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Diffusion of technology: Trends in robotic-assisted colorectal surgery

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ABSTRACT

Following FDA approval, robotic-assisted colorectal surgery (RACS) has increased in prevalence. We aimed to identify trends in utilization and patient characteristics of RACS in the United States using the University HealthSystem Consortium database between October 2011–September 2015. Outcome measures were number and percentage of procedures performed with robotic-assistance.

7100 patients were identified. The most common procedures were low anterior resection, sigmoid colectomy, abdominoperineal resection, right colectomy, rectopexy, left colectomy, and total colectomy. There was a 158% increase in RACS procedures. As a percentage of all approaches, RACS increased from 2.6% to 6.6%. The number of centers performing RACS increased from 105 to 140. Over the study period, the complexity of patients increased, with the percentage of patients with ≥3 comorbidities rising from 18% to 24% ($p = 0.03$) and patients with a moderate severity of illness score increasing from 35% to 41% ($p = 0.04$).

RACS has expanded significantly in volume, number of centers, and patient selection. Further studies evaluating outcomes and cost of RACS are required to determine whether these increases are justified by improved clinical outcomes.

1. Introduction

Robotic-assisted surgery was FDA approved for abdominal operations in 2000 and the first reported robotic-assisted colorectal procedures followed shortly thereafter in 2001.[1] The potential advantages of robotic-assisted surgery include improved visibility of the operative field, increased degrees of freedom of surgical instruments, and improved ergonomics.[2]

A 2013 systematic review demonstrated that for colon surgery, robotic-assisted and conventional laparoscopy had comparable short-term outcomes and early post-operative complications, with robotics having longer operative times and higher cost.[3] A systematic review of rectal resections demonstrated an association with lower open conversion rates with robotics compared to laparoscopy; however no statistically significant improvement in outcomes including anastomotic leak rate, circumferential resection margin positivity, and preservation of autonomic function have been demonstrated.[4] In addition, robotic rectal resections were associated with longer operative times and higher cost.[4] Thus, despite the evolution of robotic-assisted surgery over the past 15 years, the exact role of robotics as a tool in colon and rectal surgery remains unclear.[5–7]

A staged model of how surgical innovations progress has been described by Barkun et al.[8] The earliest stages of innovation consists of a new technology practiced by few surgeons on highly selected patients. Eventually, if an innovation is successful, it reaches a stage where the technology is used by most surgeons on most patients and is no longer affected by a learning curve. While robotic-assisted colorectal surgery (RACS) has clearly moved past the early innovation stage, it is unclear where robotic technology sits on the curve at this point. Prior studies have evaluated national trends of RACS on a single year basis, but were unable to capture longitudinal data or more recent trends.[9] We hypothesize that there has been an increase in the utilization and scope of RACS.

2. Materials and methods

The University HealthSystem Consortium (UHC) Clinical Database is an administrative database consisting of inpatient data from

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approximately 95% of U.S. non-profit medical centers (120 university hospitals and 299 of their affiliates).[10,11] After obtaining exemption status from the Institutional Review Board, a single year (October 2011 to September 2012) of the UHC database was queried for the most common robotic-assisted procedures on the colon and rectum in adult patients using the ICD-9 procedure codes 17.41, 17.42, and 17.49. Results were narrowed to the 7 most commonly performed procedures on the colon and/or rectum (ICD-9 procedure codes 17.33, 17.35 17.36, 45.73, 45.81, 45.82, 45.83, 48.61, 48.62, 48.63, 48.69, 45.75, 45.76, 48.50, 48.51, 48.52, 48.59, 48.75, and 48.76). After identifying the index procedures and corresponding ICD-9 procedure codes, the UHC database was queried from October 2011 to September 2015 (Fiscal Year (FY) 2012–2015) for the complete data set.

The primary outcome measures were the number and percentage of RACS procedures. Using the corresponding ICD-9 procedure codes for the top 7 RACS procedures, we identified the number of these procedures performed open, laparoscopic, and robotic-assisted over the study period. Secondary outcomes included sociodemographic and clinical characteristics, indication for procedure, hospital volume, and 3M© APR-DRG Admission Severity of Illness Score (3M Health Information Systems, Salt Lake City, UT). Further details of the UHC database and available variables for analysis have been previously described by Damle et al.[10] Continuous variables were analyzed with analysis of variance and categorical variables with chi-squared tests. All analyses were performed using Stata© IC version 12.1.

3. Results

A total of 7100 RACS patients were identified from FY 2012 through 2015. The most common procedure was low anterior resection (LAR) with rectal procedures overall making up 57% of the cohort. Over the study period, there was a 158% increase in the raw number of RACS procedures performed from 2012 to 2015 (Fig. 1). The average patient age was 58, and were 50% male, 79% white, 53% privately insured, 56% with zero or one comorbidity, and 53% with a minor severity of illness score (Table 1). The most common medical comorbidities were hypertension, diabetes, COPD, and obesity. These demographic and clinical characteristics remained largely consistent across the study period, however, there were some notable changes. There was a decrease in patients with minor severity of illness score (58%–52%, $p = 0.04$) corresponding with an increase in patients with a moderate severity of illness score (35%–41%, $p = 0.04$). In addition, there was an increase in patients with anemia (6.6%–10%, $p = 0.01$), obesity (11%–15%, $p = 0.01$), and three or more medical co-morbidities (18%–24%, $p = 0.03$). The indication for the majority of abdominoperineal resections (APR), LARs, and left colectomies was cancer, where as the majority of sigmoid and total abdominal colectomies were for benign disease (Table 2).

When evaluated as a percentage of all approaches, robotics increased from 2.6% to 6.6% (Fig. 2). The largest increase was for robotic rectopexy which increased from 15% to 27%. Increases in robotic-assisted procedures were associated with a decrease in their open counterparts ranging from a 5.7% decrease in open right colectomy to a 12.1% decrease for open rectopexy. Laparoscopic approaches overall increased from 30% to 32%.

As the number of total robotic-assisted procedures has increased, so have both the number of centers performing these procedures and the number of procedures performed per center (Fig. 3). The number of centers performing RACS increased from 105 in 2012 to 140 in 2015. The 50th percentile for volume per center increased from 6 to 12 procedures per year, while the 99th percentile increased from 42 to 93 RACS procedures per year.

4. Discussion

4.1. Volume

The practice of RACS is spreading rapidly. There has been an increase in the raw number of procedures, the percentage of procedures performed robotically, the number of centers performing RACS, and the volume of procedures per center. The key question is whether this increased utilization is driven by availability of the technology, patient outcomes, or something else entirely.

One reason for the increase in RACS may be from surgeons who primarily perform open procedures moving to take advantage of the benefits of minimally invasive surgery, including smaller incisions, faster recovery time, fewer respiratory complications, fewer surgical infections, and decreased hospital stay.[12–14] While laparoscopic rectal resections are technically challenging and require a learning curve of 60–80 cases to achieve proficiency the learning curve for robotic-assisted rectal resections has been described as

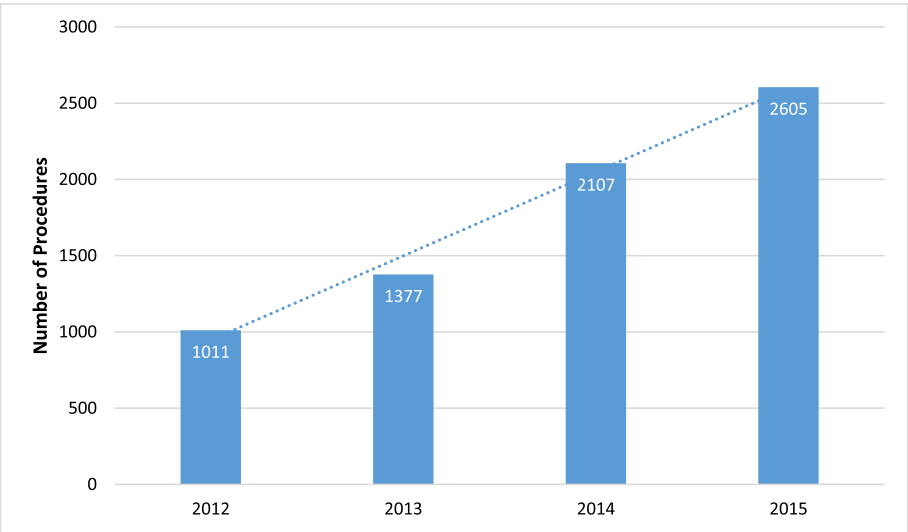

Fig. 1. Number of top 7 robotic-assisted colorectal surgery operations per year per UHC database (n = 7100).

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