


# Early outcomes of robotic-assisted inguinal hernia repair in obese patients: a multi-institutional, retrospective study

Ramachandra Kolachalam<sup>1</sup>  · Eugene Dickens<sup>2</sup> · Lawrence D'Amico<sup>3</sup> · Christopher Richardson<sup>4</sup> · Jorge Rabaza<sup>5</sup> · Reza Gamagami<sup>6</sup> · Anthony Gonzalez<sup>5</sup>

Received: 8 April 2017 / Accepted: 6 June 2017 / Published online: 23 June 2017  
© Springer Science+Business Media, LLC 2017

## Abstract

**Background** Minimally invasive inguinal hernia repair (IHR) in general and particularly in obese patients has not been widely adopted, potentially due to the perceived technical challenges and the well-documented learning curve associated with laparoscopic repair. Outcomes in robotic-assisted IHR in obese (BMI  $\geq 30$  kg/m<sup>2</sup>) patients have not been described and warrant study.

**Methods** Seven surgeons conducted a multicenter retrospective chart review of their early robotic-assisted IHR (RHR) cases and compared them with their open IHR (OHR) cases. Demographics, operative characteristics, and perioperative morbidity were compared for unadjusted and propensity-matched populations.

**Results** 651 robotic-assisted cases and 593 open cases were collected. The outcomes of 148 RHRs to 113 OHRs in obese patients were compared. For obese populations—

whether unadjusted (robotic-assisted,  $n = 148$ ; open,  $n = 113$ ) or matched (1:1) (robotic-assisted,  $n = 95$ ; open,  $n = 93$ )—the robotic-assisted and open cohorts were comparable in terms of demographics and baseline characteristics. Significantly higher percentages of OHR patients experienced postoperative complications post-discharge (unadjusted: 11.5% vs. 2.7%,  $p = 0.005$ ; and matched: 10.8% vs. 3.2%,  $p = 0.047$ ). More concomitant procedures and bilateral repairs were conducted in obese RHR patients than in obese OHR patients (unadjusted 29.7% vs. 16.8%,  $p = 0.019$ ; and unadjusted 35.1% vs. 11.5%,  $p < 0.0001$ —respectively). Prior laparoscopic IHR experience did not affect 30-day outcomes.

**Conclusions** Obese patients who undergo RHR have a lower rate of postoperative complications compared to obese patients who undergo OHR. Previous laparoscopic IHR experience, more bilateral repairs, and more concomitant procedures were not associated with increased complications in RHR patients. These outcomes may facilitate increased adoption of minimally invasive IHR approaches in the obese population.

Presented at the SAGES 2017 Annual Meeting, March 22–25, 2017, Houston, Texas.

✉ Ramachandra Kolachalam  
Rkolachalam@gmail.com

- <sup>1</sup> Department of Surgery, Providence-Providence Park Hospital, 26850, Providence Pkwy, Suite 460, Novi, MI 48374, USA
- <sup>2</sup> Hillcrest Medical Center and Oklahoma Physician Group, Tulsa, OK, USA
- <sup>3</sup> ValleyCare Health System of Ohio, Trumbull Memorial Hospital, Warren, OH, USA
- <sup>4</sup> Rochester General Hospital, Rochester, NY, USA
- <sup>5</sup> Department of General and Bariatric Surgery, Baptist Health South Florida, Miami, FL, USA
- <sup>6</sup> Silver Cross Hospital, New Lenox, IL, USA

**Keywords** Inguinal hernia repair · Robotic-assisted · Da Vinci · Laparoscopic · Minimally invasive surgery · Obesity

Approximately 750,000 inguinal hernia repairs (IHRs) are performed annually in the United States, with most surgeons preferring the open approach [1]. Preference for the open approach over a laparoscopic approach may be especially true for IHR in obese patients as these patients pose technical challenges for the surgeon [2]. The effect of obesity on early postoperative inguinal hernia repair has been the subject of recent National Surgical Quality

Improvement Program (NSQIP) database studies [2, 3]. Although the study indicated trending higher 30-day complications in obese patients having open inguinal hernia repair (OHR) compared with obese patients having laparoscopic inguinal hernia repair (LHR)—especially in unadjusted patient populations—the authors concluded that both open and laparoscopic approaches are associated with similar early postoperative outcomes. With adjustment for age and for bilateral and recurrent inguinal hernia, obese patients who underwent laparoscopic repair were significantly less likely to return to the operating room [3]. However, laparoscopy as a minimally invasive approach to IHR in general, and in the obese population in particular, has not yet been widely adopted. Although the potential advantages of less pain and earlier recovery with lower rates of postoperative complications of chronic pain and numbness have been associated with a minimally invasive approach, perceived technical challenges and a steep learning curve associated with a laparoscopic repair are among the reasons often cited for the lack of adoption of this approach [1, 4]. Consequently, OHR remains by far the most commonly performed procedure across all groups of patients [1, 4]. Furthermore, obesity and body habitus may further increase the technical difficulty of LHR, leading to a patient selection process of LHR vs OHR that is hard to define or quantify in the hands of many surgeons. This selection process of LHR is not often addressed.

The robotic-assisted minimally invasive approach to IHR in obese ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ) patients has not yet been described in the literature and warrants study. The aim of this multicenter, retrospective study is to describe the clinical characteristics and early outcomes of robotic-assisted transabdominal preperitoneal repair (RHR) in obese patients. The general surgeons in the study have experience with the open approach, but only variable experience with the laparoscopic approach prior to starting RHR. Patient characteristics and outcomes in obese patients undergoing RHR was compared with obese patients undergoing OHR repair. The associated hypothesis was that the technology of robotic-assisted surgery—with its magnified three-dimensional imaging and wrist-like instrumentation—may improve 30-day postoperative outcomes. Whether these outcomes and technical advantages translate to increased acceptance of minimally invasive inguinal hernia repair remains to be seen.

## Materials and methods

The institutional review board (IRB) at each participating site approved and provided a study-specific informed consent waiver for retrospective data collection from existing medical records of patients who underwent either

robotic-assisted or open IHR from May 2006 to March 2016. The study period began with approximately each surgeon's first robotic-assisted surgery patient to 30 days prior to the later date of the institution's IRB approval and fully executed data collection agreement. The consecutive robotic-assisted IHR cases were then compared with the same surgeons' open IHR cases that were performed for up to 5 years prior to their initiation of robotic-assisted surgery. Eligible patients were at least 18 years of age with documented or calculable baseline BMI who underwent IHR by either an open or robotic-assisted procedure. Other than BMI and age, there were no patient-related inclusion or exclusion criteria; furthermore, any potential variability in perioperative characteristics was mitigated by matching covariates as part of the data analysis.

All patient information remained confidential and was managed according to the requirements of the Health Insurance Portability and Accountability Act of 1996. Each principal investigator or designee gathered data uniformly from hospital and/or office charts. Parameters of interest, which were in study-specific data collection forms, included age, gender, BMI, comorbidities, surgical times, inpatient and outpatient length of stay (LOS), intraoperative and postoperative complications, and reoperations through 30 days post procedure.

## Surgical approaches

All patients who underwent robotic-assisted IHR had the standard transabdominal preperitoneal procedure under general anesthesia [5]. Patient position was either supine or lithotomy with slight Trendelenburg. A camera port was placed superior to the umbilicus with either the  $0^\circ$  or  $30^\circ$  camera and two additional ports (5-mm or 8-mm) placed bilaterally in the midclavicular line at just above or at the umbilical level. A fourth assist port was used at the discretion of the surgeon as necessary. All robotic-assisted procedures were carried out with the da Vinci<sup>®</sup> Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA) with either parallel side docking, hip docking, or pelvic docking. Patients were asked to void preoperatively and Foley catheters were not routinely placed. Prophylactic first-generation cephalosporins were administered.

The peritoneum was incised at the level of the arcuate line from the medial umbilical ligament transversely to the level of the anterior superior iliac spine. The preperitoneal, avascular space was then developed, medially to the symphysis pubis, laterally to the level of the anterior superior iliac spine, inferior to below the Cooper's ligament, and retroperitoneally for 4 cm exposing the iliopsoas muscle. The hernia sac was reduced in most patients. In a patient with a very large indirect sac, the sac was transected with the distal portion left in situ at the discretion of the

surgeon. The proximal peritoneal defect was closed with a purse-string absorbable suture at the final phase of the peritoneal flap re-approximation. Subjects had mesh repairs with fixation using suture or tacks at Cooper's ligament or repairs with self-fixating polyester mesh with micro-grips without fixation.

Open repairs were by one of three tension-free approaches: plug-and-patch, Lichtenstein, or the Prolene hernia system [6–8]. Each surgeon used their preferred approach; the most common was plug-and-patch.

### Statistical methods

Univariate methods were applied to the data analysis in each group. Outcomes were summarized in terms of frequencies, percentages, means, and standard deviations. Analyses were based on available data only, i.e., missing data were excluded from calculations. Propensity score matching (1:1) of the populations with BMI  $\geq 30$  kg/m<sup>2</sup> was performed based on the covariates age, BMI, gender, presence of concomitant procedure, primary versus recurrent hernia, presence of comorbidities, American Society of Anesthesiologists (ASA) classification, previous abdominal surgery, and unilateral/bilateral repair. Categorical variables were compared using Chi-square test or, when sample sizes were small, Fisher's exact test. Continuous variables were compared using Student's *t* test. In all cases,  $p < 0.05$  indicated statistical significance. Data were analyzed with SAS version 9.4 (SAS, Inc., Cary, NC).

### Results

Seven general surgeons at six medical centers within the United States provided a total of 1244 IHR patients with calculable or reported BMI from May 2006 to March 2016. Of these patients, 593 consecutive open repairs and 651 consecutive RHR patients were available for analysis.

#### Body Mass Index $\geq 30$ kg/m<sup>2</sup>: robotic-assisted and open—unadjusted and matched populations

No differences were observed between the robotic-assisted and open cohorts in terms of age, BMI, gender distribution, presence of comorbidities, or ASA score (Table 1), regardless of whether the compared populations were unadjusted (RHR,  $n = 148$ ; OHR,  $n = 113$ ) or matched (RHR,  $n = 95$ ; OHR,  $n = 93$ ).

In the unadjusted analysis, a higher percentage of RHR patients than OHR patients underwent bilateral repair (35.1% vs. 11.5%;  $p < 0.0001$ ). In the matched analysis, the distribution of unilateral/bilateral repair for each cohort was comparable, as this parameter was one of the

covariates used for matching. Additionally, a significantly higher number of patients in the RHR group had at least 1 concomitant procedure performed (29.7% vs. 16.8%;  $p = 0.019$ ) in the unmatched group, but the matched group had comparable rates of concomitant procedures as the presence of at least 1 concomitant procedure was a matching covariate. The most common concomitant procedure in both groups was separate hernia repair (unmatched and matched populations); in the matched population, 14 patients in the RHR group and 8 patients in the OHR group had a concomitant hernia repair (i.e., umbilical hernia repair). Regardless of the applied analytical method, surgical times for the robotic-assisted group were significantly longer than for the open group. Patients in the two cohorts—whether unadjusted or matched—were treated primarily as outpatients and had comparable LOS. The difference in inpatient LOS between that for the RHR patients was lower than that for the open patients in the unadjusted comparison: ( $1.8 \pm 0.8$  days vs.  $3.7 \pm 3.1$  days [ $p = 0.041$ ]) and was comparable in the matched comparison ( $1.9 \pm 0.9$  days vs.  $4.4 \pm 3.6$  days [ $p = 0.095$ ]). However, the inpatient sample sizes were small in both cohorts.

Morbidity generally was comparable between the two cohorts, whether the analysis was unadjusted or matched. Conversion ( $n = 3$ ) rates observed in the RHR were 2.0% in unmatched group and 3.2% in the matched group; new conversions were not identified, but the rates differed due to the reduced denominator in the matched cohort. Reasons for these conversions were the following: two patients had anatomies not amenable to a minimally invasive approach, and in the third patient, a conversion was necessitated by the need to remove mesh from a previous surgery.

However, there were parameters of significant difference between the cohorts. In both the unadjusted and matched analyses, significantly higher percentages of patients in the OHR group experienced postoperative complications from the time of their discharge to 30 days follow-up (unadjusted: 11.5% vs. 2.7%,  $p = 0.005$ ; and matched: 10.8% vs. 3.2%,  $p = 0.047$ ). In the matched analysis, the RHR group experienced the following complications post-discharge to 30 days: urinary retention ( $n = 2$ ) and a seroma that did not require treatment ( $n = 1$ ). Patients in the open group in the matched analysis experienced the following complications in the same period: unexpected testicular swelling ( $n = 3$ ), urinary retention ( $n = 1$ ), deep vein thrombosis ( $n = 1$ ), seroma not requiring intervention ( $n = 1$ ), hematoma requiring reoperation ( $n = 1$ ), wound dehiscence requiring closure ( $n = 1$ ), surgical site infection ( $n = 1$ ), and skin necrosis ( $n = 1$ ). In the unadjusted comparison, 4 OHR patients (vs. 0 RHR patients) underwent reoperations after discharge and the difference was significant [ $p = 0.034$ ]. However,

**Table 1** Comparative patient demographics, operative characteristics, and perioperative morbidities for both unadjusted and matched robotic-assisted (RHR) and open cohorts with BMI  $\geq 30$  kg/m<sup>2</sup>

Parameter	Unadjusted			Matched <sup>a</sup>		
	RHR <i>n</i> = 148	Open <i>n</i> = 113	<i>p</i> value	RHR <i>n</i> = 95	Open <i>n</i> = 93	<i>p</i> value
<b>Demographics</b>						
Mean age, years ( $\pm$ SD)	54.6 (12.4)	54.5 (15.3)	0.955	53.5 (11.9)	54.0 (14.5)	0.794
Mean BMI, kg/m <sup>2</sup> ( $\pm$ SD)	34.2 (4.9)	34.2 (5.0)	0.968	33.6 (3.8)	34.2 (5.2)	0.412
Gender, <i>n</i> (%)			0.68			0.477
Female	13 (8.8)	12 (10.6)		8 (8.4)	11 (11.8)	
Male	135 (91.2)	101 (89.4)		87 (91.6)	82 (88.2)	
Prior abdominal surgery, <i>n</i> (%)	65 (43.9)	51 (45.1)	0.900	42 (44.2)	41 (44.1)	1.00
$\geq 1$ Comorbidity, <i>n</i> (%)	110 (74.3)	78 (69.0)	0.404	65 (68.4)	67 (72.0)	0.6341
ASA score, <i>n</i> (%)			0.152			0.251
1 (mild)	6 (4.1)	14 (12.6)		5 (5.3)	12 (12.9)	
2 (moderate)	86 (58.1)	58 (51.3)		56 (58.9)	50 (53.8)	
3 (moderate-to-severe)	53 (35.8)	37 (32.7)		31 (32.6)	29 (31.2)	
4 (severe)	3 (2.0)	2 (1.8)		3 (3.2)	2 (2.1)	
Missing	0 (0)	2 (1.8)		0 (0)	0 (0)	
<b>Operative characteristics</b>						
Repair, <i>n</i> (%)			<0.0001			0.832
Unilateral	96 (64.9)	100 (88.5)		83 (87.4)	80 (86.0)	
Bilateral	52 (35.1)	13 (11.5)		12 (12.6)	13 (14.0)	
Mean skin-to-skin time, min ( $\pm$ SD)	87.9 (35.6)	50.2 (21.9)	<0.0001	82.9 (35.7)	51.5 (20.9)	<0.001
Setting of care, <i>n</i> (%)			0.836			0.794
Outpatient	134 (90.5)	101 (89.4)		88 (92.6)	85 (91.4)	
Inpatient	14 (9.5)	12 (10.6)		7 (7.4)	8 (8.6)	
Mean length of stay ( $\pm$ SD)						
Outpatient, h	7.6 (3.6)	7.4 (2.8)	0.717	7.6 (3.9)	7.4 (2.8)	0.695
Inpatient, days	1.8 (0.8)	3.7 (3.1)	0.041	1.9 (0.9)	4.4 (3.6)	0.095
Blood transfusion, <i>n</i> (%)						
Intraoperative	0 (0)	0 (0)	–	0 (0)	0 (0)	–
Postoperative	0 (0)	1 (0.88%)	0.433	0 (0)	0 (0)	–
$\geq 1$ Concomitant procedures, <i>n</i> (%)	44 (29.7)	19 (16.8)	0.019	17 (17.9)	18 (19.4)	0.853
Conversions, <i>n</i> (%)	3 (2.0)	n/a	–	3 (3.2)	n/a	–
<b>Perioperative morbidities</b>						
Complications, <i>n</i> (%)						
Intraoperative	1 (0.7)	0 (0)	1.00	1 (1.1)	0 (0)	1.00
Postoperative (prior to discharge)	1 (0.7)	2 (1.8)	0.580	1 (1.1)	1 (1.1)	1.00
Postoperative (discharge—30 days)	4 (2.7)	13 (11.5)	0.005	3 (3.2)	10 (10.8)	0.047
Readmissions related to index IHR <sup>b</sup> , <i>n</i> (%)	2 (1.4)	4 (3.5)	0.408	1 (1.0)	2 (2.2)	0.619
Reoperations, related to index IHR, <i>n</i> (%)						
Postoperative (prior to discharge)	0 (0)	0 (0)	–	0 (0)	0 (0)	–
Postoperative (discharge—30 days)	0 (0)	4 (3.5)	0.034	0 (0)	2 (2.2)	0.243

BMI body mass index, SD standard deviation of the mean, ASA American Society of Anesthesiologists, IHR inguinal hernia repair, RHR robotic-assisted inguinal hernia repair

<sup>a</sup> Covariates used for matching include: age, BMI, gender, presence of concomitant procedure, primary versus recurrent hernia, presence of comorbidities, ASA classification, previous abdominal surgery, and unilateral/bilateral repair

<sup>b</sup> Discharge through 30 days

in the matched analysis, 2 patients in the OHR group experienced reoperation (hematoma evacuation and reclosure of the inguinal incision in the operating room, and this difference was not significant [ $p = 0.243$ ]).

### Impact of surgeon experience

Of the 7 surgeons in the study, 3 described their laparoscopic experience (prior to their adoption of the robotic-assisted approach) as none to low with 0–9% of their previous IHRs having been conducted laparoscopically; these 3 surgeons provided in the aggregate the most patients characterized by obesity ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ) ( $n = 81$ ). The four additional surgeons, who provided 67 patients ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ), had moderate-to-advanced (10 to >50%) laparoscopic experience prior to their adoption of RHR. The patients were comparable demographically and clinically at baseline to the obese patients of the moderate-to-advanced laparoscopic surgeons (Table 2). In terms of perioperative morbidities, all measured parameters were comparable between the surgeons with low or no previous laparoscopic IHR experience and those with moderate-to-advanced experience. Of note, the 1 intraoperative complication and all 3 conversions observed in the obese population were observed in the none-to-low experience group. The only exception was skin-to-skin time, which was significantly shorter for the early experience surgeons:  $81.0 \pm 34.8 \text{ min}$  versus  $96.3 \pm 34.9 \text{ min}$ ; however, the experienced group had a slightly higher rate of concomitant procedures and bilateral repairs.

### Discussion

The goals of minimally invasive surgery are to minimize patient discomfort while maximizing clinical outcomes. However, the popularity of laparoscopic hernia repair has not increased at the same rate as other laparoscopic operations. Surprisingly, contrary to other laparoscopic procedures that evidence increased adoption during the same timeframe, LHR has not experienced the same growth [9]. The ideal minimally invasive operation in obese patients should provide similar rates of short-term and long-term complications that are achieved using minimally invasive approaches in non-obese patients. These outcomes should be similar or better than those achieved with OHR. Although the degree of technical difficulty with different body habitus and high BMI is hard to measure, ideally a minimally invasive approach should be no more difficult in obese patients.

Despite the advantages of reduced pain with earlier recovery and fewer late complications of chronic pain and numbness associated with the laparoscopic approach, OHR

remains the most common approach to hernia repair in both non-obese and obese patients [1, 4, 5]. The steep learning curve of laparoscopic IHR is often cited as one of the reasons for its lack of adoption by most surgeons [10]. Obesity further increases the technical difficulty of the laparoscopic approach and leads to a patient selection process that is hard to define or quantify in the hands of many surgeons.

In this study for obese patients requiring IHR, the robotic-assisted approach provided comparable and in some cases improved outcomes to those achieved with the open approach. The unadjusted comparison of RHR in patients with  $\text{BMI} \geq 30 \text{ kg/m}^2$  indicated that more bilateral repairs and concomitant procedures occurred within the robotic-assisted group. In addition, a trend toward fewer postoperative complications was observed with RHR compared with OHR in patients with comparable BMI.

In the propensity-matched analysis of populations with  $\text{BMI} \geq 30 \text{ kg/m}^2$  undergoing either RHR or OHR, shorter hospital LOS—both inpatient and outpatient—was experienced by those patients undergoing the robotic-assisted procedure. For those patients who were treated in an inpatient setting, this difference trended toward statistical significance. There was no difference in intraoperative or postoperative complications prior to discharge. However, a significantly higher rate of complications from discharge to 30 days occurred in the open group than in the robotic-assisted group. Readmission and reoperation rates related to the index surgery were statistically comparable between both groups, although two patients in the open group required subsequent operations. The only area of consistent statistical difference for the open approach was the shorter surgical time; however, the RHR cohort had a higher proportion of patients undergoing bilateral and concomitant procedures, which may have contributed to this finding.

Published studies of IHR in non-obese to obese populations suggest that obesity confers a protective advantage to patients; that is, inguinal hernias have a lower incidence in obese populations [11–14]. However, the increased surgical morbidity associated with this population warrants investigation of minimally invasive surgical approaches that might decrease complications among this group. Minimally invasive surgery has been associated with reduced rates of postoperative wound complications [2]. The perceived lower learning curve to proficiency with the robotic-assisted system may allow surgeons to adopt a minimally invasive approach with associated clinical advantages for their patients—including patients with different body habitus. Additionally, outcomes of robotic-assisted hernia surgery in obese patients in this study appeared to be unrelated to the surgeons' previous

**Table 2** Comparative patient demographics, operative characteristics, and perioperative morbidity for RHR patients with BMI  $\geq 30$  kg/m<sup>2</sup> according to surgeon experience (none/low and moderate/advanced)

Parameter	BMI $\geq 30$ kg/m <sup>2</sup>		p value
	None/low n = 81	Moderate/advanced n = 67	
<b>Demographics</b>			
Mean age, years ( $\pm$ SD)	53.4 (12.9)	56.1 (11.5)	0.190
Mean BMI, kg/m <sup>2</sup> ( $\pm$ SD)	34.6 (5.2)	33.8 (4.6)	0.347
Gender, n (%)			0.773
Female	8 (9.9)	5 (7.4)	
Male	73 (90.1)	62 (92.5)	
Prior abdominal surgery, n (%)	38 (46.9)	27 (40.3)	0.522
$\geq 1$ Comorbidity, n (%)	62 (76.5)	48 (71.6)	0.624
ASA score, n (%)			0.999
1 (mild)	5 (6.2)	1 (1.5)	
2 (moderate)	45 (55.6)	41 (61.2)	
3 (moderate-to-severe)	28 (34.6)	25 (37.3)	
4 (severe)	3 (3.7)	0 (0)	
<b>Operative characteristics</b>			
Repair, n (%)			0.489
Unilateral	55 (67.9)	41 (61.2)	
Bilateral	26 (32.1)	26 (38.2)	
Mean skin-to-skin time, min ( $\pm$ SD)	81.0 (34.8)	96.3 (34.9)	0.009
Setting of care, n (%)			0.163
Outpatient	76 (93.8)	58 (86.6)	
Inpatient	5 (6.2)	9 (13.4)	
Mean length of stay ( $\pm$ SD)			
Outpatient, h	6.5 (2.0)	9.0 (4.6)	<0.0001
Inpatient, days	2 (1.0)	1.7 (0.7)	0.478
Blood transfusion, n (%)			
Intraoperative	0 (0)	0 (0)	–
Postoperative	0 (0)	0 (0)	–
$\geq 1$ Concomitant procedures, n (%)	20 (24.7)	24 (35.8)	0.196
Conversions, n (%)	3 (3.7)	0 (0)	0.252
<b>Perioperative morbidities</b>			
Complications, n (%)			
Intraoperative	1 (1.2)	0 (0)	1.00
Postoperative (prior to discharge)	0 (0)	1 (1.5)	0.453
Postoperative (discharge–30 days)	1 (1.2)	3 (4.5)	0.329
Readmissions related to index IHR <sup>a</sup> , n (%)	1 (1.2)	1 (1.5)	1.00
Reoperations related to index IHR, n (%)			
Postoperative (prior to discharge)	0 (0)	0 (0)	–
Postoperative (discharge–30 days)	0 (0)	0 (0)	–

BMI body mass index, SD standard deviation of the mean, ASA American Society of Anesthesiologists, IHR inguinal hernia repair, RHR robotic-assisted inguinal hernia repair

<sup>a</sup> Discharge through 30 days

laparoscopic hernia repair experience, although the patient sample sizes were small.

This study is not without limitations, including its retrospective design and small patient samples. It should be noted that postoperative hematoma rates contributed to the

outcomes; however, long-term anticoagulant use was not collected in either the RHR or OHR cohorts, which can impact postoperative hematoma rates. In addition, because of the retrospective design of the study, pain, quality of life and cost could not be quantified or described. However, use



of propensity-matched analysis and the heterogeneous surgeon experience with previous laparoscopic hernia repair provide perspective regarding outcomes that are possible with the robotic-assisted approach. All data were consistently and uniformly collected directly from existing medical records by the surgeons or their appointees using the same data collection forms; however, as commonly observed in retrospective studies, data for some variables may have been missing for some patients. The authors had full control over the interpretation of data and the development of the manuscript.

Patients with and without obesity have similar short-term outcomes after RHR. Obese patients who undergo RHR have a lower rate of post-discharge to 30-day complications compared to obese patients who undergo OHR. In addition, robotic-assisted inguinal hernia repair could lead to increased acceptance of minimally invasive hernia repair with the associated clinical benefits to patients, including those who are obese with higher comorbidities and higher ASA scores. A prospective study of obesity in RHR is warranted to confirm our findings.

**Acknowledgements** The authors thank Sundeep Master (Manager, Clinical Affairs; Intuitive Surgical) for organizing the multitude of components required for the preparation and completion of the study, Usha Seshadri Kreaden (Principal Biostatistician; Intuitive Surgical) for completing the statistical analysis of the collected data, and Wainwright Medical Communications for independent research and editorial guidance.

**Funding** Study is sponsored by Intuitive Surgical, Inc. for data collection, statistical analysis, and independent editorial support. Authors retained full control of the review of the data analysis and the development and final approval of the manuscript.

#### Compliance with ethical standards

**Disclosures** Drs. Kolachalam, Gamagami, Dickens, Gonzalez, D'Amico, Richardson, and Rabaza received clinical research grants for data collection from Intuitive Surgical. Drs. Dickens, Gamagami, Gonzalez, and D'Amico receive personal fees for consulting and education from Intuitive. Dr. Dickens receives personal fees for consulting and education from Covidien and is an advisor (with ownership) to GibLab. Dr. D'Amico receives consulting fees from Ethicon.

#### References

1. Trevisonno M, Kaneva P, Watanabe Y, Fried GM, Feldman LS, Lebedeva E, Vassiliou MC (2015) A survey of general surgeons regarding laparoscopic inguinal hernia repair: practice patterns,

barriers, and educational needs. *Hernia* 19(5):719–724. doi:10.1007/s10029-014-1287-8

2. Willoughby AD, Lim RB, Lustik MB (2017) Open versus laparoscopic unilateral inguinal hernia repairs: defining the ideal BMI to reduce complications. *Surg Endosc* 31:206–214. doi:10.1007/s00464-016-4958-y
3. Froylich D, Haskins IN, Aminian A, O'Rourke CP, Khorgami Z, Boules M, Sharma G, Brethauer SA, Schauer PR, Rosen MJ (2017) Laparoscopic versus open inguinal hernia repair in patients with obesity: an American College of Surgeons NSQIP clinical outcomes analysis. *Surg Endosc* 31(3):1305–1310. doi:10.1007/s00464-016-5112-6
4. McCormack K, Wake B, Perez J, Fraser C, Cook J, McIntosh E, Vale L, Grant A (2005) Laparoscopic surgery for inguinal hernia repair: systematic review of effectiveness and economic evaluation. *Health Technol Assess* 9(14):1–203
5. Escobar Dominguez JE, Gonzalez A, Donkor C (2015) Robotic inguinal hernia repair. *J Surg Oncol* 112(3):310–314. doi:10.1002/jso.23905
6. Magnusson J, Nygren J, Gustafsson UO, Thorell A (2016) UltraPro Hernia System, Prolene Hernia System and Lichtenstein for primary inguinal hernia repair: 3-year outcomes of a prospective randomized controlled trial. *Hernia* 20(5):641–648. doi:10.1007/s10029-016-1507-5
7. Chatzimavroudis G, Papaziogas B, Koutelidakis I, Galanis I, Atmatzidis S, Christopoulos P, Doulias T, Atmatzidis K, Makris J (2014) Lichtenstein technique for inguinal hernia repair using polypropylene mesh fixed with sutures vs. self-fixating polypropylene mesh: a prospective randomized comparative study. *Hernia* 18(2):193–198. doi:10.1007/s10029-013-1211-7
8. Köckerling F, Schug-Pass C (2014) Tailored approach in inguinal hernia repair—decision tree based on the guidelines. *Front Surg* 1:20. doi:10.3389/fsurg.2014.00020
9. Lim PC, Crane JT, English EJ, Farnam RW, Garza DM, Winter ML, Rozeboom JL (2016) Multicenter analysis comparing robotic, open, laparoscopic, and vaginal hysterectomies by high-volume surgeons for benign indications. *Int J Gynecol Obstet* 133:359–364. doi:10.1016/j.ijgo.2015.11.010
10. Tadaki C, Lomelin D, Simorov A, Jones R, Humphreys M, DaSilva M, Choudhury S, Shostrom V, Boilesen E, Kothari V, Oleynikov C, Goede M (2016) Perioperative outcomes and costs of laparoscopic versus open inguinal hernia repair. *Hernia* 20(3):399–404. doi:10.1007/s10029-016-1465-y
11. Zendejas B, Hernandez-Irizarry R, Ramirez T, Lohse CM, Grossardt BR, Farley DR (2014) Relationship between body mass index and the incidence of inguinal hernia repairs: a population-based study in Olmsted County, MN. *Hernia* 18:283–288. doi:10.1007/s10029-013-1185-5
12. Rosemar A, Angeras U, Rosengren A, Nordin P (2010) Effect of body mass index on groin hernia surgery. *Ann Surg* 252:397–401. doi:10.1097/SLA.0b013e3181e985a1
13. Rosemar A, Angeras U, Rosengren A (2008) Body mass index and groin hernia: a 34-year follow-up study in Swedish men. *Ann Surg* 247:1064–1068. doi:10.1097/SLA.0b013e31816b4399
14. Liem MS, Van der Graf Y, Zwart RC, Geurts I, van Vroonhoven TJ (1997) Risk factors for inguinal hernia in women: a case-control study. The Coala Trial Group. *Am J Epidemiol* 146:721–726