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Comparative perioperative and 5-year outcomes of robotic and laparoscopic or open inguinal hernia repair: a study of 153,727 patients in the state of New York

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Abstract

Objective This study aimed to examine the perioperative outcomes of robotic inguinal hernia repair as compared to the open and laparoscopic approaches utilizing large-scale population-level data.

Methods This study was funded by the SAGES Robotic Surgery Research Grant (2019). The New York Statewide Planning and Research Cooperative System (SPARCS) administrative database was used to identify all adult patients undergoing initial open (O-IHR), laparoscopic (L-IHR), and robotic (R-IHR) inguinal hernia repair between 2010 and 2016. Perioperative outcome measures [complications, length of stay (LOS), 30-day emergency department (ED) visits, 30-day readmissions] and estimated 1/3/5-year recurrence incidences were compared. Propensity score (PS) analysis was used to estimate marginal differences between R-IHR and L-IHR or O-IHR, using a 1:1 matching algorithm.

Results During the study period, a total of 153,727 patients underwent inguinal hernia repair (117,603 [76.5%] O-IHR, 35,565 [23.1%] L-IHR; 559 [0.36%] R-IHR) in New York state. Initial univariate analysis found R-IHR to have longer LOS (1.74 days vs. 0.66 O-IHR vs 0.19 L-IHR) and higher rates of overall complications (9.3% vs. 3.6% O-IHR vs 1.1% L-IHR), 30-day ED visits (11.6% vs. 6.1% O-IHR vs. 4.9% L-IHR), and 30-day readmissions (5.6% vs. 2.4% O-IHR vs. 1.2% L-IHR) (p < 0.0001). R-IHR was associated with higher recurrence compared to L-IHR. Following PS analysis, there were no differences in perioperative outcomes between R-IHR and L-IHR, and the difference in recurrence was found to be sensitive to possible unobserved confounding factors. R-IHR had significantly lower risk of complications (Risk difference – 0.09, 95% CI [-0.13, -0.056]; p < 0.0001) and shorter LOS (Ratio 0.53, 95% CI [0.45, 0.62]; p < 0.0001) compared to O-IHR. **Conclusion** In adult patients, R-IHR may be associated with comparable to more favorable 30-day perioperative outcomes as compared with L-IHR and O-IHR, respectively.

Keywords Robotic surgery · Inguinal hernia · Outcomes · Recurrence

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Hernia repair remains one of the most common surgical procedures performed in the United States, with an estimated 800,000 inguinal hernia repairs (IHR) performed annually [1]. Until the late twentieth century, inguinal hernias were repaired using an open approach. Since then, advancements in minimally invasive techniques allowed for the introduction of laparoscopic, and more recently, robotic hernia repair [2].

Robotic preperitoneal IHR was first described in urologic literature as a concurrent operation in patients undergoing robotic prostatectomy [3, 4]. With wider availability of the robotic platform, the last decade has seen an exponential increase in the utilization of robotic inguinal hernia repair (R-IHR) [5, 6]. Despite this rapid growth, data comparing open (O-IHR), laparoscopic (L-IHR), and R-IHR outcomes are limited to small case series and retrospective reviews with short follow-up.

This study aimed to examine the perioperative outcomes and recurrence incidence of R-IHR as compared to the open and laparoscopic approaches, utilizing large-scale population-level data.

Materials and methods

This study was funded by the SAGES Robotic Surgery Research Grant (2019). It was approved by the Institutional Review Board and informed consent was not required as data were collected from a large database containing deidentified data. The New York Statewide Planning and Research Cooperative System (SPARCS) administrative database was used to identify all adult patients undergoing O-IHR, L-IHR, and R-IHR (direct/indirect/femoral) between 2010 and 2016 in New York state. Current Procedural Terminology (CPT) and International Classification of Diseases (ICD)-9 & -10 codes were used to identify outpatient and inpatient procedures, respectively. Exclusion criteria included patients with recurrent hernia repair as their first procedure during the study period, duplicated records, age ≤ 18 , or missing/ unknown gender. Perioperative outcomes [complications, length of stay (LOS), 30-day emergency department (ED) visits, 30-day readmissions] and estimated 1/3/5-year recurrence rates were compared.

Statistical analysis

ANOVA under the assumption of unequal variance and Pearson's chi-squared test with p-values from Monte Carlo simulation were used to compare patient characteristics and clinical information among different surgery groups (open, laparoscopic, robotic), as well as other clinical outcomes including any complication, 30-day readmission, and 30-day ED visit. Cumulative incidences of recurrent hernia were calculated and deaths were treated as competing risk events. Time to recurrent hernia was defined as the gap between the discharge date of the initial surgery and the admission date of the recurrent hernia, death, or last follow-up date, whichever occurred earliest. Corresponding 95% confidence intervals were reported [7].

Propensity score (PS) analysis was used to estimate the marginal (population average) differences between patients with robotic surgeries and ones with laparoscopic or open surgeries, using a 1:1 matching algorithm. A 1:1 design, as opposed to 1:1:1, was chosen to avoid driving down the sample size too low. Additionally, the differences between L-IHR and O-IHR have been extensively studied, whereas the differences between these approaches and R-IHR have

not been fully investigated. All patient characteristics and comorbidities were used to estimate PS according to a logistic regression model with robotic surgery as the modeled outcome. Balanced PS matching was used to select patients from the samples with laparoscopic or open surgeries to form 1:1 pairs with the counterparts with the smallest absolute PS differences in a greedy search using the PSMATCH procedure in SAS. If for any record, no counterpart record lied within the range of 0.2 standard deviations of the logit of the estimated PS, then this record was discarded. Unmatched records were also discarded. The quality of the PS matching was assessed by checking standardized differences between groups before and after matching. Standardized differences less than 10% were considered minimal [8, 9]. Based on matched samples, McNemar's tests were carried out for any complication, 30-day readmission, and 30-day ED visits. Wilcoxon signed rank test was performed for LOS and stratified log rank tests were used to compare recurrent hernia [10–12]. Sensitivity analysis for PS matching was carried out to determine the potential impact of unmeasured confounding variables on the significance of the observed outcome differences [12]. Statistical significance was set at 0.05 and analysis was done using SAS 9.4 (SAS Institute Inc., Cary, NC).

Results

From 2010 through 2016, a total of 153,727 patients underwent initial IHR in the state of New York. The majority of patients underwent O-IHR (n = 117,603, 76.5%) and L-IHR (n=35,656, 23.1%). A minority of cases (n=559, 3.1%)0.36%) were performed robotically. Patient demographics, clinical information, and comorbidities are reviewed in Table 1. There was an increasing trend of laparoscopic and robotic hernia repairs during the study period. The majority (n=419, 75%) of R-IHR were performed in an inpatient setting, whereas most L-IHR and O-IHR were outpatient procedures (L-IHR 94.8%, O-IHR 88.3%, R-IHR 25.0%; p < 0.0001). Patients undergoing R-IHR were generally older with $59.4\% \ge 61$ years of age compared to L-IHR (34.4\%) and O-IHR (47.2%) (p < 0.0001). Patients with R-IHR also had higher rates of comorbidities compared to L-IHR and O-IHR (65.3% versus 38.0% versus 45.1%, respectively; p < 0.0001), most commonly hypertension (43.7%), COPD (10.9%), and obesity (7.5%) (Table 1).

Univariate analysis found patients with R-IHR to have higher rates of any complication (9.3%, O-IHR 3.6%, L-IHR 1.1%; p < 0.0001), 30-day readmission (5.6%, O-IHR 2.4%, L-IHR 1.2%; p < 0.0001), and 30-day ED visits (11.6%, O-IHR 6.1%, L-IHR 4.9%; p < 0.0001) (Table 2). Complications were mostly cardiopulmonary in nature, such as cardiac complications (n = 5 [0.89%] vs. O-IHR n = 276

Table 1 Patient demographics, clinical information, and comorbidities by surgery type

| Variable | Level | Total $(n = 153, 727)$ | Laparoscopic ($n = 35,565$) | Open $(n = 117,603)$ | Robotic $(n = 559)$ | p value |
|-------------------------------|--------------|------------------------|-------------------------------|----------------------|---------------------|----------|
| Patient characteristics | | | | | | |
| Age (mean) | | 57.14 ± 16.45 | 53.44 ± 15.15 | 58.24 ± 16.68 | 61.15 ± 11.55 | < 0.0001 |
| Age group | 19–45 | 36,499 (23.8%) | 10,372 (29.2%) | 26,080 (22.2%) | 47 (8.4%) | < 0.0001 |
| | 46-60 | 49,204 (32%) | 12,978 (36.5%) | 36,046 (30.6%) | 180 (32.2%) | |
| | ≥61 | 68,024 (44.2%) | 12,215 (34.3%) | 55,477 (47.2%) | 332 (59.4%) | |
| Sex | F | 17,209 (11.2%) | 2533 (7.1%) | 14,621 (12.4%) | 55 (9.8%) | < 0.0001 |
| | М | 136,518 (88.8%) | 33,032 (92.9%) | 102,982 (87.6%) | 504 (90.2%) | |
| Race | Asian | 4299 (2.8%) | 800 (2.2%) | 3495 (3%) | - (0.7%) | < 0.0001 |
| | Black | 13,622 (8.9%) | 2410 (6.8%) | 11,175 (9.5%) | 37 (6.6%) | |
| | Hispanic | 15,384 (10%) | 3186 (9%) | 12,174 (10.4%) | 24 (4.3%) | |
| | White | 97,248 (63.3%) | 24,381 (68.6%) | 72,429 (61.6%) | 438 (78.4%) | |
| | Other | 23,174 (15.1%) | 4788 (13.5%) | 18,330 (15.6%) | 56 (10%) | |
| Insurance | Commercial | 101,796 (66.2%) | 26,938 (75.7%) | 74,502 (63.4%) | 356 (63.7%) | < 0.0001 |
| | Medicaid | 7206 (4.7%) | 1359 (3.8%) | 5821 (4.9%) | 23 (4.1%) | |
| | Medicare | 42,547 (27.7%) | 6731 (18.9%) | 35,644 (30.3%) | 172 (30.8%) | |
| | Other | 2178 (1.4%) | 537 (1.5%) | 1633 (1.4%) | -(1.4%) | |
| Region | Close to NYC | 14,840 (9.7) | 3562 (10%) | 11,238 (9.6%) | 40 (7.2%) | < 0.0001 |
| | Long Island | 27,985 (18.2%) | 6962 (19.6%) | 20,967 (17.8%) | 56 (10%) | |
| | Mid/North | 23,727 (15.4%) | 6565 (18.5%) | 17,062 (14.5%) | 100 (17.9%) | |
| | NYC area | 64,649 (42.1%) | 14,529 (40.9%) | 49,955 (42.5%) | 165 (29.5%) | |
| | West | 22,526 (14.7%) | 3947 (11.1%) | 18,381 (15.6%) | 198 (35.4%) | |
| Surgery-related clinical info | ormation | | | | | |
| Patient type | Inpatient | 16,065 (10.5%) | 1844 (5.2%) | 13,802 (11.7%) | 419 (75%) | < 0.0001 |
| | Outpatient | 137,662 (89.5%) | 33,721 (94.8%) | 103,801 (88.3%) | 140 (25%) | |
| Annual hospital primary | High | 77,769 (50.6%) | 22,313 (62.7%) | 55,152 (46.9%) | 304 (54.4%) | < 0.0001 |
| volume | Low | 75,958 (49.4%) | 13,252 (37.3%) | 62,451 (53.1%) | 255 (45.6%) | |
| Year | 2010 | 23,400 (100%) | 4322 (18.5%) | 19,016 (81.3%) | 62 (0.3%) | < 0.0001 |
| | 2011 | 23,290 (100%) | 4448 (19.1%) | 18,768 (80.6%) | 74 (0.3%) | |
| | 2012 | 22,694 (100%) | 4766 (21%) | 17,852 (78.7%) | 76 (0.3%) | |
| | 2013 | 22,592 (100%) | 5229 (23.1%) | 17,283 (76.5%) | 80 (0.4%) | |
| | 2014 | 20,814 (100%) | 5328 (25.6%) | 15,400 (74%) | 86 (0.4%) | |
| | 2015 | 20,596 (100%) | 5690 (27.6%) | 14,825 (72%) | 81 (0.4%) | |
| | 2016 | 20,341 (100%) | 5782 (28.4%) | 14,459 (71.1%) | 100 (0.5%) | |
| Comorbidity | | | | | | |
| Any comorbidity ^a | | 66,886 (43.5%) | 13,501 (38%) | 53,020 (45.1%) | 365 (65.3%) | < 0.0001 |
| Alcohol abuse | | 845 (0.6%) | 132 (0.4%) | 702 (0.6%) | 11 (2%) | < 0.0001 |
| Chronic blood loss anemia | | 80 (0.1%) | - (0.01%) | 77 (0.1%) | 0 (0%) | 0.0040 |
| COPD | | 11,045 (7.2%) | 2105 (5.9%) | 8879 (7.6%) | 61 (10.9%) | < 0.0001 |
| Coagulopathy | | 747 (0.5%) | 86 (0.2%) | 656 (0.6%) | - (0.9%) | < 0.0001 |
| CHF | | 2230 (1.5%) | 173 (0.5%) | 2048 (1.7%) | - (1.6%) | < 0.0001 |
| Deficiency anemias | | 2366 (1.5%) | 249 (0.7%) | 2097 (1.8%) | 20 (3.6%) | < 0.0001 |
| Diabetes | | 9969 (6.5%) | 1753 (4.9%) | 8165 (6.9%) | 51 (9.1%) | < 0.0001 |
| Hypertension | | 44,087 (28.7%) | 8468 (23.8%) | 35,375 (30.1%) | 244 (43.7%) | < 0.0001 |
| Liver disease | | 1034 (0.7%) | 167 (0.5%) | 861 (0.7%) | - (1.1%) | < 0.0001 |
| Obesity | | 3942 (2.6%) | 834 (2.4%) | 3066 (2.6%) | 42 (7.5%) | < 0.0001 |
| Peripheral vascular disease | | 1698 (1.1%) | 188 (0.5%) | 1505 (1.3%) | - (0.9%) | < 0.0001 |
| Renal failure | | 2384 (1.6%) | 228 (0.6%) | 2131 (1.8%) | 25 (4.5%) | < 0.0001 |
| RA/CVD | | 785 (0.5%) | 140 (0.4%) | 643 (0.6%) | - (0.4%) | 0.0044 |

Table 1 (continued)

| Variable | Level | Total (<i>n</i> = 153,727) | Laparoscopic ($n = 35,565$) | Open (<i>n</i> = 117,603) | Robotic $(n = 559)$ | p value |
|------------------|-------|-----------------------------|-------------------------------|----------------------------|---------------------|----------|
| Tobacco use | | 10,457 (6.8%) | 2325 (6.5%) | 8090 (6.9%) | 42 (7.5%) | 0.0646 |
| Valvular disease | | 3060 (2%) | 507 (1.4%) | 2537 (2.2%) | 16 (2.9%) | < 0.0001 |
| Weight loss | | 611 (0.4%) | 32 (0.1%) | 578 (0.5%) | - (0.2%) | < 0.0001 |

COPD chronic obstructive pulmonary disease, CHF congestive heart failure, RA/CVD Rheumatoid Arthritis/Collagen Vascular Disease

-not shown to avoid possible patient identification issue

^aOther specific comorbidities included in the "Overall Comorbidity" but not listed below include Acquired Immune Deficiency Syndrome (AIDS), depression, drug abuse, fluid and electrolyte disorders, hypothyroidism, lymphoma, metastatic cancer, other neurological disorders, paralysis, psychoses, and solid tumor without metastasis

| Outcome | Total $(n = 153, 727)$ | Laparoscopic $(n=35,565)$ | Open (<i>n</i> =117,603) | Robotic $(n=559)$ | p value |
|-------------------------------|------------------------|---------------------------|---------------------------|-------------------|----------|
| Any complication ^a | 4686 (3.1%) | 373 (1.1%) | 4261 (3.6%) | 52 (9.3%) | < 0.0001 |
| Abscess | 37 (0.02%) | - (0.01%) | 33 (0.03%) | 0 (0%) | 0.2 |
| Cardiac arrest | 53 (0.05%) | - (0.01%) | 48 (0.04%) | 0 (0%) | 0.0557 |
| Cardiac complication | 309 (0.20%) | 28 (0.08%) | 276 (0.23%) | - (0.89%) | < 0.0001 |
| Dehiscence | 13 (0.01%) | - (0.01%) | 11 (0.01%) | 0 (0%) | 0.58 |
| Hemorrhage | 151 (0.1%) | - (0.02%) | 144 (0.12%) | - (0.18%) | < 0.0001 |
| Myocardial infarction | 9 (0.01%) | - (0.01%) | - (0.01%) | 0 (0%) | 1 |
| Pneumonia | 756 (0.49%) | 33 (0.09%) | 718 (0.6%) | - (0.89%) | < 0.0001 |
| Pulmonary edema | 56 (0.04%) | - (0.02%) | 50 (0.04%) | 0 (0%) | 0.0593 |
| Pulmonary embolism | 50 (0.03%) | -(<0.01%) | 47 (0.04%) | - (0.36%) | 0.0010 |
| Renal failure | 1120 (0.73%) | 62 (0.17%) | 1050 (0.89%) | - (1.43%) | < 0.0001 |
| Reoperative hemorrhage | 90 (0.06%) | - (0.01%) | 87 (0.07%) | 0 (0%) | 0.0031 |
| Respiratory arrest | 2 (<0.01%) | 0 (0%) | - (<0.01%) | 0 (0%) | 1 |
| Respiratory failure | 866 (0.56%) | 47 (0.13%) | 815 (0.69%) | - (0.72%) | < 0.0001 |
| Shock | 367 (0.24%) | 18 (0.05%) | 348 (0.30%) | - (0.18%) | < 0.0001 |
| Tracheostomy | 60 (0.04% | - (0.01%) | 55 (0.05%) | 0 (0%) | 0.0331 |
| Vascular | 20 (0.01%) | - (0%) | 19 (0.02%) | 0 (0%) | 0.127 |
| Ventilation | 220 (0.14%) | - (0.02%) | 212 (0.18%) | 0 (0%) | < 0.0001 |
| 30-day readmission | 3201 (2.1%) | 412 (1.2%) | 2758 (2.4%) | 31 (5.5%) | < 0.0001 |
| 30-day ED visit | 8972 (5.8%) | 1730 (4.9%) | 7177 (6.1%) | 65 (11.6%) | < 0.0001 |
| Length of stay | 0.55 ± 3.27 | 0.19 ± 1.29 | 0.66 ± 3.66 | 1.74 ± 2.47 | < 0.0001 |

 Table 2
 Unadjusted clinical outcome comparison by surgery type

-not shown to avoid possible patient identification issue

^aOther specific complications included in "Any Complication" but not listed below include anastomotic, atherosclerosis, bacterial disease, collapsed, digestive, enteritis, intestinal, liver complication, nervous system complication, phlebitis, surgical error, and systemic inflammation

[0.23%] vs. L-IHR n = 28 [0.08%]) and pneumonia (n = 5 [0.89%] vs. O-IHR n = 718 [0.6%] vs. L-IHR n = 33 [0.09%]). There were no cases of wound-related complications (abscess, wound dehiscence) with R-IHR. LOS was greatest with R-IHR (1.74 days, O-IHR 0.66 days, L-IHR 0.19 days; p < 0.0001).

Table 3 and Fig. 1 review the unadjusted estimated cumulative incidence of recurrent hernia at 1, 3, and 5 years after initial IHR. Before propensity matching, the mean overall follow-up time was 636.1 days, with a mean follow-up time of 619.2 days for those without any recurrent hernia and 1133.3 days for those with recurrent hernia. The cumulative incidence of recurrence was greatest after O-IHR, and lowest after L-IHR. The overall incidence of recurrence was 6.4% at 5 years (L-IHR 3.9%, R-IHR 6.5%, O-IHR 7.0%). In this unadjusted cohort, overall mean recurrence-free time was 622.8 days (L-IHR 529.9 days, R-IHR 641.6 days, O-IHR 650.8 days).

PS analysis found 346 matched pairs of R-IHR and L-IHR (Table 4) and 459 matched pairs of R-IHR and

 Table 3
 Unadjusted estimated cumulative incidence of recurrent hernia at 1, 3, and 5 years after initial inguinal hernia repair

| Surgery | Year 1 | Year 3 | Year 5 |
|--------------|-------------|-------------|-------------|
| Overall | 1.9% (1.8%– | 4.3% (4.1%– | 6.4% (6.2%– |
| | 2.0%) | 4.4%) | 6.6%) |
| Laparoscopic | 0.9% (0.8%– | 2.4% (2.2%– | 3.9% (3.5%– |
| | 1.1%) | 2.7%) | 4.3%) |
| Open | 2.2% (2.1%– | 4.7% (4.6%– | 7.0% (6.8%– |
| | 2.3%) | 4.9%) | 7.3%) |
| Robotic | 1.9% (0.8%– | 4.6% (2.5%– | 6.5% (3.5%– |
| | 3.8%) | 7.8%) | 10.9%) |

Death was treated as a competing risk event

O-IHR (Table 5). McNemar's test demonstrated no difference in any complication, 30-day readmission, or 30-day ED visit between R-IHR and L-IHR (Table 6). There was no significant difference in LOS between the matched pairs. In comparing R-IHR and O-IHR, McNemar's test found a lower risk of any complication with robotic surgery, with an estimated risk difference of -0.0915 (95% CI [-0.1273, -0.0557]; p < 0.0001) (Table 6). Using Wilcoxon signed rank tests and generalized linear regression model, patients with R-IHR had a significantly shorter LOS than O-IHR (estimated ratio = 0.53, 95% CI [0.45, 0.62]; p < 0.0001). Sensitivity analysis found these differences (any complication and LOS) to persist even after adjusting for potential unmeasured confounding variables.

Matched samples were compared for time to recurrent hernia using stratified log rank tests. For R-IHR versus L-IHR, the mean overall follow-up time was 568.3 days, with a mean follow-up time of 557.7 days for those without recurrent hernia and 1018.3 days for those with recurrent hernia. For R-IHR versus O-IHR, the mean overall follow-up time was 651.1 days, with a mean follow-up time of 638.4 days for those without recurrent hernia and 1087.1 days for those



Fig. 1 Unadjusted cumulative incidence curve of recurrent hernia by surgery type

| Variable | Level | Total (<i>n</i> =692) | Laparoscopic (n=346) | Robotic $(n=346)$ | Standardized dif- ference (matched sample) | Standardized dif- ference (original sample) |
|------------------------------|---------------|------------------------|----------------------|-------------------|---|---|
| Patient characteristics | | | | | | |
| Age group | 19–45 | 74 (10.69%) | 37 (10.69%) | 37 (10.69%) | 0 | 0.81 |
| | 46-60 | 246 (35.55%) | 123 (35.55%) | 123 (35.55%) | | |
| | ≥61 | 372 (53.76%) | 186 (53.76%) | 186 (53.76% | | |
| Sex | F | 64 (9.25%) | 32 (9.25%) | 32 (9.25%) | 0 | 0.1 |
| | Μ | 628 (90.75%) | 314 (90.75%) | 314 (90.75%) | | |
| Race | Black | 36 (5.20%) | 18 (5.20%) | 18 (5.20%) | 0 | 0.62 |
| | Hispanic | 30 (4.34%) | 15 (4.34%) | 15 (4.34%) | | |
| | White | 550 (79.48%) | 275 (79.48%) | 275 (79.48%) | | |
| | Other | 76 (10.98%) | 38 (10.98%) | 38 (10.98%) | | |
| Insurance | Commercial | 464 (67.05%) | 232 (67.05%) | 232 (67.05%) | 0 | 0.28 |
| | Medicaid | 26 (3.76%) | 13 (3.76%) | 13 (3.76%) | | |
| | Medicare | 198 (28.61%) | 99 (28.61%) | 99 (28.61%) | | |
| | Other | 4 (0.58%) | 2 (0.58%) | 2 (0.58%) | | |
| Region | Close to NYC | 52 (7.51%) | 26 (7.51%) | 26 (7.51%) | 0 | 0.84 |
| | Long Island | 64 (9.25%) | 32 (9.25%) | 32 (9.25%) | | |
| | Mid/North | 132 (19.08%) | 66 (19.08%) | 66 (19.08%) | | |
| | NYC area | 244 (35.26%) | 122 (35.26%) | 122 (35.26%) | | |
| | West | 200 (28.90%) | 100 (28.90%) | 100 (28.90%) | | |
| Surgery-related clinical | l information | | | | | |
| Patient type | Inpatient | 442 (63.87%) | 221 (63.87%) | 221 (63.87%) | 0 | 2.03 |
| | Outpatient | 250 (36.13%) | 125 (36.13%) | 125 (36.13%) | | |
| Annual hospital | High | 354 (51.16%) | 177 (51.16%) | 177 (51.16%) | 0 | 0.17 |
| primary volume | Low | 338 (48.84%) | 169 (48.84%) | 169 (48.84%) | | |
| Comorbidity | | | | | | |
| Alcohol abuse | No | 690 (99.71%) | 345 (99.71%) | 345 (99.71%) | 0 | 0.15 |
| | Yes | 2 (0.29%) | 1 (0.29%) | 1 (0.29%) | | |
| Chronic blood loos anemia | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.01 |
| COPD | No | 633 (91.47%) | 318 (91.91%) | 315 (91.04%) | 0.03 | 0.18 |
| | Yes | 59 (8.53%) | 28 (8.09%) | 31 (8.96%) | | |
| Coagulopathy | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.09 |
| CHF | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.11 |
| Deficiency anemias | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.2 |
| Diabetes | No | 666 (96.24%) | 333 (96.24%) | 333 (96.24%) | 0 | 0.16 |
| | Yes | 26 (3.76%) | 13 (3.76%) | 13 (3.76%) | | |
| Hypertension | No | 424 (61.27%) | 220 (63.58%) | 204 (58.96%) | 0.1 | 0.43 |
| | Yes | 268 (38.73%) | 126 (36.42%) | 142 (41.04%) | | |
| Liver disease | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.07 |
| Obesity | No | 666 (96.24%) | 333 (96.24%) | 333 (96.24%) | 0 | 0.24 |
| | Yes | 26 (3.76%) | 13 (3.76%) | 13 (3.76%) | | |
| Peripheral vascular disease | No | 692 (100%) | 346 (100%) | 346 (100%) | | |
| Renal failure | No | 688 (99.42%) | 344 (99.42%) | 344 (99.42%) | 0 | 0.24 |
| | Yes | 4 (0.58%) | 2 (0.58%) | 2 (0.58%) | | |
| RA/CVD | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.01 |
| Tobacco use | No | 662 (95.66%) | 331 (95.66%) | 331 (95.66%) | 0 | 0.04 |
| | Yes | 30 (4.34%) | 15 (4.34%) | 15 (4.34%) | | |

 Table 4
 Distribution of patient characteristics after matching robotic surgeries with laparoscopic surgeries & corresponding standardized differences before and after matching

Table 4 (continued)

| Variable | Level | Total (<i>n</i> =692) | Laparoscopic ($n = 346$) | Robotic $(n=346)$ | Standardized dif- ference (matched sample) | Standardized dif- ference (original sample) |
|------------------|-------|------------------------|----------------------------|-------------------|---|---|
| Valvular disease | No | 686 (99.13%) | 343 (99.13%) | 343 (99.13%) | 0 | 0.01 |
| | Yes | 6 (0.87%) | 3 (0.87%) | 3 (0.87%) | | |
| Weight loss | No | 692 (100%) | 346 (100%) | 346 (100%) | | 0.02 |

with recurrent hernia. R-IHR was suggested to have significantly higher risk of recurrent hernia compared with L-IHR (p=0.0455), with a *z*-statistic equal to 2 (positive *z*-statistic indicating more observed events than expected, implying higher risk of recurrent hernia). This significant difference was found to be sensitive to possible unmeasured confounding factors in the sensitivity analysis. There was no significant difference in time to recurrent hernia between R-IHR and O-IHR (p=1; z-statistic=0).

Discussion

In accordance with national trends, utilization of R-IHR in the state of New York increased annually from 2010 to 2016 [5, 6]. Despite this rise in robotic operative volume, O-IHR remained the most common approach followed by L-IHR. Univariate analysis demonstrated R-IHR to have longer LOS and higher rates of overall complications compared to both O-IHR and L-IHR. Higher rates of overall complications in R-IHR compared to other approaches was consistent with data from a recent univariate analysis performed by Huerta et al. [13] However, these trends did not persist on PS analysis. Poorer outcomes on the univariate analysis may be explained by the higher baseline incidence of cardiopulmonary comorbidities and obesity in the robotic cohort (Table 1). After 1:1 propensity matching, there were no differences in perioperative outcomes between R-IHR and L-IHR. Furthermore, R-IHR was found to have a significantly lower risk of complications and shorter LOS compared to O-IHR.

In terms of recurrence, R-IHR was associated with a higher incidence of recurrence compared to L-IHR; however, this was found to be sensitive to possible unobserved confounding factors. As discussed in the meta-analysis conducted by Aiolfi et al., such factors may include surgeon experience [14]. With propensity matching, we accounted for hospital volume as a surrogate for surgeon volume and experience, but there remains room for error. Future studies will need to investigate if the incidence of recurrence changes over time as surgeon experience increases, particularly with newer generations of robotic technology. While this study was not designed to specifically compare L-IHR with O-IHR, there was a remarkably lower risk of complications and recurrence with the laparoscopic approach. This may be a consequence of baseline patient characteristics or the acuity with which patients presented, allowing for selection bias. Patients undergoing O-IHR had higher rates of baseline comorbidities and higher rates of inpatient procedures compared to L-IHR (Table 1). These patients may have presented more acutely, necessitating an emergent procedure, contributing to the decision for an open procedure and subsequent outcomes. Alternatively, these outcomes may suggest that as we are later in the learning curve for laparoscopy, we are seeing improved outcomes compared to historical studies comparing the open and laparoscopic approaches.

Previously, several small-scale studies have reported on the feasibility and short-term outcomes of R-IHR. The largest case series to date was published by Tam et al., reporting short-term outcomes of 335 consecutive R-IHR across seven hospitals [15]. They found a low incidence of intraoperative complications (0.6%) and an overall complication rate of 16%, which were most commonly urinary retention (4.2%) and scrotal swelling (3.9%). This was a retrospective review over 19 months with a mean follow-up of only 18 days.

Comparative outcomes data are scarce and limited mostly to retrospective reviews with short-term outcomes. In a propensity-matched study performed by Bittner et al., R-IHR and L-IHR patients reported similar acute postoperative groin pain through surveys that used the validated Numeric Pain Rating Scale to objectively quantify pain [16]. Analogous findings were demonstrated in a randomized clinical trial conducted by Prabhu et al., which found no significant differences in R-IHR and L-IHR postoperative pain as measured through the Visual Analog Scale [17]. Like the results of the 1:1 propensity matching of the present study, these studies suggest insignificant difference in the perioperative outcomes between R-IHR and L-IHR patients. However, these studies were limited by their overall sample size (patient matches in Bittner et al. were 83 R-IHR to 83 L-IHR and 85 R-IHR to 85 O-IHR, and only 102 total patients were included in Prabhu et al.) as well as the breadth of their respective outcomes.

| | Variable | Level | Total (<i>n</i> =918) | Open (<i>n</i> =459) | Robotic $(n=459)$ | Standardized dif- ference (matched sample) | Standardized dif- ference (original sample) |
|--|---------------------------------------|--------------|------------------------|-----------------------|-------------------|---|---|
| Age group19-4580 (8.71%)40 (8.71%)40 (8.71%)40 (8.71%)00.3346-60302 (3.20%)151 (3.20%)151 (3.20%)151 (3.20%)151 (3.20%)SexF84 (0.15%)42 (0.15%)42 (0.15%)42 (0.15%)00.88RaceBlack54 (8.88%)21 (5.88%)10 (0.95%)170.88Hispanic42 (4.58%)21 (4.58%)21 (4.58%)100.88MaceBlack54 (8.95%)44 (0.59%)21 (4.58%)10.04InsuranceMedicaie38 (4.14%)19 (4.14%)10.04Maclicaie274 (2.9.58%)137 (2.9.8.5%)137 (2.9.8.5%)0.03AggionClose to NC74 (8.06%)37 (8.06%)47 (3.0.9%)1RegionClose to NC74 (8.06%)37 (8.0.5%)47 (3.2.0.5%)1Mationa180 (1.7.1%)19 (7.1.1%)79 (7.1.2%)00.73AggionClose to NC74 (8.0.6%)32 (7.1.2.4%)10 (1.5.1%)1Mationa180 (1.7.1%)12 (2.8.7.6%)13 (2.9.7.6%)11AggionClose to NC74 (8.0.6%)32 (7.1.2.4%)10 (1.5.1%)1AggionClose to NC74 (8.0.6%)12 (2.8.7.6%)17 (2.9.4%)11Aggion16 (2.7.7.6%)12 (2.8.7.6%)12 (2.8.7.6%)111Aggion16 (2.7.7.6%)12 (2.8.7.6%)12 (2.8.7.6%)111Aggion16 (2.7.7.6%)12 | Patient characteristics | | | | | | |
| 4-60302 (32.90%)151 (32.90%)243 (35.83%)248SexF84 (9.15%)42 (9.15%)42 (9.15%)00.08RaceHispanic42 (4.58%)21 (4.58%)21 (4.58%)00.88RaceHispanic24 (4.58%)21 (4.58%)21 (4.58%)00.88InsuranceCommercia896 (4.92%)236 (7.9.96%)367 (7.9.96%)00.04Minic38 (4.9.05%)44 (0.50%)44 (0.50%)44 (0.50%)44 (0.50%)44 (0.50%)InsuranceCommercia966 (4.92%)137 (29.85%)00.04Matica274 (29.85%)137 (29.85%)137 (29.85%)00.73RagionCifker137 (29.85%)137 (29.85%)00.73Matica274 (29.85%)137 (29.85%)00.73Matica137 (29.85%)137 (29.85%)00.73Matica137 (29.85%)137 (29.85%)00.73Matica137 (29.85%)137 (29.85%)147 (20.37%)0Matica138 (19.23%)137 (29.85%)147 (20.37%)147 (20.37%)Matica138 (19.23%)137 (29.85%)147 (20.37%)147 (20.37%)Patient typeInpatient64 (17.12%)327 (17.24%)327 (17.24%)0Matin Amath158 (17.12%)157 (15.65%)147 (20.37%)147 (20.37%)Valuence104154 (13.65%)147 (20.37%)147 (20.37%)147 (20.37%)Valuence104 (18.65%)157 (19.65%) | Age group | 19–45 | 80 (8.71%) | 40 (8.71%) | 40 (8.71%) | 0 | 0.33 |
| SexSeiSei (S3.39%)Sei (S3.39% | | 46-60 | 302 (32.90%) | 151 (32.90%) | 151 (32.90%) | | |
| SexF84 (9.15%)42 (9.15%)42 (9.15%)00.08RaceBlack64 (5.85%)27 (5.85%)27 (5.85%)00.88RaceBlack74 (9.96%)27 (5.85%)27 (5.85%)00.88RaceNoter42 (4.55%)21 (4.55%)21 (4.55%)00.04InsuranceOther88 (9.59%)44 (9.59%)44 (9.59%)10InsuranceCommercial59 (64.92%)298 (64.92%)00.04RagionCommercial74 (9.85%)137 (29.85%)137 (29.85%)00.03RagionColor 10 (1.09%)5 (1.09%)5 (1.09%)00.7300.73Noter10 (1.09%)5 (1.09%)79 (17.21%)147 (20.39%)00.73Norance10 (30.85%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)Streger-related climical information10 (30.65%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)Norance10 (30.65%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)Norance10 (10 (10 %) (5 (1.05%))154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%) | | ≥61 | 536 (58.39%) | 268 (58.39%) | 268 (58.39%) | | |
| NameN | Sex | F | 84 (9.15%) | 42 (9.15%) | 42 (9.15%) | 0 | 0.08 |
| RaceBlack94 (5.8%)27 (5.8%)27 (5.8%)00.88Hispanic42 (4.58%)21 (4.58%)21 (4.58%)21 (4.58%)21 (4.58%)21 (4.58%)InsuranceWhite73 (7.99.6%)367 (79.96%)367 (79.96%)44 (9.59%)44 (9.59%)InsuranceComercial38 (4.14%)19 (4.14%)19 (4.14%)19 (4.14%)19 (4.14%)Medicaid38 (4.14%)19 (4.14%)19 (4.14%)19 (4.14%)10 (4.16%)RegionColter NYC74 (8.06%)37 (8.06%)37 (8.06%)00.73RegionColtes INYC74 (8.06%)37 (8.05%)37 (8.05%)00.73Widfworth184 (9.15%)42 (9.15%)42 (9.15%)19 (1.21%)19 (1.21%)Patient typeIndivforth184 (3.23%)147 (32.03%)147 (32.03%)14 (32.05%)Surgery-related clinical inForm294 (32.05%)154 (33.55%)154 (33.55%)154 (33.55%)Patient typeInpatient654 (71.24%)327 (71.24%)327 (71.24%)01.66Outpatient654 (71.24%)327 (71.24%)127 (71.24%)01.66Outpatient654 (71.24%)327 (71.24%)127 (1.24%)127 (1.24%)128 (1.24%)Outpatient654 (71.24%)127 (1.24%)127 (1.24%)128 (1.24%)128 (1.24%)Outpatient654 (71.24%)127 (1.24%)127 (1.24%)128 (1.24%)128 (1.24%)Outpatient654 (71.24%)127 (1.24%)127 (1.24%)128 (1.24%)128 | | М | 834 (90.85%) | 417 (90.85%) | 417 (90.85%) | | |
| Hispanic24 (4.8%)21 (4.5%)21 (4.5%)21 (4.5%)Winic734 (79.96%)367 (79.96%)44 (9.5%)44 (9.5%)InsuranceCommercial506 (64.92%)298 (64.92%)00.04Medicaid376 (14.92%)19 (4.14%)19 (4.14%)19 (4.14%)Medicaid274 (28.98%)137 (29.85%)137 (29.85%)137 (29.85%)RegionClose to NYC01 (1.90%)5 (1.09%)5 (1.09%)0Mid/North158 (17.21%)79 (17.21%)79 (17.21%)Weat308 (33.55%)147 (32.03%)147 (32.03%)Surgerorelated clinical information158 (17.12%)127 (1.24%)126 (3.65%)Surgerorelated clinical information64 (71.24%)127 (1.24%)127 (71.24%)Patient typeIngainen654 (71.24%)122 (28.76%)12 (28.76%)Outpatien64 (71.24%)127 (1.24%)12 (28.76%)0Outpatien64 (71.24%)12 (28.76%)12 (28.76%)0Outpatient64 (71.24%)12 (28.76%)12 (28.76%)0Outpatient64 (0.12%)41 (3.16%)00.02Outpatient64 (0.12%)457 (19.56%)10 (0.16%)0.04CombridiuNo918 (100.00%)459 (100.00%)0.020.04CombridiuNo918 (100.00%)459 (100.00%)0.040.04CombridiuNo918 (100.00%)459 (100.00%)0.040.04CombridiuNo918 (100.00%)459 (100.00%)0.04 <td>Race</td> <td>Black</td> <td>54 (5.88%)</td> <td>27 (5.88%)</td> <td>27 (5.88%)</td> <td>0</td> <td>0.88</td> | Race | Black | 54 (5.88%) | 27 (5.88%) | 27 (5.88%) | 0 | 0.88 |
| White74 (79,96%)367 (79,96%)347 (79,96%)InsuranceOther88 (9,59%)28 (64,92%)00.04Insurance86 (64,92%)28 (64,92%)00.04Medicaid38 (41,4%)19 (41,4%)19 (41,4%)19 (41,4%)RegionClose to NV74 (29,85%)137 (29,85%)137 (29,85%)RegionClose to NV74 (80,6%)37 (80,6%)00.03Mid/North158 (17,21%)79 (17,21%)79 (17,21%)10 (17,21%)West0.04 (23,035%)147 (32,03%)147 (32,03%)147 (32,03%)Stegrey-related clinical information158 (17,21%)127 (12,4%)01.66Mid/North158 (17,21%)127 (12,4%)01.66Annal hospital primaG48 (53,16%)122 (28,76%)12< (28,76%) | | Hispanic | 42 (4.58%) | 21 (4.58%) | 21 (4.58%) | | |
| InsuranceOther88 (9.59%)44 (9.59%)44 (9.59%)98 (44.92%)00.04InsurancePedicial38 (4.14%)19 (4.14%)19 (4.14%)19 (4.14%)19 (4.14%)Medicau274 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)RegionClose to NYC74 (8.06%)37 (8.06%)70 (8.06%)00.73Mid/Nort158 (17.21%)79 (17.21%)79 (17.21%)147 (32.03%)147 (32.03%)147 (32.03%)Nort Carea154 (31.55%)154 (31.55%)154 (31.55%)154 (31.55%)154 (31.55%)154 (31.55%)Streper-leated clinical information164 (28.57%)132 (28.76%)132 (28.76%)132 (28.76%)147 (32.03%)VolumicCompatible Net Streper St | | White | 734 (79.96%) | 367 (79.96%) | 367 (79.96%) | | |
| InsuranceCommercial596 (64.92%)298 (64.92%)90 (64.92%)00.04Medicane37 (40.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)137 (29.85%)147 (32.03%) </td <td></td> <td>Other</td> <td>88 (9.59%)</td> <td>44 (9.59%)</td> <td>44 (9.59%)</td> <td></td> <td></td> | | Other | 88 (9.59%) | 44 (9.59%) | 44 (9.59%) | | |
| Medicaid38 (4.14%)19 (4.14%)19 (4.14%)Medica274 (29.55%)137 (29.55%)137 (29.55%)Other10 (1.09%)5 (1.09%)5 (1.09%)Close to NYC74 (8.06%)37 (8.06%)37 (8.06%)0Long Island84 (0.15%)42 (9.15%)42 (9.15%)MidNorth158 (17.21%)79 (17.21%)79 (17.21%)NY Carea294 (32.03%)147 (32.03%)Pattert typeInpatient654 (71.24%)127 (71.24%)0Pattert typeInpatient654 (71.24%)127 (71.24%)0Outpatient654 (71.24%)123 (28.76%)132 (28.76%)147Annual hospital primaHigh488 (53.16%)244 (53.16%)244 (53.16%)0Volume164216 (46.84%)215 (46.84%)15164Comorbidity1720.04%20.0412Chronic blood loos anemiaNo918 (100.06)459 (100.06%)100.020.02CogulopathyNo918 (100.06%)459 (100.06%)100.04Chronic blood loos anemiaNo918 (100.07%)450 (99.56%)00.01CogulopathyNo918 (100.07%)459 (190.07%)100.0210.04Chronic blood loos anemiaNo918 (100.07%)450 (190.07%)10.04CogulopathyNo918 (100.07%)451 (190.57%)00.01CogulopathyNo918 (100.07%)51 (190.77%)453 (191.77%)10.14Chronic blood loos ane | Insurance | Commercial | 596 (64.92%) | 298 (64.92%) | 298 (64.92%) | 0 | 0.04 |
| Medicare174 (29.85%)137 (29.85%)137 (29.85%)OrberOrber10 (1.09%)5 (1.09%)5 (1.09%)Close to NV74 (8.06%)37 (8.06%)00.73Long Island84 (9.15%)42 (9.15%)42 (9.15%)42 (9.15%)Mid/North158 (1.721%)79 (17.21%)79 (17.21%)79 (17.21%)West308 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)Sargery-related clinical informator154 (1.74%)327 (71.24%)00.15Outpatient654 (71.24%)127 (71.24%)217 (1.24%)00.15Outpatient644 (8.76%)132 (28.76%)124 (53.16%)00.15volume104488 (53.16%)244 (53.16%)00.12Volume104914 (9.56%)457 (99.56%)457 (99.56%)00.12Comorbidity17848 (0.000%)459 (100.00%)459 (100.00%)0.04COpPDNo918 (100.00%)459 (100.00%)459 (100.00%)0.04COpPDNo918 (100.00%)459 (100.00%)459 (100.00%)0.04CHORine IsologianphinyNo918 (100.00%)459 (100.00%)10.12ConstructionNo918 (100.00%)459 (100.00%)10.04COPDNo918 (100.00%)459 (100.00%)10.04COPDNo918 (100.00%)459 (100.00%)10.14ChORine IsologianphinyNo918 (100.00%)459 (100.00%)10.04CHORINE IsologianphiNo< | | Medicaid | 38 (4.14%) | 19 (4.14%) | 19 (4.14%) | | |
| RegionOther10 (1.0%)5 (1.0%)5 (1.0%)7 (8.0%)7 (8.0%)00.73RegionClose tNC74 (8.0%)42 (0.1%) | | Medicare | 274 (29.85%) | 137 (29.85%) | 137 (29.85%) | | |
| RegionClose to NYC74 (8,06%)37 (8,06%)37 (8,06%)00.73 $Lorg Island84 (0,15%)42 (0,15%)42 (0,15%)42 (0,15%)42 (0,15%)42 (0,15%)NYC area294 (32,03%)147 (32,03%)147 (32,03%)147 (32,03%)147 (32,03%)West308 (33,55%)154 (33,55%)154 (33,55%)154 (33,55%)154 (33,55%)Surgery-related clinical information10654 (71,24%)327 (71,24%)01.66Annual hospital primaryvolume10654 (71,24%)122 (28,76%)122 (28,76%)00.15Annual hospital primaryvolume116654 (71,24%)125 (46,84%)125 (46,84%)00.15Comorbidity11648 (53,16%)125 (46,84%)12 (28,76%)00.15Comorbidio126 (28,76%)157 (99,56%)457 (99,56%)00.04Comorbidity128 (10,00%)459 (100,00%)459 (100,00%)0.04CorpolNo829 (09,17%)458 (98,95%)0.020.12CogulopathyNo918 (100,00%)459 (100,00%)459 (100,00%)0.04CHFNo914 (99,56%)457 (99,56%)00.11Chronic blood loos anemiaNo918 (100,00%)454 (98,91%)00.11Chronic primeryNo914 (99,56%)51 (109%)100.04CHFNo908 (98,91%)454 (98,91%)00.11Chronic blood loos anemiaNo916 (10,00%)51 (109%)$ | | Other | 10 (1.09%) | 5 (1.09%) | 5 (1.09%) | | |
| Long Island84 (9.15%)42 (9.15%)42 (9.15%)Mid/North158 (17.21%)79 (17.21%)79 (17.21%)NYC area294 (32.03%)147 (32.03%)147 (32.03%)NYC area294 (32.03%)147 (32.03%)147 (32.03%)West308 (33.55%)154 (33.55%)154 (33.55%)Surgery-related clinical informetor264 (28.76%)327 (71.24%)0Annual hospital primary volumeHigh488 (53.16%)244 (53.16%)132 (28.76%)Annual hospital primary volumeLow430 (46.84%)215 (46.84%)215 (46.84%)ComorbidityE156 (46.84%)215 (46.84%)216 (46.84%)ComorbidityV2 (0.44%)2 (0.44%)00.12Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)0.020.12CogaulopathyNo914 (99.56%)457 (99.56%)100.00%)0.04COPDNo918 (100.00%)459 (100.00%)450 (100.00%)0.04CHFNo914 (99.56%)457 (99.56%)00.01CHFNo918 (100.00%)459 (100.00%)50 (100.00%)0.04CHFNo914 (99.56%)457 (99.56%)00.01CHFNo914 (99.56%)457 (99.56%)00.01CHFNo918 (100.00%)459 (100.00%)50 (100.00%)0.04CHFNo918 (100.00%)51 (10.9%)51 (10.9%)00.02DiabetesNo870 (94.77%)435 (94. | Region | Close to NYC | 74 (8.06%) | 37 (8.06%) | 37 (8.06%) | 0 | 0.73 |
| Mid/North158 (17.21%)79 (17.21%)79 (17.21%)NYC area294 (32.03%)147 (32.03%)147 (32.03%)WC area308 (33.55%)154 (33.55%)154 (33.55%)Surgery-related clinical information54 (71.24%)327 (71.24%)327 (71.24%)0Patient typeInpatient654 (71.24%)327 (71.24%)101.66Outpatient264 (28.76%)132 (28.76%)122 (28.76%)00.15Annual hospital primaryHip488 (53.16%)244 (53.16%)215 (46.84%)215ComorbidityLow430 (46.84%)215 (46.84%)215 (46.84%)216ComorbidityYes410 (49.56%)457 (99.56%)457 (99.56%)00.012Chonic blood loos anemiaNo918 (100.00%)459 (100.00%)0.040.04COPDNo918 (100.00%)459 (100.00%)459 (100.00%)0.04Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)0.020.12CogaulopathyNo918 (100.00%)459 (100.00%)459 (100.00%)0.01Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)0.020.01Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)0.020.01Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)100.00%0.01Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)100.00%100.01Chronic blood loos anemiaNo918 (100.0 | - | Long Island | 84 (9.15%) | 42 (9.15%) | 42 (9.15%) | | |
| NYC area294 (32.03%)147 (32.03%)147 (32.03%)147 (32.03%)West308 (33.55%)154 (33.55%)154 (33.55%)154 (33.55%)Surgery-related clinical information10654 (71.24%)327 (71.24%)01.66Patient typeInpatient264 (28.76%)132 (28.76%)132 (28.76%)00.15Annual hospital primary volumeHigh488 (53.16%)244 (53.16%)244 (53.16%)00.15Comorbidity10125 (46.84%)215 (46.84%)215 (46.84%)1200.12Comorbidity1220.44%)2 (0.44%)2 (0.44%)00.04Cohonic blood loos anemiaNo918 (100.00%)459 (100.00%)459 (100.00%)0.020.12CoagulopathyNo918 (100.00%)459 (100.00%)459 (100.00%)0.040.04CHFNo918 (100.00%)459 (100.00%)459 (100.00%)0.010.01Chife querientiasNo918 (100.00%)459 (100.00%)459 (100.00%)0.01Chefe querientiasNo918 (100.00%)459 (100.00%)459 (100.00%)0.01Chefe querientiasNo918 (100.00%)459 (100.00%)459 (100.00%)0.01Chefe querientiasNo918 (100.00%)459 (100.00%)16 (10.02%)0.01Chefe querientiasNo918 (100.00%)459 (100.00%)16 (10.02%)16 (10.02%)CoagulopathyNo918 (100.00%)459 (100.00%)15 (10.9%)16 (10.9%) | | Mid/North | 158 (17.21%) | 79 (17.21%) | 79 (17.21%) | | |
| West308 (33.55%)154 (33.55%)154 (33.55%)Surgery-related clinical informatorImpatient654 (71.24%)327 (71.24%)01.66Outpatient264 (28.76%)132 (28.76%)122 (28.76%)00.15Annual hospital primary volumeHigh488 (53.16%)244 (53.16%)244 (53.16%)00.15ComorbidityLow430 (46.84%)215 (46.84%)215 (46.84%)00.15ComorbidityKas2 (0.44%)2 (0.44%)2 (0.44%)0.04Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)0.04COPDNo829 (90.31%)413 (89.98%)413 (89.98%)0.020.12CoagulopathyNo918 (100.00%)459 (100.00%)0.040.04CHFNo918 (100.00%)459 (100.00%)0.040.04CHFNo918 (100.00%)459 (100.00%)0.020.12CoagulopathyNo918 (100.00%)459 (100.00%)0.040.04CHFNo918 (100.00%)459 (100.00%)0.040.04CHFNo918 (100.00%)459 (100.00%)0.010.11CHFNo908 (98.91%)454 (98.91%)00.11CHFNo908 (98.91%)454 (98.91%)00.11CHFNo908 (98.91%)454 (98.91%)00.11CHFNo908 (98.91%)451 (98.56%)727 (59.56%)00.04CHFNo918 (100.00%) | | NYC area | 294 (32.03%) | 147 (32.03%) | 147 (32.03%) | | |
| Surgery-related clinical information Inpatient 654 (71.24%) 327 (71.24%) 327 (71.24%) 0 1.66 Patient type Inpatient 264 (28.76%) 132 (28.76%) 132 (28.76%) 0 0.15 Annual hospital primary High 488 (53.16%) 244 (53.16%) 244 (53.16%) 0 0.15 Comorbidity Low 430 (46.84%) 215 (46.84%) 215 (46.84%) 0 0.12 Comorbidity Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 0.02 0.12 Chronic blood loos anemia No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 COPD No 829 (90.31%) 413 (89.98%) 0.02 0.12 Cogaulopathy No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 CHronic blood loos anemia No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.01 Cogaulopathy No 918 (100.00%) 459 (100.00%) 450 (100.00%) 0.01 0.11 Periciency anemias No 918 (95.6%) 457 (99.56%) 47 (94.5%) 0 0. | | West | 308 (33.55%) | 154 (33.55%) | 154 (33.55%) | | |
| Parine typeInpatient 654 (71.24%) 327 (71.24%) 327 (71.24%) 0 1.66 Outpatient 264 (28.76%) 132 (28.76%) 132 (28.76%) 0 0.15 Annual hospital primary volumeHigh 488 (53.16%) 244 (53.16%) 244 (53.16%) 0 0.15 ComorbidityLow 430 (46.84%) 215 (46.84%) 0 0.12 ComorbidityKalcohol abuseNo 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.12 Chronic blood loos anemiaNo 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.02 0.04 COPDNo 829 (90.31%) 413 (89.98%) 0.02 0.02 0.12 CoagulopathyNo 918 (100.00%) 459 (100.00%) 450 (100.27%) 0.04 CHFNo 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.01 Chronic blood loos anemiaNo 918 (100.00%) 459 (100.00%) 460 (10.02%) 0.04 Chronic blood loos anemiaNo 918 (100.00%) 459 (100.00%) 0.02 0.11 CoagulopathyNo 918 (100.00%) 50 (100.9%) 0 0.11 Chronic blood loos 806 (96.81%) 216 (452.3%) 24 (52.3%) 24 (52.3%) 24 (52.3%)Deficiency anemiasNo 998 (98.91%) 454 (98.91%) 0 0.08 Teres 48 (52.35%) 24 (52.3%) 24 (52.3%) 24 (52.3%) 24 | Surgery-related clinical inform | nation | | | | | |
| Outpatient $264 (28,76\%)$ $132 (28,76\%)$ $132 (28,76\%)$ $132 (28,76\%)$ Annual hospital primary volumeHigh $488 (53,16\%)$ $244 (53,16\%)$ $244 (53,16\%)$ 0 0.15 ComorbidityLow $430 (46,84\%)$ $215 (46,84\%)$ $215 (46,84\%)$ 0 0.12 ComorbidityYes $4 (0,44\%)$ $2 (0,44\%)$ $2 (0,44\%)$ 0.04 Chronic blood loos anemiaNo $914 (99,56\%)$ $457 (99,56\%)$ 0 0.02 Chronic blood loos anemiaNo $918 (100,00\%)$ $459 (100,00\%)$ $459 (100,00\%)$ 0.04 COPDNo $829 (90,31\%)$ $413 (89,98\%)$ $413 (89,98\%)$ 0.02 0.12 CoagulopathyNo $918 (100,00\%)$ $459 (100,00\%)$ $459 (100,00\%)$ 0.04 CHFNo $918 (100,00\%)$ $457 (99,56\%)$ $457 (99,56\%)$ 0 0.01 Peficiency anemiasNo $918 (100,00\%)$ $454 (98,91\%)$ 0 0.11 Yes $4 (0,44\%)$ $2 (0,44\%)$ $2 (0,44\%)$ 0 0.11 Yes $10 (1.09\%)$ $5 (1.09\%)$ $5 (1.09\%)$ 0 0.01 Deficiency anemiasNo $980 (98,91\%)$ $454 (98,91\%)$ 0 0.01 Yes $3 (0 4,77\%)$ $3 (5 (4,77\%)$ $3 (5 (4,77\%)$ 0 0.08 Yes $3 (2 (4,52\%)$ $5 (1.09\%)$ $0 (0.04)$ 0.04 UrrerYes $3 (2 (4,52\%)$ $2 (2 (4,52\%)$ 0.01 0.28 Yes $3 (2 (4,52\%)$ $2 (10 (0,00\%)$ | Patient type | Inpatient | 654 (71.24%) | 327 (71.24%) | 327 (71.24%) | 0 | 1.66 |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $ | | Outpatient | 264 (28.76%) | 132 (28.76%) | 132 (28.76%) | | |
| volumeLow430 (46.84%)215 (46.84%)215 (46.84%)ComorbidityAlcohol abuseNo914 (99.56%)457 (99.56%)00.12Yes4 (0.44%)2 (0.44%)2 (0.44%)0.04Chronic blood loos anemiaNo918 (100.00%)459 (100.00%)459 (100.00%)0.02CopDNo829 (90.31%)413 (89.98%)413 (89.98%)0.020.12CoagulopathyNo918 (100.00%)459 (100.00%)459 (100.00%)0.04CHFNo914 (99.56%)457 (99.56%)00.01Yes8 (9.69%)457 (99.56%)457 (99.56%)00.01Chronic panemiasNo908 (98.91%)454 (98.91%)00.11Yes10 (1.09%)5 (1.09%)5 (1.09%)00.11Yes10 (1.09%)5 (1.09%)5 (1.09%)00.08JiabetesNo870 (94.77%)435 (94.77%)00.08Yes372 (40.52%)185 (40.31%)187 (40.74%)187 (40.74%)Liver diseaseNo918 (100.00%)459 (100.00%)459 (100.00%)0.04ObesityNo886 (96.51%)443 (96.51%)00.23Yes32 (3.49%)16 (3.49%)16 (3.49%)16 (3.49%)16 (3.49%)Peripheral vascular diseaseNo914 (99.56%)457 (99.56%)457 (99.56%)00.04ObesityNo918 (100.00%)459 (100.00%)16 (3.49%)16 (3.49%)16 (3.49%) <t< td=""><td>Annual hospital primary</td><td>High</td><td>488 (53.16%)</td><td>244 (53.16%)</td><td>244 (53.16%)</td><td>0</td><td>0.15</td></t<> | Annual hospital primary | High | 488 (53.16%) | 244 (53.16%) | 244 (53.16%) | 0 | 0.15 |
| Comorbidity Alcohol abuse No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.12 Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 0.04 0.04 Chronic blood loos anemia No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.02 0.04 COPD No 829 (90.31%) 413 (89.98%) 413 (89.98%) 0.02 0.04 Coagulopathy No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 CHF No 914 (99.56%) 457 (99.56%) 0 0.01 Peficiency anemias No 908 (98.91%) 454 (98.91%) 0 0.11 Tiskes 10 (1.09%) 5 (1.09%) 5 (1.09%) 0 0.08 Peripherasion No 908 (98.91%) 455 (94.77%) 0 0.08 Yes 10 (1.09%) 5 (1.09%) 5 (1.09%) 0 0.01 Upsettension No 974 (52.48%) 24 (5.23%) 0 0.01 Yes 372 (40.52%) 185 (40.31%) 187 (40.74%) 0 0.23 < | volume | Low | 430 (46.84%) | 215 (46.84%) | 215 (46.84%) | | |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | Comorbidity | | | | | | |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | Alcohol abuse | No | 914 (99.56%) | 457 (99.56%) | 457 (99.56%) | 0 | 0.12 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | | Yes | 4 (0.44%) | 2 (0.44%) | 2 (0.44%) | | |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $ | Chronic blood loos anemia | No | 918 (100.00%) | 459 (100.00%) | 459 (100.00%) | | 0.04 |
| Yes $89 (9.69\%)$ $46 (10.02\%)$ $46 (10.02\%)$ CoagulopathyNo $918 (100.00\%)$ $459 (100.00\%)$ $50 (100.00\%)$ 0.04 CHFNo $914 (99.56\%)$ $457 (99.56\%)$ $457 (99.56\%)$ 0 0.01 Peficiency anemiasNo $908 (98.91\%)$ $454 (98.91\%)$ $2 (0.44\%)$ 0 0.11 Deficiency anemiasNo $908 (98.91\%)$ $454 (98.91\%)$ 0 0.11 DiabetesNo $870 (94.77\%)$ $435 (94.77\%)$ $5 (1.09\%)$ 0 0.08 PiertensionNo $546 (59.48\%)$ $274 (59.69\%)$ $272 (59.26\%)$ 0.01 0.28 Liver diseaseNo $918 (100.00\%)$ $459 (100.00\%)$ $459 (100.00\%)$ 0.04 ObesityNo $886 (96.51\%)$ $443 (96.51\%)$ 0 0.23 Peripheral vascular diseaseNo $914 (99.56\%)$ $457 (99.56\%)$ $61 (3.49\%)$ 0 0.04 Renal failureNo $902 (98.26\%)$ $451 (98.26\%)$ 0 0.04 ReXCVDNo $918 (100.00\%)$ $459 (100.00\%)$ $50 (100.00\%)$ 0.04 | COPD | No | 829 (90.31%) | 413 (89.98%) | 413 (89.98%) | 0.02 | 0.12 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | | Yes | 89 (9.69%) | 46 (10.02%) | 46 (10.02%) | | |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $ | Coagulopathy | No | 918 (100.00%) | 459 (100.00%) | 459 (100.00%) | | 0.04 |
| Yes $4 (0.44\%)$ $2 (0.44\%)$ $2 (0.44\%)$ Deficiency anemiasNo908 (98.91\%) $454 (98.91\%)$ $454 (98.91\%)$ 00.11Yes10 (1.09\%) $5 (1.09\%)$ $5 (1.09\%)$ 00.08DiabetesNo $870 (94.77\%)$ $435 (94.77\%)$ $435 (94.77\%)$ 00.08Yes $48 (5.23\%)$ $24 (5.23\%)$ $24 (5.23\%)$ HypertensionNo $546 (59.48\%)$ $274 (59.69\%)$ $272 (59.26\%)$ 0.010.28Yes $372 (40.52\%)$ $185 (40.31\%)$ $187 (40.74\%)$ Liver diseaseNo918 (100.00\%) $459 (100.00\%)$ 459 (100.00\%)0.04ObesityNo $886 (96.51\%)$ $443 (96.51\%)$ $443 (96.51\%)$ 00.23Yes $32 (3.49\%)$ $16 (3.49\%)$ 16 (3.49\%)Peripheral vascular diseaseNo914 (99.56\%) $457 (99.56\%)$ $457 (99.56\%)$ 00.04Kenal failureNo902 (98.26\%) $451 (98.26\%)$ $451 (98.26\%)$ 00.15Yes $16 (1.74\%)$ $8 (1.74\%)$ $8 (1.74\%)$ $8 (1.74\%)$ RA/CVDNo918 (100.00\%) $459 (100.00\%)$ $459 (100.00\%)$ 0.03 | CHF | No | 914 (99.56%) | 457 (99.56%) | 457 (99.56%) | 0 | 0.01 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | | Yes | 4 (0.44%) | 2 (0.44%) | 2 (0.44%) | | |
| Yes $10(1.09\%)$ $5(1.09\%)$ $5(1.09\%)$ $5(1.09\%)$ DiabetesNo $870(94.77\%)$ $435(94.77\%)$ $435(94.77\%)$ 0 0.08 Yes $48(5.23\%)$ $24(5.23\%)$ $24(5.23\%)$ 0.01 0.28 HypertensionNo $546(59.48\%)$ $274(59.69\%)$ $272(59.26\%)$ 0.01 0.28 Yes $372(40.52\%)$ $185(40.31\%)$ $187(40.74\%)$ 0 0.04 DiseaseNo $918(100.00\%)$ $459(100.00\%)$ 0.04 0.04 ObesityNo $886(96.51\%)$ $443(96.51\%)$ $443(96.51\%)$ 0 0.23 Yes $32(3.49\%)$ $16(3.49\%)$ $16(3.49\%)$ 0 0.04 ObesityNo $914(99.56\%)$ $457(99.56\%)$ $457(99.56\%)$ 0 0.04 Peripheral vascular diseaseNo $914(99.56\%)$ $457(99.56\%)$ $451(98.26\%)$ 0 0.015 Renal failureNo $902(98.26\%)$ $451(98.26\%)$ $451(98.26\%)$ 0 0.15 RA/CVDNo $918(100.00\%)$ $459(100.00\%)$ $459(100.00\%)$ 0.03 | Deficiency anemias | No | 908 (98.91%) | 454 (98.91%) | 454 (98.91%) | 0 | 0.11 |
| DiabetesNo $870 (94.77\%)$ $435 (94.77\%)$ $435 (94.77\%)$ 0 0.08 Yes $48 (5.23\%)$ $24 (5.23\%)$ $24 (5.23\%)$ 0 0.01 0.28 HypertensionNo $546 (59.48\%)$ $274 (59.69\%)$ $272 (59.26\%)$ 0.01 0.28 Yes $372 (40.52\%)$ $185 (40.31\%)$ $187 (40.74\%)$ 0 0.04 Liver diseaseNo $918 (100.00\%)$ $459 (100.00\%)$ $459 (100.00\%)$ 0.04 ObesityNo $886 (96.51\%)$ $443 (96.51\%)$ $443 (96.51\%)$ 0 0.23 Peripheral vascular diseaseNo $914 (99.56\%)$ $457 (99.56\%)$ $457 (99.56\%)$ 0 0.04 Renal failureNo $902 (98.26\%)$ $451 (98.26\%)$ $451 (98.26\%)$ 0 0.15 RA/CVDNo $918 (100.00\%)$ $459 (100.00\%)$ $459 (100.00\%)$ 0.03 | , | Yes | 10 (1.09%) | 5 (1.09%) | 5 (1.09%) | | |
| Yes 48 (5.23%) 24 (5.23%) 24 (5.23%) Hypertension No 546 (59.48%) 274 (59.69%) 272 (59.26%) 0.01 0.28 Yes 372 (40.52%) 185 (40.31%) 187 (40.74%) 0 0.04 Liver disease No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 Obesity No 886 (96.51%) 443 (96.51%) 443 (96.51%) 0 0.23 Yes 32 (3.49%) 16 (3.49%) 16 (3.49%) 0 0.04 Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 743 (100.00%) 0.03 | Diabetes | No | 870 (94.77%) | 435 (94.77%) | 435 (94.77%) | 0 | 0.08 |
| Hypertension No 546 (59.48%) 274 (59.69%) 272 (59.26%) 0.01 0.28 Yes 372 (40.52%) 185 (40.31%) 187 (40.74%) 0 0.04 Liver disease No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 Obesity No 886 (96.51%) 443 (96.51%) 443 (96.51%) 0 0.23 Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 0 0.04 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 0 0.3 | | Yes | 48 (5.23%) | 24 (5.23%) | 24 (5.23%) | | |
| Yes 372 (40.52%) 185 (40.31%) 187 (40.74%) Liver disease No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 Obesity No 886 (96.51%) 443 (96.51%) 443 (96.51%) 0 0.23 Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 0.03 | Hypertension | No | 546 (59.48%) | 274 (59.69%) | 272 (59.26%) | 0.01 | 0.28 |
| Liver disease No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.04 Obesity No 886 (96.51%) 443 (96.51%) 443 (96.51%) 0 0.23 Yes 32 (3.49%) 16 (3.49%) 16 (3.49%) 0 0.04 Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 0 0.04 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) RA/CVD No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.03 | 51 | Yes | 372 (40.52%) | 185 (40.31%) | 187 (40.74%) | | |
| Desity No 886 (96.51%) 443 (96.51%) 443 (96.51%) 0 0.23 Yes 32 (3.49%) 16 (3.49%) 16 (3.49%) 0 0.23 Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 2 (0.44%) 0 0.15 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 0 0.03 | Liver disease | No | 918 (100.00%) | 459 (100.00%) | 459 (100.00%) | | 0.04 |
| Yes 32 (3.49%) 16 (3.49%) 16 (3.49%) 0 0.04 Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 0 0 0.15 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 0 0.03 | Obesity | No | 886 (96.51%) | 443 (96.51%) | 443 (96.51%) | 0 | 0.23 |
| Peripheral vascular disease No 914 (99.56%) 457 (99.56%) 457 (99.56%) 0 0.04 Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) 2 (0.44%) 0 0.04 Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 0 0.03 | · · · · · · · · · · · · · · · · · · · | Yes | 32 (3.49%) | 16 (3.49%) | 16 (3.49%) | | |
| Yes 4 (0.44%) 2 (0.44%) 2 (0.44%) Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 0 0.03 | Peripheral vascular disease | No | 914 (99.56%) | 457 (99.56%) | 457 (99.56%) | 0 | 0.04 |
| Renal failure No 902 (98.26%) 451 (98.26%) 451 (98.26%) 0 0.15 Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) 8 (1.74%) 0 0.3 | r | Yes | 4 (0.44%) | 2 (0.44%) | 2 (0.44%) | | |
| Yes 16 (1.74%) 8 (1.74%) 8 (1.74%) RA/CVD No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.03 | Renal failure | No | 902 (98.26%) | 451 (98.26%) | 451 (98.26%) | 0 | 0.15 |
| RA/CVD No 918 (100.00%) 459 (100.00%) 459 (100.00%) 0.03 | | Yes | 16 (1.74%) | 8 (1.74%) | 8 (1.74%) | - | 0.10 |
| | RA/CVD | No | 918 (100.00%) | 459 (100.00%) | 459 (100.00%) | | 0.03 |

 Table 5
 Distribution of patient characteristics after matching robotic surgeries with laparoscopic surgeries & corresponding standardized differences before and after matching

Table 5 (continued)

| Variable | Level | Total (<i>n</i> =918) | Open (<i>n</i> =459) | Robotic $(n=459)$ | Standardized dif- ference (matched sample) | Standardized dif- ference (original sample) |
|------------------|-------|------------------------|-----------------------|-------------------|--|---|
| Tobacco use | No | 868 (94.55%) | 434 (94.55%) | 434 (94.55%) | 0 | 0.02 |
| | Yes | 50 (5.45%) | 25 (5.45%) | 25 (5.45%) | | |
| Valvular disease | No | 900 (98.04%) | 450 (98.04%) | 450 (98.04%) | 0 | 0.05 |
| | Yes | 18 (1.96%) | 9 (1.96%) | 9 (1.96%) | | |
| Weight loss | No | 918 (100.00%) | 459 (100.00%) | 459 (100.00%) | | 0.05 |

Table 6Comparison of clinicaloutcomes between propensitymatch samples

| Outcome | Comparison group | Estimated risk dif- ference/ratios ^a | 95% CI | p value |
|--------------------|------------------|--|--------------------|----------|
| Any complication | R-IHR vs. L-IHR | - 0.0260 | - 0.0564, 0.0044 | 0.1360 |
| | R-IHR vs. O-IHR | - 0.0915 | - 0.1273, - 0.0557 | < 0.0001 |
| 30-day readmission | R-IHR vs. L-IHR | 0.0202 | - 0.0080, 0.0485 | 0.2295 |
| | R-IHR vs. O-IHR | 0.0087 | - 0.0189, 0.0364 | 0.6440 |
| 30-day ED visit | R-IHR vs. L-IHR | 0.0289 | - 0.0134, 0.0712 | 0.2288 |
| | R-IHR vs. O-IHR | 0.0109 | - 0.0289, 0.0507 | 0.6683 |
| Length of stay | R-IHR vs. L-IHR | 0.82 | 0.62, 1.10 | 0.2018 |
| | R-IHR vs. O-IHR | 0.53 | 0.45, 0.62 | < 0.0001 |

L-IHR laparoscopic inguinal hernia repair, O-IHR open inguinal hernia repair, R-IHR robotic inguinal hernia repair

^aEstimated ratios were reported for length of stay

A 2018 retrospective review of the American College of Surgeons National Surgical Quality Improvement Program database found R-IHR to have longer operative times, but similar rates of postoperative adverse events and readmissions compared to L-IHR and O-IHR [18]. The study was limited by the overall small sample size of patients undergoing R-IHR (R-IHR n = 69, L-IHR n = 241, O-IHR n = 191). The present study is a similar retrospective review, but includes a much larger sample size, particularly R-IHR. More recently, Pokala et al. compared the outcomes of all three approaches using the national Vizient clinical database [19]. This study included a larger sample size of robotic procedures (n = 594) and found R-IHR to have the lowest overall complication rate (0.67%) compared to L-IHR (4.44%) and O-IHR (3.85%), p < 0.05. The authors concluded that minimally invasive IHR had outcomes superior to open repair despite higher cost. The present study supports these data with the addition of long-term recurrence data.

There are limitations to our study inherent to the use of a retrospective administrative database. The data rely on proper coding with the potential for clerical error. Clinical data are limited as the SPARCS database does not provide operative data related to hernia size, mesh use, type of mesh, and method of mesh fixation. Hospital cost is also a variable which is not captured by the database. Additionally, as mentioned previously, it is difficult to take surgeon experience into account as this is not a captured variable. In the present study, we used hospital volume as a proxy, which is less precise. Selection bias should also be considered, particularly in the decision for an open versus minimally invasive (robotic or laparoscopic) approach. Surgeon comfort level or experience and patient acuity may have contributed to the surgical approach and subsequent outcomes. Despite these limitations, the ability to track patients longitudinally statewide allows for comparison of long-term outcomes.

Conclusion

This study demonstrates that in adult patients in New York state, R-IHR may be associated with comparable to more favorable 30-day perioperative outcomes, as compared with L-IHR and O-IHR, respectively, but with longer LOS. Further randomized studies are needed to assess the clinical variables contributing to these outcomes.

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Compliance with ethical standards

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