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ORIGINAL ARTICLE

A comparison of the da Vinci Xi vs. the da Vinci Si Surgical System for Roux-En-Y gastric bypass

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Abstract

Purpose The da Vinci Surgical System family remains the most widely used surgical robotic system for laparoscopy. Data about gastric bypass surgery with the Xi Surgical System are not available yet. We compared Roux-en-Y gastric bypass surgery performed at our institution with the da Vinci Xi and the da Vinci Si Surgical System.

Methods All robotic gastric bypass procedures performed between January 2013 and September 2016 were analyzed retrospectively. Patient demographics and operative and postoperative outcomes up to 30 days were compared for the da Vinci Xi and Si Surgical System. Robotic costs per procedure were modeled including posts for a standard set of robotic instruments, capital investment, and yearly maintenance.

Results One-hundred forty-four Xi Surgical System and 195 Si Surgical System procedures were identified. Mean age ($p = 0.9$), gender distribution ($p = 0.8$), BMI ($p = 0.6$), and ASA scores ($p > 0.5$) were similar in both cohorts. Operating room times were similar in both groups (219.4 ± 58.8 vs. 227.4 ± 60.5 min for Xi vs. Si, $p = 0.22$). Docking times were significantly longer with the Xi compared with the Si Surgical System (9 ± 4.8 vs. 5.8 ± 4 min, $p < 0.0001$). There was no difference in incidence of minor (13.9 vs. 10.3%, $p = 0.3$) and major complications (5.6 vs. 5.1%, $p = 1$ for Xi vs. Si). Costs were higher for the Xi Surgical System caused by higher capital investment and yearly maintenance.

Conclusions Roux-en-Y gastric bypass surgery can be safely performed with the Xi Surgical System, while drawbacks include longer docking times and higher costs.

Keywords Robotic surgery · da Vinci Si Surgical System · da Vinci Xi Surgical System · Roux-en-Y gastric bypass

Introduction

Minimally invasive surgery has become an integral part in the care of severe obese patients. Although conventional laparoscopy is the gold standard for most bariatric procedures, overall complication rates of laparoscopic bariatric surgery including anastomotic leak and stricture rates remain important [1].

Former studies showed that robotic technology might facilitate surgical procedures and improve clinical outcomes in Roux-en-Y gastric bypass surgery with lower anastomotic leak and stricture rates [2, 3]. However, more recent studies, including one meta-analysis [4] and three database analyses [5–7], showed no advantage of robot-assisted over laparoscopic surgery with regard to complication rates, while longer operative times, higher readmission rates, and higher costs were reported for robot-assisted gastric bypass. Two propensity score matched database analyses showed contradictory results, with in one study showing higher complication rates [8] and another more recent study showing better postoperative outcomes [9] after robot-assisted gastric bypass.

At present, the da Vinci Surgical System Family (Intuitive Surgical Inc., Sunnyvale, CA, USA) is the most widely used surgical robotic system for minimal invasive surgery. The da Vinci Xi Surgical System, its 4th generation, was released in 2014. It has been developed to facilitate complex multiquadrant procedures and to streamline the user experience. We have previously reported our early clinical experience in different digestive surgery procedures with the Xi Surgical System showing that the da Vinci Xi might facilitate single-setups of totally robotic gastric bypass and colorectal surgeries [10]. Both, the da Vinci Si and Xi Surgical System, contain

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three components with surgical console, surgical cart, and vision tower. In comparison with the Si Surgical System, the Xi Surgical System offers:

- Adapted user interface offering more assistance with robotic setup and installation.
- Torpedo-shaped robotic arms that are mounted on a rotating beam.
- Universal arms where a camera can be docked onto any arm.
- A new vision architecture with chip-at-the-tip technology and camera, endoscope, and cable integrated into one handheld design.
- Longer instruments.
- Integrated energy with a single device for mono- and bipolar energy.
- Standard integration of Firefly Fluorescence Imaging.

We herein report our data of robot-assisted Roux-en-Y gastric bypass surgery with the da Vinci Xi compared with the da Vinci Si Surgical System.

Materials and methods

We retrospectively analyzed all robot-assisted Roux-en-Y gastric bypass procedures performed between January 2013, when a detailed database was available, and September 2016 at our institution. Until March 2015, the da Vinci Si Surgical System was used for all robotic procedures. Since April 2015, the da Vinci Xi Surgical System was introduced at our institution and we performed gastric bypass procedures exclusively with the new system.

Surgical procedure with Si System

With the Si Surgical System, we performed a hybrid robotic procedure combining laparoscopic and robotic steps of the gastric bypass procedure. We performed first a laparoscopic gastric pouch creation with manual stapling and measurement of the biliary limp. After docking of the da Vinci System, we then performed a hand-sutured gastrojejunal anastomosis, measurement of the alimentary limb, and a hand-sutured jejunojejunal anastomosis.

Surgical procedure with Xi System

After introduction of the Xi Surgical System, we changed our technique to a near-total robotic procedure with at first a laparoscopic exploration, positioning of the trocars, and cholecystectomy at the surgeon's discretion followed by docking of the robot. The gastric bypass was then performed robot-assisted, including gastric pouch creation using manual stapling or robotic staplers, measurement of the biliary limb, creation of a hand-sutured gastrojejunal anastomosis, measurement of the alimentary limb, and creation of a hand-sutured jejunojejunal anastomosis.

Data were collected prospectively in our institutional database. Patient characteristics including age, gender, body mass index (BMI), main comorbidities, and ASA classification were analyzed. Operative outcomes were analyzed using recorded operating room times, docking times, and time to create gastrojejunal and jejunojejunal anastomoses. Postoperative complications up to 30 days after surgery were analyzed according to the Clavien-Dindo classification with grades I and II classified as minor and grades III and IV classified as major complications [11]. Comparative cost analysis of purchase, maintenance, and instrument costs was performed using EU price lists as stated by Intuitive Surgical (Intuitive Surgical Sàrl, Aubonne, Switzerland). Robotic instrument costs of the da Vinci Si and Xi Surgical System were calculated for a standard gastric bypass procedure by simple addition of instrument costs as performed in our center. A standard set of instruments for the Si and Xi System included 1 column drape (only Xi), 1 camera head and 1 camera arm drape (only Si), instrument arm drapes, 4 cannula seals, 1 bladeless obturateur, 1 large needle driver, 1 fenestrated bipolar forceps, 1 long tip forceps, 2 cadière forceps, 1 permanent cautery hook, and 1 ultrasonic energy instrument (Harmonic ACE Curved Shears), all by Intuitive Surgical (Intuitive Surgical Inc., Sunnyvale, CA, USA). We excluded costs for stapling devices from our analysis as gastric pouch creation was inconsistently created with either a manual laparoscopic or robotic stapling device.

Continuous data were expressed as mean ± standard error of the mean (SEM). For comparison between groups, a *t* test was performed for continuous data and Fisher's test was performed for categorical data. A p value < 0.05 was considered significant. All statistical analyses were performed using QuickCalcs GraphPad (GraphPad Software Inc., La Jolla, CA, USA).

Results

We performed 195 robotic gastric bypass procedures between January 2013 and March 2015, all with the da Vinci Si Surgical System. One-hundred forty-four robotic gastric bypass procedures were subsequently performed with the da Vinci Xi Surgical System as from April 2015 up to September 2016. Patient characteristics are shown in Table 1. There were no significant differences in gender ($p = 0.8$), age ($p = 0.93$), BMI ($p = 0.63$), nor ASA classification ($p = 0.51$, $p = 0.91$, and $p = 1$ for ASA I, ASA II, and ASA III, respectively) between the two groups. The rate of diabetes

Table 1 Patient characteristics

Parameter	da Vinci Si Surgical System ($n = 195$)	da Vinci Xi Surgical System ($n = 144$)	p value
Age, years			
Mean (SD)	43.1 (11)	43.0 (9.9)	0.93
Gender, n (%)			
Female	144 (73.8)	109 (75.7)	0.80
Male	51 (26.2)	35 (24.3)	
Body mass index, kg/m^2			
Mean (SD)	43.1 (5.9)	42.8 (6.4)	0.63
ASA score, n (%)			
I	2 (1)	–	0.51
II	131 (67.2)	98 (68.1)	0.91
III	62 (31.8)	46 (31.9)	1
Comorbidities, n (%)			
Diabetes	50 (25.6)	33 (22.9)	0.61
Hypertension	59 (30.3)	46 (31.9)	0.81
Sleep apnea	66 (33.8)	53 (36.8)	0.65

($p = 0.61$), hypertension ($p = 0.81$), and sleep apnea ($p = 0.65$) as obesity-related comorbidities were similar in both groups.

As for surgical procedures, 187 (95.9%) and 139 (96.5%) procedures were primary Roux-en-Y gastric bypasses for the da Vinci Si and Xi group, respectively ($p = 1$). There were 4 (2.1%) and 5 (3.5%) revisional procedures from gastric banding to Roux-en-Y gastric bypass in the da Vinci Si and Xi group, respectively ($p = 0.5$).

Furthermore, there were 4 (2%) revisional procedures to Roux-en-Y gastric bypass in the da Vinci Si group ($n = 2$ after Nissen fundoplication ($p = 0.5$), $n = 1$ after Mason procedure ($p = 1$), $n = 1$ after sleeve gastrectomy ($p = 1$)).

Operative outcomes are shown in Table 2. Significantly more patients in the da Vinci Si group had cholecystectomy during surgical procedure compared with the da Vinci Xi group ($p = 0.0005$). Total operative times were similar with the da Vinci Si and the da Vinci Xi Surgical System (227 ± 61 and 219 ± 59 min for Si and Xi, $p = 0.22$). Total operative times in procedures without cholecystectomy were comparable between both groups, as well (219 ± 57 and 212 ± 69 min for Si and Xi, $p = 0.57$). We observed significantly longer docking times with the da Vinci Xi System ($p < 0.0001$). Anastomotic times for both gastrojejunal and jejunojejunal anastomoses were significantly longer with the da Vinci Si System (gastrojejunal: 37 ± 15 vs. 26 ± 10 min for Si vs. Xi, $p < 0.0001$; jejunojejunal: 31 ± 11 vs. 22 ± 7 min for Si vs. Xi; $p < 0.0001$). During surgery, in total three robotic malfunctions including one repetitive system failure leading to conversion to laparoscopic surgery occurred with the da Vinci Xi system compared with zero robotic malfunctions with the da Vinci Si system ($p = 0.08$). In total, only one conversion occurred in the Xi group compared with zero conversions in the Si group ($p = 0.42$) (Table 2).

Table 2 Operative outcomes

Parameter	RYGB with Si ($n = 195$)	RYGB with Xi ($n = 144$)	p value
Cholecystectomy, n (%)	150 (76.9)	85 (59)	0.0005
Total operative time, min			
Mean (SD)	227.4 (60.5)	219.4 (58.8)	0.22
Total operative time (w/o cholecystectomy), min	($n = 45$)	($n = 57$)	
Mean (SD)	218.8 (57.3)	211.5 (68.9)	0.57
Docking time, min			
Mean (SD)	5.8 (4.0)	9.0 (4.8)	< 0.0001
Anastomotic time, min			
Mean (SD)			
Gastrojejunal	37.4 (15.1)	26.0 (10.1)	< 0.0001
Jejunojejunal	30.7 (10.5)	21.8 (7.0)	
Robotic malfunction, n (%)	–	3 (2.1)	0.08
Conversion, n (%)	–	1 (0.7)	0.42

Mean length of hospital stay was 5.7 ± 4.0 days for the Si group and 4.8 ± 3.9 days for the Xi group ($p = 0.03$). Five (2.6%) patients in the Si group and 2 (1.4%) patients in the Xi group required ICU stay for early complications (≤ 30 days after surgery) ($p = 0.70$). Within 30 days after surgery, we observed 20 (10.3%) minor complications and 10 (5.1%) major complications in the Si group compared with 20 (13.9%) minor complications and 8 (5.6%) major complications in the Xi group ($p = 0.31$ and $p = 1$ for minor and major complications, respectively). Five patients (2.6%) in the Si group and 4 patients (2.8%) in the Xi group had reoperations for early complications ($p = 1$). Complication types are detailed in Table 3. Incidences of different complication types were not significantly different in both groups (Table 3). However, we observed a trend towards a higher rate of respiratory complications in the Si group with 8.3 compared with 3.5% ($p = 0.11$).

The comparative analysis of costs is shown in Table 4. Higher acquisition costs for the first console of the da Vinci Xi Surgical System were observed compared with the Si Surgical System (1,850,000 vs. 1,590,000 EUR), whereas acquisition costs of the second console are the same (450,000 EUR). Yearly maintenance costs are the same for both systems (150,000 EUR for simple console, 175,000 EUR for double console). Costs for a standard set of robotic instruments (without stapling device) used for our robotic gastric bypass procedure are slightly higher for the da Vinci Xi Surgical System as well (2258 vs. 2123 EUR for Xi vs. Si).

Table 3 Complications < 30 days after surgery

Parameter	RYGB with Si ($n = 195$)	RYGB with Xi ($n = 144$)	p value
Pulmonary complications, n (%)	16 (8.3)	5 (3.5)	0.11
Ileus, n (%)	2 (1)	5 (3.5)	0.14
Neurologic complications, n (%)	2 (1)	4 (2.8)	0.41
Bleeding, n (%)	2 (1)	3 (2.1)	0.65
Thrombosis, n (%)	2 (1)	–	0.51
Acute renal failure, n (%)	–	2 (1.4)	0,18
Wound infections, n (%)	2 (1)	1 (0.7)	1
Urinary infection, n (%)	1 (0.5)	1 (0.7)	1
Incarcerated hernia, n (%)	1 (0.5)	1 (0.7)	1
Gastrointestinal ulcer, n (%)	1 (0.5)	1 (0.7)	1
Anastomotic leakage, n (%)	–	1 (0.7)	0.43
Biliary leakage, n (%)	–	1 (0.7)	0.43
Intestinal perforation, n (%)	–	1 (0.7)	0.43
Sepsis, n (%)	1 (0.5)	–	1
Thrombocytopenia, n (%)	–	1 (0.7)	0.43
Local hematoma, n (%)	–	1 (0.7)	0.43

Discussion and conclusion

To our knowledge, this is the first study reporting a series of gastric bypass surgeries with the da Vinci Xi Surgical System aside from the report about our early experience with the new system [10]. While our cohorts originate from two different time spans, they still are comparable as the different patient characteristics were similar. Furthermore, inclusion criteria for Roux-en-Y gastric bypass surgery stayed the same throughout the period and correspond to the guidelines of the "Swiss Society for the Study of Morbid Obesity and Metabolic Disorders (SMOB)" (http://www.smob.ch/fr/directives. Last accessed October 10, 2018.).

We observed in our study significantly longer docking times with the da Vinci Xi compared with the da Vinci Si Surgical System. A former report about our early experience with the da Vinci Xi Surgical System observed already longer docking times with the Xi System [10]. While the former report reflected the early experience with the Xi System including the learning curve for docking, present data reflect our long-term experience with the Xi System and still show longer docking times. The observation is most likely due to some space constraints in our operating rooms caused by firmly installed overhead frames for airflow as already stated [10]. Although the da Vinci Xi Surgical System was developed to facilitate the setup procedure, its hardware including the patient cart is more voluminous than the prior da Vinci Si System. Our observation therefore attests the importance of an adequate operating room design when using the da Vinci Xi Surgical System.

The lower rate of cholecystectomy in the da Vinci Xi cohort is due to a recent modification of our surgical protocol towards realizing cholecystectomy only in patients presenting gallstones on a preoperative ultrasound. Literature has shown evidence that concomitant cholecystectomy during gastric bypass should not be performed in patients without cholelithiasis. A national database study has shown higher rates of postoperative complications, reinterventions, and mortality as well as longer hospital stay in patients who underwent concomitant cholecystectomy [12]. A meta-analysis has shown very low risks of developing choledocholithiasis (0.2%), biliary pancreatitis (0.2%), or suffering from surgery-related complications in case of subsequent cholecystectomy (0.1%) for patients after gastric bypass without cholecystectomy [13]. Despite a lower rate of cholecystectomy in the Xi cohort, mean total operative times were similar in both cohorts. Even after excluding patients who underwent cholecystectomy, there was no difference of mean total operative time between the two cohorts. Since introduction of the Xi system, the surgical team in our center has partially changed. The change of the surgical team should not have significantly influenced operating room times as learning curves have been shown to be very short in robotic gastric bypass surgery [14, 15].

Interestingly, we observed shorter anastomotic times in the da Vinci Xi group. The reason might be a recent standardization of our anastomotic suturing technique. As the core technology of the da Vinci system including Endowrist

Table 4 Comparative cost analysis

Parameter	da Vinci Si System (Intuitive Surgical)	da Vinci Xi System (Intuitive Surgical)
Acquisition costs, EUR		
Robot simple console	1,590,000	1,850,000
Robot 2nd console	450,000	450,000
Maintenance costs, EUR/year		
Robot simple console	150,000	150,000
Robot double console	175,000	175,000
Standard set of instruments*, EUR	2095	2258

Prices are shown in EUR as indicated by the local sales representative as of November 2018

*Set includes the following: 1 da Vinci Harmonic ACE, 1 needle driver, 1 long tip forceps, 2 cadière forceps, 1 permanent cautery hook, 1 fenestrated bipolar forceps, necessary accessories (drapes etc.)—all by Intuitive Surgical Inc., Sunnyvale, CA, USA

Instrumentation and Intuitive Motion technology (www.intuitivesurgical.com) is part of both Si and Xi system, ergonomics did not change between the systems and do not explain the observed differences. At the origin of shorter anastomotic times might be an increased range of motion and reach of instruments with the Xi system. The Xi system allows adjustments to the patient clearance joints of each robot arm gaining 28° of movement over the Si system at maximum instrument reach [16]. Both anastomoses during our bypass gastric procedure are performed in the left upper quadrant, but suturing of the jejunojejunal anastomosis needs particular high range of motion and reach of instruments as it is performed near the left abdominal wall.

Changing to the Xi robotic system did not generate a higher conversion rate as only one conversion to a laparoscopic procedure occurred in the Xi group. Conversion was due to repetitive system failure of the Xi robot. Overall robotic malfunction and system failure rates were very low with both systems. We still observed a trend towards higher malfunction rates with the recently introduced Xi system. Overall, with the larger dimensions of the Xi system, we observed more physical damage of the Xi Surgical System and we suspect an overall higher sensitivity of the system to wear and tear. Still, these observations are in accordance with previously reported low malfunction rates in robotic general surgery procedures from 2006 until 2012 in our center with a trend a towards lower malfunction rates with increased experience [17].

Minor complication rates between 10 and 14% and major complication rates between 5 and 6% correspond to overall complication rates reported for robotic gastric bypass procedures ranging between 2 and 29% [1]. Overall similar clinical outcomes were also reported for the da Vinci Si and Xi systems in multi-quadrant robotic colorectal surgery with notably no increase with the Xi system in operative time, bleeding, or postoperative complications [18]. Still, as overall complication rates are low in bariatric surgery, higher case numbers than in our study would be necessary to draw a conclusion about similar complication rates.

In our cost analysis, we did not consider costs for stapling devices as we used different types of staplers over the time span of this study. A recently published study from our center compared costs for manual with robotic stapling device and concluded higher costs for the robotic stapling device due to the shorter length of the robotic stapler and hence need for more stapling recharges [19].

Our study has the known limitations of a retrospective study. Another drawback is that cohorts originate from two different time spans with different surgeons and evolving techniques of, for example, anastomotic suturing over time.

Our study shows that, while gastric bypass procedures can be safely performed with both the da Vinci Xi and the da Vinci Si Surgical System, overall costs are higher for the Xi Surgical System.

Still there might be several reasons to invest in the Xi Surgical System. First of all, multidisciplinary programs including complex multi-quadrant procedures, as for example colorectal surgery, should benefit from the Xi Surgical System [10]. There might be interests of positioning a robotic program as state-of-the-art facility on a competitive market using a more recent technology. By attracting new patients, payer mix of health care costs might be influenced.

On the other hand, in markets with lower level of competition the purchase of the Xi Surgical System might not be reasonable. Furthermore, programs that target only few different and no multi-quadrant procedures might not benefit from the Xi Surgical System and choose the less costly option of the Si Surgical System.

Robotic surgery is currently a highly evolutive market with new robotic surgical systems that have been released or will be released in the near future. Senhance Surgical Robotic System (TransEnterix Inc., Morrisville, NC, USA) is a recently released new robotic surgical system. It has a lower system level but attractive costs compared with the da Vinci Surgical System. Examples for currently developed robotic systems are Verb Surgical (Verb Surgical Inc., Mountain View, CA, USA) and Medtronic (Medtronic plc, Dublin, Ireland). Intuitive Surgical (Intuitive Surgical Inc., Sunnyvale, CA, USA) has recently released the new da Vinci X Surgical System. The X Surgical System has combined elements of both the Si and the Xi system and is a less expensive alternative to the Xi System. In contrast to the Xi System, the X Surgical System is not meant for multi-quadrant surgery and might replace the Si System in the future. Therefore, health care providers who are not targeting surgical procedures during which the Xi feature brings incremental value might choose a less costly option.

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Authors' contributions Nadja Niclauss, Philippe Morel, and Monika E. Hagen were implicated in study conception and design. All authors realized acquisition of data. Nadja Niclauss and Monika E. Hagen performed analysis and interpretation of data. Nadja Niclauss and Monika E. Hagen wrote the manuscript draft. All authors revised the manuscript.

Compliance with ethical standards

Conflict of interest Nadja Niclauss and Philippe Morel have no conflicts of interest to declare. Minoa K. Jung received fellowship grants non-related to the research from Ethicon Inc. and Intuitive Surgical Inc. Monika E. Hagen received personal fees and non-financial support from Intuitive Surgical Inc. and Ethicon Inc., outside this project.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards with the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

1. Jung MK, Hagen ME, Buchs NC, Bühler LH, Morel P (2017) Robotic bariatric surgery: a general review of the current status. Int J Med Robot 13:e1834–e1840
2. Snyder BE, Wilson T, Leong BY, Klein C, Wilson EB (2010) Robotic-assisted Roux-en-Y gastric bypass: minimizing morbidity and mortality. Obes Surg 20:265–270
3. Markar SR, Karthikesalingam AP, Venkat-Ramen V, Kinross J, Ziprin P (2011) Robotic vs. laparoscopic Roux-en-Y gastric bypass in morbidly obese patients: systematic review and pooled analysis. Int J Med Robot 7:393–400
4. Wang L, Yao L, Yan P, Xie D, Han C, Liu R, Yang K, Guo T, Tian L (2018) Robotic versus laparoscopic Roux-en-Y gastric bypass for morbid obesity: a systematic review and meta-analysis. Obes Surg 28:3691–3700
5. Khorgami Z, Aminian A, Shoar S, Andalib A, Saber AA, Schauer PR, Brethauer SA, Sclabas GM (2017) Cost of bariatric surgery and factors associated with increased cost: an analysis of national inpatient sample. Surg Obes Relat Dis 13:1284–1289
6. Sharma G, Strong AT, Tu C, Brethauer SA, Schauer PR, Aminian A (2018) Robotic platform for gastric bypass is associated with more resource utilization: an analysis of MBSAQIP dataset. Surg Obes Relat Dis 14:304–310
7. Lundberg PW, Wolfe S, Seaone J, Stoltzfus J, Claros L, El Chaar M (2018) Robotic gastric bypass is getting better: first results from the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program. Surg Obes Relat Dis 14:1240–1245
8. Celio AC, Kasten KR, Schwoerer A, Pories WJ, Spaniolas K (2017) Perioperative safety of laparoscopic versus robotic gastric bypass: a propensity matched analysis of early experience. Surg Obes Relat Dis 13:1847–1852
9. Sebastian R, Howell MH, Chang KH, Adrales G, Magnuson T, Schweitzer M, Nguyen H (2019) Robot-assisted versus laparoscopic Roux-en-Y gastric bypass and sleeve gastrectomy: a propensity score-matched comparative analysis using the 2015-2016 MBSAQIP database. Surg Endosc 33:1600–1612
10. Hagen ME, Jung MK, Ris F, Fakhro J, Buchs NC, Buehler L, Morel P (2017) Early clinical experience with the da Vinci Xi Surgical System in general surgery. J Robotic Surg 11:347–353
11. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213
12. Worni M, Guller U, Shah A, Gandhi M, Shah J, Rajgor D, Pietrobon R, Jacobs DO, Ostbye T (2012) Cholecystectomy concomitant with laparoscopic gastric bypass: a trend analysis of the nationwide inpatient sample from 2001 to 2008. Obes Surg 22: 220–229
13. Warschkow R, Tarantino I, Ukegjini K, Beutner U, Güller U, Schmied BM, Müller SA, Schultes B, Thurnheer M (2013) Concomitant cholecystectomy during laparoscopic Roux-en-Y gastric bypass in obese patients is not justified: a meta-analysis. Obes Surg 23:397–407
14. Mohr CJ, Nadzam GS, Alami RS, Sanchez BR, Curet MJ (2006) Totally robotic laparoscopic Roux-en-Y gastric bypass: results from 75 patients. Obes Surg 16:690–696
15. Buchs NC, Pugin F, Bucher P, Hagen ME, Chassot G, Koutny-Fong P, Morel P (2012) Learning curve for robot-assisted Roux-en-Y gastric bypass. Surg Endosc 26:1116–1121
16. Ngu JC, Tsang CB, Koh DC (2017) The da Vinci Xi: a review of its capabilities, versatility, and potential role in robotic colorectal surgery. Robot Surg 4:77–85
17. Buchs NC, Pugin F, Volonté F, Morel P (2014) Reliability of robotic system during general surgical procedures in a university hospital. Am J Surg 207:84–88
18. Protyniak B, Jorden J, Farmer R (2018) Multiquadrant robotic colorectal surgery: the da Vinci Xi vs. Si comparison. J Robotic Surg 12:67–74
19. Hagen ME, Jung MK, Fakhro J, Buchs NC, Buehler L, Mendoza JM, Morel P (2018) Robotic versus laparoscopic stapling during robotic Roux-en-Y gastric bypass surgery: a case-matched analysis of costs and clinical outcomes. Surg Endosc 32:472–477