Trends and Demographics in Robotic Surgery

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Introduction

Over the past three decades, robotic assisted laparoscopic surgery (RALS) has made its way to every surgical field. In order to better understand the benefits of investment in this technology, the Institute of Medicine set comparative analysis of RALS as a high priority, to better understand what the benefits are of this relatively new technology (1). Since then, studies have shown RALS to result in fewer deaths, shorter hospital stays, complications, transfusions, and more routine discharges (2–7).

Regardless of the potential benefits, it is clear that there has been a sustained trend across several fields towards increased adoption of RALS (2, 8). Though previous studies have explored trends in specific specialties for increased utilization of RALS, there is a paucity of article that show the trends that are permeating all inpatient surgical practice. In this study, we characterize trends for RALS across all specialties in the period spanning 2009 to 2014. We highlight six procedures in order to establish a comparison between patients and surgeons involved in RALS procedures and their non-RALS counterparts.

Methods

Database

This study used data from the Statewide Planning and Research Cooperative System (SPARCS) as well as from the American Medical Association (AMA) Physician Masterfile. The SPARCS dataset is a New York State all payer database established in 1979, and compiled by the New York State Department of Health Office of Quality and Patient Safety. New York State law mandates the collection of certain data from all inpatient centers in the state of New York. The SPARCS database provides a unique opportunity to examine inpatient physician trends due both to its completeness and the availability of a physician identifier that may then be linked to other resources. The AMA Physician Masterfile was established in 1906 and includes current and historical data for more than 1.4 million physicians, residents, and medical students in the United States.

The SPARCS database includes information on patient characteristics such as age, race, ethnicity, gender, and zip code. Up to 3 physicians, listed as “operating”, “attending”, and “other” are identified for each encounter, enabling the identification of associated physicians. The AMA

Physician Masterfile provides information of a physician's completed residencies, allowing verification of urology residency completion.

Study Sample

Prior to the commencement of this study, the study design was approved by the institutional review board of the Icahn School of Medicine at Mount Sinai. Using the SPARCS dataset, the study sample was collected for all inpatient procedures that were coded using an ICD-9 robotic modifier (ICD-9 17.4*). Since the ICD-9 robotic modifier codes were established in October 2008, we set our period of interest from the start of 2009 to the end of 2014. A small number of encounters involving patients with HIV/AIDS were not included (N=335) due to the protected status of data associated with this group. Further, encounters involving patients under the age of 18 were also excluded (N=509). Physician state license numbers associated with each encounter were recorded. The AMA Physician Masterfile was used to identify what residency or fellowship training each participating physician had completed.

Additionally, six procedures that represented a large proportion of RALS cases in different fields were highlighted for comparison in patient and physician data: radical prostatectomy (RP) (ICD-9 60.5), hysterectomy (HM) (ICD-9 68.3, 68.4, 68.5, 68.6, 68.7, 68.9), total knee replacement (knee arthroplasty) (TKR) (ICD-9 81.54), single internal mammary coronary artery bypass (CAB) (ICD-9 36.15), partial nephrectomy (PN) (ICD-9 55.4), and rectal resection (RR) (ICD-9 48.6). Patient zip code was recorded and mapped to poverty rate as recorded in US Census Bureau data (9).

Categorization of Encounters

Every encounter was categorized using two methodologies. In the first methodology, we categorized each encounter by the residency or fellowship completed by the operating physician. If the operating physician was ambiguous, we would rely on the two other fields provided. This allowed us to categorize encounters without making assumptions about which specialty does which procedure. In the second methodology, we categorized each procedure into groups of practice: urological, gynecological, cardio-thoracic, general, otolaryngological, orthopedic, and uncategorized. This was provided for comparison. The categorizations are viewable in Supplemental Table 1.

Key Variables of Interest

The outcome variables most relevant to this study were the proportion of RALS cases handled by each category. The key independent variable is year. Comparative analysis on patient demographic data as well as comorbidity and primary payer data was completed to compare the differences between patients receiving RALS as opposed to non-RALS care. The number of comorbidities for each patient was determined for each encounter was derived using the Quan adaptation of Charlson comorbidity scoring algorithm (10). Physician demographics data was also compared.

Statistical Analysis

Analysis was completed using the Python for data cleaning and R (version 3.2.3) for analysis. Initial data exploration and data extraction was completed utilizing a purpose-built program (11). Odds ratios were computed using logistic regression to calculate the propensity of undergoing RALS or non-RALS based on all covariates described. Two sample t-tests were used to compare means. Linear trends were assessed with the Cochran-Armitage test for trends.

Results

RALS Procedure Frequencies

Of the 63,725 robot cases analyzed, 29,464 (46.2%) were performed by a urologist, 617 (1.0%) by a otolaryngologist, 7,207 (11.3%) by a general surgeon, 4,217 (6.7%) by a cardio-thoracic surgeon, 17,739 (27.8%) by a gynecologist, 2,215 (3.5%) by an orthopedic surgeon, and 2,243 (3.5%) were uncategorized. Figure 1 shows the evolution of RALS cases using this classification over the period of interest. Using the alternate classification involving division by procedure done, 30,051 (47.2%) of procedures were categorized as urology-related, 635 (1.0%) were otolaryngology-related, 7,686 (12.1%) were general-related, 3,660 (5.7%) were cardio-thoracic-related, 18,111 (28.4%) were gynecology-related, 2,410 (3.8%) were orthopedics related, and 1,172 (1.8%) were uncategorized. Figure 2, similar to Figure 1, shows the evolution RALS cases using this alternate classification. The high concordance between these two alternate classification systems is supportive of the validity of both methods. For the purposes of our analysis, we used the first classification system, based on training completed as reported in the AMA Masterfile.

The number of RALS cases handled by cardio-thoracic-trained surgeons per year rose from 197 (3.1% of all cases) to 1,159 (8.7%), general-trained surgeons from 198 (3.2%) to 2,559 (19.1%), orthopedic-trained surgeons from 55 (0.8%) to 985 (7.4%), otolaryngology-trained surgeons from 21 (0.3%) to 155 (1. 2%), urology-trained surgeons from 4,063 (64.8%) to 5,226 (39.1%), and gynecology-trained surgeons from 1,560 (24.9%) to 2,744 (20.5%). Linear regression of the number of cases by year for each specialty yields the following: for cardio-thoracic, 211 cases/year (180 to 243), for general, 491 (389 to 592), for gynecology, 294 (-88 to 675), for orthopedic, 176 (107 to 246), for otolaryngology, 26 (16 to 36), and for urology 186 (-12 to 385).

Highlighted Procedures' Frequency

A total of 6 procedures were highlighted due either to their contribution to the total RALS cases or due to their significant contribution to their category. A total of 392,197 cases were analyzed. Figure 3 presents these cases over time divided by whether they were identified as being RALS or non-RALS. The proportion of RALS cases for RP rose from 68.1% to 85.5%, for HM rose from 5.9% to 16.4%, for TKR from 0.2% to 2.1%, for CAB from 0.7% to 1.4%, for PN from 18.3% to 52.7%, for RR from 1.7% to 20.0%.

Characteristics of Highlighted Procedures' Study Sample

Tables 1 and 2 describe the breakdown of these cases as well as provide comparative analysis of the patients involved in RALS cases against their non-RALS counterparts. Differences in

patient age between RALS and non-RALS cases were found to be statistically significant ($p < 0.01$) for all but RP ($p=0.30$) and PN ($p=0.70$). Differences in poverty rate were found to be significant for all procedures but PN ($p=0.08$). Tables 3 and 4 provide a comparative analysis of the physicians performing RALS procedures against those performing the non-RALS alternative.

Discussion

This study surveys the evolving changes in inpatient medicine and across several specialties as it adapts to robotic technology. To our knowledge, this is the first such study to chart changes in RALS cases over time and provide comparative analysis of both patients and surgeons involved in these procedures, across several specialties. This study found that the quantity of RALS cases for each category rose during the period of interest, however, the rise was asymmetric across categories. The proportion of all RALS cases decreased for urologists and gynecologists, while increasing for all other surgeons. In general, surgeons involved in RALS cases were more likely to be younger, male, and a non-foreign medical graduate (FMG), as compared to surgeons involved in non-RALS cases. Patients receiving RALS care were more likely to be young, male, white, and from a more affluent area, than patients receiving non-RALS care.

While there was a significant increase in the number of RALS cases for orthopedic surgeons, otolaryngologists, cardio-thoracic surgeons and general surgeons. This increase is not seen for urologists and gynecologists. This is likely due to their earlier adoption of RALS technique in urology and gynecology. One study, for example, noted the proportion of radical prostatectomy cases rose from 10% to 68% in the two year period spanning 2007 to 2009 (12). Interestingly, our study picks up right where the other study dropped off, showing the rise continue, albeit at a slower rate, to 85.5%. The clear domination of RALS in radical prostatectomy makes it unique among procedures and its rapid adoption underlies how quickly technology can drastically change practice, an observation mirrored in many fields that are similarly adapting to new technologies. The lack of a significant rise in the number of RALS cases for both urologists and gynecologists, may suggest that uptake of RALS in urology and gynecology has reached a saturation point, where all procedures for which RALS is advantageous have already come to utilize it. This conclusion may be complicated by influences on the general number of procedures being done and so require comparative analysis of RALS against non-RALS cases on a procedure-by-procedure basis as was done in this study. It is clear, however, that a majority of RALS cases are no longer handled by urologists, instead, while urologists still handle a plurality of these cases, RALS cases are increasingly spread across many specialties.

Looking at the highlighted procedures, we see that the proportion that are handed through RALS has increased universally. The most dramatic changes are seen in RR and PN. In RR, especially, we see the steady rise in the proportion of RALS cases from a negligible proportion to 20.0%. This trend is seen despite the decreases in the quantity of procedures seen in HM, RP, and CAB.

The declining number of cases for HM have been corroborated elsewhere in literature (13). For RP and CAB, we were unable to find previous research showing decline in caseload over time. As with HM, there may be several factors influencing the decline in the number of cases. A number of less invasive alternatives have diffused into practice over the past decade for treatment. Also, declining reimbursement may be discouraging these more invasive procedures, with their higher likelihood for complications, and encouraging non-invasive treatment.

As stated before, this study found that surgeons involved in RALS cases were more likely to be younger, male, and a non-FMG than surgeons who were involved in the non-RALS alternatives. Gender divides are well attested to in literature, with disparate treatment and varying priorities often cited as a root cause (14). Another reason may stem from the varying hospital accreditation practices for attainting RALS privileges or from gatekeepers of RALS training. This sort of gatekeeping can result in biased selection. These same factors may create the observed divide for FMGs as well. For age, the explaining factor may be greater access to RALS during training or higher willingness to take on the training after residency in order to attain RALS privileges. Also of note, there are exceptions to the generalization. For HM, for example, surgeons were more likely to be female. We found that female surgeons tended to be younger on average, likely do to the recent rise in females completing gynecology residencies. Another exception was found in CAB where there was no difference in age between the RALS and non-RALS surgeons as well as higher likelihood for FMGs to be using RALS procedures.

Patients receiving RALS care were more likely to be younger, white, and from a more affluent area, than patients receiving non-RALS care. For procedures where males and females receive care, males were more likely to receive RALS care than females. This result underscores the socioeconomic divisions that exist in the provision of RALS care. Previous studies have consistently shown better outcomes for RALS procedures. The apparent division of care based on socioeconomic status is concerning as it suggests that economically disadvantaged persons may be subjected to inferior quality of care. Previous studies have seen similar socioeconomic divisions in the dispensation of other care widely regarded as superior, such as higher odds for utilization of radical prostatectomy as opposed to nephron-sparing PN as linked to lower socioeconomic status (15). Limitations in access to surgeons providing RALS care, perhaps due to centralization of care, or limitation in resources may explain this apparent disparity. It should also be noted that for TKR, CAB, and RR, patients with multiple comorbidities were less likely to receive RALS care, while for HM they were more likely to receive RALS care. This may indicate differences in perceived indication for RALS. As before, there were exceptions to this generalization. No difference in poverty rate was found for PN and RR, and the reverse trend was found for CAB. However, for all cases, patients paying with Medicaid were far less likely to receive RALS care than non-RALS care, further highlighting socioeconomic divisions in the provision of RALS care.

The main limitation of this study is that the SPARCS dataset only collects information from and was confined to New York State. New York, however, is the 3rd largest state in terms of population and contains both urban and rural environments, a diversity of socioeconomic and ethnic backgrounds, and diversity of hospital types (9). The SPARCS dataset provides a unique

and comprehensive view into this population that does not exclude any occurrences of the procedures being studied over a substantial length of time and is therefore fully representative of its study sample.

Conclusion

Robotic assisted laparoscopic surgery (RALS) cases are diversifying. While previously a majority of RALS cases were handled by urologists and gynecologists, general, orthopedic, cardio-thoracic, and otolaryngological surgeons have begun performing a significant proportion of RALS cases. In general, surgeons involved in RALS cases were more likely to be younger, male, and a non-foreign medical graduate, as compared to surgeons involved in non-RALS cases. Patients receiving RALS care were more likely to be young, white, and from a more affluent area, than patients receiving non-RALS care. In procedures that serve males and females, males were more likely to receive RALS care than females. These trends suggest that the benefits of RALS for both the surgeon and patient have not been distributed equally.

These results have implications for surgeons planning for future practice and hospital administrators adapting to the rapidly changing medical landscape. RALS requires significant capital investments and should be weighed as part of a strategic plan for future growth.

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