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# Exploring the paradigm of robotic surgery and its contribution to the growth of surgical volume☆

Emily A. Grimsley, MD [a,*], Tara M. Barry, MD [a], Haroon Janjua, MSc [a], Emanuel Eguia, MD [b], Christopher DuCoin, MD [a], Paul C. Kuo, MD [a]

[a] Department of Surgery, USF Morsani College of Medicine, University of South Florida, Tampa, FL, USA
[b] Loyola University Chicago Stritch School Of Medicine, Maywood, IL, USA

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ABSTRACT

*Background:* Robotic surgery is an appealing option for both surgeons and patients. The question around the introduction of new surgical technology, such as robotics, with the potential link to increased procedure-specific volume has not been addressed. We hypothesize that hospital adoption of robotic technology increases the total volume of specific procedures as compared to nonrobotic hospitals.
*Methods:* The 2010–2020 Florida Agency for Health Care Administration Inpatient database was queried for open, laparoscopic, and robotic colectomy, lobectomy, gastric bypass, and antireflux procedures. *International Classification of Diseases, 9th and 10th Revisions,* codes were used. Difference in difference method was used to evaluate the impact of robotics on total procedure-specific volume of robotic hospitals versus nonrobotic hospitals before and after adopting robotic technology. Incident rate ratios from the difference in difference analysis determined the significance of adding robotics. Patient demographics were evaluated using $\chi^2$ test.
*Results:* A total of 291,826 procedures were performed at 217 hospitals, 151 with robotic capabilities. Robotic hospitals experienced a 37% increase in surgical volume due to robotic technology (incident rate ratio 1.37, $P < .05$), which was consistent for each surgery except antireflux procedures (incident rate ratio 0.95). Robotic procedures had significantly higher charges for medical/surgical supplies; however, the mean length of stay for robotic procedures was significantly shorter than that of laparoscopic and open cases.
*Conclusion:* Hospital adoption of robotic technology significantly increases surgical volume for select procedures. Hospitals should consider the benefits of introducing robotic technology which leads to higher volume and decreased length of stay, benefitting both hospital systems and patients.


## INTRODUCTION

The utilization of robotic surgery is growing; however, its impact on hospital systems and patient care is still being established. Research has that shown select robotic procedures (as compared to laparoscopic and/or open) carry a shorter length of stay (LOS) but higher cost [1]. The upfront cost of purchasing the robot and accoutrement can also not be ignored. One study suggested that the cost of adding a robot to a hospital was more than US$2.6 million [2].

Knowing that there is a high startup cost, hospital systems want to ensure a return on investment. As one could postulate that increasing surgical volume would increase revenue, our study sought to evaluate the effect of adding robotic technology to hospitals in terms of change in overall surgical volume. We hypothesized that the addition of robotic technology would increase hospital surgical volumes when studying select surgical procedures.

## METHODS

This study was exempt from our institutional review board given that it was querying a deidentified database and did not contain HIPAA-protected information.

The 2010–2020 Florida Agency for Health Care Administration Inpatient database was queried for open, laparoscopic, and robotic colectomy, pulmonary lobectomy (lobectomy), gastric bypass, and antireflux surgeries [3]. These 4 procedures were chosen because they are very common operations performed in all 3 procedure types: open, laparoscopic (or thoracoscopic), and robotic. *International Classification of Diseases, 9th*

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* Corresponding author at: Department of Surgery, University of South Florida Morsani College of Medicine, 2 Tampa General Circle, Tampa, FL 33606. Tel: 813-974-4115; fax: 813-974-4115.
*E-mail address:* grimsley@usf.edu (E.A. Grimsley).

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*and 10th Revisions* (*ICD9* and *ICD10*), codes were used to capture the 3 procedure types (open, laparoscopic, and robotic) using the primary procedure code. Open and laparoscopic procedures were coded based on their primary procedure code. The procedure was labeled "robotic" if a robotic qualifier appeared with the primary procedure code. A total of 257 procedure codes were used including the robotic qualifiers: 65 *ICD9* codes (17 robotic qualifiers) and 192 *ICD10* codes (234 robotic qualifiers; see Supplementary Material).

Patient demographics including sex, age, race, ethnicity, payer types, and Charlson comorbidity index (CCI) were studied. Stata software version 16 was used for all the data preparation steps and computing the descriptive statistics. R Studio was used to implement all the machine learning models using packages and libraries including "readstata13," "tableone," "MatchIT," "Matching," and "ICD." $\chi^2$ tests were performed to quantify the statistical significance among the 3 types of procedures and the descriptive categorical variables.

As our dataset did not include information on cost to hospital, we used the available data on charges to formulate a comparison between the different procedure types (open/laparoscopic/robotic). Analysis of similarities and differences between the procedure types (open/laparoscopic/robotic) for gross total charges, operating room charges, medical/surgical supply charges, anesthesia charges, and recovery room charges was completed with ANOVA with post hoc analysis; these analyses were risk-adjusted using CCI and separately by procedure type (open/laparoscopic/robotic). Data are presented as mean ± standard deviation.

Propensity score matching was used for a more comparative analysis between the 3 procedure types [4,5]. One-to-one matching was used to find the best and closest match for each robotic procedure in the open/

**Table 1**
Patient characteristics

| | *Open* | | *Lap* | | *Robotic* | | *Total* | |
|---|---|---|---|---|---|---|---|---|
| | n = *139,796* | | n = *119,886* | | n = *32,144* | | n = *291,826* | |
| | n | *%* | n | *%* | n | *%* | n | *%* |
| Patient sex | | | | | | | | |
| Female | 74,446 | 53% | 73,028 | 61% | 19,714 | 61% | 167,188 | 57% |
| Male | 65,350 | 47% | 46,858 | 39% | 12,430 | 39% | 124,638 | 43% |
| Age range | | | | | | | | |
| ≤30 | 3663 | 3% | 7217 | 6% | 835 | 3% | 11,715 | 4% |
| 31–50 | 18,490 | 13% | 27,126 | 23% | 5505 | 17% | 51,121 | 18% |
| 51–70 | 62,278 | 45% | 53,534 | 45% | 15,470 | 48% | 131,282 | 45% |
| 71–90 | 53,035 | 38% | 31,203 | 26% | 10,231 | 32% | 94,469 | 32% |
| 90+ | 2330 | 2% | 806 | 1% | 103 | 0% | 3239 | 1% |
| Race | | | | | | | | |
| White | 118,253 | 85% | 100,116 | 84% | 27,389 | 85% | 245,758 | 84% |
| Black | 14,044 | 10% | 12,541 | 10% | 2596 | 8% | 29,181 | 10% |
| Asian | 942 | 1% | 707 | 1% | 256 | 1% | 1905 | 1% |
| American Indian | 162 | 0% | 154 | 0% | 48 | 0% | 364 | 0% |
| Hawaiian Pacific Islander | 55 | 0% | 46 | 0% | 14 | 0% | 115 | 0% |
| Other | 6340 | 5% | 6322 | 5% | 1841 | 6% | 14,503 | 5% |
| Ethnicity | | | | | | | | |
| Hispanic or Latino | 20,029 | 14% | 22,790 | 19% | 6866 | 21% | 49,685 | 17% |
| Non-Hispanic or Latino | 119,767 | 86% | 97,096 | 81% | 25,278 | 79% | 242,141 | 83% |
| Admission source | | | | | | | | |
| Non–health care facility point of origin | 104,816 | 75% | 86,513 | 72% | 22,900 | 71% | 214,229 | 73% |
| Clinic or physician's office | 26,650 | 19% | 30,184 | 25% | 8910 | 28% | 65,744 | 23% |
| Transfer from a hospital | 1846 | 1% | 1070 | 1% | 173 | 1% | 3089 | 1% |
| Transfer from a skilled nursing facility (SNF) or intermediate care facility (ICF) | 858 | 1% | 184 | 0% | 21 | 0% | 1063 | 0% |
| Transfer from another health care facility | 393 | 0% | 154 | 0% | 22 | 0% | 569 | 0% |
| Other transfers | 5233 | 4% | 1781 | 1% | 118 | 0% | 7132 | 2% |
| Admission priority | | | | | | | | |
| Emergency | 58,905 | 42% | 19,800 | 17% | 1894 | 6% | 80,599 | 28% |
| Urgent | 13,684 | 10% | 9165 | 8% | 2680 | 8% | 25,529 | 9% |
| Elective | 67,207 | 48% | 90,921 | 76% | 27,570 | 86% | 185,698 | 64% |
| Payer types | | | | | | | | |
| Commercial health insurance | 37,943 | 27% | 44,346 | 37% | 11,720 | 36% | 94,009 | 32% |
| Medicaid | 9409 | 7% | 8652 | 7% | 1317 | 4% | 19,378 | 7% |
| Medicare | 81,898 | 59% | 56,756 | 47% | 17,515 | 54% | 156,169 | 54% |
| Other govt | 3112 | 2% | 3786 | 3% | 854 | 3% | 7752 | 3% |
| Self-pay | 4764 | 3% | 4646 | 4% | 462 | 1% | 9872 | 3% |
| All others | 2670 | 2% | 1700 | 1% | 276 | 1% | 4646 | 2% |
| Charlson comorbidity index | | | | | | | | |
| Low | 38,905 | 28% | 45,334 | 38% | 9583 | 30% | 93,822 | 32% |
| Moderate | 19,859 | 14% | 24,372 | 20% | 4939 | 15% | 49,170 | 17% |
| Severe | 81,032 | 58% | 50,180 | 42% | 17,622 | 55% | 148,834 | 51% |
| Discharge status | | | | | | | | |
| Discharged to home or self-care | 67,143 | 48% | 93,671 | 78% | 24,134 | 75% | 184,948 | 63% |
| Discharged or transferred to a skilled nursing facility | 17,545 | 13% | 4970 | 4% | 899 | 3% | 23,414 | 8% |
| Discharged or transferred to a short-term care facility | 1301 | 1% | 423 | 0% | 83 | 0% | 1807 | 1% |
| Discharged or transferred to home under care of home health care organization | 38,613 | 28% | 17,817 | 15% | 6433 | 20% | 62,863 | 22% |
| Expired | 5701 | 4% | 920 | 1% | 185 | 1% | 6806 | 2% |
| Discharged or transferred to a long-term care facility | 9493 | 7% | 2085 | 2% | 410 | 1% | 11,988 | 4% |

All *P* values < .001 within category by $\chi^2$.

**Table 2**
Difference in difference analysis and incident rate ratios

| | n (# hospitals) | IRR | 95% CI | P value |
|---|---|---|---|---|
| Colectomy | | | | |
| Robotic hospitals | 133 | 1.38 | 1.36–1.40 | <.0001 |
| Nonrobotic hospitals | 78 | | | |
| Lobectomy | | | | |
| Robotic hospitals | 124 | 1.11 | 1.07–1.14 | <.0001 |
| Nonrobotic hospitals | 46 | | | |
| Gastric bypass | | | | |
| Robotic hospitals | 82 | 1.73 | 1.67–1.79 | <.0001 |
| Nonrobotic hospitals | 110 | | | |
| Antireflux | | | | |
| Robotic hospitals | 141 | 0.95 | 0.91–1.00 | NS |
| Nonrobotic hospitals | 50 | | | |
| All procedures combined | | | | |
| Robotic hospitals | 151 | 1.37 | 1.36–1.39 | <.0001 |
| Nonrobotic hospitals | 66 | | | |

IRRs shown for the overall difference in difference analysis and for each procedure. *CI*, confidence interval; *NS*, not significant.

laparoscopic groups based on age, sex, and CCI. One-to-one matching helped capture the closest match precisely based on defined factors and reduced effect of confounding. After propensity one-to-one matching, 32,144 robotic cases were compared with 32,144 open and 32,144 laparoscopic cases, which enabled us to perform a comparison between like cases.

For each hospital in each year, the total volume of each procedure type was calculated by adding the open, laparoscopic, and robotic cases together. Hospital classification as "robotic" or "nonrobotic" was done by flagging hospitals that performed at least 1 procedure (within our set procedure types) labeled with a robotic qualifier. We used a difference in difference (DID) method to test our hypothesis by analyzing the difference of total procedure volume in robotic hospitals pre- and postadoption of robotic technology and compared this to the difference in total procedure volume for nonrobotic hospitals across the same years using our propensity-matched cohorts. The DID is a causal analysis that uses longitudinal data from a treatment and a control group to estimate a causal effect of a specific intervention/treatment. The DID method is based on Poisson regression and is used to predict a response (a dependent variable in the form of "count data") that is impacted by 1 or more independent variables. DID was used to assess the relationship between total procedure volumes of robotic versus nonrobotic hospitals (the dependent variable) before and after adopting robotics (the independent variable). This DID analysis was performed for all procedures together and then individually for colectomy, lobectomy, gastric bypass, and antireflux. Incident rate ratios (IRRs) from the DID analysis determined the size of the effect adding robotics to a hospital had on surgical volume [6–8]. We regressed total procedure volume for robotic versus nonrobotic hospitals in addition to time when a hospital started performing robotic procedures. All data preparation methods and modeling codes used can be accessed electronically [9].

## RESULTS

A total of 291,826 surgical cases of our selected types were performed at 217 hospitals within the database: 139,796 open, 119,886 laparoscopic, and 32,144 robotic cases. Of these 217 hospitals, 151 had robotic capabilities. Our analysis was performed on a propensity-matched cohort to the robotic cases such that we had a total *N* of 96,432 with 32,144 each of robotic, laparoscopic, and open cases. Most patients were female (57%), white (84%), non-Hispanic or Latino (83%), and ages 51–70 (45%). Overall, 64% of procedures were elective; 9%, urgent; and 28%, emergent. Most patients (51%) fell into the severe CCI (CCI 3; all $P < .001$; Table 1).

Altogether, robotic hospitals had a 37% increase in procedure volume (IRR 1.37, $P < .0001$). This significant increase held true for all procedure types except antireflux procedures where there was no such significant increase in surgical volume at robotic hospitals (IRR 0.959, $P = .079$). The largest increase in volume due to robotics (73% increase) was seen in gastric bypass surgeries (IRR 1.735, $P < .0001$), which were performed at 82 robotic hospitals and 110 nonrobotic hospitals (Table 2).

Hospital charges were reviewed as well among our propensity-matched cohort of 32,144 of each procedure type. Overall, the mean total charge was $122,141 for open surgery, $90,178 for laparoscopic, and $125,998 for robotic. On the whole, charges for robotic surgeries were statistically significantly higher than charges for open or laparoscopic surgeries except for total charges for robotic lobectomy ($119,301), gastric bypass ($112,411), and antireflux surgery ($121,383), which were statistically significantly less

**Table 3a**
Charges risk-adjusted by procedure type for Charlson comorbidity index 1

| | Open | Laparoscopic | Robotic | ANOVA | | |
|---|---|---|---|---|---|---|
| Colectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 94,655.3 ± 88,353 | 76,514.33 ± 55,136.63 | 127,846.5 ± 84,364.81 | <.001 | <.001 | <.001 |
| OR | 30,595.23 ± 26,390.61 | 26,763.32 ± 20,082.41 | 60,259.28 ± 49,747.44 | <.001 | <.001 | <.001 |
| Med/surg supply | 12,218.95 ± 11,752.53 | 12,978.54 ± 9165.513 | 19,799.81 ± 14,281.85 | .016 | <.001 | <.001 |
| Anesthesia | 7468.17 ± 7103.78 | 6776.745 ± 6044.73 | 12,045.52 ± 10,739.19 | .001 | <.001 | <.001 |
| PACU | 3538.424 ± 3065.859 | 3264.919 ± 2581.371 | 4356.761 ± 5260.719 | .005 | <.001 | <.001 |
| Lobectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 115,739.1 ± 133,786.3 | 80,050.61 ± 58,726.24 | 96,493.48 ± 58,177.91 | <.001 | <.001 | <.001 |
| OR | 30,173.05 ± 23,166.78 | 26,626.55 ± 19,925.29 | 33,472.99 ± 29,094.21 | .003 | .008 | <.001 |
| Med/surg supply | 15,858.9 ± 15,926.35 | 13,191.21 ± 12,295.53 | 20,595.75 ± 15,991.59 | <.001 | <.001 | <.001 |
| Anesthesia | 7777.866 ± 7176.86 | 5929.962 ± 5322.601 | 6348.524 ± 5751.171 | <.001 | <.001 | .244 |
| PACU | 2654.527 ± 3067.164 | 2926.067 ± 2911.612 | 3424.7 ± 3134.339 | .105 | <.001 | <.001 |
| Gast bypass | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 124,560.6 ± 136,137 | 63,949.3 ± 33,410.63 | 105,120 ± 52,473.49 | <.001 | <.001 | <.001 |
| OR | 39,071.56 ± 39,179.89 | 23,545.11 ± 17,324.75 | 52,867.78 ± 36,980.87 | <.001 | <.001 | <.001 |
| Med/surg supply | 15,554.51 ± 13,620.4 | 17,150.05 ± 13,086.07 | 22,820.6 ± 15,008.82 | .002 | <.001 | <.001 |
| Anesthesia | 8571.887 ± 8306.492 | 5509.143 ± 5646.901 | 8318.006 ± 8544.746 | <.001 | .576 | <.001 |
| PACU | 3872.312 ± 3327.858 | 3899.316 ± 3318.818 | 3180.95 ± 2497.934 | .963 | <.001 | <.001 |
| Antireflux | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 119,073.9 ± 155,409.1 | 67,875.53 ± 66,148.05 | 105,970.4 ± 76,132.32 | <.001 | <.001 | <.001 |
| OR | 31,627.63 ± 31,163.36 | 26,518.71 ± 19,863.28 | 52,371.57 ± 35,721.58 | <.001 | <.001 | <.001 |
| Med/surg supply | 11,720.7 ± 17,223.87 | 11,681.67 ± 11,154.39 | 14,376.24 ± 11,737.29 | .995 | <.001 | <.001 |
| Anesthesia | 8365.69 ± 10,183.23 | 6724.682 ± 6113.568 | 9421.881 ± 9044.877 | <.001 | <.001 | <.001 |
| PACU | 3586.774 ± 3222.567 | 3299.32 ± 2690.251 | 4014.039 ± 4009.335 | .012 | <.001 | <.001 |

**Table 3b**
Charges risk-adjusted by procedure type for Charlson comorbidity index 2

| | *OPEN* | *LAPAROSCOPIC* | *ROBOTIC* | | *ANOVA* | |
|---|---|---|---|---|---|---|
| Colectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 116,726.8 ± 127,949.1 | 87,195 ± 66,374.52 | 145,269.6 ± 98,417.39 | *<.001* | *<.001* | *<.001* |
| OR | 31,195.01 ± 25,793.25 | 28,158.21 ± 21,154.61 | 64,582.55 ± 52,536.78 | .054 | *<.001* | *<.001* |
| Med/surg supply | 13,476.14 ± 13,700.66 | 13,628.27 ± 9897.232 | 21,573.38 ± 15,857.79 | .949 | *<.001* | *<.001* |
| Anesthesia | 7779.025 ± 7234.903 | 7176.901 ± 6338.175 | 13,075.71 ± 10,580.75 | .118 | *<.001* | *<.001* |
| PACU | 3918.997 ± 3791.265 | 3500.623 ± 2883.185 | 4487.421 ± 3658.178 | *.003* | *<.001* | *<.001* |
| Lobectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 119,043.7 ± 129,993.5 | 90,642.78 ± 73,291.32 | 106,638.6 ± 69,672.1 | *<.001* | *.025* | *.001* |
| OR | 29,376.23 ± 29,251.75 | 25,076.32 ± 17,000.02 | 36,076.22 ± 30,924.79 | *.001* | *<.001* | *<.001* |
| Med/surg supply | 15,335.22 ± 15,560.47 | 14,126.52 ± 14,577.15 | 21,001.52 ± 16,114 | .213 | *<.001* | *<.001* |
| Anesthesia | 7150.308 ± 6690.582 | 5756.216 ± 4830.622 | 6677.189 ± 5969.829 | *<.001* | .248 | *.002* |
| PACU | 2870.329 ± 3370.97 | 3160.028 ± 2922.892 | 3513.992 ± 3293.657 | .125 | *<.001* | *.047* |
| Gast bypass | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 136,978.3 ± 148,591.1 | 66,958.55 ± 37,563.16 | 110,261.6 ± 61,864.17 | *<.001* | *<.001* | *<.001* |
| OR | 36,904.11 ± 36,789.47 | 23,987.67 ± 18,813.92 | 53,697.37 ± 36,038.01 | *<.001* | *<.001* | *<.001* |
| Med/surg supply | 16,553.82 ± 14,974.09 | 17,957.27 ± 12,676.55 | 22,903 ± 14,285.01 | *.01* | *<.001* | *<.001* |
| Anesthesia | 8658.287 ± 9076.686 | 5984.756 ± 4918.212 | 9728.854 ± 10,212.45 | *<.001* | *.001* | *<.001* |
| PACU | 4206.803 ± 4235.797 | 3894.175 ± 3470.711 | 3388.174 ± 2517.72 | *.022* | *<.001* | *<.001* |
| Antireflux | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 129,643 ± 152,427.1 | 82,237.19 ± 89,221.29 | 130,900.1 ± 109,153.7 | *<.001* | .97 | *<.001* |
| OR | 31,440.65 ± 33,740.25 | 29,438.11 ± 25,948.48 | 57,494.21 ± 42,963.13 | .402 | *<.001* | *<.001* |
| Med/surg supply | 11,015.4 ± 12,687.59 | 12,355.68 ± 11,048.87 | 14,679.51 ± 11,805.91 | *.03* | *<.001* | *<.001* |
| Anesthesia | 8294.456 ± 9168.844 | 7304.118 ± 6700.476 | 11,167.05 ± 10,608.35 | *.035* | *<.001* | *<.001* |
| PACU | 3691.341 ± 3833.096 | 3572.346 ± 3083.741 | 4456.894 ± 4070.033 | .749 | *<.001* | *<.001* |

than open lobectomy ($122,283; $P = .041$), gastric bypass ($135,094; $P < .0001$), and antireflux surgery ($133,372; $P < .0001$), respectively. These findings held true when risk-adjusted for CCI except for CCI 3 patients where robotic cost was not statistically significantly less than open (Tables 3a–3c). Across all procedure types, total charges for robotic surgery were higher than those for laparoscopic, which remained true when risk-adjusted for CCI (Tables 3a–3c). When the data were separated out by procedure type (open/laparoscopic/robotic) and then within those data risk-adjusted by CCI, CCI 3 patients had higher total charges than CCI 1 patients except in open lobectomy cases (Tables 3d–3f).

LOS was statistically significantly shorter for robotic surgery when compared to open and laparoscopic ($P < .0001$) except when comparing robotic versus laparoscopic gastric bypass (2.56 vs 2.47 days; $P = .788$) and antireflux surgery (3.86 vs 3.55 days; $P = .104$), where there was no statistically significant difference. When risk-adjusted for CCI, this held true except for CCI 1 and CCI 2 colectomy patients, and CCI 1 lobectomy patients where robotic versus laparoscopic LOS was not statistically different (Table 4a). Table 4b displays the LOS risk-adjusted by procedure type; in general, the more severe CCI (2 or 3), the longer the length of stay regardless of procedure type (open/laparoscopic/robotic).

## DISCUSSION

This study establishes that robotic surgery increases surgical volume, decreases LOS, and, for select procedures studied, has lower total charges, which may have great benefit for both hospitals and

**Table 3c**
Charges risk-adjusted by procedure type for Charlson comorbidity index 3

| | *Open* | *Laparoscopic* | *Robotic* | | *ANOVA* | |
|---|---|---|---|---|---|---|
| Colectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 121,332.9 ± 150,154.1 | 99,170.39 ± 86,102.06 | 154,037.1 ± 115,172.1 | *<.001* | *<.001* | *<.001* |
| OR | 32,168.89 ± 30,385.56 | 29,735.09 ± 24,490.73 | 64,474.09 ± 51,866 | *.003* | *<.001* | *<.001* |
| Med/surg supply | 13,387.41 ± 12,195.15 | 13,702.23 ± 10,430.27 | 20,701.21 ± 16,771.37 | .467 | *<.001* | *<.001* |
| Anesthesia | 7881.825 ± 7796.974 | 7569.164 ± 6904.681 | 13,488.04 ± 11,299.49 | .181 | *<.001* | *<.001* |
| PACU | 3781.377 ± 3457.973 | 3661.935 ± 3397.939 | 4605.33 ± 4165.976 | .236 | *<.001* | *<.001* |
| Lobectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 123,053.9 ± 117,855.8 | 108,845 ± 88,317.8 | 122,476.1 ± 82,267.99 | *<.001* | .903 | *<.001* |
| OR | 33,472.23 ± 29,066.97 | 32,825.86 ± 24,277.44 | 43,288.45 ± 38,464.6 | .299 | *<.001* | *<.001* |
| Med/surg supply | 17,030.9 ± 15,469.1 | 18,102.37 ± 16,023.67 | 23,987.32 ± 17,297.48 | *<.001* | *<.001* | *<.001* |
| Anesthesia | 8278.606 ± 7268.962 | 7062.693 ± 6300.246 | 7755.483 ± 6707.74 | *<.001* | *<.001* | *<.001* |
| PACU | 2967.321 ± 3219.008 | 2991.406 ± 3001.685 | 3661.673 ± 3760.589 | .863 | *<.001* | *<.001* |
| Gast bypass | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 139,395.7 ± 156,939.1 | 84,956.56 ± 70,259.85 | 130,049.5 ± 109,754 | *<.001* | .088 | *<.001* |
| OR | 29,586.87 ± 26,458.96 | 27,623.76 ± 23,316.61 | 54,290.94 ± 39,256.42 | .109 | *<.001* | *<.001* |
| Med/surg supply | 15,473.54 ± 15,031.02 | 20,590.08 ± 14,436.88 | 24,583.38 ± 17,193.01 | *<.001* | *<.001* | *<.001* |
| Anesthesia | 7573.191 ± 6981.913 | 6912.194 ± 6105.275 | 11,702.16 ± 12,566.22 | *.049* | *<.001* | *<.001* |
| PACU | 4024.848 ± 3690.569 | 3612.774 ± 3056.891 | 3667.342 ± 2694.047 | *.001* | *.005* | .909 |
| Antireflux | | | | Lap vs open | Rob vs open | Rob vs lap |
| Total charges | 172,160 ± 162,225.3 | 100,524.2 ± 104,854.5 | 157,878.2 ± 139,023.8 | *<.001* | .108 | *<.001* |
| OR | 34,281.75 ± 29,831.23 | 29,685.62 ± 21,350.46 | 60,532.18 ± 42,258.57 | *.015* | *<.001* | *<.001* |
| Med/surg supply | 13,558.15 ± 17,008.62 | 13,181.86 ± 10,980.11 | 17,156.97 ± 14,556.07 | .871 | *<.001* | *<.001* |
| Anesthesia | 9445.393 ± 10,327.4 | 7606.396 ± 6524.486 | 12,616.67 ± 12,692.79 | *.001* | *<.001* | *<.001* |
| PACU | 3813.73 ± 3510.809 | 3478.583 ± 2976.502 | 4793.128 ± 4549.322 | .187 | *<.001* | *<.001* |

For Tables 3a–3c: charges (mean ± standard deviation), risk-adjusted per procedure type, after separating by CCI. Post-Hoc ANOVA with pairwise comparison of the means, *P* values presented with *significant values in italics*. *PACU*, recovery room charges; *Gast bypass*, gastric bypass; *Lap*, laparoscopic.

**Table 3d**
Charges risk-adjusted by Charlson comorbidity index for open procedures

| | *CCI 1* | *CCI 2* | *CCI 3* | *ANOVA* | | |
|---|---|---|---|---|---|---|
| Colectomy | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 94,655.3 ± 88,353 | 116,726.8 ± 127,949.1 | 121,332.9 ± 150,154.1 | *<.001* | *<.001* | .462 |
| OR | 30,595.23 ± 26,390.61 | 31,195.01 ± 25,793.25 | 32,168.89 ± 30,385.56 | .78 | *.025* | .5 |
| Med/surg supply | 12,218.95 ± 11,752.53 | 13,476.14 ± 13,700.66 | 13,387.41 ± 12,195.15 | *.003* | *<.001* | .97 |
| Anesthesia | 7468.17 ± 7103.78 | 7779.025 ± 7234.903 | 7881.825 ± 7796.974 | .383 | *.026* | .894 |
| PACU | 3538.424 ± 3065.859 | 3918.997 ± 3791.265 | 3781.377 ± 3457.973 | *.001* | *.002* | .374 |
| Lobectomy | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 115,739.1 ± 133,786.3 | 119,043.7 ± 129,993.5 | 123,053.9 ± 117,855.8 | .843 | .189 | .648 |
| OR | 30,173.05 ± 23,166.78 | 29,376.23 ± 29,251.75 | 33,472.23 ± 29,066.97 | .841 | *.003* | *<.001* |
| Med/surg supply | 15,858.9 ± 15,926.35 | 15,335.22 ± 15,560.47 | 17,030.9 ± 15,469.1 | .775 | .079 | *.01* |
| Anesthesia | 7777.866 ± 7176.86 | 7150.308 ± 6690.582 | 8278.606 ± 7268.962 | .186 | .118 | *<.001* |
| PACU | 2654.527 ± 3067.164 | 2870.329 ± 3370.97 | 2967.321 ± 3219.008 | .366 | *.015* | .703 |
| Gast bypass | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 124,560.6 ± 136,137 | 136,978.3 ± 148,591.1 | 139,395.7 ± 156,939.1 | .069 | *.008* | .871 |
| OR | 39,071.56 ± 39,179.89 | 36,904.11 ± 36,789.47 | 29,586.87 ± 26,458.96 | .183 | *<.001* | *<.001* |
| Med/surg supply | 15,554.51 ± 13,620.4 | 16,553.82 ± 14,974.09 | 15,473.54 ± 15,031.02 | .164 | .985 | .059 |
| Anesthesia | 8571.887 ± 8306.492 | 8658.287 ± 9076.686 | 7573.191 ± 6981.913 | .954 | *<.001* | *<.001* |
| PACU | 3872.312 ± 3327.858 | 4206.803 ± 4235.797 | 4024.848 ± 3690.569 | *.046* | .437 | .292 |
| Antireflux | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 119,073.9 ± 155,409.1 | 129,643 ± 152,427.1 | 172,160 ± 162,225.3 | .183 | *<.001* | *<.001* |
| OR | 31,627.63 ± 31,163.36 | 31,440.65 ± 33,740.25 | 34,281.75 ± 29,831.23 | .987 | .091 | .126 |
| Med/surg supply | 11,720.7 ± 17,223.87 | 11,015.4 ± 12,687.59 | 13,558.15 ± 17,008.62 | .491 | *.013* | *.002* |
| Anesthesia | 8365.69 ± 10,183.23 | 8294.456 ± 9168.844 | 9445.393 ± 10,327.4 | .981 | *.019* | *.034* |
| PACU | 3586.774 ± 3222.567 | 3691.341 ± 3833.096 | 3813.73 ± 3510.809 | .709 | .23 | .724 |

patients. We used propensity matching for comparison of the robotic, laparoscopic, and open procedures to minimize unaccounted for variance in the cohorts [4,5] and a DID analysis to determine what amount of the change in surgical volume can be attributed to the addition of robotic technology. The DID analysis has been used in similar studies to establish a causal relationship between a dependent and independent variable in 2 continuous groups of data that our otherwise similar, ie, propensity-matched cohorts, over time [8,10–12].

One may postulate that the decreased total charges for robotic surgery compared with open surgery (and laparoscopic compared to open) can be attributed to the significant decrease in LOS for robotic and laparoscopic surgeries compared with open operations.

Decreased LOS following robotic surgery has been proven. Several colorectal surgeries have identified decreased LOS with robotic colectomy versus laparoscopic [13–15]. One study demonstrated equivalent overall cost between robotic and laparoscopic colectomy [15], leading to the conclusion that robotic surgery is more valuable to hospitals and patients than previously thought.

In the thoracic surgery arena, it has been shown that although robotic procedure cost was higher, there was no statistically significant difference in overall cost to patients due to lower postoperative costs [16]. Two studies even documented a profit margin with robotic lobectomy [17,18]. Although we did not examine cost, our study demonstrates significantly lower charges for robotic lobectomy versus open but still significantly higher charges for robotic versus laparoscopic. Interestingly, the LOS for robotic lobectomy was statistically significantly less when compared with open and laparoscopic lobectomy, pointing to the fact that decreasing LOS alone does not result in decreased overall charges to patient. Based on our risk-adjusted analysis, there is a strong element to patient severity of illness/comorbidities that contributes to LOS across procedure types. That said, one must also consider that a decreased LOS could mean less complications, risk of

**Table 3e**
Charges risk-adjusted by Charlson comorbidity index for laparoscopic procedures

| | *CCI 1* | *CCI 2* | *CCI 3* | *ANOVA* | | |
|---|---|---|---|---|---|---|
| Colectomy | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 76,514.33 ± 55,136.63 | 87,195 ± 66,374.52 | 99,170.39 ± 86,102.06 | *<.001* | *<.001* | *<.001* |
| OR | 26,763.32 ± 20,082.41 | 28,158.21 ± 21,154.61 | 29,735.09 ± 24,490.73 | .106 | *<.001* | *.045* |
| Med/surg supply | 12,978.54 ± 9165.513 | 13,628.27 ± 9897.232 | 13,702.23 ± 10,430.27 | .081 | *.002* | .965 |
| Anesthesia | 6776.745 ± 6044.73 | 7176.901 ± 6338.175 | 7569.164 ± 6904.681 | .111 | *<.001* | .1 |
| PACU | 3264.919 ± 2581.371 | 3500.623 ± 2883.185 | 3661.935 ± 3397.939 | *.031* | *<.001* | .169 |
| Lobectomy | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 80,050.61 ± 58,726.24 | 90,642.78 ± 73,291.32 | 108,845 ± 88,317.8 | *.007* | *<.001* | *<.001* |
| OR | 26,626.55 ± 19,925.29 | 25,076.32 ± 17,000.02 | 32,825.86 ± 24,277.44 | .239 | *<.001* | *<.001* |
| Med/surg supply | 13,191.21 ± 12,295.53 | 14,126.52 ± 14,577.15 | 18,102.37 ± 16,023.67 | .311 | *<.001* | *<.001* |
| Anesthesia | 5929.962 ± 5322.601 | 5756.216 ± 4830.622 | 7062.693 ± 6300.246 | .768 | *<.001* | *<.001* |
| PACU | 2926.067 ± 2911.612 | 3160.028 ± 2922.892 | 2991.406 ± 3001.685 | .138 | .749 | .169 |
| Gast bypass | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 63,949.3 ± 33,410.63 | 66,958.55 ± 37,563.16 | 84,956.56 ± 70,259.85 | .088 | *<.001* | *<.001* |
| OR | 23,545.11 ± 17,324.75 | 23,987.67 ± 18,813.92 | 27,623.76 ± 23,316.61 | .741 | *<.001* | *<.001* |
| Med/surg supply | 17,150.05 ± 13,086.07 | 17,957.27 ± 12,676.55 | 20,590.08 ± 14,436.88 | .12 | *<.001* | *<.001* |
| Anesthesia | 5509.143 ± 5646.901 | 5984.756 ± 4918.212 | 6912.194 ± 6105.275 | *.015* | *<.001* | *<.001* |
| PACU | 3899.316 ± 3318.818 | 3894.175 ± 3470.711 | 3612.774 ± 3056.891 | .999 | *.031* | *.045* |
| Antireflux | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 67,875.53 ± 66,148.05 | 82,237.19 ± 89,221.29 | 100,524.2 ± 104,854.5 | *<.001* | *<.001* | *<.001* |
| OR | 26,518.71 ± 19,863.28 | 29,438.11 ± 25,948.48 | 29,685.62 ± 21,350.46 | *.001* | *.003* | .972 |
| Med/surg supply | 11,681.67 ± 11,154.39 | 12,355.68 ± 11,048.87 | 13,181.86 ± 10,980.11 | .241 | *.006* | .293 |
| Anesthesia | 6724.682 ± 6113.568 | 7304.118 ± 6700.476 | 7606.396 ± 6524.486 | *.041* | *.004* | .603 |
| PACU | 3299.32 ± 2690.251 | 3572.346 ± 3083.741 | 3478.583 ± 2976.502 | *.029* | .322 | .785 |

**Table 3f**
Charges risk-adjusted by Charlson comorbidity index for robotic procedures

| | *CCI 1* | *CCI 2* | *CCI 3* | *ANOVA* | | |
|---|---|---|---|---|---|---|
| Colectomy | | | | CCI 2 *vs* CCI 1 | CCI 3 *vs* CCI 1 | CCI 3 *vs* CCI 2 |
| Total charges | 127,846.5 ± 84,364.81 | 145,269.6 ± 98,417.39 | 154,037.1 ± 115,172.1 | *<.001* | *<.001* | *.017* |
| OR | 60,259.28 ± 49,747.44 | 64,582.55 ± 52,536.78 | 64,474.09 ± 51,866 | *.024* | *<.001* | .997 |
| Med/surg supply | 19,799.81 ± 14,281.85 | 21,573.38 ± 15,857.79 | 20,701.21 ± 16,771.37 | *.001* | *.02* | .179 |
| Anesthesia | 12,045.52 ± 10,739.19 | 13,075.71 ± 10,580.75 | 13,488.04 ± 11,299.49 | *.01* | *<.001* | .453 |
| PACU | 4356.761 ± 5260.719 | 4487.421 ± 3658.178 | 4605.33 ± 4165.976 | .647 | *.028* | .684 |
| Lobectomy | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 96,493.48 ± 58,177.91 | 106,638.6 ± 69,672.1 | 122,476.1 ± 82,267.99 | *.022* | *<.001* | *<.001* |
| OR | 33,472.99 ± 29,094.21 | 36,076.22 ± 30,924.79 | 43,288.45 ± 38,464.6 | .312 | *<.001* | *<.001* |
| Med/surg supply | 20,595.75 ± 15,991.59 | 21,001.52 ± 16,114 | 23,987.32 ± 17,297.48 | .874 | *<.001* | *<.001* |
| Anesthesia | 6348.524 ± 5751.171 | 6677.189 ± 5969.829 | 7755.483 ± 6707.74 | .551 | *<.001* | *<.001* |
| PACU | 3424.7 ± 3134.339 | 3513.992 ± 3293.657 | 3661.673 ± 3760.589 | .868 | .116 | .54 |
| Gast bypass | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 105,120 ± 52,473.49 | 110,261.6 ± 61,864.17 | 130,049.5 ± 109,754 | .051 | *<.001* | *<.001* |
| OR | 52,867.78 ± 36,980.87 | 53,697.37 ± 36,038.01 | 54,290.94 ± 39,256.42 | .746 | .516 | .9 |
| Med/surg supply | 22,820.6 ± 15,008.82 | 22,903 ± 14,285.01 | 24,583.38 ± 17,193.01 | .983 | *.003* | *.007* |
| Anesthesia | 8318.006 ± 8544.746 | 9728.854 ± 10,212.45 | 11,702.16 ± 12,566.22 | *<.001* | *<.001* | *<.001* |
| PACU | 3180.95 ± 2497.934 | 3388.174 ± 2517.72 | 3667.342 ± 2694.047 | *.021* | *<.001* | *.008* |
| Antireflux | | | | CCI 2 vs CCI 1 | CCI 3 vs CCI 1 | CCI 3 vs CCI 2 |
| Total charges | 105,970.4 ± 76,132.32 | 130,900.1 ± 109,153.7 | 157,878.2 ± 139,023.8 | *<.001* | *<.001* | *<.001* |
| OR | 52,371.57 ± 35,721.58 | 57,494.21 ± 42,963.13 | 60,532.18 ± 42,258.57 | *.001* | *<.001* | .25 |
| Med/surg supply | 14,376.24 ± 11,737.29 | 14,679.51 ± 11,805.91 | 17,156.97 ± 14,556.07 | .793 | *<.001* | *<.001* |
| Anesthesia | 9421.881 ± 9044.877 | 11,167.05 ± 10,608.35 | 12,616.67 ± 12,692.79 | *<.001* | *<.001* | *.011* |
| PACU | 4014.039 ± 4009.335 | 4456.894 ± 4070.033 | 4793.128 ± 4549.322 | *.013* | *<.001* | .222 |

For Tables 3d–3f: charges (mean ± standard deviation), risk-adjusted by CCI, after separating by procedure type (open, laparoscopic, or robotic). Post-hoc ANOVA with pairwise comparison of the means, *P* values presented with *significant values in italics*.

hospital-acquired infection, and faster recovery; these should all be further studied.

Our study does show decreased LOS across 4 major surgical procedures and adds the next step of identifying an overall increase in surgical volume in 3 out of 4 procedures. It will be interesting to see the long-term effects of adding robotic technology. The increase in volume may be short-lived because the prevalence of disease is likely not increasing and other hospitals will adopt robotic technology as time goes on. This phenomenon demonstrates 2 of Porter's 3 competitive strategies: cost leadership and differentiation.

Robotic technology does come with a high upfront cost to the hospital (and theoretically explains the relative lack of robotic surgery at ambulatory surgery centers). There is also a higher charge per procedure for robotics, although how each hospital establishes this cost/charge is unknown. Do they add in a base-charge for use of the robot to recuperate cost to purchase said robot? And if they do, for how long will they do that given the fixed startup cost? The answer to these questions is unknown and likely hospital-specific, but these are prudent questions as we move forward in a robot-centric surgical world.

Retrospective database review is an inherent limitation as one's conclusions are limited to the data provided. The data set we queried did not include hospital information that may also have an impact on surgical volumes, such as expansion of surgical space (adding operating rooms), personnel, marketing, and quality measures. The data set did not include information about surgeon training or information about length of surgery and postoperative complications. In the future, a prospective collection of surgical volume data with more hospital-specific data may be warranted to further evaluate the effects of adding robotics, as being able to control for other factors would help narrow the focus and increase the power of the study. Additionally, our data set was limited to the state of Florida, and 84% of the patients in the set were white; this reduces generalizability to the rest of the United States and warrants a larger exploration into similar data in different parts of the country.

**Table 4a**
Length of stay risk-adjusted per Charlson comorbidity index

| | Open | Lap | Robotic | ANOVA | | |
|---|---|---|---|---|---|---|
| Colectomy | | | | Lap vs open | Rob vs open | Rob vs lap |
| CCI 1 | 6.66 ± 5.38 | 4.67 ± 4.02 | 4.47 ± 3.51 | *<.001* | *<.001* | .114 |
| CCI 2 | 8.17 ± 8.45 | 5.47 ± 4.72 | 5.30 ± 5.03 | *<.001* | *<.001* | .754 |
| CCI 3 | 8.67 ± 11.47 | 6.51 ± 5.97 | 5.98 ± 5.73 | *<.001* | *<.001* | *.003* |
| Lobectomy | | | | | | |
| CCI 1 | 6.89 ± 7.03 | 4.07 ± 3.70 | 3.66 ± 3.51 | *<.001* | *<.001* | .107 |
| CCI 2 | 8.44 ± 7.89 | 5.58 ± 6.06 | 4.34 ± 3.95 | *<.001* | *<.001* | *<.001* |
| CCI 3 | 7.73 ± 7.28 | 5.83 ± 5.57 | 4.78 ± 4.98 | *<.001* | *<.001* | *<.001* |
| Antireflux | | | | | | |
| CCI 1 | 7.15 ± 8.70 | 2.83 ± 4.86 | 3.02 ± 3.89 | *<.001* | *<.001* | .553 |
| CCI 2 | 8.57 ± 9.05 | 3.79 ± 5.27 | 4.32 ± 5.34 | *<.001* | *<.001* | .192 |
| CCI 3 | 12.03 ± 10.31 | 5.63 ± 7.21 | 5.95 ± 7.02 | *<.001* | *<.001* | .763 |
| Gast bypass | | | | | | |
| CCI 1 | 7.54 ± 10.61 | 2.06 ± 1.97 | 2.12 ± 1.98 | *<.001* | *<.001* | .907 |
| CCI 2 | 8.78 ± 11.40 | 2.27 ± 2.05 | 2.32 ± 2.44 | *<.001* | *<.001* | .96 |
| CCI 3 | 11.16 ± 12.17 | 3.47 ± 4.87 | 3.79 ± 6.62 | *<.001* | *<.001* | .678 |

Length of stay (mean ± standard deviation), risk-adjusted per CCI, comparing laparoscopic (Lap) versus open, robotic (Rob) versus open, and Rob versus Lap. Post-hoc ANOVA with pairwise comparison of the means, *P* values presented with *significant values in italics*.

**Table 4b**
Length of stay risk-adjusted per procedure type

| | CCI 1 | CCI 2 | CCI 3 | ANOVA | | |
|---|---|---|---|---|---|---|
| Colectomy | | | | CCI 2 *vs* CCI 1 | CCI 3 *vs* CCI 1 | CCI 3 *vs* CCI 2 |
| Open | 6.66 ± 5.38 | 8.17 ± 8.45 | 8.67 ± 11.47 | *<.001* | *<.001* | .182 |
| Laparoscopic | 4.67 ± 4.02 | 5.47 ± 4.72 | 6.51 ± 5.97 | *<.001* | *<.001* | *<.001* |
| Robotic | 4.47 ± 3.51 | 5.30 ± 5.03 | 5.98 ± 5.73 | *<.001* | *<.001* | *<.001* |
| Lobectomy | | | | | | |
| Open | 6.89 ± 7.03 | 8.44 ± 7.89 | 7.73 ± 7.28 | *<.001* | *.003* | *.026* |
| Laparoscopic | 4.07 ± 3.70 | 5.58 ± 6.06 | 5.83 ± 5.57 | *<.001* | *<.001* | .306 |
| Robotic | 3.66 ± 3.51 | 4.34 ± 3.95 | 4.78 ± 4.98 | *.009* | *<.001* | *.043* |
| Antireflux | | | | | | |
| Open | 7.15 ± 8.70 | 8.57 ± 9.05 | 12.03 ± 10.31 | *<.001* | *<.001* | *<.001* |
| Laparoscopic | 2.83 ± 4.86 | 3.79 ± 5.27 | 5.63 ± 7.21 | *<.001* | *<.001* | *<.001* |
| Robotic | 3.02 ± 3.89 | 4.32 ± 5.34 | 5.95 ± 7.02 | *<.001* | *<.001* | *<.001* |
| Gast bypass | | | | | | |
| Open | 7.54 ± 10.61 | 8.78 ± 11.40 | 11.16 ± 12.17 | *.012* | *<.001* | *<.001* |
| Laparoscopic | 2.06 ± 1.97 | 2.27 ± 2.05 | 3.47 ± 4.87 | .061 | *<.001* | *<.001* |
| Robotic | 2.12 ± 1.98 | 2.32 ± 2.44 | 3.79 ± 6.62 | .184 | *<.001* | *<.001* |

Length of stay (mean ± standard deviation), risk-adjusted per procedure type—open, laparoscopic, and robotic—comparing CCI for each patient in the cohort. Post hoc ANOVA with pairwise comparison of the means, *P* values presented with *significant values in italics*.

## Conclusions

By using propensity matching and difference-in-difference method to control for changes over time, we found that hospitals that adopt robotic technology increase their overall surgical volume by 37%. Robotic surgeries had decreased LOS but higher charges than their laparoscopic or open counterparts. Our study is limited by inability to control for all other factors, and a prospective trial or larger database review should be performed to reduce bias and increase generalizability of our findings.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sopen.2022.06.002.

## Author Contribution

- Dr. Emily Grimsley: methodology, data curation, writing – original draft, writing – review & editing
- Dr. Tara Barry: conceptualization, investigation, methodology, data curation, software
- Dr. Haroon Janjua: data curation, formal analysis, methodology, software
- Dr. Emanuel Eguia: conceptualization, investigation, methodology, supervision
- Dr. Christopher DuCoin: supervision, writing – review & editing
- Dr. Paul Kuo: conceptualization, investigation, methodology, supervision, validation, writing – review & editing.

## Conflict of Interest

The authors have no related conflicts of interest to declare.

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## Ethics Approval

This study was exempt from the Institutional Review Board given that it was a query of a deidentified database.

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