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Original Research

Two years of experience with robot-assisted anti-reflux surgery: A retrospective cohort study

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HIGHLIGHTS

- Robot-assisted anti-reflux surgery was compared to laparoscopy.
- All patients over a study period of two years was included.
- Robot-assisted anti-reflux surgery had longer duration of surgery.
- There was no significant advantages to robot-assisted surgery.
- There was no significant learning curve for an experienced surgeon.

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ABSTRACT

Background and aims: Robot-assisted anti-reflux surgery (RAAS) is an alternative to conventional laparoscopic anti-reflux surgery (CLAS). The purpose of this study was to evaluate initial Danish experiences with robot-assisted anti-reflux surgery compared to conventional laparoscopic anti-reflux surgery incorporating follow-up and evaluation of possible learning curve.

Material and methods: Patients undergoing primary RAAS or CLAS at The Department of Surgery A, Odense University Hospital and The Department of General Surgery, Kolding Hospital from April 2013 to April 2015 was included. Demographic data, comorbidity, docking time, length of procedure, type of fundic wrap as well as perioperative complications and postoperative complications, need for reoperation or any upper gastrointestinal endoscopy from surgery to final follow-up was retrospectively extracted from patient records.

Results: 103 patients were included in this study. 39 patients underwent RAAS and 64 patients underwent CLAS. There were no statistically significant differences in demographic data or comorbidities except distribution of heart disease (RAAS: 5.1% vs. CLAS: 18.8%, $p = 0.05$) and previous abdominal surgery (RAAS: 28.2% vs. CLAS: 48.4%, $p = 0.04$). Duration of surgery was significantly increased in patients undergoing RAAS (RAAS: 135 ± 27 min vs. CLAS: 86 ± 19 min, $p < 0.01$). There was no statistical significant difference in intraoperative complications ($p = 0.20$), 30-day postoperative complication rate ($p = 0.20$) or mortality ($p = 1.00$).

At follow-up in April 2016, there were no statistically significant differences in patients having undergone upper endoscopy postoperatively ($p = 0.92$), the use of anti-secretory drugs ($p = 0.46$) or patients having undergone reoperation ($p = 0.60$).

Reasons for reoperation were significantly dependent on type of fundic wrap with reoperation of Nissen fundoplication being dysphagia and reoperation of Toupet being recurrent reflux ($p = 0.008$). There was no clearly determined learning curve.

Conclusions: RAAS was safe, feasible and with equal efficacy to CLAS. There were however no particular advantages to performing antireflux surgery as robot-assisted procedures neither intra-operatively nor at follow-up.

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1. Introduction

Conventional laparoscopic anti-reflux surgery (CLAS) is the gold standard for surgical treatment of gastroesophageal reflux disease with high patient satisfaction and excellent results compared to medical treatment [1]. The development of anti-reflux surgery from open to a minimal invasive laparoscopic approach has resulted in reduced postoperative pain and shorter procedure-related length of stay without compromising patient satisfaction [2].

Robotic surgical platforms have been introduced and applied for a variety of surgical procedures. In the United States, 31.867 procedures, approximately 4.3% of all general surgery operations, were performed with robotic assistance in 2009 [3]. Robotic technology offers technical improvements to conventional laparoscopy by integrating 3D visualization, offering increased maneuverability of applied instruments and improving ergonomic comfort for the surgeon [4].

Robot-assisted anti-reflux surgery (RAAS) has been performed and evaluated with six randomized clinical trials and subsequent meta-analysis [5,6], demonstrating longer operating time and non-superiority compared to the conventional laparoscopic approach, but the included studies are small, heterogeneous, include only short-term follow-up and lack focus on the possible differences between complete and partial fundoplication.

The purpose of this study was to evaluate initial Danish experiences with robot-assisted anti-reflux surgery, comparing the technique to conventional laparoscopic anti-reflux surgery incorporating operative parameters as well as follow-up of complications and possible reoperation. Furthermore the purpose was to investigate whether a learning curve was present when introducing the robot-assisted procedure to experienced laparoscopic surgeons.

2. Methods and materials

2.1. Patient selection and preoperative evaluation

Included in this retrospective cohort study were all consecutive patients undergoing primary anti-reflux surgery as either laparoscopic or robot-assisted procedure at The Department of Surgery A, Odense University Hospital and The Department of General Surgery, Kolding Hospital for a two year period (April 2013–April 2015). Patients with a hiatal hernia larger than 5 cm were excluded from the study as was patients undergoing cholecystectomy and fundoplication as a combined procedure. Doing the study period, no patients were selected for primary open surgery.

All patients had been evaluated preoperatively with upper gastrointestinal endoscopy, 24-h pH measurement and esophageal manometry as recommended before anti-reflux surgery [7]. All included patients had pathological gastroesophageal reflux disease verified by pH-measurement and inadequate effect of medical treatment with split-dose proton-pump inhibitors.

Demographic data on age, sex and body mass index (BMI) was registered preoperatively. Comorbidity in the form of American Society of Anastesiologists (ASA)-score, diabetes, heart disease, cerebrovascular disease, lung disease, hypertension, hypercholesterolemia, history of smoking and/or alcohol abuse (defined as consumption of >21 units of 12 g of alcohol per week for men and >14 units of 12 g of alcohol per week for women) and previous abdominal surgery, was also registered preoperatively.

2.2. Surgical technique

Pneumoperitoneum was established and trocars placed. If the surgery was performed as a robot-assisted procedure, the robotic platform (Da Vinci SI, Intuitive Surgical, Sunnyvale, California, USA) was docked.

Using a bipolar vessel sealer and divider (laparoscopy: Ligasure, Covidien, Copenhagen, Denmark. Robotic platform: Vessel Sealer, Intuitive Surgical, Sunnyvale, California, USA) the gastrohepatic ligament was divided along the lesser curvature, exposing the right crus (Picture 1). The short gastric vessels (Picture 2) and gastrosplenic ligament were divided to the angle of His and the left crus exposed. If a hiatal hernia was present, the hernia sac was completely reduced with careful attention not to harm the pleura, esophagus and vagus nerves. The esophagus was mobilized to allow for at least 3 cm of tension-free intraabdominal esophagus. No Collis gastroplasty was performed in any of the cases.

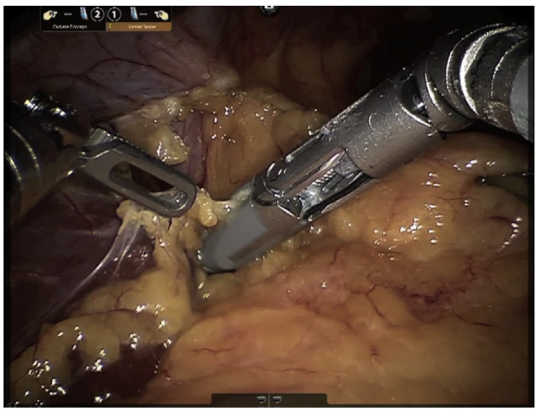
Cruraplasty was now performed with sutured closure using figure-eight non-absorbable multifilament sutures (TiCron, Covidien, Copenhagen, Denmark) (Picture 3). Mesh was not used to reinforce the crural closure as tension-free adequate closure was possible in all cases Hereafter fundoplication was performed, either as 360° Nissen procedure or if manometry had demonstrated reduced esophageal motility, using the 270° posterior Toupet procedure. Toupet procedure was also performed if a sufficiently floppy wrap could not be achieved during Nissen fundoplication. Routinely, a 56Fr Bougie was used to calibrate the fundic wrap. Both procedures were performed using nonabsorbable multifilament sutures (TiCron, Covidien, Copenhagen, Denmark) and anchored with single sutures at the most lateral parts of the wrap, to the right and left crus respectively (Picture 4). Finally all trocars were removed under direct vision and at 12 mm trocar sites the fascia was closed, before the skin-incisions were sutured.

Docking time, length of procedure, type of fundic wrap and intraoperative complications defined as lesion or perforation of pleura, stomach, esophagus, liver or spleen, aspiration or myocardial infarction during anesthesia, conversion to open or laparoscopic surgery and blood loss above 100 ml, was registered immediately postoperatively.

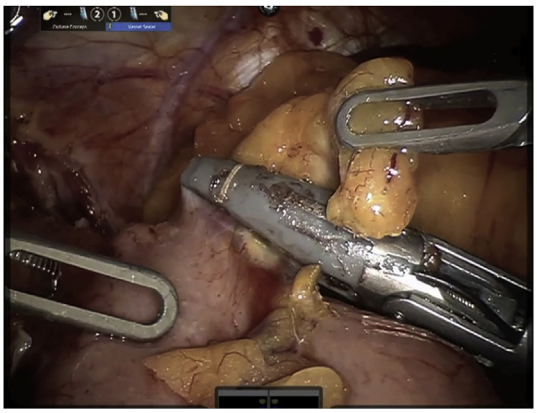
Patients were treated with paracetamol/acetaminophen and ibuprofen for pain relief postoperatively. All proton pump inhibitors and other anti-secretory drugs were discontinued immediately after surgery. Patients were discharged as soon as postoperative pain was sufficiently managed and they were able to ingest liquids orally.

2.3. Follow-up

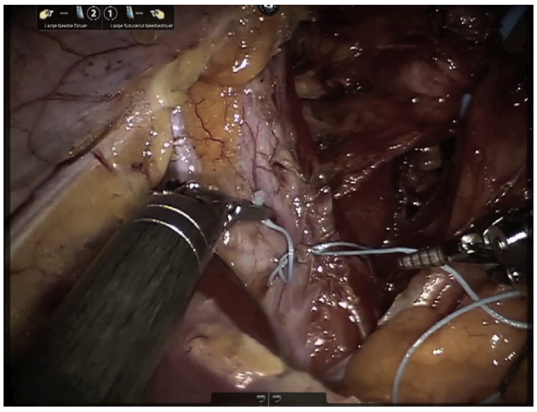
Postoperative complications within 30 days, defined as complications with a score of 2 or more according to the Clavien-Dindo



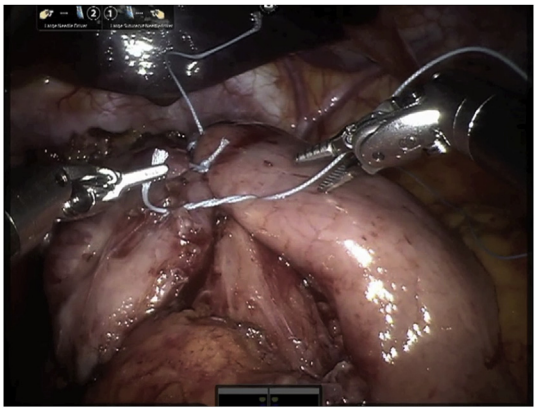
Picture 1. Opening of the gastrohepatic ligament.



Picture 2. Division of the short gastric vessels.



Picture 3. Crural closure.



Picture 4. Suturing the Nissen fundoplication.

classification [8,9], 30-day mortality and need for reoperation, or any upper gastrointestinal endoscopy from surgery to final follow-up, was retrospectively extracted from patient records. Follow-up was conducted in April 2016 resulting in a follow-up period of 1–3 years.

Therefore demographic data, comorbidity and operative data was registered prospectively and only follow-up performed retrospectively.

2.4. Statistical analysis

Patients were divided into two groups based on whether the procedure was performed purely as a laparoscopic procedure or as a robot-assisted procedure. Demographic data, comorbidity, perioperative data and postoperative follow-up data were compared using Chi^2 and students t-test for categorical and continuous variables respectively using STATA 14 (Statacorp, College Station, Texas, USA).

To assess development over time, all robot-assisted anti-reflux procedures were divided into four equal groups based on chronological occurrence. Mean operative time, docking and admission were compared using Wilks Lambda and perioperative complications, postoperative complications, use of PPI at follow-up, any upper endoscopy performed during follow up and any reoperation during followup, were compared using Chi^2 test.

Furthermore reoperation was subject to subanalysis by cause of reoperation, type of index surgery and type of fundic wrap at index surgery. Analysis was performed using Chi^2.

Risk analysis and regression was not performed in the primary analysis due to the small sample size. Likewise sub-analysis could not be performed on patients undergoing reoperation, as expected rate of reoperation was 5% in accordance with previously published literature [10], yielding a very small sample.

3. Results

103 patients were included in the study. 39 patients underwent RAAS and 64 patients underwent CLAS. There was no statistical difference in age (RAAS: 52,0 ± 14.6 years vs. CLAS: 49.4 ± 15.4 years, $p = 0.40$), distribution of sex (RAAS: 46.1% male vs. CLAS: 35.9% male, $p = 0.30$) or BMI (RAAS: 26.5 ± 3.1 kg/m^2 vs. CLAS: 26.9 ± 3.4 kg/m^2, $p = 0.57$).

3.1. Comorbidity

There were no significant differences in distribution of ASA-score ($p = 0.16$), diabetes ($p = 0.20$), cerebrovascular disease ($p = 0.17$), lung disease ($p = 0.44$), hypercholesterolemia ($p = 0.07$), hypertension ($p = 0.91$), smoking ($p = 0.67$) or alcohol abuse ($p = 0.43$) when comparing patients undergoing RAAS with patients undergoing CLAS. There was a significant difference in distribution of heart disease (RAAS: 5.1% vs. CLAS: 18.8%, $p = 0.05$) and previous abdominal surgery (RAAS: 28.2% vs. CLAS: 48.4%, $p = 0.04$) with the most common previous surgical procedures being gynecological procedures, appendectomy and cholecystectomy. Demographic data and comorbidities are summarized in Table 1.

3.2. Operative data

Operative time was significantly increased in patients undergoing RAAS (RAAS: 135 ± 27 min vs. CLAS: 86 ± 19 min, $p < 0.01$). Docking with the robotic platform was per definition only relevant for RAAS and was 6.4 ± 3.4 min. There was a significant difference in fundic wrap type when comparing RAAS and CLAS (RAAS; 360° Nissen: 38.5%, 270° Toupet: 61.5% vs. CLAS; 360° Nissen: 76.6%, 270° Toupet: 23.4%. $p < 0.01$). There was no statistical significant difference in occurrence of intraoperative complications (RAAS: 2.6% vs. CLAS: 0%, $p = 0.20$), blood loss above 100 ml (RAAS: 5.2% vs. CLAS: 0%, $p = 0.07$), conversion rate (RAAS: 2.6% vs. CLAS: 0%, $p = 0.20$) or length of stay (RAAS: 1.1 ± 0.6 days vs. CLAS: 1 ± 0 day $p = 0.20$).

A single intraoperative complication occurred during robot-assisted fundoplication: an intraoperative perforation of the stomach. The perforation was sutured and the patient was

Table 1
Demographic data and comorbidity of included patients. Age and BMI reported as mean ± standard deviation. Statistically significant differences highlighted.

	RAAS	CLAS	P-value
	N = 39	*N = 64*	
Demographic data			
Age	52.0 ± 14.6	49.4 ± 15.4	0.40
Sex (% male)	46.1% (n = 18)	35.9% (n = 23)	0.30
BMI	26.5 ± 3.1 kg/m^2	26.9 ± 3.4 kg/m^2	0.57
Comorbidities			
ASA (%)			0.16
- ASA 1	30.8% (n = 12)	28.1% (n = 18)	0.77
- ASA 2	66.6% (n = 26)	57.8% (n = 37)	0.37
- ASA 3	2.6% (n = 1)	14.1% (n = 9)	0.06
Diabetes (%)	2.6% (n = 1)	0% (n = 0)	0.20
Heart disease (%)	**5.1% (n = 2)**	**18.8% (n = 12)**	**0.05**
Cerebrovascular (%)	0% (n = 0)	4.7% (n = 3)	0.17
Lung disease (%)	7.7% (n = 3)	12.5% (n = 8)	0.44
Hypercholesterolemia (%)	28.2% (n = 11)	14.1% (n = 9)	0.07
Hypertension (%)	30.8% (n = 12)	29.7% (n = 19)	0.91
Smoking (%)	20.5% (n = 8)	17.2% (n = 11)	0.67
Alcohol abuse (%)	0% (n = 0)	1.6% (n = 1)	0.43
Previous abdominal surgery (%)	**28.2% (n = 11)**	**48.4% (n = 31)**	**0.04**

discharged on postoperative day one without further complications.

3.3. Follow-up

All patients were subject to follow-up (n = 109). There was no significant difference in 30-day postoperative complication rate (RAAS: 2.6% vs. CLAS: 0%, p = 0.20) or mortality (RAAS: 0% vs. CLAS: 0%, p = 1.00). At follow-up in April 2016, there were no statistically significant differences in patients having undergone unscheduled upper endoscopy postoperatively (RAAS: 18.0% vs. CLAS: 18.8%, p = 0.92) or the use of anti-secretory drugs (RAAS: 23.1% vs. CLAS: 17.1%, p = 0.46) There was also no statistically significant difference in duration of follow-up (RAAS: 26 (12–38) months vs. CLAS: 25 (13–37) months, p = 0.58). Operative and follow-up data are summarized in Table 2.

A single postoperative complication with a Clavien-Dindo score of ≥2 occurred after robot-assisted fundoplication, as a patient had prolonged pain postoperatively and was subject to a CT-scan on postoperative day three. The scan could not demonstrate any procedure-related complication and the patient were discharged on postoperative day five after adequate pain management.

3.4. Reoperation

7 patients were subject to reoperation during follow-up; 6 patients who received Nissen fundoplication at index surgery and 1 patients receiving Toupet fundoplication at index surgery. There was no statistical difference in reoperation based on type of surgery (RAAS: 5.1% vs. CLAS: 7.8%, p = 0.60) or type of fundic wrap (Nissen; 9.4% vs. Toupet: 2.6%, p = 0.18). There was a statistical significant difference when comparing cause of fundoplication and type of fundic wrap (Nissen: 100% dysphagia-related, Toupet: 100% related to recurrence of reflux, p = 0.008). Data on cause of reoperation are summarized in Table 3.

Table 3
Subanalysis of reoperation by type of fundoplication.

	Nissen (360°)	Toupet (270°)	P-value
	N = 6	*N = 1*	
Index surgery type			**0.495**
RAAS	100% (n = 2)	0% (n = 0)	
CLAS	80% (n = 4)	20% (n = 1)	
Cause of reoperation			**0.008**
Dysphagia	100% (n = 6)	0% (n = 0)	
Recurrent reflux	0% (n = 0)	100% (n = 1)	

Table 2
Operative data and follow-up. Docking time, operative time and length of stay reported as mean ± standard deviation. Duration of follow-up reported as mean and range in months. As no docking is performed during CLAS, no p-value was calculated. Statistically significant differences highlighted.

	RAAS	CLAS	P-value
	N = 39	*N = 64*	
Operative data			
Docking time	**6.4 ± 3.4 min**	–	–
Operative time	**135 ± 27 min**	**86 ± 19 min**	**<0.01**
Type of wrap (%Nissen/%Toupet)	**38.5%/61.5%**	**76.6%/23.4%**	**<0.01**
Conversion (%)	2.6% (n = 1)	0% (n = 0)	0.20
Blood loss >100 ml (%)	5.2% (n = 2)	0% (n = 0)	0.07
Intraoperative complications (%)	2.6% (n = 1)	0% (n = 0)	0.20
Length of stay	1.1 ± 0.6 days	1 ± 0 day	0.20
Follow-up			
Postoperative complications (%)	2.6% (n = 1)	0% (n = 0)	0.20
30-day mortality (%)	0% (n = 0)	0% (n = 0)	1.00
Upper endoscopy (%)	18.0% (n = 7)	18.8% (n = 12)	0.92
Reoperation (%)	5.1% (n = 2)	7.8% (n = 5)	0.60
Use of anti-secretory drugs (%)	23.1% (n = 9)	17.2% (n = 11)	0.46
Duration of follow-up	26 (12–38) months	25 (13–37) months	0.58

3.5. Learning curve

Comparing operative time, docking time, intra- and postoperative complication and length of stay, no statistical difference could be found over time. No statistical difference could be demonstrated over time regarding use of PPI, utilization of upper endoscopy or need for reoperation at follow-up. Data on possible learning curve are summarized in Table 4. Development of operative time is displayed in Fig. 1.

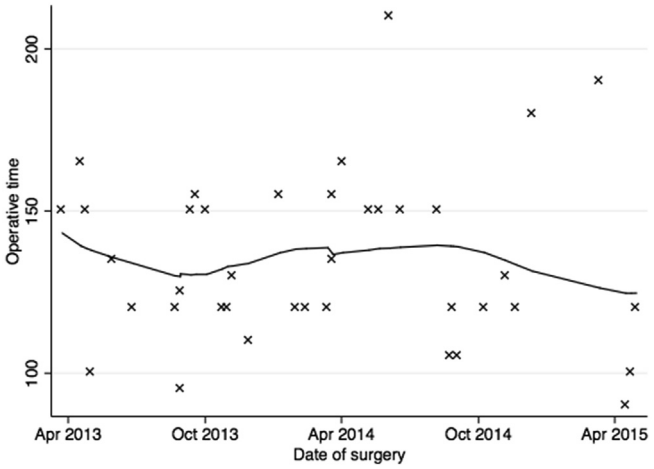


Fig. 1. Development in operative time during the study period with trend.

4. Discussion

Patients selected for CLAS had a higher rate of previous abdominal surgery and heart disease. Operative time was significantly prolonged in RAAS and there was a significant difference in distribution of Toupet and Nissen fundoplication when comparing RAAS and CLAS. However when assessing Toupet fundoplication and Nissen fundoplication separately there was still a significantly prolonged operative time when comparing RAAS and CLAS (Toupet: $p < 0.01$, Nissen: $p < 0.01$). Although selection of patients for surgery was performed in the same way regardless of whether CLAS or RAAS was used, we did not randomize patients and there is a possible selection bias reflected in the difference in preoperative comorbidity. However, as this did not result in increased rate of intraoperative or postoperative complications, we consider this a random effect with little influence on the results of this study. In our data we cannot establish whether the different distribution of type of fundic wrap is due to a higher degree of esophageal dysmotility or simply because a "floppy" Nissen was not possible to achieve in patients undergoing robot-assisted surgery.

Docking time has been considered to contribute substantially to the overall operative time in robot-assisted surgery and decreased during the two years of performing RAAS. There was a statistically significant decrease in docking time when comparing the four consecutive time-periods of RAAS ($p = 0.08$) but as docking time was already low, the reduction was not clinically significant. We consider docking inconvenient but without marked effect on total operative time. The short docking time is contributed to a dedicated robotic surgical team with experience from other types of robot-assisted surgeries. In any other relevant parameter including operative time, postoperative complications and reoperation, we could not demonstrate a statistically significant reduction over time and no learning curve could be established. This could be attributed to the fact, that the operating surgeons are capable laparoscopic surgeons or could be due to a significant variance and small sample size in this study. When comparing surgeons, there was no statistical significance in operative time or outcome when adjusting for type of surgery.

RAAS was safe compared to CLAS with no statistically significant increase in intraoperative complications and conversion rate from robotic to laparoscopic approach was low. No procedures were converted to open surgery. Meta-analysis has not been able to demonstrate a significant difference in intraoperative complications when comparing robot-assisted to conventional laparoscopic approach [6]. However, including previously published series [11–15], a total of five unique patients, including our single case, experienced intraoperative perforation of the stomach. This is a very rare complication in conventional laparoscopic fundoplication and may be a consequence of the lack of haptic feedback combined with the inhuman strength of the robotic platform.

RAAS and CLAS were comparable with regards to utilization of upper endoscopy during follow-up, the use of anti-secretory drugs and reoperation. Upper endoscopy was most often performed as part of examination for postoperative dysphagia and anti-secretory drugs used were in all cases proton pump inhibitors. The use of anti-secretory drugs after fundoplication was similar to rates reported in a recent nationwide Danish registry-based study [16], but just as in the registry-based study we did not perform pH-measurement to establish whether recurrence of symptoms actually represented recurrence of reflux. None of the patients were prescribed proton pump inhibitors by the surgeons. The indication for anti-secretory treatment is unknown in this study, as the majority of PPI were prescribed in primary care. This is comparable to known literature [17].

We could not demonstrate a higher reoperation rate in patients undergoing primary RAAS or higher degree of upper endoscopy as a surrogate endpoint of postoperative dysphagia. It has previously been theorized that the lack of haptic feedback during robot-

Table 4
Evaluation of possible learning curve of RAAS. Docking time, operative time and length of stay reported as mean ± standard deviation.

	Period I	Period II	Period III	Period IV	*P-value*
	N = 10	*N = 10*	*N = 10*	*N = 9*	
Operative data					
Operative time	131 ± 7.3 min	137.5 ± 6.9 min	147.5 ± 9.2 min	121.7 ± 9.5 min	0.19
Docking	8.1 ± 1.0 min	7.3 ± 1.2 min	4.8 ± 1.1 min	5.3 ± 0.6 min	0.08
Intraoperative complications	0% (n = 0)	0% (n = 0)	10% (n = 1)	0% (n = 0)	0.40
Postoperative complications	0% (n = 0)	0% (n = 0)	0% (n = 0)	11.1% (n = 1)	0.33
Length of stay	1 ± 0 days	1 ± 0 days	1 ± 0 days	1.4 ± 0.4 days	0.35
Follow-up					
Use of PPI	20% (n = 2)	40% (n = 4)	10% (n = 1)	22.2% (n = 2)	0.45
Upper endoscopy	30% (n = 3)	20% (n = 2)	0% (n = 0)	22.2% (n = 2)	0.35
Reoperation	10% (n = 1)	10% (n = 1)	0% (n = 0)	0% (n = 0)	0.57

assisted surgery makes constructing a suitably loose wrap more difficult resulting in increased rates of dysphagia with a higher rate of reoperation [5,18–20]. However the reason for this not occurring in our population may be that RAAS was primarily conducted as partial fundoplication, previously demonstrated to have lower rate of postoperative dysphagia and equal symptom relief to total fundoplication in conventional laparoscopy [21]. There was no statistical difference in frequency of reoperation based on wrap type, however reoperations of Nissen fundoplications were in all cases a result of dysphagia whereas Toupet fundoplication were redone due to recurrence of reflux ($p = 0.008$). When investigating robot-assisted anti-reflux surgery in systematic reviews and meta-analysis, the use and consequence of partial fundoplication has not been properly evaluated.

In published metananalysis [5,6], no operative aspects of robot-assisted anti-reflux surgery, has been proved to be superior to conventional laparoscopy. However, in a randomized controlled trial, Frazzoni et al. [22] demonstrated significantly reduced acid exposure time in patients having undergone robot-assisted Nissen fundoplication compared to conventional laparoscopy. The study could not demonstrate any significant difference in symptom relief or patient satisfaction. The technical adequacy of robotic anti-reflux surgery must be considered satisfactory even though there is no clinical significant difference in postoperative results.

The strength of our study relies on its inclusion of consecutive patients over two years and follow-up of at least 1 year for all patients. All surgeries were performed by one of two experienced laparoscopic surgeons utilizing the same procedural technique whether the surgery was performed as robot-assisted or as conventional laparoscopy. The weaknesses of this study are its retrospective design and the lack of systematic quality of life follow-up to screen for possible dysphagia not requiring redo-surgery as well as the lack of objective pH-measurement at follow-up. As previously mentioned, we cannot exclude the possibility of selection bias when choosing type of surgery, and we do not believe that heart disease or previous abdominal surgery should be considered a contraindication for robot-assisted surgery.

From a surgeons perspective there is a significant advantage of using the robotic surgical platform: ergonomic comfort. Conventional laparoscopy causes significant strain on the surgeon resulting in muscular pain [23]. Robotic surgery allows for different movements for the surgeon and seems promising in reducing muscular strain [24]. Only long-term use of robotic surgical platforms will demonstrate whether this can reduce pain in surgeons compared to conventional laparoscopy or whether the strain from using robotic platforms may simply be of a different nature.

When discussion robot-assisted surgery, the subject of cost must be mentioned. In our study, we did not register the cost of each procedure, however studies on cost of robot-assisted anti-reflux surgery has demonstrated significantly increased expenses compared to conventional laparoscopy [5,6], even if the initial cost of the robotic platform is excluded. Higgins et al. [25] performed a thorough supply cost analysis of robot-assisted anti-reflux surgery and concluded that expenses were doubled compared to laparoscopy. In a Danish setting, this is particularly problematic as anti-reflux surgery is reimbursed at the same rate regardless of robotic or conventional technique. This makes robot-assisted surgery less profitable especially when considering, that the prolonged operative time results in fewer possible procedures each day.

In our experience, the true improvement in robotic surgery compared to conventional laparoscopy is integrated 3D imaging technology. When using the robotic platform, dissection tends to be slower, there is a need for more large trocars and docking with the robotic platform, although minimized in our setup, does prolong surgery. However the robotic surgical platform is continuously developing and new models have reduced operative time and increased success in other types of surgery [26]. Continuous evaluation of robot-assisted anti-reflux surgery is required to take this development into account. At the present stage, with the technology available to us, we prefer 3D laparoscopy to the robotic platform when performing anti-reflux surgery. This also allows for the use of advanced laparoscopic bipolar dissection devices that in our opinion are both faster and more reliable than the bipolar dissection devices available to us on the robotic platform.

This study adds to the current body of knowledge by providing 1–3 years of follow-up including possible reoperation. It provides a small retrospective cohort of Danish patients, reviewing robot-assisted anti-reflux surgery in a setting, that is distinctively different from previously published papers on the subject. It also considers type of fundoplication, which has not previously been addressed in literature on robot-assisted anti-reflux surgery. Learning curve was also examined and there was no significant learning period for experienced laparoscopic surgeons.

5. Conclusion

RAAS was safe, feasible and with equal efficacy to CLAS. Operative time was significantly prolonged. In our study no significant learning curve could be demonstrated with experienced laparoscopic surgeons. Nissen fundoplication was more prone to result in dysphagia-related reoperation. There were no particular advantages when performing anti-reflux surgery as robot-assisted procedures, neither intra-operatively nor at follow-up. Continuous development of the robotic surgical platform may improve operating time and should be prospectively evaluated with randomization of patients to either 3D laparoscopy or robot-assisted partial fundoplication to ensure comparability and optimal patient outcome.

Ethical approval

The study was approved by the Danish Health and Medicines Authority (reference number 3-3013-1313/1).

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Author contribution

JS Jensen: Study design, Data collection, Data analysis, writing, manuscript editing, approved the final version.

HK Antonsen: Study design, Data collection, manuscript editing, approved the final version.

J Durup: Study design, Data collection, manuscript editing, approved the final version.

Declaration of conflicting interests

All named authors hereby declare that they have no conflicts of interest to disclose.

Trial registry

researchregistry1684.

Guarantor

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References

[1] N. Rickenbacher, T. Kotter, M.M. Kochen, M. Scherer, E. Blozik, Fundoplication versus medical management of gastroesophageal reflux disease: systematic review and meta-analysis, Surg. Endosc. 28 (2014) 143–155.

[2] M. Catarci, P. Gentileschi, C. Papi, A. Carrara, R. Marrese, A.L. Gaspari, G.B. Grassi, Evidence-based appraisal of antireflux fundoplication, Ann. Surg. 239 (2004) 325–337.

[3] M. Salman, T. Bell, J. Martin, K. Bhuva, R. Grim, V. Ahuja, Use, cost, complications, and mortality of robotic versus nonrobotic general surgery procedures based on a nationwide database, Am. Surg. 79 (2013) 553–560.

[4] B.P. Müller-Stich, M.A. Reiter, M.N. Wente, V.V. Bintintan, J. Köninger, M.W. Büchler, C.N. Gutt, Robot-assisted versus conventional laparoscopic fundoplication: short-term outcome of a pilot randomized controlled trial, Surg. Endosc. 21 (2007) 1800–1805.

[5] D. Falkenback, C.W. Lehane, R.V. Lord, Robot-assisted oesophageal and gastric surgery for benign disease: antireflux operations and Heller's myotomy, ANZ J. Surg. 85 (2015) 113–120.

[6] Z. Wang, Q. Zheng, Z. Jin, Meta-analysis of robot-assisted versus conventional laparoscopic Nissen fundoplication for gastro-oesophageal reflux disease, ANZ J. Surg. 82 (2012) 112–117.

[7] B.A. Jobe, J.E. Richter, T. Hoppo, J.H. Peters, R. Bell, W.C. Dengler, K. DeVault, R. Fass, C.P. Gyawali, P.J. Kahrilas, B.E. Lacy, J.E. Pandolfino, M.G. Patti, L.L. Swanstrom, A.A. Kurian, M.F. Vela, M. Vaezi, T.R. DeMeester, Preoperative diagnostic workup before antireflux surgery: an evidence and experience-based consensus of the Esophageal Diagnostic Advisory Panel, J. Am. Coll. Surg. 217 (2013) 586–597.

[8] P.A. Clavien, J. Barkun, M.L. de Oliveira, J.N. Vauthey, D. Dindo, R.D. Schulick, E. de Santibañes, J. Pekolj, K. Slankamenac, C. Bassi, R. Graf, R. Vonlanthen, R. Padbury, J.L. Cameron, M. Makuuchi, The Clavien-Dindo classification of surgical complications: five-year experience, Ann. Surg. 250 (2009) 187–196.

[9] D. Dindo, N. Demartines, P.-A. Clavien, Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey, Ann. Surg. 240 (2004) 205.

[10] P. Funch-Jensen, A. Bendixen, M.G. Iversen, H. Kehlet, Complications and frequency of redo antireflux surgery in Denmark: a nationwide study, 1997-2005, Surg. Endosc. 22 (2008) 627–630.

[11] M. Al-Naami, M.N. Anjum, A. Aldohayan, K. Al-Khayal, H. Alkharji, Robotic general surgery experience: a gradual progress from simple to more complex procedures, Int. J. Med. Robot. 9 (2013) 486–491.

[12] G. Ceccarelli, A. Patriti, A. Biancafarina, A. Spaziani, A. Bartoli, R. Bellochi, L. Casciola, Intraoperative and postoperative outcome of robot-assisted and traditional laparoscopic Nissen fundoplication, Eur. Surg. Res. 43 (2009) 198–203.

[13] M. Talamini, K. Campbell, C. Stanfield, Robotic gastrointestinal surgery: early experience and system description, J. Laparoendosc. Adv. Surg. Tech. A 12 (2002) 225–232.

[14] G.B. Cadière, J. Himpens, O. Germay, R. Izizaw, M. Degueldre, J. Vandromme, E. Capelluto, J. Bruyns, Feasibility of robotic laparoscopic surgery: 146 cases, World J. Surg. 25 (2001) 1467–1477.

[15] G.B. Cadière, J. Himpens, M. Vertruyen, J. Bruyns, O. Germay, G. Leman, R. Izizaw, Evaluation of telesurgical (robotic) NISSEN fundoplication, Surg. Endosc. 15 (2001) 918–923.

[16] A. Lodrup, A. Pottegard, J. Hallas, P. Bytzer, Use of proton pump inhibitors after antireflux surgery: a nationwide register-based follow-up study, Gut 63 (2014) 1544–1549.

[17] P. Haastrup, M.S. Paulsen, J.E. Zwisler, L.M. Begtrup, J.M. Hansen, S. Rasmussen, D.E. Jarbøl, Rapidly increasing prescribing of proton pump inhibitors in primary care despite interventions: a nationwide observational study, Eur. J. Gen. Pract. 20 (2014) 290–293.

[18] B.P. Müller-Stich, M.A. Reiter, A. Mehrabi, M.N. Wente, L. Fischer, J. Köninger, C.N. Gutt, No relevant difference in quality of life and functional outcome at 12 months' follow-up-a randomised controlled trial comparing robot-assisted versus conventional laparoscopic Nissen fundoplication, Langenbecks Arch. Surg. 394 (2009) 441–446.

[19] I.E. Nakadi, C. Mélot, J. Closset, V. DeMoor, K. Bétroune, P. Feron, P. Lingier, M. Gelin, Evaluation of da Vinci Nissen fundoplication clinical results and cost minimization, World J. Surg. 30 (2006) 1050–1054.

[20] W.A. Draaisma, J.P. Ruurda, R.C. Scheffer, R.K. Simmermacher, H.G. Gooszen, H.G. Rijnhart-de Jong, E. Buskens, I.A. Broeders, Randomized clinical trial of standard laparoscopic versus robot-assisted laparoscopic Nissen fundoplication for gastro-oesophageal reflux disease, Br. J. Surg. 93 (2006) 1351–1359.

[21] J.A. Broeders, F.A. Mauritz, U. Ahmed Ali, W.A. Draaisma, J.P. Ruurda, H.G. Gooszen, A.J. Smout, I.A. Broeders, E.J. Hazebroek, Systematic review and meta-analysis of laparoscopic Nissen (posterior total) versus Toupet (posterior partial) fundoplication for gastro-oesophageal reflux disease, Br. J. Surg. 97 (2010) 1318–1330.

[22] M. Frazzoni, R. Conigliaro, G. Colli, G. Melotti, Conventional versus robot-assisted laparoscopic Nissen fundoplication: a comparison of postoperative acid reflux parameters, Surg. Endosc. 26 (2012) 1675–1681.

[23] T. Dalager, K. Søgaard, K. Bech, O. Mogensen, P.T. Jensen, in: 19th International Meeting of the European Society of Gynecological Oncology (ESGO 2015), Int. J. Gynecol. Cancer, 25, 2015. ESGO–0780.

[24] A.M. Zihni, I. Ohu, J.A. Cavallo, S. Cho, M.M. Awad, Ergonomic analysis of robot-assisted and traditional laparoscopic procedures, Surg. Endosc. 28 (2014) 3379–3384.

[25] R.M. Higgins, M.J. Frelich, M.E. Bosler, J.C. Gould, Cost analysis of robotic versus laparoscopic general surgery procedures, Surg. Endosc. 31 (2017) 185–192.

[26] L. Morelli, S. Guadagni, G. Di Franco, M. Palmeri, G. Caprili, C. D'Isidoro, L. Cobuccio, E. Marciano, G. Di Candio, F. Mosca, Use of the new da Vinci Xi® during robotic rectal resection for cancer: a pilot matched-case comparison with the da Vinci Si®, Int. J. Med. Robot. (Jan 25, 2016) http://dx.doi.org/10.1002/rcs.1728 [Epub ahead of print].