Use, Costs and Comparative Effectiveness of Robotic Assisted, Laparoscopic and Open Urological Surgery

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Abbreviations and Acronyms

DS = data suppressed per Nationwide Inpatient Sample for 0<n<11

LOS = length of hospital stay

LS = laparoscopic surgery

OS = open surgery

NIS = Nationwide Inpatient Sample

RALS = robotic assisted laparoscopic surgery

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Purpose: Although robotic assisted laparoscopic surgery has been aggressively marketed and rapidly adopted, there are few comparative effectiveness studies that support its purported advantages compared to open and laparoscopic surgery. We used a population based approach to assess use, costs and outcomes of robotic assisted laparoscopic surgery vs laparoscopic surgery and open surgery for common robotic assisted urological procedures.

Materials and Methods: From the Nationwide Inpatient Sample we identified the most common urological robotic assisted laparoscopic surgery procedures during the last quarter of 2008 as radical prostatectomy, nephrectomy, partial nephrectomy and pyeloplasty. Robotic assisted laparoscopic surgery, laparoscopic surgery and open surgery use, costs and inpatient outcomes were compared using propensity score methods.

Results: Robotic assisted laparoscopic surgery was performed for 52.7% of radical prostatectomies, 27.3% of pyeloplasties, 11.5% of partial nephrectomies and 2.3% of nephrectomies. For radical prostatectomy robotic assisted laparoscopic surgery was more prevalent than open surgery among white patients in high volume, urban hospitals (all $p \leq 0.015$). Geographic variations were found in the use of robotic assisted laparoscopic surgery vs open surgery. Robotic assisted laparoscopic surgery and laparoscopic surgery vs open surgery were associated with shorter length of stay for all procedures, with robotic assisted laparoscopic surgery being the shortest for radical prostatectomy and partial nephrectomy (all $p < 0.001$). For most procedures robotic assisted laparoscopic surgery and laparoscopic surgery vs open surgery resulted in fewer deaths, complications, transfusions and more routine discharges. However, robotic assisted laparoscopic surgery was more costly than laparoscopic surgery and open surgery for most procedures.

Conclusions: While robotic assisted and laparoscopic surgery are associated with fewer deaths, complications, transfusions and shorter length of hospital stay compared to open surgery, robotic assisted laparoscopic surgery is more costly than laparoscopic and open surgery. Additional studies are needed to better delineate the comparative and cost-effectiveness of robotic assisted laparoscopic surgery relative to laparoscopic surgery and open surgery.

Key Words: robotics, urologic surgical procedures, laparoscopy, treatment outcome, costs and cost analysis

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WITH more than 1,400 robotic surgical systems installed in United States hospitals, with some having up to 5 systems, and the number of robotic systems in other countries doubling from 200 to 400 between 2007 and 2009,[1] robotic assisted laparoscopic surgery has been rapidly adopted without population based evidence demonstrating superior outcomes compared to laparoscopic surgery and open surgery. As a result the Institute of Medicine has prioritized RALS for comparative effectiveness research.[2] Direct to consumer advertising has fueled patient demand for RALS,[3] particularly for radical prostatectomy. However, men who underwent radical prostatectomy with RALS vs OS were more likely to be diagnosed with incontinence and erectile dysfunction, and more likely to experience treatment regret.[4,5]

Most existing studies that demonstrate better outcomes with RALS are single surgeon series, whereby investigators may receive educational or research funding from the device manufacturer (Intuitive Surgical®, Sunnyvale, California). Moreover estimates of RALS use are provided primarily by the manufacturer.[1,6] In this study we characterize population based RALS use and patterns of care for urological procedures, and compare perioperative costs and outcomes with LS and OS.

MATERIALS AND METHODS

Data Source

Subjects were identified from the HCUP (Healthcare Cost and Utilization Project) NIS (Nationwide Inpatient Sample), sponsored by the Agency for Healthcare Research and Quality.[7] NIS is a 20% stratified probability sample that encompasses approximately 8 million acute hospital stays from more than 1,000 hospitals in 42 states per year. It is the largest all-payer inpatient care observational cohort in the United States and represents approximately 90% of all hospitalizations.

Study Cohort

During the last quarter of 2008 there were 2,093,300 hospitalizations within the NIS. Using NIS discharge weights these represent more than 9.8 million patients. We used the ICD-9 code 17.4x for RALS, initiated on October 1, 2008, to identify RALS procedures approved by the U.S. Food and Drug Administration. RALS were comprised of 64% urological, 32% gynecologic, 2% cardiac and 2% general surgical procedures. Procedures with a laparoscopic designation (ICD-9 54.21, 54.51) were classified as LS, while those without LS or RALS designations/codes were classified as OS. To adequately power analyses we analyzed urological procedures with 40 or more unweighted procedures including radical prostatectomy (ICD-9 60.5), nephrectomy (ICD-9 55.51, 55.52, 55.54), partial nephrectomy (ICD-9 55.4) and pyeloplasty (ICD-9 55.87).

Covariates

For each procedure we examined hospital and patient level characteristics that may be associated with outcomes. Hospital characteristics included U.S. census region, urban vs rural location, teaching status and bed size. Hospital surgical volume was assessed by stratifying each procedure into high, intermediate and low volume tertiles to minimize cell counts of less than 11 (for which DS is required per NIS). Patient level characteristics include age, number of comorbidities, race, median income and primary payer (private vs government health plans).

Outcomes

ICD-9 diagnosis and procedure codes were used to identify blood transfusions and complications (cardiac, respiratory, genitourinary, vascular, wound, miscellaneous medical and miscellaneous surgical).[4] NIS specific outcomes included death, hospital LOS, discharge disposition (routine [home] vs other [rehabilitation, skilled nursing facility, etc]) and total costs. Costs were derived from total charges using the HCUP cost-to-charge ratio.

Statistical Analysis

Use of RALS, LS and OS during the study period was characterized for each procedure. Stratification, clustering and survey weights were used in accordance with NIS sampling. Because characteristics of subjects undergoing RALS and LS differed from those undergoing OS, propensity scoring methods were used to adjust for potential bias associated with selection for open vs minimally invasive procedures.[8] This approach controls for factors that may confound group assignment and outcomes by adjusting discharge weights, with the goal of balancing characteristics among groups. Adjustments were conducted using multivariate logistic regression models to calculate the propensity of undergoing RALS, LS or OS based on all covariates described, and weighted by the inverse propensity of being in one of the treatment groups.[9] Propensity scoring models were constructed for each of the 4 procedures examined. Balance of covariates across procedures was verified following propensity adjustment. Linear and logistic regressions were used to examine univariable and multivariable effects of surgical approach on outcomes. LOS comparisons were modeled using log-normal linear regression. All analyses were performed with SAS® version 9.2 and all tests were considered statistically significant at $p \leq 0.05$.

RESULTS

Procedure Frequencies

The relative use of RALS, LS and OS is shown in the figure. Radical prostatectomy was the only procedure in which RALS (52.7%) was more prevalent than OS (44.4%) and LS (2.8%) combined. OS was the predominant surgical approach for all other procedures. LS was least prevalent among all procedures except laparoscopic nephrectomy, in which RALS was least prevalent.

Characteristics of Study Sample

Patient and hospital characteristics are shown in table 1. Propensity adjustment balanced covariates for all procedures except for pyeloplasty age and hospital