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Robotic right hemicolectomy with CME: Surgical platform strategies for the new Hugo™ RAS System

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Robotic right hemicolectomy with CME: Surgical platform strategies for the new Hugo™ RAS System

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Abstract

Introduction
The introduction of novel robotic platforms requires adaptation of established surgical workflows and dedicated training. The Hugo™ Robotic-Assisted Surgery (RAS) System features independently positioned arm carts, providing flexibility but requiring precise setup and docking strategies. This study aimed to establish a standardized setup for robotic right hemicolectomy with complete mesocolic excision (CME) using the “critical view” technique and to evaluate associated learning curves.

Methods
A prospective, single-center simulation study was conducted at the Center for Medical Innovation and Technology (CeMIT), University Hospital Cologne, between April and October 2025. A three-dimensional printed anatomical model based on an anonymized patient CT scan was used. A standardized trocar and cart configuration was developed through iterative testing. Six surgical residents and five experienced robotic surgeons performed four standardized operative views, docking, and emergency de-docking, with five repetitions per participant. Procedure times were analyzed using linear mixed-effects models.

Results
An optimized “critical view” setup was established, consisting of a diagonal trocar configuration with individually defined tilt and angulation parameters. Experienced surgeons performed operative steps significantly faster than residents ($p = 0.018$). Both groups demonstrated significant improvement with repeated procedures ($p < 0.001$), with comparable learning effects ($p = 0.489$). Procedure times decreased by 30% among residents and 24% among experienced surgeons between the first and second repetition. Docking was significantly faster in experienced surgeons ($p = 0.002$), whereas improvement over repetitions was more pronounced among residents ($p = 0.016$).

Emergency de-docking also demonstrated significant learning effects in both groups ($p < 0.001$).

Discussion
A standardized “critical view” setup for right hemicolectomy using the Hugo™ RAS System is feasible in simulation. Repeated training significantly improved performance in both experienced surgeons and residents. These findings support structured simulation-based training, including operative steps, docking, and emergency de-docking. Clinical validation is warranted.

Keywords: Hugo™ RAS System; robotic surgery; right hemicolectomy; complete mesocolic excision; simulation training; learning curve

Introduction

Surgery remains the mainstay of curative treatment for colon cancer. Complete oncologic resection with adequate lymphadenectomy is the cornerstone of therapy in non-metastatic colon cancer. With regard to right-sided colon or caecal cancer, surgical treatment should include complete mesocolic excision (CME), which is now widely accepted in the literature as the gold standard [1]. In addition to systematic lymphadenectomy, the CME concept also aims to minimize the incidence of local recurrence by maximizing the radicality and quality of surgical resection. Similar to the mesorectum, a mesocolon is also present in right-sided colon surgery, containing lymphnodes along the supplying arteries and therefore serving as an anatomical landmark for oncologic resection. The technique was first described by Hohenberger et al. in 2009 [2].

The “critical view” concept provides a standardized approach to minimally invasive right hemicolectomy with CME, integrating anatomical landmarks and predefined safety checkpoints throughout the procedure. The technique emphasizes meticulous mobilization of the colon and mesocolon along the embryological planes, with complete separation from the retroperitoneal structures before central vascular ligation. By dividing the procedure into eight consecutive critical views, the concept facilitates systematic identification of the relevant vascular anatomy and ensures controlled central vascular ligation and D3 lymphadenectomy. Importantly, failure to achieve an individual critical view should prompt reassessment of the surgical anatomy and dissection plane before proceeding, thereby enhancing procedural standardization and surgical safety [3].

With regard to advanced tumor stages, adjuvant chemotherapy is considered [4],[5].

The introduction of minimally invasive approaches, including laparoscopic and robotic-assisted techniques, has progressively transformed surgical management, aiming to improve recovery without compromising oncologic outcomes [6], [7] [8]. The introduction of robotic systems has aimed to overcome the inherent limitations of standard laparoscopy, such as a reduced instrument articulartion and two-dimensions visualization, providing greater precision and dexterity [9]. Recent comparative studies have confirmed that robotic and laparoscopic resection achieve comparable oncologic outcomes, with robotic surgery offering potential advantages including lower conversion rates, improved nerve preservation, and a shorter learning curve [8], [10]. This technological progression represents one of the most significant advances in modern colorectal cancer management,

combining minimal invasiveness with uncompromised oncologic efficacy. In the last 20 years, robotic-assisted surgery has been increasingly adopted across almost every surgical specialty. With the commercial approval of the Da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) in the 2000s, robotic surgery rapidly expanded and proved feasible in multiple fields of general surgery [11], [12]. Several advantages of robotic surgery compared with laparoscopy have been described, including improved ergonomics and increased degrees of freedom in instrument motion [13] [14], [15] [9]



Figure 1 Hugo™ RAS Console

Recently, novel robotic platforms have emerged on the market, introducing new technological features. The Hugo™ Robotic-Assisted Surgery (RAS) System (Medtronic, Minneapolis, MN, USA) was introduced in the European market in March 2022. The Hugo™ platform consists of a system tower, an open console (Figure 1), and four independent arm-carts (Figure 2). Each robotic arm has six joints and can be positioned individually, offering flexibility in setup[16][17]. The surgeon operates from an open console equipped with a 32-inch widescreen HD-3D display and 3D glasses. Handgrips are designed to simulate a “pistol grip,” while the footswitch panel controls the camera, energy devices, and the reserve arm. The safety and feasibility of the Hugo™ system has already been demonstrated in urological and gynecological procedures [18], [19]. In general surgery, studies have explored its application in cholecystectomy, bariatric surgery, adrenalectomy, and more recently in colorectal surgery [20], [21], [22], [23].

The standardization of port placement and operative setup in our center was inspired by the approach described by Strey et al. in their work on laparoscopic right hemicolectomy with complete mesocolic excision (CME) using the “critical view ” concept [24]. This model illustrates a representation of the anatomical layers seen as pages of a book. This model allows for a distinction between the extent of resection of standard right hemicolectomy and extended hemicolectomy. In particular, right hemicolectomy is limited to mesocolic excision. Extended right hemicolectomy encompasses partial removal of mesogastric page. This concept provides a structured framework that we adapted to the robotic setting with the Da Vinci Surgical System to ensure consistent and reproducible surgical procedures.



Figure 2: The Hugo™ RAS arm cart in resting position

Medtronic has provided predefined recommendations for patient positioning, tilt, and robotic arm docking angles for right hemicolectomy performed with the Hugo™ RAS system. These are summarized in the work of Arroyo and colleagues which described the setup and docking strategies for various colorectal procedures[25]. The authors reported that adherence to standardized positioning and docking protocols facilitated smoother instrument motion, reduced external arm collisions, contributed to shorter docking times and optimized surgical ergonomics. In addition, the modularity of the arms provides a variety of arm configurations adjusted to the patient’s body features.

Building on our clinical experience with the Da Vinci Surgical System, where we have implemented the “critical view” concept, the present investigation aimed to translate this workflow into an experimental laboratory environment using the Hugo™ RAS system. The objective was to replicate the established Da Vinci setup within the Hugo™ RAS system to assess procedural transferability and comparability.

Materials and Methods

Study design

The measurements were performed at the training laboratory Center for Medical Innovation and Technology (CeMIT) at the University Hospital of Cologne from April to October 2025. The objective of this prospective, single- center simulation study was to identify a feasible set up for right hemicolectomy. The purpose of this preclinical study was to evaluate the feasibility and reproducibility of a dedicated trocar and cart setup for the Hugo™ RAS System with regard to the "critical view" method. Additionally, the learning curve of participants with different robotic experience was evaluated while performing right hemicolectomy, docking and de-docing scenarios.

At the beginning, all participants received a structured and standardized introduction. Teaching included the "buttonology" of the robot, including basic handling of the robotic console and controller. Moreover, all participants were introduced in the docking and de-docking of the robotic system. All instructors were specifically trained in handling the Hugo™ RAS System by representatives of Medtronic.



Figure 3: The 3D-printed anatomical model

Anatomical model

A three-dimensional anatomical model was developed by the Department of Engineering at the University of Pavia, Italy, using an anonymized CT scan from a patient of our department (Figure 3). This model was specifically designed for right hemicolectomy with CME and contained the entire colon and its vascular supply. It was fabricated using a 3D printer. The model was positioned within a robotic training box and oriented in a 7° Trendelenburg and 10° left-side tilt to simulate intraoperative patient positioning.

Participants

The study involved two groups of surgeons: the first cohort consisted of experienced robotic surgeons who had extensive exposure to robotic platforms other than the Hugo™ RAS System, while the second group included junior surgeons with limited robotic background. All surgeons were affiliated with the Department for General, Visceral, Thoracic and Transplant Surgery at the University Hospital Cologne.

Robotic setup

Trocar placement and cart orientation followed a standardized configuration (Figure 4 and 5). The optimal tilt and angle settings for each trocar were determined through two experimental simulation sessions conducted on the 3D model, aiming to minimalize

external arm collisions and ensure adequate internal range of motion. The final trocar configuration is presented in Table 1.

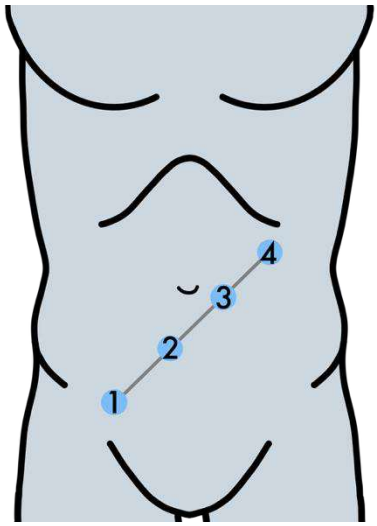

Figure 4: Schematic overview of the robotic setup for right hemicolectomy

Tasks and evaluation

Before the simulation, each surgeon received a brief introduction of the Hugo™ RAS System. During this briefing, all the available robotic instruments were presented as well as the surgical steps for right hemicolectomy according to the standardized model of Strey et. al. [24]. Moreover, docking and de-docking scenarios were explained.

In a pre-docking phase, one of the study-assistants positioned the robotic carts and adjusted the predefined tilts according to the standardized configuration.



Figure 5: Standardized trocar placement and robotic set up for right hemicolectomy

In the docking phase, the surgeons performed the docking of the robotic arm to the trocars in a predefined angle. Furthermore, the participants were asked to insert the instruments into the operative field. The instruments were placed in a standardized manner (Table 1).

In the operative phase, each surgeon was required to reproduce four surgical steps for right hemicolectomy based on the “critical view” model. The first step consisted in the mobilization of coecum by elevating it, in order to obtain a V-view. This view contains a caudal perspective on the V-shaped confluence of the ileocolic and the superior

	Tilt	Angle	Instrument
Trocar 1	-10	235	Cardier forceps / Needle driver
Trocar 2	+5	155	Camera
Trocar 3	-45	260	Cardier forceps
Trocar 4	+20	75	Double fenestrated Cardier grasper / Needle driver

Table 1: Tilts and Angle positions and overview of instruments for every trocar

mesenteric vessels. In this step the left arm (trocar 1) grasps the coecum to lift it up. The first right arm (trocar 3) elevates the trasverse colon with a silicon loop and the second right arm (trocar 4) grasps the transverse colon to stabilize it (Figure 6 and 7).

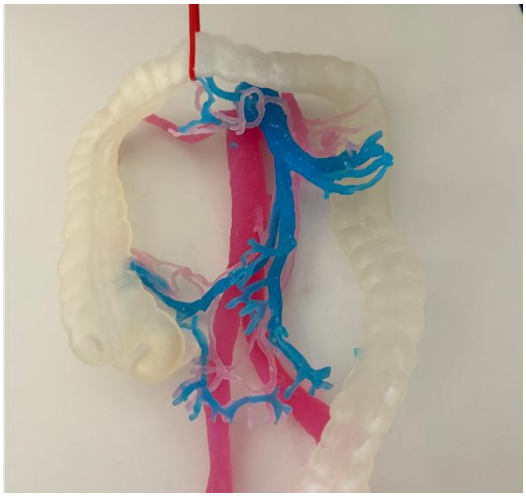

Figure 6: View 1: Image presented to the candidates

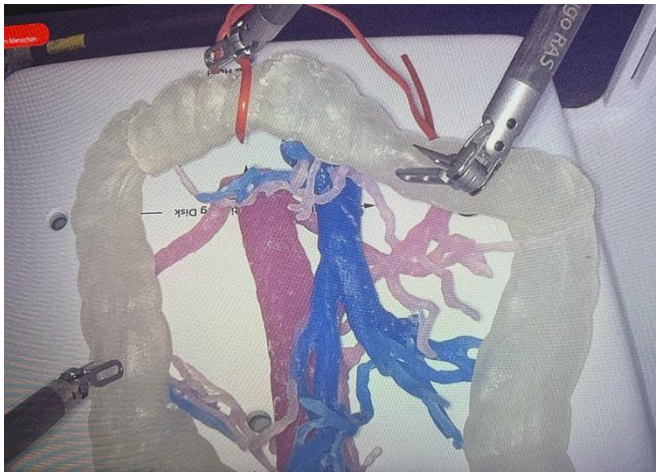

Figure 7: View 1: Intaoperative image

The second view contains the exposure of the ileocolic vessels. In our model it was simulated by centrally encircling the ileocolic vascular pedicle. The left arm (trocar 1) lifts the ileocolic artery with a red silicon loop, the first right arm (trocar 3) lifts the ileocolic vein with a blue silicon loop and the second right arm (trocar 4) grasps the trasverse colon, enhancing the tension on the superior mesenteric trunk (Figure 8 and 9).

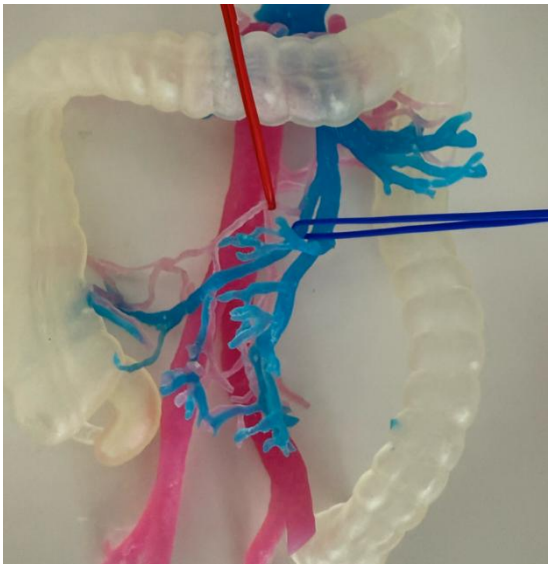

Figure 8: View 2: Image presented to the candidates

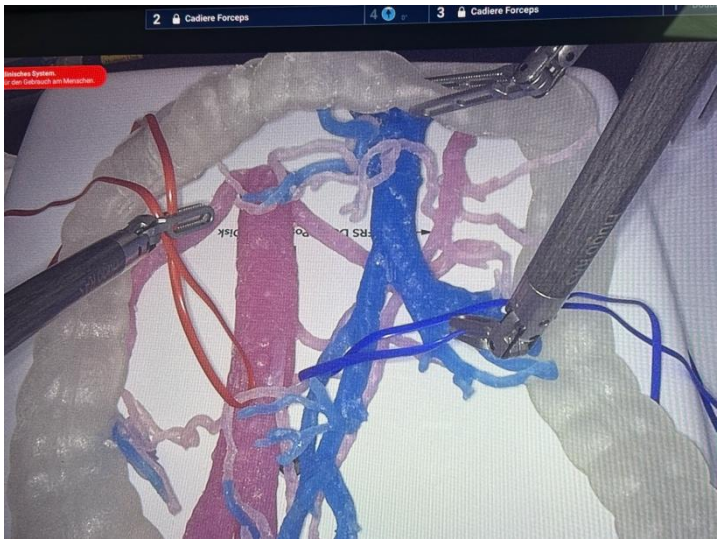

Figure 9: View 2: Intraoperative image

The third operative view represents the “sulcus view”. The participants were asked to present the sulcus between transverse mesocolon and pancreatic head. In our model the third view was obtained by pulling the transverse colon upwars and positioning the camera into the sulcus. The left arm (trocar 1) pulls the encircled proximal transverse colon upwards, the first right arm (trocar 3) mobilizes the colon ascendens laterally and the second right arm (trocar 4) grasps and pulls the distal transverse colon downwards (Figure 10 and 11).

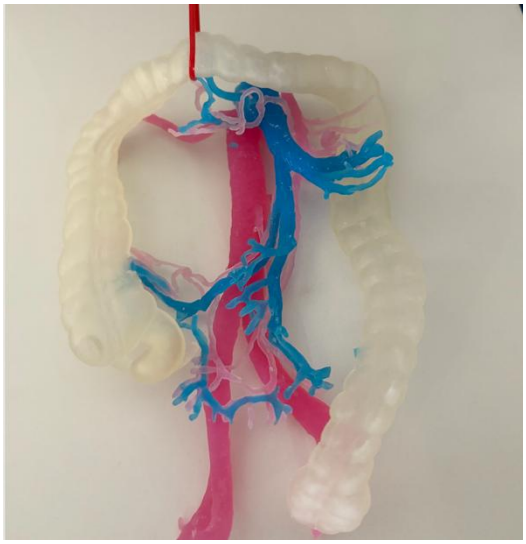

Figure 10: View 3: Image presented to the candidates

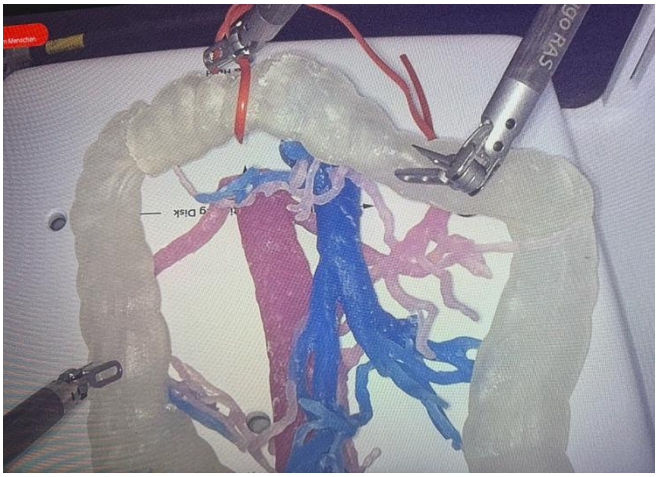

Figure 11: View 3: Intraoperative image

The fourth view involves preparation for an intracorporal ileotransverse anastomosis, simulated by placing a holding suture at the antimesenteric border of the small bowel and on the taenia libera of the colon, followed by insertion of a stapler. In our model, the left arm (trocar 1) holds the preplaced sutures in the right upper abdomen. The first right arm (trocar 3) and the second right arm (trocar 4) stabilize the transverse colon. The table-assistant inserts the stapler (Figure 12 and 13).

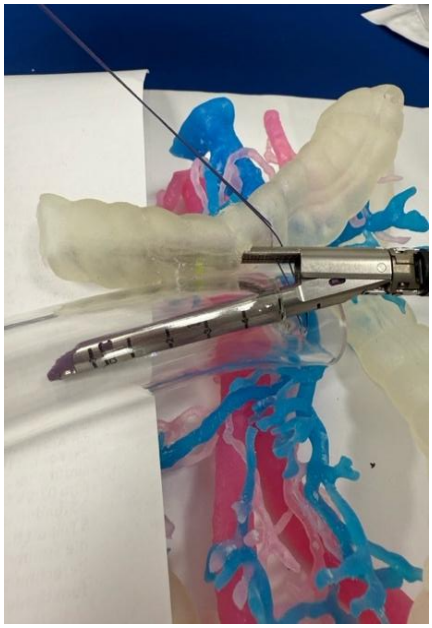

Figure 12: View 4: Image presented to candidates

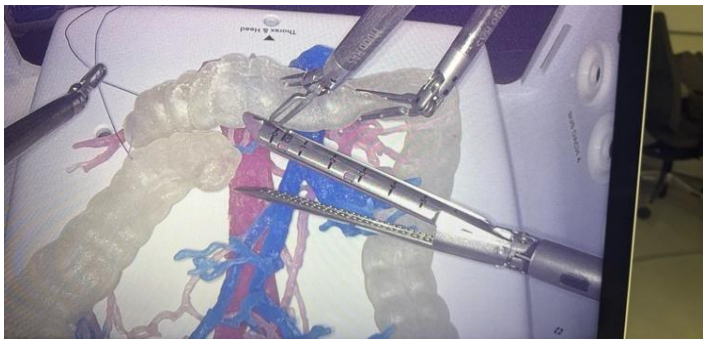

Figure 13: View 4: Intraoperativ image

In the undocking phase, the surgeon, with the help of the instructor, simulated an emergency undocking setting and performed a full undocking, including instruments removal and withdrawal of the robotic carts from the operating table.

The time of each phase was measured by the study supervisor who additionally verified whether all four critical views were correctly achieved. The entire process was repeated 5 times for each surgeon.

Outcome

The primary outcome was to determine docking and de-docking times, measured in minutes. Additionally, the study aimed to provide an initial evaluation of the learning curve associated with repeated docking and acquisition of the surgical views.

Ethics

Ethics Committee approval was obtained before the study (Ethics Committee, University of Cologne), and the current study adheres to the criteria of our local ethics committee (No. 23-1415). All subjects gave written informed consent before study inclusion.

Statistical analysis

Descriptive statistics of quantitative data are mean ± standard deviation. Qualitative data is presented by absolute and relative frequencies. Linear mixed-effects models with a random intercept and an autocorrelation of first order were used to estimate the log-transformed times required for the procedural steps, which were repeatedly measured for each participant, in dependence of the groups of surgeons and the number of repetitions of the procedure. The number of repetitions was treated as a factor variable to enable the investigation of non-linear effects and an interaction term with the group indicating variable was included to explore possible differences in the learning curve between groups. All estimates of group differences and trends with 95% confidence intervals, as well as statistical hypothesis testing of effects, were derived from these models. Analyses were performed in R version 4.1.3 (The R Foundation for Statistical Computing).

Results

Study cohort

The study cohort consists of 6 surgical residents and 5 robotic experts. The participants‘ characteristics are summarized in Table 2.

Nine participants were right-handed. Around one third of the participants were wearing glasses.

Concerning the gaming experience, five of six surgical residents were in possession of a gaming console, and three of five robotic experts. The surgical residents had the most gaming experience, averaging 17.0 years per participant and were gaming 75.0 minutes per day during their active years of gaming - considerably longer than the robotic experts.

The robotic experts had an average of 5.2 years of robotic experience, whereas only four of six of the surgical residents had been trained as table assistants.

	Surgical Residents	**Robotic experts**
Age (years)	34	44
Sex (male)	67%	100%
Handness (right)	83%	83%
Glasses (yes)	33%	20%
Owning a gaming console (yes)	83%	60%
Years of gaming	17	8
Minutes of gaming/day	75	22
Years of surgical training	6.5	15.0
Surgical experience	middle	high
Robotic experience	33% none, 66%table assist	5,2 years console surgeon

Table 2: Characteristics of study cohort

Experimental evaluation of optimal setup for right hemicolectomy

The aim of the presented study was to translate the setup for right hemicolectomy performed with the da Vinci Surgical System to the Hugo™ RAS system. Medtronic provides setup cards for various surgical procedures. Figure 14 illustrates trocar positioning for right hemicolectomy as recommended by Medtronic, including the corresponding tilt and angle specifications (Table 3).

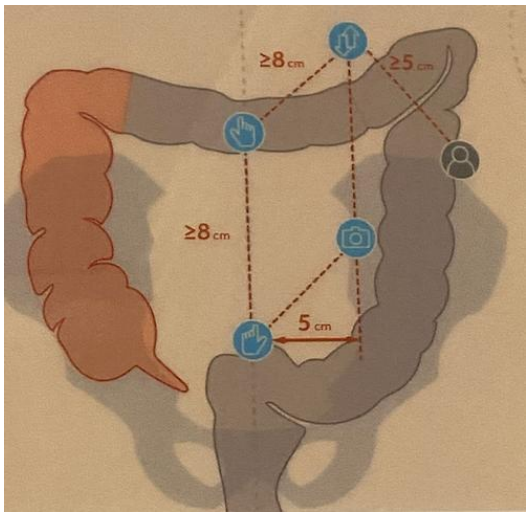

Figure 14: Trocar positioning by Medtronic for right hemicolectomy

Our objective was to establish a diagonal arrangement of trocars, beginning in the right lower abdomen (trocar 1) and ending in the left upper abdomen (trocar 4). This trocar configuration is further illustrated in Figure 4. Modifications in trocar positioning were accompanied by corresponding adjustments in tilt and angulation.

In an experimental setup, the docking of the arm carts was initially adapted to diagonal trocar positions. In contrast to the configuration proposed by Medtronic, we positioned two arm carts on the right and two on the left side of the patient (Figure 15). This resulted in adjustment of tilt and angle parameters defined as “Version 1” (Table 3).

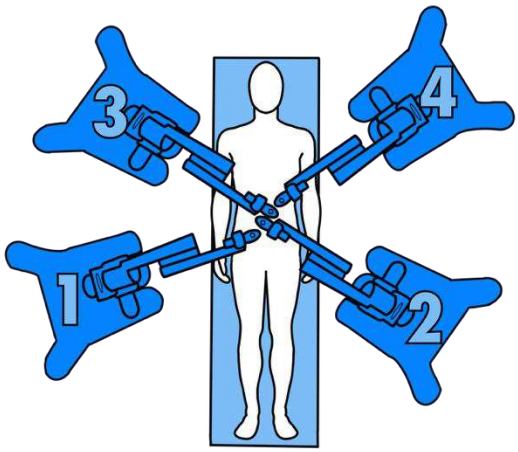

Figure 15: Cart positioning of right hemicolectomy performed in open-book technique

To optimize tilt and angulation, right hemicolectomy was subsequently performed on our 3D-model by an experienced robotic surgeon in two iterations (Version 2 and Version final). During this process, tilt and angle parameters were further adjusted to prevent external collisions of the robotic arms. In addition, the positioning of the arm carts was refined to achieve an optimal intraoperative viewing angle throughout all stages of the procedure. The tilt and angle settings determined to be optimal for our setup are presented as the final version in Table 3.

	Trocar 1 Tilt	Trocar 1 Angle	Trocar 2 Tilt	Trocar 2 Angle	Trocar 3 Tilt	Trocar 3 Angle	Trocar 4 Tilt	Trocar 4 Angle
Medtronic	-15°	230°	15°	120°	-30°	315°	15°	45°
Version 1	-15°	220°	15°	115°	-15°	300°	15°	40°
Version 2	-15°	220°	-15°	120°	-30°	285°	-30°	35°
Version final	-10°	235°	5°	155°	-45°	260°	20°	75°

Table 3:Tilts and Angles for every trocar proposed by Medronic in comparison to the open-book setup

Learning curves

Right hemicolectomy

In Figure 16 the learning curve of residents (orange) and experienced robotic surgeons (green) are presented. Across the five repetitions, the steps of right hemicolectomy were performed significantly faster by experienced robotic surgeons than by residents (p = 0.018). The more frequently the exercises are repeated, the less time is required to complete them (p < 0.001), while this effect was comparable in both groups (p=0.489).

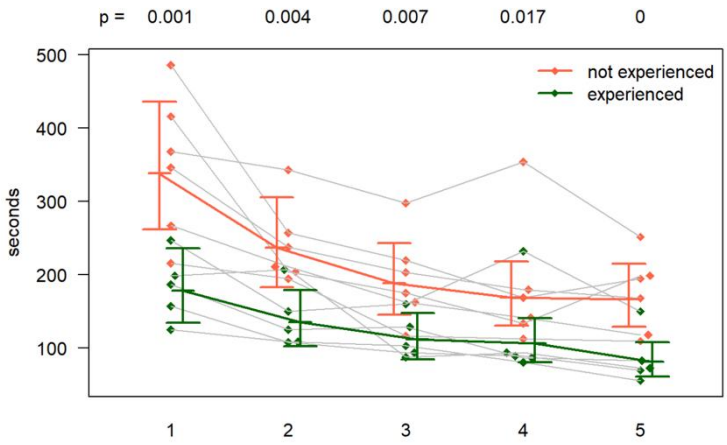

Figure 16: Learning curves of right hemicolectomy, x-axis: task repetitions; y-axis: time (seconds); Error bars are 95% confidence intervals around average values; heading p-values compare groups at each repetition

Figure 17 displays the average ratio of the required times between subsequent repetitions. From repetition 1 to repetition 2, residents and experienced surgeons become faster by 30% and 24% (according to average ratios of 0.70 and 0.76), respectively. This effect plateaus after the third repetition with average time savings at the fourth repetition of 10% and 5%.

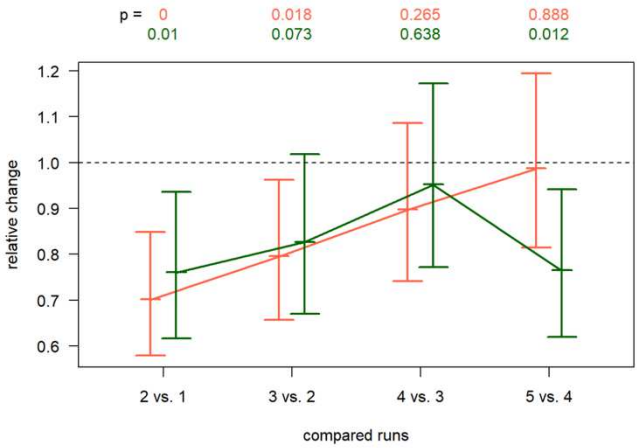

Figure 17: Multivariant analysis of right hemicolectomy, x-axis: compared runs; y-axis: relative change; p < 0.05

Docking

For the docking task, experienced surgeons were also significantly faster than surgical residents across all five repetitions (p = 0.002). Both groups required less time with an increasing number of repetitions (p < 0.001), while this improvement was even more expressed in residents (p = 0.016). Data are presented in Figure 18.

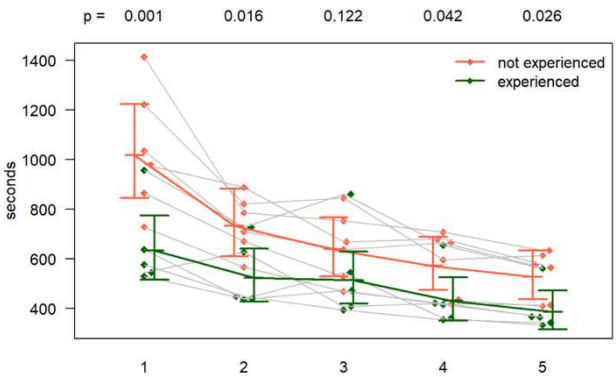

Figure 18: Learning curves of docking, x-axis: task repetitions; y-axis: time (seconds)); Error bars are 95% confidence intervals around average values; heading p-values compare groups at each repetition

De-Docking

The analysis of the learning curve for emergency de-docking demonstrates that experienced surgeons were consistently and significantly faster than residents across all repetitions (Figure 19, p =

0.005).Both groups became faster ($p < 0.001$) and learning curve was steeper for residents (0.017).

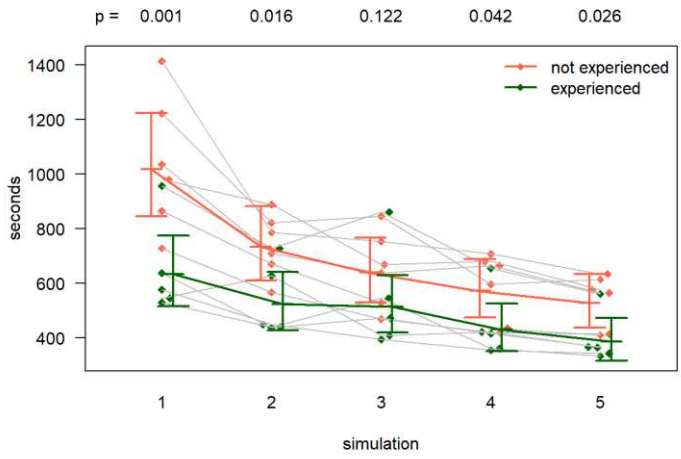

Figure 19: Learning curves of De-Docking, x-axis: task repetitions; y-axis: time (seconds)); Error bars are 95% confidence intervals around average values; heading p-values compare groups at each repetition

Discussion

Surgical techniques have undergone substantial evolution in recent years. Across all surgical specialties, the proportion of minimally invasive procedures—particularly robot-assisted interventions—has steadily increased [26]. In colorectal surgery in particular, the REAL trial demonstrated a significantly prolonged disease-free survival in the robotic cohort compared with laparoscopy. Additionally, a reduction in local recurrence rates was observed [27].

Due to the high demand for robotic systems, the market is currently undergoing rapid development. The Da Vinci Surgical System by Intuitive is the market leader with decades of innovation. However, Intuitive is increasingly facing competition from alternative providers. One in particular is the Hugo™ RAS System developed by Medtronic. A key challenge is the transfer of established surgical setups from one system to another. This issue is addressed in the presented study.

With regard to the existing literature, only a limited number of studies have addressed the application and setup of Hugo™ RAS system. In a series of five patients, outcome following transabdominal adrenalectomy were reported. Furthermore, the authors provided recommendations for the robotic setup [22]. With regard to general surgical procedures, there are limited publications adressing outcome parameters and setup guidelines [21] [28].

The available evidence regarding the practical application of the Hugo™ RAS system in colorectal surgery and especially right hemicolectomy is limited [23] [29] [30]. Port placement, as well as angulation and tilt of the arm carts are not standardized but vary depending on the authors' preferences and the specific procedure performed. The challenges associated with the Hugo™ system include the absence of procedural setup memory and its modular design, both of which require a higher level of device-specific expertise from the surgical team. Moreover, the Hugo™ platform is not yet widely distributed, resulting in a limited availability of experienced proctors. Consequently, surgeons adopting the Hugo™ system are required to invest substantial pioneering effort to facilitate its implementation and to support future users of the platform.

The primary objective of our study was to translate the setup for right hemicolectomy to the Hugo™ RAS system. Many centers have established their own standardized surgical setup for the Da Vinci Surgical System. We favor the open-book technique for right hemicolectomy and, when using the Da Vinci Surgical System, employ a trocar configuration arranged along a diagonal line extending from the right lower abdomen to the left upper abdomen. We aimed to preserve this setup and adapt it to the Hugo™ RAS system.

A key advantage of this robotic system is the independent positioning of the arm carts. However, this modularity necessitates careful preoperative planning of a precise setup, including predefined tilt and angle configurations.

In the first part of this study, we established these tilt and angle parameters for the open-book technique on the Hugo™ RAS system through a detailed, multi-step process. For this purpose, we utilized a custom 3D-printed model based on a patient we had previously

operated on, along with prior definition of the relevant procedural steps of right hemicolectomy. An experienced robotic surgeon repeatedly tested various setups until no external collisions occurred and optimal instrument handling within the surgical field was achieved

In the second part of the present study, we assembled a cohort of surgical residents and robotic experts to evaluate the learning curve of right hemicolectomy using our established setup. To the best of our knowledge, this is the first study to investigate the learning curve in colorectal surgery with the Hugo™ RAS system.

As expected, the robotic experts completed the procedural steps of right hemicolectomy significantly faster than the surgical residents across all iterations. However, both groups demonstrated a significant learning effect over successive repetitions, with a progressive reduction in time required for task completion. Notably, the learning curve reached a plateau after the third repetition. In contrast to the limited number of studies addressing the learning curve, we were able to demonstrate a training effect even among surgeons with prior experience in robotic surgery [31]. This further demonstrates the importance of a structured robotic training curriculum with the active integration of simulation-based training [32-34].

Not only the operative steps must be learned and practiced, but also docking of the robotic arms [35]. With regard to the residents in our study cohort, this task represents their first with robotic surgery. Four of six of the residents have already gained initial experience as table assistants. Learning the docking procedure on the Hugo™ RAS system appears to be rapid following structured instruction. Accordingly, the learning curve for docking among residents reaches a plateau as early as the third attempt.

Ensuring patient safety requires the practice of emergency de-docking in situations where an intraoperative complication necessitates conversion to an open procedure. In our study design, undocking was conducted as a team-based task, highlighting that such scenarios must also be practiced collectively. Within our study cohort, both residents and robotic experts demonstrated a significant learning curve with regard to emergency de-docking. To the best of our knowledge, the learning curve and training associated with docking and undocking have not yet been addressed in the existing literature.

A key limitation of our presented study is the experimental setup using a 3-D model. The next step will be to translate the now established setup for right hemicolectomy to the clinical setting.

In conclusion, our setup based on the open-book method with the Hugo™ RAS system is feasible. Furthermore, a structured simulation program is worthwhile with regard to the learning curve for both residents and experienced robotic surgeons.

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