approved a RM to identify robot-assisted procedures. We determined practice patterns and perioperative outcomes of open and minimally invasive PN (LPN and RPN) since the introduction of RM using the NIS.

MATERIALS AND METHODS

Data Source

We abstracted NIS data between 1998 and 2010 to determine long-term trends in PN. To assess the impact of RM the data were narrowed to October 1, 2008 to December 31, 2010. This was the cohort for all subsequent analysis. The NIS contains inpatient discharge data collected by the Agency for HCUP (Healthcare Research and Quality Healthcare Cost and Utilization Project). As of 2010, it held 8 million hospital stays from more than 1,000 hospitals in a total of 44 states, representing approximately 20% of American hospitals, including public and academic hospitals. It is the only American database with charge information on all patients regardless of payer.

Study Cohort

Patients 18 years old or older with a primary diagnosis of kidney cancer were identified using the ICD-9-CM diagnostic code 189.0. Secondary diagnostic codes (ICD-9-CM 197.0, 197.7 and 198.x) were used to identify those with metastasis, who were excluded from further analysis. We abstracted data on patients who underwent PN (ICD-9-CM 55.4). As recognized by the National Center of Health Statistics, and Centers for Medicare and Medicaid Services, beginning October 1, 2008 the RM code (ICD-9-CM 17.4x) was used to identify RPN. Patients with the minimally invasive modifier code (ICD-9-CM 54.21) without RM were classified as having undergone LPN. The remaining patients were determined to have undergone OPN. Hospital sampling weights were used to estimate the total number of these procedures.

Patient and Hospital Characteristics

For all patients the available variables were age, race, CCI and insurance status, ie private, Medicare, Medicaid or other (self-pay). Baseline CCI was calculated and adapted according to Deyo et al as 0, 1, 2, or 3 or greater.¹² All demographic characteristics were weighted according to HCUP discharge level estimates. Hospital characteristics included hospital region (Northeast, Midwest, South

or West) obtained from the AHA (American Hospital Association) Annual Survey of Hospitals, as defined by the United States Census Bureau. Hospitals were divided into academic and nonacademic institutions and status was obtained from the AHA. Hospital case load was defined according to the number of PNs performed annually, as previously described.¹³

Complications, LOS and In-Hospital Mortality

The NIS records up to 15 diagnoses and procedures per stay. The presence of any complication was defined using ICD-9 diagnoses 2 to 15 and previously published methodology.¹⁴ Intraoperative complications consisted of surgical laceration of the bowel, ureter and nerves, and/or vessels during a procedure (ICD-9 998.2). Blood transfusion recipients were identified using the ICD-9 procedure codes 99.02 and 99.04. Seven groups of postoperative complications were identified, consisting of cardiac, respiratory or vascular events, as well as other events, such as genitourinary, digestive, neurological, operative wound and postoperative infection. Perioperative mortality was coded from patient disposition. LOS was calculated by subtracting the hospital admission date from the date of discharge. We defined pLOS as hospitalization beyond the 75th percentile. Excess charges were calculated as overall hospital charges beyond the 75th percentile after adjusting for inflation in 2012 dollars.

Statistical Analysis

The median and IQR were generated for continuously coded variables, and the frequency and proportion were generated for categorical variables. The Mann-Whitney and chi-square tests were used to assess the statistical significance of medians and proportions, respectively. Binary logistic regression analysis was done to compare perioperative outcomes of OPN vs RPN and OPN vs LPN. Evaluated outcomes included the odds of 1) blood transfusion, 2) intraoperative complication, 3) postoperative complication during hospitalization, 4) pLOS and 5) in-hospital mortality. Models were adjusted for age, race, gender, baseline CCI, hospital teaching status, region, location, hospital case load, surgery year and insurance status. All tests were 2-sided with statistical significance considered at $p < 0.05$. R, version 2.15.2 (<http://www.r-project.org/>) was used for all analysis.

RESULTS

A weighted national estimate of 118,330 PNs was performed from 1998 to 2010, of which 84.7%, 7.7% and 7.5% were OPN, RPN and LPN, respectively. From October 1, 2008 to December 31, 2010 a weighted estimate of 38,064 PNs was performed, of which 66.9%, 23.9% and 9.2% were OPN, RPN and LPN, respectively. The figure shows changes in the number of PNs done from 1998 to 2010 with notable increases in RPN from 2009. In 2010 the relative annual increase in OPN, RPN and LPN was 7.9%, 45.4% and 6.1%, respectively.

The supplementary table (<http://jurology.com/>) lists the characteristics of the patient populations

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