Resident Involvement in Urologic Robotic Surgeries

By

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Overall Abstract

Resident inexperience in the operating room has long been debated as a contributor to adverse patient outcomes. Since its introduction, robotic surgery has become an integral part of health care delivery, particularly for the surgical treatment of prostate cancer. The purpose of this paper is to examine the outcomes of resident involvement in urologic robotic procedures. The first section includes a systematic review of the available literature, evaluating the aforementioned topic and identifying potential gaps in this collection of studies. Examination of the four articles that met inclusion criteria demonstrated preliminarily encouraging results of the safety of resident involvement, as well as a need for studies with larger sample sizes and more generalizable results.

The second section is original research reporting the results of patient outcomes with and without resident participation in robotic prostatectomies (RP), one of the most common urologic robotic surgeries. Using the National Surgical Quality Improvement Program database (2005 – 2011), 5,087 patients who underwent RP were identified to evaluate this relationship. After adjusting for potential confounders, resident involvement did not affect 30-day mortality, serious morbidity or overall morbidity. Resident involvement did, however, result in significantly longer operative times. Nevertheless, the results support that resident participation in RPs appears safe, regardless of postgraduate year level. To date, this study is unique among many of those assessed during the systematic review as it utilizes standardized data from over 200 participating medical centers and includes a significantly larger sample size than any other previously published study on this topic.

A Systematic Review of Studies Assessing the Outcomes of Resident Involvement in Robotic Surgeries

INTRODUCTION

Since its introduction, the popularity and application of robotic surgery has grown rapidly in various fields of surgery over the past ten to fifteen years,(1, 2) in part because of its numerous potential benefits, including decreased blood loss and postoperative pain, shorter recovery time and improved cosmesis.(3) As such, many surgical residency programs have expanded their curricula to include robotic procedures and techniques.(2, 4)

Concurrent with these changes in surgical training is a shift in the delivery of health care in the United States. Multiple national organizations (including the Institute of Medicine, the National Committee for Quality Assurance and the Agency for Healthcare Research and Quality) have issued reports emphasizing the importance of patient-centered, high-quality care.(5-7) This shift has prompted a reevaluation of surgical residency training and the effects of resident involvement in the operating room, which has long been debated as contributor to adverse patient outcomes.(8)

Many studies have explored the relationship between resident participation in surgery and patient outcomes;(8-11) however, I was unaware of any studies that had done so looking specifically at robotic surgery. With that in mind, the overarching goal of this systematic review was to identify published studies that examined the effect of resident involvement on post-operative outcomes of robotic surgeries.

MATERIALS AND METHODS

Literature Search

A systematic literature search of the MEDLINE database was conducted in May 2013 to identify studies analyzing the effects of resident involvement on outcomes in robotic surgery. Specifically, I sought articles that addressed outcomes, resident education and robotic surgery. To be included in this review, articles had to address all three of these subcategories. A 'text word search' strategy was used for all key words/search strings, unless indicated otherwise, to improve sensitivity.(2) The subcategory of Outcomes was searched using the following key words: *Postoperative Complications, Intraoperative Complications, Treatment Outcome, outcome*,* or *complication**. MeSH terms were used for these first three key words. The subcategory of Resident/Education was searched using the following key words: Internship and Residency, resident*, fellow*, or education. MeSH terms was used for *Internship and Residency*, while a subheading search was used for *education*. The subcategory of Robot was defined with the following search strings: *robot** or *telesurg**.

Eligibility Criteria

To be included, relevant articles had to contrast post-operative outcomes (either complication rates or operative time) of robotic surgeries in which residents and/or fellows were present or absent. No large, randomized trials analyzing this topic exist, so all study types were included in the review. All opinion pieces and review articles were excluded with the intent of keeping only original research. Studies were limited to those published in English language.

Abstraction of Data and Quality Assessments

I reviewed all included articles in their entirety to identify the following characteristics: study year and design, relevant specialty and procedure, sample size, author's intent and quality rating (of

internal validity). The quality rating was assigned as good, fair or poor based on the degree to which the study addressed the researchers' primary aims and the potential for selection bias, measurement bias and confounding.

RESULTS

Overview

The search described above produced 181 unique citations. Screening on title and abstract resulted in the exclusion of 171 citations (most of which were opinion-editorial articles, assessments of surgeons' learning curves or reports on educational curricula. The remaining ten articles were screened on full text. After excluding six articles (three were learning curve studies,(12-14) two compared surgeons' outcomes to themselves,(15, 16) and one focused on individual steps of the procedure and patient characteristics as opposed to resident involvement (17)), a total of four relevant articles were included in the review (Figure 1).

The four remaining publications (Table 1) included three retrospective reviews of charted information (14, 18-20) and one prospective cohort study,(21) all of which reported data from their respective individual institutions. Three of the studies included urologic surgeries, and one included a combined urologic and gynecologic procedure.

Retrospective Studies

Bedaiwy et al (18) analyzed surgical outcomes of 41 patients who underwent robotic-assisted sacrocolpopexy (RASCP), just over half of which had significant involvement by a urology and/or gynecology resident. The team reviewed vaginal vault support at 24 weeks, in addition to operative and PACU times, blood loss and intraoperative complications between groups with and without resident

participation, and found comparable outcomes across all variables. Despite the limitation of a small sample size, the authors concluded that incorporating residents during RASCP allows for effective teaching of robotic techniques without prolonging operative time or affective overall surgical outcomes.

Erdeljan et al (19) studied the outcomes of 88 patients who underwent robotic pyeloplasty, ten of which had a significant resident or fellow teaching involvement. They compared operative time and surgical outcomes (using symptom resolution and imaging as proxies) between the two groups of attending surgeons and one group of residents/fellows. The authors observed similar operative times and outcomes across all groups. Given the minuscule sample size of robotic pyeloplasties with significant resident/fellow involvement, the study is minimally powered to make broad statements based on the results; however, the authors aim more to present the details of their country's first experience with the procedure rather than to draw sweeping conclusions about trainee involvement.

Schroeck et al (20) assessed their structured teaching program by evaluating perioperative outcomes of robotic prostatectomies of residents participating in the program compared to those of an experienced surgeon. The authors looked at operative times, blood loss and positive surgical margin rates of 383 patients undergoing robotic prostatectomies from their database. The authors found no difference in median overall operative time, blood loss and positive surgical margin rates between the attending surgeon and his trainees. Although this study had significantly larger sample sizes than those discussed previously, the authors note that the study's results are not necessarily generalizable as its purpose was to evaluate the safety of their specific teaching program. They also comment that their study focused only on immediate perioperative outcomes as opposed to those requiring longer follow-up.

Prospective Study

Davis et al (21), aimed to assess their ability to teach a robotic procedure based on a structured curriculum. They measured the time and subjective quality of various steps of 178 robotic prostatectomies performed by either resident/fellow involvement or their mentor alone. Trainees were evaluated on each step based on how long it took and the quality of the results, which was admittedly somewhat subjective. The study demonstrated a significant increase in operative time when residents and/or fellows were participating in the procedure. Even still, the trainees performed well according to the quality of individual steps they completed. The study's intent was not to directly compare outcomes with and without trainee involvement; however, the authors concluded from overall data that training did not adversely affect outcomes.

DISCUSSION

This research has demonstrated that resident involvement in a variety of robotic procedures appears safe as all included studies found no difference in complications between the resident present or absent groups. Concerning the effect of resident involvement on operative time, studies differed in their conclusions. The three retrospective studies observed comparable operative times between groups, while the prospective study found that trainee involvement resulted in significantly longer procedure times. The latter appears to be more consistent with similar literature on non-robotic surgeries with explanations of time needed to teach residents during procedures.(8, 9)

The studies assessing structured curricula with no difference in outcomes or in operative time show promising results for their specific training plans. However, each of the included studies only evaluated a small number of trainees (usually four to seven) and mentors (one to two). The studies present encouraging preliminary results about the integration of residents into their robotic programs, but the results are not particularly generalizable given the few institutions and physicians involved.

Limitations

A key limitation of this review is that all relevant articles may not have been identified with the search strategy described above. Although a 'text word search' strategy was used to increase the number of articles identified, studies that addressed the question of interest may not have included keywords of all three subcategories. Additionally, only the MEDLINE database was used to perform this search, and therefore, relevant articles found only in other databases may have been missed. Furthermore, studies suggesting that resident involvement adversely affects patient outcomes may be unpopular and, therefore, selective reporting and publication bias may influence the results presented in this review.

Future Research

As the use of these minimally-invasive procedures and the drive towards evidence-based medicine grows, so too will the amount of available data on the outcomes of patients undergoing robotic procedures with and without resident involvement. High-quality patient care is of paramount significance, and these data should be used to ensure that experienced surgeons – with and without resident assistance – are providing high levels of surgical care. The four included articles demonstrated encouraging results with resident participation, but these results should be interpreted with some caution given the studies' respective limitations. More research, both beyond single institutional reviews and with larger study populations, needs to be done to assess current training of surgical residents in appropriate robotic technique. Furthermore, this research should improve on the shortcomings identified in the four included articles and employ mechanisms to control for and/or minimize confounding.

References

1. Ahmed K, Khan MS, Vats A, Nagpal K, Priest O, Patel V, et al. Current status of robotic assisted pelvic surgery and future developments. Int J Surg. 2009 Oct;7(5):431-40.

2. Schreuder HW, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RH. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG. 2012 Jan;119(2):137-49.

3. Abboudi H, Khan MS, Aboumarzouk O, Guru KA, Challacombe B, Dasgupta P, et al. Current status of validation for robotic surgery simulators - a systematic review. BJU Int. 2013 Feb;111(2):194-205.

4. Berlinger NT. Robotic surgery--squeezing into tight places. N Engl J Med. 2006 May 18;354(20):2099-101.

5. Institute of Medicine. Crossing the quality chasm: A new health system for the 21st century. Report Brief. Washington, D.C.: National Academy Press; 2001.

6. National Committee for Quality Assurance. NCQA patient-centered medical home 2011: Health care that revolves around you. Washington, DC: NCQA; 2011.

7. Peikes D, Genevro J, Scholle SH, Torda P. The patient-centered medical home: Strategies to put patients at the center of primary care. Rockville, MD: Agency for Healthcare Research and Quality; 2011. Report No.: 11-0029.

8. Advani V, Ahad S, Gonczy C, Markwell S, Hassan I. Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? an analysis of 16,849 cases from the ACS-NSQIP. Am J Surg. 2012 Mar;203(3):347,51; discussion 351-2.

9. Kiran RP, Ahmed Ali U, Coffey JC, Vogel JD, Pokala N, Fazio VW. Impact of resident participation in surgical operations on postoperative outcomes: National surgical quality improvement program. Ann Surg. 2012 Sep;256(3):469-75.

10. Raval MV, Wang X, Cohen ME, Ingraham AM, Bentrem DJ, Dimick JB, et al. The influence of resident involvement on surgical outcomes. J Am Coll Surg. 2011 May;212(5):889-98.

11. Hernandez-Irizarry R, Zendejas B, Ali SM, Lohse CM, Farley DR. Impact of resident participation on laparoscopic inguinal hernia repairs: Are residents slowing us down? J Surg Educ. 2012 Nov-Dec;69(6):746-52.

12. Hong YM, Sutherland DE, Linder B, Engel JD. "Learning curve" may not be enough: Assessing the oncological experience curve for robotic radical prostatectomy. J Endourol. 2010 Mar;24(3):473-7.

13. Koga T, Shin M, Maruyama K, Kurita H, Kawamoto S, Saito N. Contribution of technological progress, inter-operator difference and experience of operators in gamma knife radiosurgery for arteriovenous malformation. Acta Neurochir (Wien). 2011 Apr;153(4):879-82.

14. Charland PJ, Robbins T, Rodriguez E, Nifong WL, Chitwood RW,Jr. Learning curve analysis of mitral valve repair using telemanipulative technology. J Thorac Cardiovasc Surg. 2011 Aug;142(2):404-10.

15. Link BA, Nelson R, Josephson DY, Lau C, Wilson TG. Training of urologic oncology fellows does not adversely impact outcomes of robot-assisted laparoscopic prostatectomy. J Endourol. 2009 Feb;23(2):301-5.

16. Wolanski P, Chabert C, Jones L, Mullavey T, Walsh S, Gianduzzo T. Preliminary results of robot-assisted laparoscopic radical prostatectomy (RALP) after fellowship training and experience in laparoscopic radical prostatectomy (LRP). BJU Int. 2012 Dec;110 Suppl 4:64-70.

17. Thiel DD, Francis P, Heckman MG, Winfield HN. Prospective evaluation of factors affecting operating time in a residency/fellowship training program incorporating robot-assisted laparoscopic prostatectomy. J Endourol. 2008 Jun;22(6):1331-8.

18. Bedaiwy MA, Abdelrahman M, Deter S, Farghaly T, Shalaby MM, Frasure H, et al. The impact of training residents on the outcome of robotic-assisted sacrocolpopexy. Minim Invasive Surg. 2012;2012:289342.

19. Erdeljan P, Caumartin Y, Warren J, Nguan C, Nott L, Luke PP, et al. Robot-assisted pyeloplasty: Follow-up of first Canadian experience with comparison of outcomes between experienced and trainee surgeons. J Endourol. 2010 Sep;24(9):1447-50.

20. Schroeck FR, de Sousa CA, Kalman RA, Kalia MS, Pierre SA, Haleblian GE, et al. Trainees do not negatively impact the institutional learning curve for robotic prostatectomy as characterized by operative time, estimated blood loss, and positive surgical margin rate. Urology. 2008 Apr;71(4):597-601.

21. Davis JW, Kamat A, Munsell M, Pettaway C, Pisters L, Matin S. Initial experience of teaching robot-assisted radical prostatectomy to surgeons-in-training: Can training be evaluated and standardized? BJU Int. 2010 Apr;105(8):1148-54.

TABLES AND FIGURES

Figure 1. Study Selection

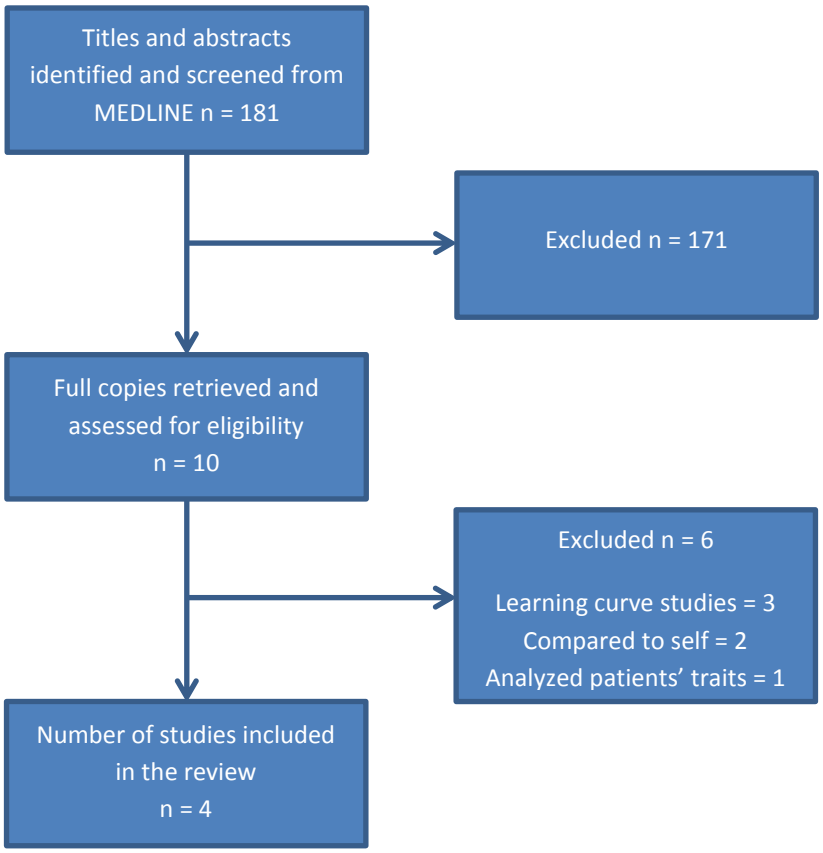

Table 1. Summary of Studies in Review

Study	Year	Type	Specialty/ Procedure	Primary Aims	Comments	Quality Rating	Concerns
Bedaiwy et al	2012	Single center retrospective review of medical records	Urology and Gynecology/ robotic sacrocolpopexy ± supracervical hysterectomy	To evaluate outcomes before and after resident participation	41 cases by single attending surgeon, 21 of which had resident involvement	Poor: large potential for selection bias and confounding	Patients allocation based on earlier or later surgery, which may be correlated with outcomes
Erdeljan et al	2010	Single center retrospective review of prospectively collected data	Urology/robot-assisted pyeloplasty (RAP)	To present Canada's first experience with RAP comparing experienced and trainee surgeons	88 cases, 10 of which had resident/fellow involvement	Poor: initial comparability unclear; large potential for confounding	Small sample size of 10 patients with resident participation
Schroeck et al	2008	Single center retrospective review of medical records	Urology/robotic prostatectomy	To assess a structured teaching program by assessing learning curves and outcomes of experienced and trainee surgeons	254 cases with attending/ resident data, 116 of which had resident involvement	Fair: authors do not overstate results; initial comparability unclear	Results likely not generalizable outside of authors' structured teaching program
Davis et al	2010	Single center prospective cohort study	Urology/robotic prostatectomy (RP)	To measure time and subjective quality of steps of RP performed by trainee surgeons	178 cases by single attending surgeon, 124 of which had resident/fellow involvement	Fair: authors attempt to adjust for experience; initial comparability unclear; potential for confounding	Evaluations used were unvalidated and potentially unreliable; complications rates were compared to previously published results as opposed to comparison group within same study

Resident Involvement and Experience as Predictive Factors for Peri-Operative Outcomes Following Robotic Prostatectomy

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Abstract (238 words)

Introduction

Most urologic training programs use robotic prostatectomy (RP) as an introduction to teach residents appropriate robotic technique. However, concerns may exist regarding differences in RP outcomes with resident involvement. Our objective was therefore to evaluate whether resident involvement affects complications, operative time, or length of stay following RP.

Materials & Methods

Using the National Surgical Quality Improvement Program database (2005 – 2011), we identified patients who underwent robotic prostatectomy, stratified them by resident presence or absence during surgery, and compared hospital length of stay (LOS), operative time, and post-operative complications using bivariable and multivariable analyses. A secondary analysis comparing outcomes of interest across postgraduate year (PGY) levels was also performed.

Results

5,087 patients who underwent RPs were identified, in which residents participated in 56%, during the study period. After controlling for potential confounders, resident present and absent groups were similar in 30-day mortality (0.0% vs. 0.2%, $p = 0.08$), serious morbidity (1.7% vs. 1.9%, $p = 0.47$), and overall morbidity (5.0% vs. 5.1%, $p = 0.90$). While resident involvement did not affect LOS, operative time was longer when residents were present (median: 209 vs. 184 minutes, $p < 0.001$). Similar findings were noted when assessing individual PGY levels.

Conclusions

Regardless of PGY level, resident involvement in RPs appears safe and does not appear to affect post-operative complications or length of stay. While resident involvement in RPs does result in longer operative times, this is necessary and likely inconsequential.

INTRODUCTION

Intra-operative participation by residents is an integral part of any surgical training program. With recent advancements in technology and an emphasis on minimally invasive procedures, residency training has expanded to include robotic procedures in numerous fields of surgery, including that of Urology.(1-3) Many urologic training programs currently utilize robotic prostatectomy (RP) as the initial procedure to familiarize residents with appropriate robotic technique.(4)

Concurrent with changes in surgical training curricula is a shift in the delivery of U.S. health care. Multiple national organizations now emphasize the importance of patient-centered, high-quality care.(5-8) An example of this emphasis is evident in the National Surgical Quality Improvement Program (NSQIP), a quality care initiative sponsored by the American College of Surgeons which tracks provider characteristics and patient outcomes. NSQIP is a nationally validated, risk-adjusted, outcomes-based program with the primary goal to measure and improve the quality of surgical care. Outcomes-centered databases like NSQIP have inspired a reevaluation of surgical residency training and the effects of resident experience. Resident inexperience in the operating room has long been debated as a contributor to adverse patient outcomes.(9) A clearer understanding of the relationship between resident involvement in surgical operations and patient outcomes will continue to direct surgical training along a path towards higher quality care.(10) Several studies in other surgical fields have used NSQIP data to analyze the effect of resident involvement on postoperative outcomes.(9-19) However, to our knowledge, the relationship between resident involvement and surgical outcomes following robotic surgery has not yet been explored in the urological literature. We chose to analyze outcomes following RP because of its early importance in urologic robotic training. The objective of this study is therefore to evaluate whether resident involvement and resident post-graduate year level affects complications,

operative time, or length of stay following robotic prostatectomy using a national prospective surgical database.

MATERIALS AND METHODS

Data Collection

As a quality care initiative sponsored by the American College of Surgeons, NSQIP prospectively collects patient data on 135 variables, including preoperative risk factors, peri-operative variables, 30-day post-operative complications and mortality on a sample of all major surgeries at participating institutions.(20) NSQIP data have been validated as accurate, and its methods have been shown to be reliable for the measurement and improvement of surgical care quality.(21-24) All NSQIP data are collected by formally trained surgical clinical reviewers using standardized methods at all sites and then entered into a web-based data collection system. To ensure data quality across sites, inter-rater reliability audits are performed periodically across various participating sites.(11, 20)

Using the NSQIP 2005 – 2011 Participant Use File, we identified 8,424 patients undergoing RP between January 2005 and December 2011 using Current Procedural Terminology code 55866. While this code may also reflect laparoscopic prostatectomy, the use of this modality is quite low (<1%) as demonstrated by other national samples.(25) As some variable definitions changed throughout the study period, data were carefully merged by cross-validating variables to ensure consistent definitions. Cases were excluded if important baseline characteristics or outcomes data were not collected by their respective sites (2,703 patients). Cases were also excluded if data on resident and/or attending involvement were either missing or mismatched (634 patients) (e.g. the variable for attending listed attending only, but PGY year listed a resident). Resident participation was defined as the presence of a

resident “scrubbed” during the RP. Additionally, for subgroup analysis, resident participation was classified by postgraduate year (PGY) of training such that PGY-1 through PGY-5 represented their own years individually, while PGY-6 and above (which includes fellows) were grouped together as PGY-6+.

Variables

Thirty-day postoperative complications were classified into 7 major categories, based on prior literature. (9, 26) These categories included the following: (1) any infectious complications (organ space surgical site infection [SSI], septic shock, pneumonia, superficial SSI, urinary tract infection, deep SSI), (2) cardiopulmonary complications (cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, ventilator dependence longer than 48 hours, pneumonia, pulmonary embolism, unplanned intubation), (3) wound complications (dehiscence, organ space SSI, organ space SSI, superficial SSI, deep incisional SSI), (4) neurologic/renal complications (coma > 24 hours, stroke/cerebrovascular accident with neurologic deficit, peripheral nerve injury, progressive renal insufficiency), (5) septic complications (septic shock, sepsis), (6) vascular complications (deep venous thrombosis or thrombophlebitis), and (7) bleeding requiring transfusion.

Additionally, the category of serious morbidity, as defined in prior NSQIP-based literature with modification to reflect current variable definitions, was included in the analysis.(9, 27) Serious morbidity was defined as having any of the following: wound dehiscence, organ space SSI, coma > 24 hours, stroke/cerebrovascular accident with neurologic deficit, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, pulmonary embolism, ventilator dependence longer than 48 hours, progressive renal insufficiency, sepsis or septic shock. Furthermore, overall morbidity was defined as experiencing any of the 7 major categories of postoperative complications listed above. Operative time was defined as the time between incision and closure.

Data Analysis

Baseline characteristics of the study cohort were stratified by resident involvement. These characteristics included age, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, functional status, prior surgery within 30 days, and other important risk factors such as co-morbidities (including diabetes, hypertension, smoking history, steroid use, and dialysis). Bivariable analysis was performed using the two-sample t test or Wilcoxon Rank-Sum test for continuous variables, for normal and non-normal distributions respectively. Categorical variables were compared using Pearson's Chi-square or Fisher's exact test. Multiple linear regression was used to compare hospital length of stay (LOS) and operative time between groups. For dichotomous outcomes, we fit a logistic regression model to estimate the odds ratios of post-operative complications between groups. Both models were adjusted for potential confounders, by including those characteristics that differed between groups with a p-value < 0.10. We repeated the analysis (with all covariates left in the model) stratified by PGY levels comparing outcomes to the resident absent group. All reported p-values are two-sided with $p < 0.05$ deemed statistically significant. Statistical analyses were performed using STATA, version 12 (College Station, TX).

RESULTS

Characteristics of Sample

From 2005 to 2011, 8,424 patients underwent robotic prostatectomy with 5,087 RPs remaining after exclusion for missing and/or mismatched data. These remaining patients were stratified based on resident participation into resident present (n=2,841) or absent (n=2,246). BMI and ASA classifications were not specified in 34 cases and 10 cases, respectively, with data complete on all remaining variables

in Table 1. Of the patients undergoing RP, overall mean age was 61.7 years (SD = 7.3) and mean BMI was 28.8 (SD = 5.0) (Table 1). Approximately 10% of patients had diabetes, 50% had hypertension, and just over 10% were current smokers. Among cases with a resident present compared to an attending physician alone, there were lower percentages of patients with diabetes (8.4% vs. 12.7%), hypertension (49.3% vs. 53.3%), and current smokers (11.2% vs. 15.0%) ($p < 0.01$). Age, BMI and ASA classifications, functional health status, prior surgery within 30 days, steroid use, and dialysis were each similar regardless of resident involvement (Table 1).

Postoperative Outcomes

Of the 5,087 patients included in the study, 1.9% of patients experienced at least one serious morbidity, while 5.2% experienced at least one overall in-hospital 30-day morbidity. Concerning the individual major categories of complications, rates ranged from 0.6% for vascular complications up to 2.8% for infectious complications. Overall median (IQR) values for LOS and operative time were 1 (1 – 2) days and 198 (163 – 243) minutes, respectively. 30-day mortality was less than 0.1% for the entire sample.

Unadjusted Differences in Outcomes by Presence of Resident

Prior to adjusting for any covariates, outcomes of interest were stratified by resident presence or absence and compared. No statistically significant differences were observed among any of the complication categories, including 30-day mortality (0.0% vs. 0.2%, $p = 0.07$), serious morbidity (1.8% vs. 2.1%, $p = 0.33$), or overall morbidity (5.1% vs. 5.4%, $p = 0.69$). Hospital LOS was also not significantly different between the two groups ($p = 0.96$). Operative times were clinically and statistically different between the two groups, with resident involvement resulting in longer surgical times [median (IQR): 208 (174 – 250) vs. 183 (153 – 230) minutes, $p < 0.001$] (Table 2).

Outcomes after Adjusting for Differences in Patient Characteristics

After adjusting for functional health status, diabetes, hypertension and current smoking status, no difference in 30-day mortality was noted between patients with a resident present or absent (0.0% vs. 0.2%, $p = 0.08$). Serious morbidity did not differ significantly between the two groups (1.7% vs. 1.9%, $p = 0.47$), and thirty-day post-operative complications as defined by the category of overall morbidity were also comparable between groups (5.0% vs. 5.1%, $p = 0.90$). All remaining complication categories were largely similar between the two groups.

When assessing length of stay, the difference between groups with and without resident involvement remained non-significant after adjusting for potential confounders ($p = 0.69$). Operative times were clinically and statistically different between the two groups, with resident involvement resulting in longer surgical times (median: 209 vs. 184 minutes, $p < 0.001$).

Differences by PGY Level

After assessing the differences between resident presence and absence, we explored the differences in complications among surgeries including different PGY level residents compared to surgeries performed by an attending alone. No differences in serious morbidity or overall morbidity were observed between any of the PGY subgroups and the resident absent group. Concerning the hospital LOS, a statistically significant decrease was observed in the PGY-4 subgroup ($p = 0.01$); however, the absolute difference was of questionable clinical importance. Lastly, although operative time was similar in the PGY-1 subgroup, all other subgroups of PGY levels demonstrated significantly longer operative times than did the resident absent group (Table 3).

DISCUSSION

The use of robot-assisted laparoscopic surgery and its inclusion in resident training programs has grown exponentially over the past decade.(2) Moving forward, the use of this technology (and many other aspects of surgical training curricula) will be dictated by the pursuit of patient-centered, high-quality care.(5) As such, assessing the relationship between resident participation and patient outcomes is essential in achieving this goal. Against this backdrop, our study presents the first large-scale, direct evaluation of resident involvement in robotic prostatectomy. Our analysis demonstrated that intra-operative participation of residents in RPs resulted in slightly longer operative time but similar post-operative outcomes when compared to attending surgeons alone. Serious morbidity, overall morbidity and all other categories of complications were not statistically different between the two groups. This is a reassuring finding and supports that resident involvement in urologic robotic procedures is safe. These findings are further corroborated by the robust nature of NSQIP data, in which regular auditing is used to ensure data reliability and trained third-party surgical clinical reviewers collect 30-day postoperative data, allowing objectivity in data capture. As an additional finding, our subgroup analysis of residents from different PGY levels showed no difference in complications for any of the PGY subgroups when compared to the resident absent group. This is also reassuring, suggesting that the current system appropriately involves urologic residents at each level of their training without an increased risk of complications for patients.

One concern regarding resident involvement in the operating room involves the length of surgery. Consistent with prior studies that have examined the effect of resident participation on surgical times (9, 10, 28), we found that operative time was longer for cases with a resident present. Explanations for this finding include residents' lack of efficiency compared to experienced attending surgeons as well as the need for dedicated teaching time during each case. When assessing operative

time differences by PGY level, we found that operative time in the PGY-1 subgroup did not differ from attendings alone, whereas higher level residents showed a larger difference and increased operative times. This can be explained by the fact that lower-level residents often participate in fewer portions of the case due to inexperience when compared to upper-level residents.

Despite the strengths of a large, national, prospectively ascertained dataset with the use of multivariable regression to minimize confounding, our study has several limitations. First, the detailed extent of resident involvement remains largely unknown. While some residents may simply assist, others may perform key portions of the case. While we would expect that upper-level residents are more extensively involved, the limitations of a data granularity with respect to this question preclude us from confirming this assumption. An additional limitation is the non-specific CPT code of minimally invasive prostatectomy, which includes both pure laparoscopic and robotic procedures. While we may have inadvertently included laparoscopic prostatectomy in our sample, the number is likely very low (<1%), given the predominant use of robotics in the United States in nationwide samples.(25) Additionally, complications and deaths resulting from surgery are reported for a limited 30-day period, and therefore, our analysis does not capture late morbidity with potential underreporting of complication rates. However, the majority of complications following RP occur within the first 30 days, and this is unlikely to affect our conclusions.(29) Furthermore, there exists no data on functional outcomes specific to RP, including continence and potency.

Other limitations are those inherent to cohort studies. Our study population was not randomized, leaving it vulnerable to unmeasured confounders, especially those related to the health care organization providing the RP (e.g., academic vs. non-academic medical centers) which may have biased the results.(10) Lastly, in the subgroup analysis stratified by PGY level, the power decreases

significantly as the comparative sample sizes decrease which may limit conclusions in this subgroup analysis.

CONCLUSIONS

Robotic surgery has become clearly established as an integral part of health care delivery, in particular for the surgical treatment of prostate cancer.(25) Due to widespread use of robotics, resident training in appropriate use of these new tools and techniques is essential. In this context, steps must be taken to ensure that the quality of patient care is not adversely affected as a result of these resident training programs. Our study assessed whether resident involvement in a common urologic robotic procedure (i.e., RP) adversely affected post-operative outcomes of patients. Our results revealed no difference in 30-day mortality, serious morbidity or overall morbidity with resident involvement in RP. These findings support the safety of the current system of urologic residency training in robotic surgery, which does not appear to worsen morbidity or mortality rates. As such, resident involvement in RPs should be supported and encouraged as a teaching tool for the robotic technique. While slightly longer operative times are noted for resident involvement, this is a well-known phenomenon that is unavoidable and necessary, given the time needed by urologic residents to learn techniques and refine skills.

References

1. Berlinger NT. Robotic surgery--squeezing into tight places. N Engl J Med. 2006 May 18;354(20):2099-101.

2. Schreuder HW, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RH. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG. 2012 Jan;119(2):137-49.

3. Standard operating practices (SOP's) for urologic robotic surgery [Internet].: American Urological Association; cited 22 February 2013]. Available from: http://www.auanet.org/content/residency/resident-education/SOP-Urologic-Robotic-Surgery.pdf.

4. Fulmer B, Rukstalis D, Gorbonos A, Kim E, Talavera F, Schwartz B. Laparoscopic and robotic radical prostatectomy. Medscape Reference: Drugs, Diseases & Procedures [Internet]. 2011 12/1/2011:2/23/2012. Available from: http://emedicine.medscape.com/article/458677-overview.

5. US Department of Health and Human Services. Report to congress: National strategy for quality improvement in health care. [Internet]. 2011 March 2011:2/23/2013. Available from: http://www.healthcare.gov.libproxy.lib.unc.edu/law/resources/reports/nationalqualitystrategy032011.pdf.

6. Institute of Medicine. Crossing the quality chasm: A new health system for the 21st century. Report Brief. Washington, D.C.: National Academy Press; 2001.

7. National Committee for Quality Assurance. NCQA patient-centered medical home 2011: Health care that revolves around you. Washington, DC: NCQA; 2011.

8. Peikes D, Genevro J, Scholle SH, Torda P. The patient-centered medical home: Strategies to put patients at the center of primary care. Rockville, MD: Agency for Healthcare Research and Quality; 2011. Report No.: 11-0029.

9. Advani V, Ahad S, Gonczy C, Markwell S, Hassan I. Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? an analysis of 16,849 cases from the ACS-NSQIP. Am J Surg. 2012 Mar;203(3):347,51; discussion 351-2.

10. Kiran RP, Ahmed Ali U, Coffey JC, Vogel JD, Pokala N, Fazio VW. Impact of resident participation in surgical operations on postoperative outcomes: National surgical quality improvement program. Ann Surg. 2012 Sep;256(3):469-75.

11. Reeves JG, Kasirajan K, Veeraswamy RK, Ricotta JJ,2nd, Salam AA, Dodson TF, et al. Characterization of resident surgeon participation during carotid endarterectomy and impact on perioperative outcomes. J Vasc Surg. 2012 Jan;55(1):268-73.

12. Gupta PK. Use of NSQIP to study the influence of resident involvement on surgical outcomes. J Am Coll Surg. 2011 Jul;213(1):196; author reply 196-7.

13. Raval MV, Wang X, Cohen ME, Ingraham AM, Bentrem DJ, Dimick JB, et al. The influence of resident involvement on surgical outcomes. J Am Coll Surg. 2011 May;212(5):889-98.

14. Itani KM, DePalma RG, Schifftner T, Sanders KM, Chang BK, Henderson WG, et al. Surgical resident supervision in the operating room and outcomes of care in veterans affairs hospitals. Am J Surg. 2005 Nov;190(5):725-31.

15. Kauvar DS, Braswell A, Brown BD, Harnisch M. Influence of resident and attending surgeon seniority on operative performance in laparoscopic cholecystectomy. J Surg Res. 2006 May 15;132(2):159-63.

16. Davis SS,Jr, Husain FA, Lin E, Nandipati KC, Perez S, Sweeney JF. Resident participation in index laparoscopic general surgical cases: Impact of the learning environment on surgical outcomes. J Am Coll Surg. 2013 Jan;216(1):96-104.

17. Hernandez-Irizarry R, Zendejas B, Ali SM, Lohse CM, Farley DR. Impact of resident participation on laparoscopic inguinal hernia repairs: Are residents slowing us down? J Surg Educ. 2012 Nov-Dec;69(6):746-52.

18. Jordan SW, Mioton LM, Smetona J, Aggarwal A, Wang E, Dumanian GA, et al. Resident involvement affects plastic surgery outcomes: An analysis of 10,356 patients from the NSQIP database. Plast Reconstr Surg. 2012 Dec 17.

19. Kazaure HS, Roman SA, Sosa JA. The resident as surgeon: An analysis of ACS-NSQIP. J Surg Res. 2012 Nov;178(1):126-32.

20. American College of Surgeons. ACS NSQIP: User guide for the 2011 participant use data file. 2012 October 2012.

21. Khuri SF, Daley J, Henderson W, Hur K, Demakis J, Aust JB, et al. The department of veterans affairs' NSQIP: The first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. national VA surgical quality improvement program. Ann Surg. 1998 Oct;228(4):491-507.

22. Khuri SF, Henderson WG, Daley J, Jonasson O, Jones RS, Campbell DA,Jr, et al. Successful implementation of the department of veterans affairs' national surgical quality improvement program in the private sector: The patient safety in surgery study. Ann Surg. 2008 Aug;248(2):329-36.

23. Shiloach M, Frencher SK,Jr, Steeger JE, Rowell KS, Bartzokis K, Tomeh MG, et al. Toward robust information: Data quality and inter-rater reliability in the american college of surgeons national surgical quality improvement program. J Am Coll Surg. 2010 Jan;210(1):6-16.

24. Davis CL, Pierce JR, Henderson W, Spencer CD, Tyler C, Langberg R, et al. Assessment of the reliability of data collected for the department of veterans affairs national surgical quality improvement program. J Am Coll Surg. 2007 Apr;204(4):550-60.

25. Trinh QD, Sammon J, Sun M, Ravi P, Ghani KR, Bianchi M, et al. Perioperative outcomes of robot-assisted radical prostatectomy compared with open radical prostatectomy: Results from the nationwide inpatient sample. Eur Urol. 2012 Apr;61(4):679-85.

26. Kennedy GD, Heise C, Rajamanickam V, Harms B, Foley EF. Laparoscopy decreases postoperative complication rates after abdominal colectomy: Results from the national surgical quality improvement program. Ann Surg. 2009 Apr;249(4):596-601.

27. Ingraham AM, Cohen ME, Bilimoria KY, Pritts TA, Ko CY, Esposito TJ. Comparison of outcomes after laparoscopic versus open appendectomy for acute appendicitis at 222 ACS NSQIP hospitals. Surgery. 2010 Oct;148(4):625,35; discussion 635-7.

28. Babineau TJ, Becker J, Gibbons G, Sentovich S, Hess D, Robertson S, et al. The "cost" of operative training for surgical residents. Arch Surg. 2004 Apr;139(4):366,9; discussion 369-70.

29. Agarwal PK, Sammon J, Bhandari A, Dabaja A, Diaz M, Dusik-Fenton S, et al. Safety profile of robot-assisted radical prostatectomy: A standardized report of complications in 3317 patients. Eur Urol. 2011 May;59(5):684-98.

TABLES

Table 1. Baseline characteristics of RP cases stratified by resident involvement

	Resident Present	**Resident Absent**		
Patient Characteristic	**n = 2,841**	**n = 2,246**	**p-value**	
Age, years, mean (SD)	61.8 (7.2)	61.7 (7.3)	0.50	
BMI classification, mean (SD)	28.8 (4.6)	28.7 (5.5)	0.49	
ASA classification, n (%)			0.20	
1. No disturbance	90 (3.2)	89 (4.0)		
2. Mild disturbance	1,854 (65.4)	1,424 (63.5)		
3. Severe disturbance	874 (30.8)	709 (31.6)		
4. Life threatening	17 (0.6)	20 (0.89)		
Functional health status, n (%)			0.08	
Independent	2,832 (99.7)	2,244 (99.9)		
Partially dependent	9 (0.3)	2 (0.1)		
Prior surgery within 30 days, n (%)	15 (0.5)	6 (0.3)	0.15	
Diabetes, n (%)	239 (8.4)	271 (12.7)	<0.01	
Hypertension, n (%)	1,400 (49.3)	1,197 (53.3)	<0.01	
Current smoker, n (%)	305 (10.7)	331 (14.7)	<0.01	
Steroid use, n (%)	26 (0.9)	16 (0.7)	0.43	
Dialysis, n (%)	4 (0.1)	2 (0.1)	0.59	
Resident Characteristic				
PGY of residents, n (%)				
PGY-1	45 (1.6)	----		
PGY-2	271 (9.5)	----		
PGY-3	287 (10.1)	----		
PGY-4	567 (20.0)	----		
PGY-5	821 (28.9)	----		
PGY-6+	850 (29.9)	----		

Table 2. Comparison of outcomes of patients undergoing RP with and without resident involvement

		Resident Present		**Resident Absent**		**p-value (unadjusted)**		**p-value (adjusted[1])**	**Adjusted[1] OR (95% CI)**
		n = 2,841		**n = 2,246**					
Outcome									
Hospital LOS (days), median (IQR)		1 (1-2)		1 (1-2)		0.96		0.69	----
Operative time (minutes), median (IQR),		208 (174-250)		183 (153-230)		<0.001		<0.001	----
30-day mortality, n (%)		0 (0.0)		4 (0.2)		0.07		0.08	0.15 (0.00 – 1.24)
Infectious complications, n (%)		83 (2.9)		61 (2.7)		0.66		0.50	1.12 (0.80 – 1.57)
Cardiopulmonary complications, n (%)		22 (0.8)		28 (1.3)		0.09		0.19	0.68 (0.39 – 1.20)
Wound complications, n (%)		27 (1.0)		21 (0.9)		0.96		0.91	1.03 (0.58 – 1.84)
Neurologic and renal complications, n (%)		68 (2.4)		50 (2.2)		0.69		0.52	1.13 (0.78 – 1.64)
Septic complications, n (%)		25 (0.9)		13 (0.6)		0.22		0.13	1.68 (0.86 – 3.31)
Vascular complications, n (%)		13 (0.5)		16 (0.7)		0.23		0.15	0.58 (0.27 – 1.22)
Bleeding requiring transfusion, n (%)		27 (1.0)		21 (0.9)		0.96		0.85	1.06 (0.59 – 1.88)
Serious morbidity, n (%)		50 (1.8)		48 (2.1)		0.33		0.47	0.86 (0.58 – 1.29)
Overall morbidity, n (%)		146 (5.1)		121 (5.4)		0.69		0.90	0.98 (0.77 – 1.26)
[1] adjusted for functional status, diabetes, hypertension and smoking history									

Table 3. Comparison of outcomes of patients undergoing RP with residents stratified by PGY level, each compared to those without resident involvement

	Resident Absent	PGY-1	p[1]	PGY-2	p[1]	PGY-3	p[1]	PGY-4	p[1]	PGY-5	p[1]	PGY-6+	p[1]
Outcome	**n = 2,246**	**n = 45**		**n = 271**		**n = 287**		**n = 567**		**n = 821**		**n = 850**	
Hospital LOS, days, median (IQR)	1 (1-2)	2 (1 – 2)	0.24	1 (1 – 2)	0.84	1 (1 – 2)	0.13	1 (1 – 2)	**0.01**	1 (1 – 2)	0.97	1 (1 – 2)	0.09
Operative time, min, median (IQR),	183 (153-230)	192 (171 – 237)	0.63	218 (179 – 262)	**<0.001**	203 (170 – 263)	**0.01**	208 (168 – 247)	**<0.001**	211 (178 – 255)	**<0.001**	203 (171 – 237)	**<0.001**
Serious morbidity, n (%)	48 (2.1)	1 (2.2)	0.97	4 (1.5)	0.40	4 (1.4)	0.46	10 (1.8)	0.62	29 (2.3)	0.93	12 (1.4)	0.27
Overall morbidity, n (%)	121 (5.4)	3 (6.7)	0.81	12 (4.4)	0.45	18 (6.3)	0.38	29 (5.1)	0.88	39 (4.8)	0.57	45 (5.3)	0.98

[1] p-value adjusted for age, body mass index, American Society of Anesthesiologists (ASA) classification, functional status, surgery within 30 days, diabetes, hypertension, smoking history, steroid use and dialysis

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