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Single surgeon learning curve and initial experience with Hugo™ RAS for robotic repair of hiatal hernia versus conventional laparoscopy – an observational comparative cohort study (with video)

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Single surgeon learning curve and initial experience with Hugo™ RAS for robotic repair of hiatal hernia versus conventional laparoscopy – an observational comparative cohort study (with video)

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Abstract

Background: Despite increasing adoption of the novice robotic platform Hugo™ RAS for a wide spectrum of procedures in general surgery, reports on its use for hiatal hernia repair are still scarce.

Methods: The initial experience of a single surgeon with Hugo™ RAS for robotic hiatoplasty (RH) is presented. Configurational setup and surgical technique are described in detail. The learning curve of the first 35 RH is analyzed, and clinical outcomes are retrospectively compared to a historical group of the last 35 laparoscopic hiatoplasties (LH).

Results: Patient characteristics in the RH and LH groups didn't differ. Clinical outcomes and recurrence rates of RH were equivalent to LH. A transition to proficiency in the learning curve of RH was observed after case 10. After gaining proficiency median operative time of RH was shorter than that of LH, 125 vs 155 minutes, p=0,026. The use of robotic LigaSure® device appeared to reduce operative time from 169 to 120 minutes, p=0,009. Postoperative stay in the robotic group was significantly shorter (5 vs 6 days, p=0,012).

Conclusion: Robotic repair of hiatal hernia with the Hugo™ RAS was safe and feasible and the learning curve steep. Robotic assisted surgery showed comparable outcomes and was associated with shorter postoperative stay and a trend toward shorter operative time compared to conventional laparoscopy.

Introduction

Since its introduction to the market in 2021 Hugo™ RAS (Medtronic, Minneapolis, MN, USA) has been gaining momentum as a promising alternative to the established DaVinci platform in the fields of urology and gynecology. The experience with Hugo™ RAS in general surgery is still limited. This novel system suffers from a relatively limited choice of instruments and is not cleared for major HPB and thoracic surgery. Nevertheless, the platform is widely believed to offer some ergonomical and communication advantages through its open modular architecture and has witnessed an increased interest by general surgeons for a variety of upper and lower GI procedures and abdominal wall hernia repair [1, 2]. The current evidence about the use of Hugo™ RAS for the minimally invasive repair of hiatal hernia is very limited and its results have never been compared to conventional laparoscopy [1 - 3].

The aim of this single-center retrospective observational cohort study is to describe the configurational setup and surgical technique of robotic hiatal repair with the Hugo™ RAS, explore its safety and feasibility early in the learning curve of a robotically naïve singe surgeon and to compare its results to laparoscopic hiatal hernia repair.

Materials and methods

Patients

All patients scheduled for robotic surgery signed a written informed consent to be included in the observational PSR Study by Medtronic, which was approved by the Ethics Committee of the Ruhr University Bochum (Nr. 23-7872-BR). All patients in both the robotic and laparoscopic group signed written informed consent for surgery, data collection in the German Herniamed-register, and pseudonymized use of their clinical information for this research. The study was conducted in accordance with the Declaration of Helsinki. The manuscript adheres to the STROBE guidelines for observational studies.

Data of the first 35 patients with robotic hiatoplasty (RH) at our institution was compared to a historic group of the last 35 laparoscopic hiatal hernia repairs (LH) performed by the same surgeon (OB) for the period January 2024 till August 2026. The surgeon and his team were robotically naïve, i.e. it had no previous robotic experience with other systems than Hugo™ RAS. It was the first and only robotic system installed at our institution in February 2023. Before conducting the first robotic hiatal hernia repair the surgeon had successfully performed 45 other upper and lower GI surgeries with Hugo™ RAS, and as of today a total of 300 Hugo RAS general surgical procedures.

The standard preoperative diagnostic work-up for all patients with hiatal hernia at our institution includes contrast-enhanced computed tomography of the chest and upper abdomen, oral contrast swallow, esophagogastroduodenoscopy and 24-hours continuous pH-manometry to identify the size of the hiatal defect, motility disorders of the esophagus, extent of mediastinal stomach displacement and prove the presence of gastroesophageal reflux disease (GERD). Only patients with symptomatic hiatal hernia with partial or advanced mediastinal dislocation of the stomach are scheduled for surgery. After surgery a chest X-ray is done to exclude pneumothorax, and an oral contrast swallow is performed on the day before discharge to control successful results of the surgical repair.

Standard surgical setup for robotic hiatoplasty

Patients are placed supine in French position, with arms tucked, no additional protecting bars or cushions being used. Access to the abdomen is achieved in Hasson's open technique through a skin incision 2 cm to the left of the midline and 12-14 cm below the xyphoid. An 11-mm robotic port is inserted and CO_2 insufflated to a pressure of 12 mmHg. After inspection of the abdominal cavity an 8-mm robotic port is inserted 2 cm below the left costal arch, then a second 8-mm port is inserted in the epigastric region just to the right of the midline, and a third 8-mm robotic port – 2 cm below the right costal arch. A 12-mm port (Endopath XCEL™, J&J Medtech, USA) is placed in the left middle abdomen at the level of the umbilicus at least 5 cm below the robotic ports (**Figure 1**).

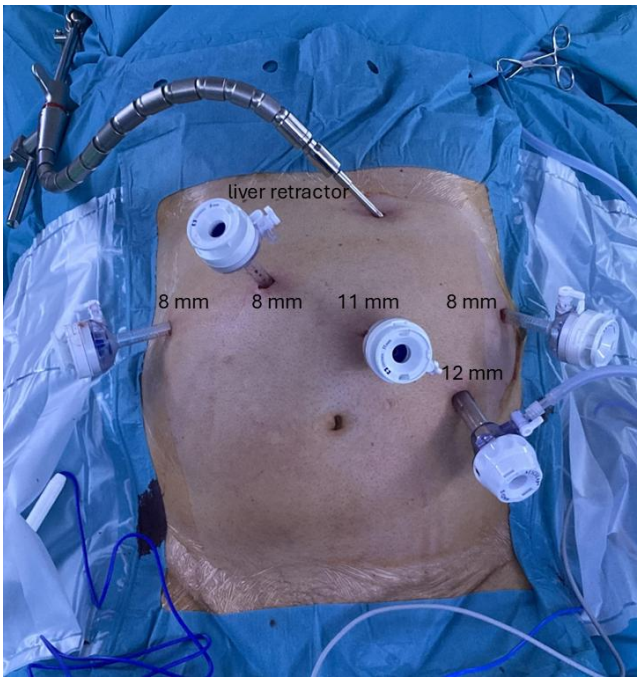


Figure 1: Port positions for RH with inserted Nathanson liver-retractor

All robotic ports are positioned at least 8 cm from each other to avoid arm collisions. As a result, in obese patients with wide upper abdomen, robotic ports stay almost in a horizontal line, while in asthenic patients the port-setup resembles an extended s-line. The standard setup includes neither an Air-Seal access port nor a liver retractor system. A Nathanson liver retractor was used only in two patients with extremely enlarged left hepatic lobe. Just before docking, the operating table is tilted 30° reverse Trendelenburg with slightly bent knees and 5° left-side-up. Arm 1 connects to the camera 11-mm port, Arm 2 – to the left subcostal port, Arm 3 - to the right subcostal port and Arm 4 - to the port right to the midline. The configuration of robotic arms is shown in **Figure 2**. During surgery, neither redocking of the arms, nor changing the table position is necessary.

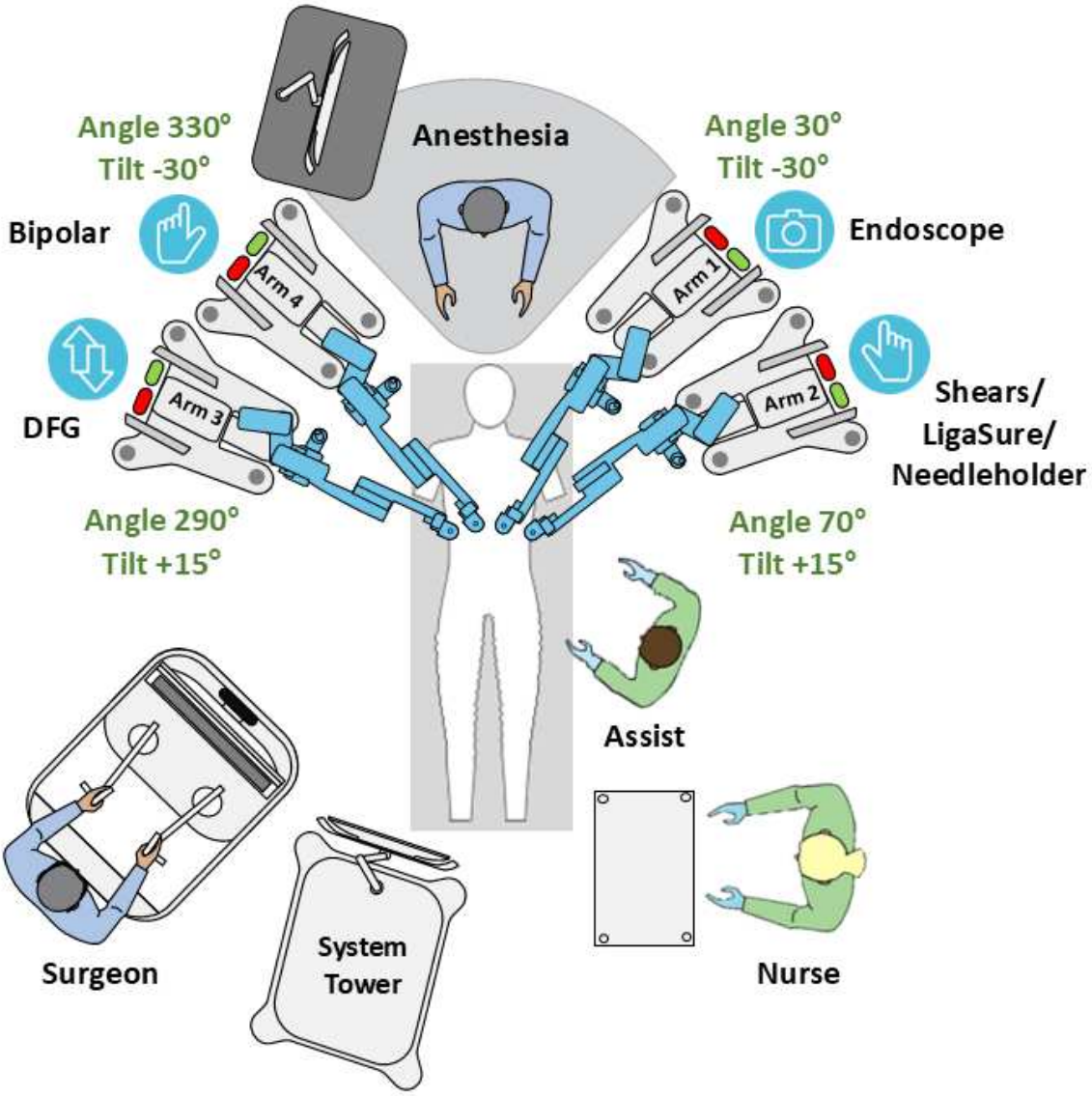


Figure 2: Configurational setup for RH

*Surgical procedure (**Suppl. Video 1**)*

Robotic surgery begins with a 0° endoscope on Arm 1, monopolar shears on the right hand (Arm 2), a bipolar grasper on the left hand (Arm 4), and a double-fenestrated grasper (DFG) as a reserve hand (Arm 3) (**Figure 3**).



Figure 3: View of operating room during RH

The hepatogastric ligament is widely opened, preserving the liver branches of the vagal nerve and a possible aberrant left hepatic artery from the left gastric artery. The esophagogastric junction is fully mobilized along the crura. The short gastric vessels are divided close to the stomach wall using a LigaSure device. In the first 20 patients the bed-side assistant used a laparoscopic LigaSure 44 cm blunt tip sealer-divider (Covidien, Mansfield, Massachusetts, USA) through the assist port. After its market introduction in October 2025, the robotic LigaSure RAS Maryland sealer-divider (Covidien, Mansfield, Massachusetts, USA) has become the standard used by the console surgeon on the right hand. The esophagogastric junction is wrapped with a gauze and manipulated by the DFG, which retracts the left lobe of the liver with its shaft at the same time. Full mobilization of the distal 10 cm of esophagus in the lower mediastinum is performed carefully protecting the pleura and the vagal nerves. The

hernial sac is excised only in cases where fundoplication is necessary. A posterior hiatoplasty is done using 3 to 4 single non-absorbable multifilament sutures of PremiCron 0 (B. Braun Surgical, Rubi, Spain). In larger defects one to two single sutures anteriorly may be added to avoid nonphysiological angulation of the esophagogastric junction. A 270° dorsal Toupet fundoplication is the method of choice performed only in cases of proven GERD. A mesh reinforcement of the hiatal repair using a DynaMesh® HIATUS visible, PVDF, 7x12 cm (PJ Dahlhausen & Co Ltd, Cologne, Germany) is performed on discretion of the surgeon in cases of weak and thin diaphragmatic crura combined with a large hiatal hernia found intraoperatively. For suturing the robotic extra-large needle holder is used on the right hand. An esophageal calibration bougie is inserted only in patients with concomitant fundoplication. In cases of mesh reinforcement, a combination of slowly absorbable staples and glue is applied by the bed assistant. A silicone drain is inserted at the end and removed on postoperative day 1.

In summary, the conventional laparoscopic hiatoplasty is performed using the same patient positioning and surgical technique, with two 12-mm and two 5-mm ports as well as a snake liver retractor through a separate 5 mm port in the right middle abdomen, a 30° endoscope and a LigaSure blunt tip for all surgical steps.

Statistics

Statistical analysis was performed using R software (version 4.4.3). Descriptive statistics were used to summarize patient characteristics. Continuous variables are presented as median with interquartile ranges and compared using the Mann-Whitney U-test. Categorical variables are presented as frequencies and percentages and compared using the Fisher's exact test. For all analyses, results with a two-sided p value of < 0.05 were considered statistically significant. For the analysis of the learning curve within the RH and LH, operative time was plotted against chronological case numbers. The association was described with Spearman rank correlation and linear regression. The trend was additionally displayed as a 5-case moving average. To identify the transition from the learning to the proficiency phase in RH, a cumulative sum (CUSUM) analysis was performed.

Results

A summary of baseline characteristics and study results is presented in **Table 1**. No significant differences were observed in key demographic characteristics, such as age, gender, height, weight, BMI and ASA-class. The intraoperatively measured area and types of hiatal hernia, symptoms leading to surgery, proven GERD and presence of extensive adhesions in the

upper abdomen due to past surgeries were similar in both groups. With respect to intraoperative details such as rates of additional anterior hiatoplasty, fundoplication, and mesh reinforcement both groups were comparable.

Table 1: Patient characteristics and summary of results

Parameter / Procedure	Laparoscopic Hiatoplasty (n=35)	Hugo RAS Hiatoplasty (n=35)	p-value
Gender - female: male	23:12	24:11	1,000
Age [years]	65 (57 – 75)	66 (59 – 71)	0,954
Height [cm]	168 (163 - 178)	168 (165 – 176)	0,550
Weight [kg]	82 (70 – 95)	90 (80 – 96)	0,076
BMI [kg/m²]	30 (27 – 33)	30 (28 – 34)	0,461
ASA class I/II/III	12/18/5	14/16/5	1,000
Hiatus area [cm²]	11 (7,5 – 14,9)	11 (6,7 – 18,8)	0,682
Type of hiatal hernia:			0,777
Type 1 sliding	15	11	
Type 2 rolling	2	3	
Type 3 mixed	11	12	
Type 4 upside-down	7	9	
Symptoms			0,685
Cardiopulmonary	14	15	
GERD	7	7	
Vomitus	6	5	
Pain	6	4	
Anemia	2	4	
Recurrent hernia	1/35	1/35	1,000
Severe adhesions	8/35	7/35	1,000
Posterior hiatoplasty only	18/35	16/35	0,811
+ anterior hiatoplasty	17/35	19/35	0,811
+ fundoplication	7/35	7/35	1,000
+ mesh augmentation	18/35	17/35	1,000
Total operative time	160 (130-180)	145 (117-184)	0,368
Operative time adjusted**	155 (130-180)	125 (114 - 167)	***0,026***
Console time	n.a.	110 (85 – 125)	n.a.
Technical problems	1/35	4/35	0,356
Conversion***	1/35 *(to open)*	1/35 *(to lap.)*	1,000
Lesion of pleura	7/35	2/35	0,151
Complications	6/35	2/35	0,259
Thoracic drainage	3/35	0/35	0,239
Length of stay	6 (5 – 7)	5 (4 – 6)	***0,012***
Follow-up [months]	32 (26 – 42)	28 (18 – 36)	0,190
Recurrence	2/35	0/35	0,493

Table legend: Median (IQR) for continuous variables presented; * skin to skin time; ** - operative times in last 20 patients of each group to adjust for the learning curve *** conversion to open in lap. group vs conversion to lap. in Hugo RAS group; ASA - American Society of Anesthesiologists; BMI – body mass index; GERD – gastroesophageal reflux disease

Total operative time showed no statistical difference between the total cohorts of RH and LH. In RH, median docking time was 7 (IQR 5 – 10) minutes, console time 110 (IQR 85 – 125) minutes. After exclusion of the first 10 RH to adjust for the effect of the learning curve, operative time of the last 25 RH was significantly shorter than operative time of the total LH

group and also when compared to the last 25 LH. The analysis of the learning curve of RH showed that operative time decreased significantly with increasing case number (Spearman ρ = -0.50, p = 0.002). Linear regression showed a reduction of 2.0 min per case (95% CI 0.9-3.2; $R^2 = 0.27$, p = 0.001), corresponding to about 1.3% per case in the exponential model. CUSUM analysis showed a peak at case 10, marking the transition from the learning phase to the proficiency phase. Median operative time was 182 min in cases 1-10 and 125 min in cases 11-35 (exploratory, p = 0.002) (**Figure 4**).

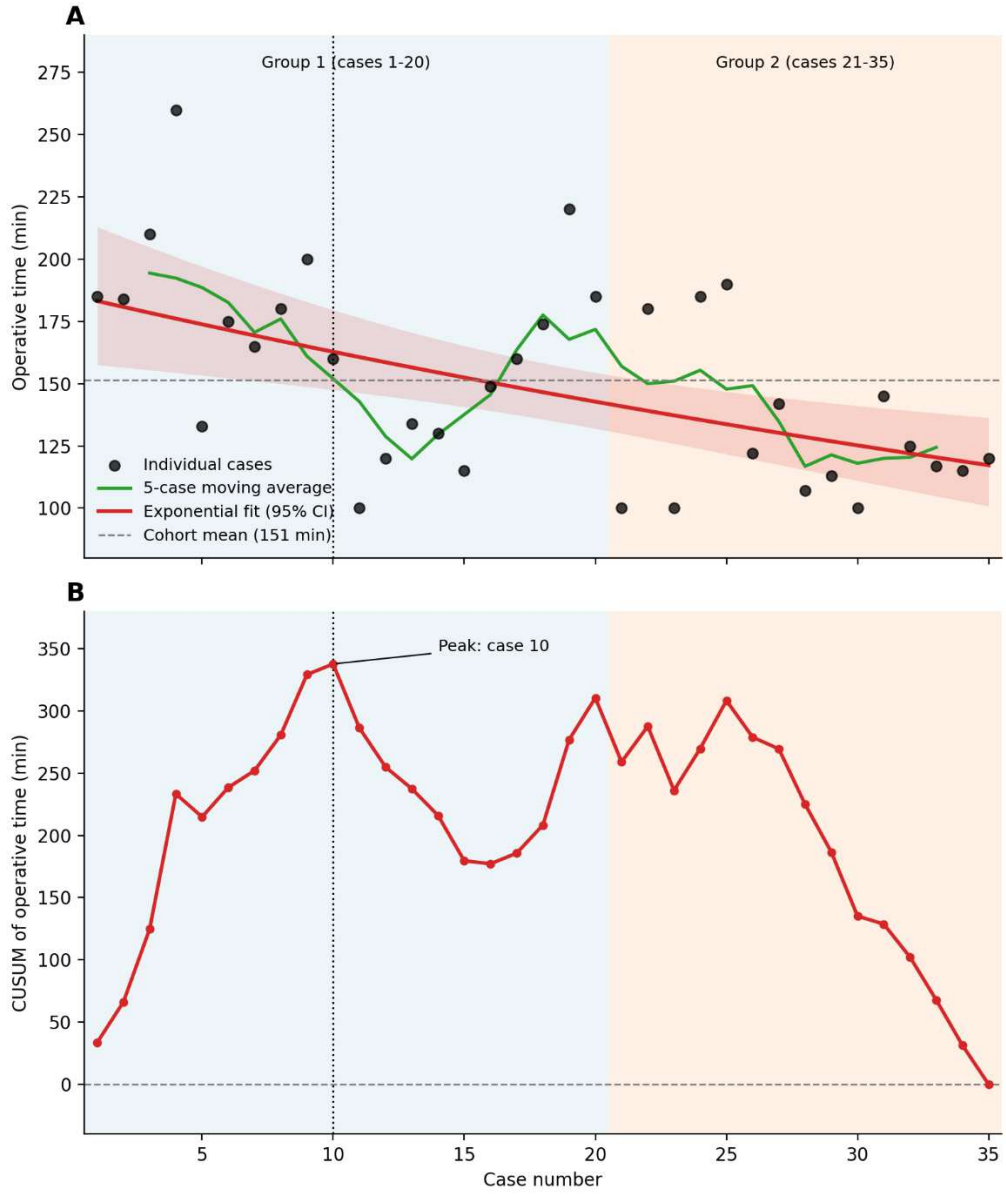


Figure 4: Learning curve for operative time in RH, n=35 consecutive cases. (A) Operative time per case with exponential fit (95% CI) and 5-case moving average; dashed line = cohort mean (151 min). (B) CUSUM of operative time relative to the cohort mean; the peak at case 10 marks the transition from the learning phase to the proficiency phase

Across the 35 consecutive LH, operative time averaged 160.8 min (SD 40.1; range 100-290) and expectedly showed no significant downward trend with case number (linear regression slope -0.19 min/case, $R^2 = 0.002$, $p = 0.78$; Spearman $\rho = -0.11$, $p = 0.52$), so no learning curve was detectable in the control laparoscopic group. The median operative time of the last 15 cases performed using LigaSure RAS by the console surgeon was 120 (IQR: 107 – 145) minutes and thus significantly shorter compared to the first 20 cases performed using the laparoscopic LigaSure by the bed assistant, 169 (IQR: 133 – 185) minutes, p=0,009 (**Figure 5**).

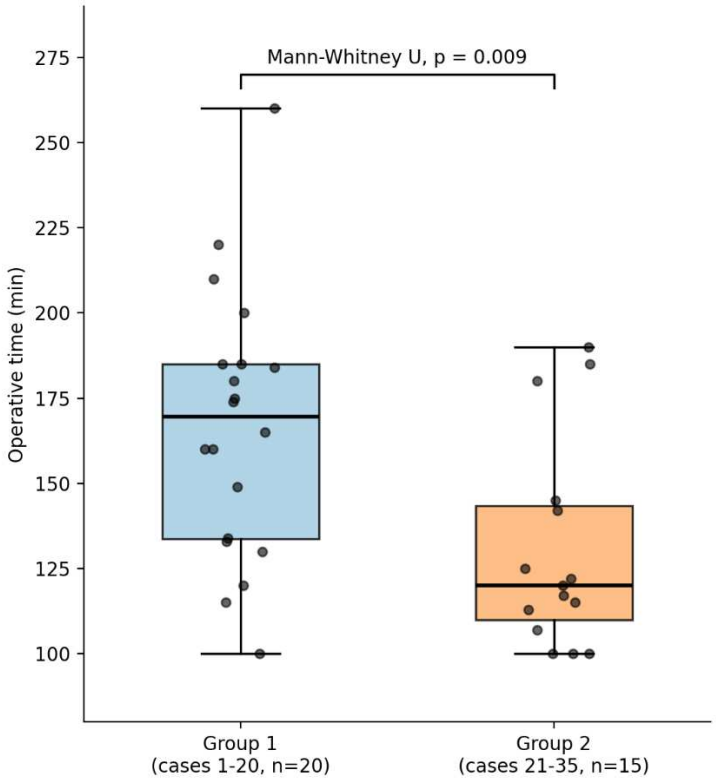


Figure 5: Box-and-whisker plots of operative time before and after introduction of LigaSure RAS

After exclusion of the first 10 cases of RH to adjust for the learning curve, there was no difference in the median duration of surgery between Hugo RAS procedures performed with laparoscopic and robotic LigaSure,141 vs 120 minutes, p=0,191. Technical problems occurred in both groups. In the laparoscopic group a recurrent technical defect in the image transmission in a patient with massive adhesions and a recurrent hiatal hernia led to a late conversion to open surgery. In 3 patients of the robotic group smaller technical problems occurred, which led only to prolongation of the total operative time without effect on the outcome of the procedure. In another patient of the RH group one of the robotic arms was repetitively unable to recognize the needle holder and the system had to be restarted. In the meanwhile, the procedure was

completed laparoscopically. Intraoperative opening of the pleura was more common in the laparoscopic group, but no statistical difference was reached. In the robotic group no pneumothorax was detected on postoperative X-ray. In the laparoscopic group a clinically relevant one-sided pneumothorax occurred in 3 patients and all of them were treated by insertion of a chest tube. No perforation, infection or bleeding occurred in both groups. Postoperative complications in the laparoscopic group included a case of peripheral pulmonary embolism, three pneumothorax and two cases of transient dysphagia. In the robotic group one patient suffered persistent chest pain which led to a full cardiologic check-up which excluded acute cardiovascular problems. Another 83-old patient with RH suffered exacerbation of his known chronic kidney failure after surgery. The postoperative length of hospital stay was significantly shorter by one day in the robotic group. During a median follow-up time of two and half years which didn't differ between both groups no difference in the recurrence rate in both groups was recorded.

Discussion

Robotic assisted surgery has emerged as a promising alternative to conventional laparoscopy for the repair of hiatal hernias, a condition affecting more than half of the population aged 50 and older [4]. Robotic hiatoplasty is believed to reduce blood loss, conversion rate to open surgery, intra- and postoperative complications, postoperative pain scores and postoperative ileus, recovery times and shorten the length of hospital stay, when compared to laparoscopy, especially in obese patients. These effects may be explained by additional precision and enhanced visualization offered by robotic platforms and by the growing experience of robotic teams [4, 5].

Early results of RH were controversial. A retrospective population-based analysis of 517864 adult patients in USA for the period of 2010-2019 found that RH was associated with higher readmission rates and significantly more complications compared to LH even in high-volume centers, 9,2% vs 6,8%, specifically respiratory failure and esophageal perforation. However, rates of complications and readmissions improved over time with increasing robotic experience. In the same analysis, costs of RH were higher, whereas length of hospital stay similar [6]. Similar results were reported by a 2024 audit of the Texas Inpatient Public Use Data File. 1772 RH were compared to 1739 LH. The robotic approach was associated with increased odds of complications, with no difference in severe complications and mortality. [7]

More recent studies found RH to be comparable and even superior to LH with respect to perioperative clinical outcomes. Several original large-scale single-center series, and two metanalyses including more than 387000 patients reported less complications, readmissions and recurrences with a shorter hospital stay for RH, whereas it remained inferior in terms of operative time and cost compared to LH [8 - 12].

Our study presents the first and currently largest series of consecutive RH performed by a single surgeon with the Hugo™ RAS platform and provides robust evidence for the safety and feasibility of the procedure. No device-related perioperative complications occurred, and the clinical outcomes were comparable to LH. The trend towards reduction of operative time in RH compared to LH within the cohort of a single surgeon is an interesting finding of the present study. Despite the presence of a learning phase and longer technical time due to arm-docking and undocking, RH took no longer than LH, and was even faster after gaining proficiency. This paradox may be explained by increasing surgeon experience over the total cohort of patients, availability of additional surgical arm allowing to omit inserting and adjusting of a separate liver retractor, enhanced and steady imaging, parallel availability and faster swap among different energy devices, as well as increased autonomy of the console surgeon with less dependence on a bed assistant. This may also partially explain the perceived improvement in operative time after the introduction of console-guided LigaSure RAS.

Regarding the learning curve of robotic hiatal repair with the Hugo™ RAS our findings correlate well with previous reports on other robotic platforms. In our cohort the transition from learning phase to proficiency appeared after 10 cases. Straatman et al. analyzed the learning curves of 4 DaVinci surgeons for RH and found that a proficiency level was reached after 7-15 procedures [13]. Garsot et al. found that previous experience in laparoscopic approach and esophagogastric surgery reduced the learning curve for RH to 14 procedures [14].

There are several technical aspects of RH which deserve to be discussed. As described in the methods, we modified the configurational setup of the vendor by positioning the left-sided two robotic ports much higher almost in line with the right ones. This allows the relatively shorter instruments of Hugo RAS to reach high in the mediastinum. Hugo instruments are at average 10 cm shorter than DaVinci ones, and this should be taken into consideration particularly in tall and/or obese patients and in those with a complete upside-down stomach. However, with careful preoperative planning of the port positioning we didn't encounter any difficulties even in patients up to 198 cm tall and with a BMI of up to 45 kg/m². Unlike LH, we do not usually use a liver retractor in RH except for cases of extreme hepatomegaly of the left

lobe or in some complex recurrent cases. There are several reasons for that: first, the presence of a third robotic arm allows the surgeon to lift the liver during parallel manipulation of the hiatus. On the other hand, the use of a laparoscopic straight liver retractor as in LH is inconvenient and risky, since the extracorporeal shaft of the retractor inevitably encounters the robotic arms. In our experience only the smallest size of a Nathanson liver retractor in the high epigastrium does not interfere with the proper movement of the robotic arms. However, its insertion might be tricky and time consuming, especially in obese patients. We do not use an AirSeal port-system too, because it is very loud and impedes proper communication in the operating room. At the same time robotic instruments and high-definition imaging allow sharp and bloodless dissection along the correct planes producing little to no surgical smoke. The authors prefer using a 0° endoscope to avoid arm collisions due to extremely low or high position of the endoscope arm. We also find the coagulation and grasping ability of the bipolar grasper better than that of a bipolar Maryland for this type of surgical procedure.

Apart from a previous report by our team on a cohort of 70 Hugo RAS procedures including our first three hiatal hernia repairs, only two additional cases of hiatoplasty and fundoplication using the Hugo™ RAS can be currently found in the literature [1 – 3]. Quijano et al. from Spain described a Nissen fundoplication with hiatoplasty in a 65-year-old woman using arm and port settings close to ours [3]. The early series of 17 robotic procedures by Gangemi et al. from Italy included a Nissen fundoplication with hiatoplasty in a 67-year-old man using a butterfly configuration of the arms [1]. Operative times in both cases were 100 and 150 minutes, respectively, correlating well to our own results. No intraoperative difficulties or complications were reported by the authors.

Limitations of our comparative study include its retrospective design, the relatively small number of patients in both groups and the lack of cost analysis. The latter is very difficult to conduct, and results will be biased, because equipment, supply costs and service charges by the vendor strongly differ around the globe and from one institution to another in this early phase of distribution of Hugo RAS. Moreover, in Germany all Hugo instruments are still certified for single use only because of administrative hurdles, so flat rates per case are currently negotiated. In other parts of the world the multiple use of Hugo instruments is allowed.

In summary, we showed that robotically assisted repair of hiatal hernia using the Hugo™ RAS platform may be safely and effectively performed by experienced laparoscopic teams, even in the absence of preexisting robotic experience. The learning curve was steep, and the short-term results were not inferior to conventional laparoscopy. Further high-volume

randomized controlled trials should answer the questions about the long-term outcomes and cost-effectiveness of Hugo™ RAS hiatoplasty.

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Declarations

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Consent to participate: Informed consent was obtained from all individual participants included in the study.

Ethics approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the Ruhr University Bochum (Date: 23.06.2023; Nr. 23-7872- BR)

Data availability statement: All raw data analysed in this article are available and saved on the data server of Katholisches Klinikum Bochum and access may be requested at any time by addressing the Ethic Committee of the Ruhr University Bochum.

Author Contributions: DA – design of the work; acquisition, analysis and interpretation of data; drafting and critical revision of the manuscript; final approval of the version to be published; agrees to be accountable for all aspects of the work.; *IS* – acquisition of data, critical revision of the manuscript, final approval of the version to be published; agrees to be accountable for all aspects of the work.; *HS* – acquisition of data, critical revision of the manuscript, final approval of the version to be published; agrees to be accountable for all aspects of the work.; *WU* – conception of the work, critical revision of the manuscript, final approval of the version to be

published; agrees to be accountable for all aspects of the work.; *OB* – conception and design of the work; acquisition, analysis and interpretation of data; drafting and critical revision of the manuscript; final approval of the version to be published; agrees to be accountable for all aspects of the work.

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Figures

Figure 1 **-** Port positions for RH with inserted Nathanson liver-retractor

Figure 2 **-** Configurational setup for RH

Figure 3 **-** View of operating room during RH

Figure 4 **-** Learning curve for operative time in RH, n=35 consecutive cases. (A) Operative time per case with exponential fit (95% CI) and 5-case moving average; dashed line = cohort mean (151 min). (B) CUSUM of operative time relative to the cohort mean; the peak at case 10 marks the transition from the learning phase to the proficiency phase

Figure 5 **-** Box-and-whisker plots of operative time before and after introduction of LigaSure RAS

Tables

Table 1 **-** Patient characteristics and summary of results

Supplementary material

Video 1 **-** Hiatal hernia repair with mesh reinforcement using the Hugo RAS

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryVideoRoboticHiatalRepairwithHugoRAS.mp4