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ORIGINAL ARTICLE

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# Surgery of the alimentary tract for benign and malignant disease with the novel robotic platform HUGO™ RAS. A first world report of safety and feasibility

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## Abstract

**Introduction:** As robotic surgery increases its reach, novel platforms are being released. We present the first 17 consecutive cases of alimentary tract surgery performed with the Hugo™ RAS (Medtronic).

**Methods:** patients were selected to undergo surgery from February through April 2023. Exclusion criteria were age <16 years, BMI>60, ASA IV.

**Results:** 17 patients underwent ileocaecal resection for Chrons disease (2 M and 1 F) and pseudo-obstruction of the terminal ileum (1 M), cholecystectomy (3 M and 5 F), subtotal gastrectomy with D2 lymphadenectomy (1 F), sleeve gastrectomy (1 F), hiatal hernia repair with Nissen fundoplication (1 M), right hemicolectomy (1 M) and sigmoidectomy (1 M). No conversion to an open approach or any arm collisions requiring corrective actions were reported.

**Conclusions:** Our preliminary experience with the Hugo™ RAS point to safety and feasibility for a rather wide spectrum of surgical procedures of the alimentary tract.

KEYWORDS

Hugo™ RAS, robotic cholecystectomy, robotic colon resection, robotic gastrectomy, robotic hiatal hernia repair, robotic ileocaecal resection, robotic nissen fundoplication, robotic right hemicolectomy, robotic sleeve, robotic surgery

## 1 | INTRODUCTION

Surgery of the alimentary tract and the general surgery field have been witnessing a surge in popularity of the robotic approach that is projected to continue for the foreseeable future. The enhanced vision and improved ergonomics, the wider range of motion and flexibility of the instruments, and the lack of physiologic tremor are well-known benefits of the robotic approach. The many technological features such as augmented reality[1] or indocyanine green (ICG)-aided fluorescent angiography or cholangiography[2,3] supported by the interface (computer)-based robotic platform have further contributed to this thriving trend.

The existing literature appears to support the theoretic technical advantages of the robotic platform as the comparison between this approach and the more traditional minimally invasive surgery (laparoscopy) shows a solid trend in favour of the former in terms of decreased rates of open conversion and intra-operative complications for complex, revisional and technically challenging surgeries or surgical conditions.[5,6] The robotic-assisted approach to the alimentary tract with the platform leading the market (daVinci™, Intuitive

Surgical, Sunnyvale, CA, USA) over the past 20 years has been extensively standardized.[9,10]

Newer and different robotic systems are being released into the market to address the growing demand for the robotic approach. Among them, the recently launched Hugo$^{TM}$ RAS (Medtronic, Minneapolis, MN, USA) offers amongst other innovative features an open console concept and a multi-modular system that allows independent docking of the four arms. The Hugo$^{TM}$ RAS has received Conformitè Europèenne CE approval for general surgery in October 2022.

Herein, we present a report of safety and feasibility and provide technical details on the setup of the Hugo$^{TM}$ RAS system for a rather wide spectrum of surgical procedures addressing both benign and neoplastic diseases of the alimentary tract.

## 2 | MATERIALS AND METHODS

Patients referred to our tertiary care centre (IRCCS Azienda Ospedaliero-Universitaria di Bologna) at the Department of the Alimentary Tract and Emergency Surgery were selected to undergo surgery with the Hugo RAS$^{TM}$ from February through April 2023. Inclusion criteria included age >16, BMI ≤59, ASA ≤ III, indication for one of the surgical procedures that have received CE approval (partial and total gastrectomy; Roux-en-Y-gastric bypass; sleeve gastrectomy; Cholecystectomy; splenectomy; resection of the small intestine; appendectomy; lysis of adhesions; partial and total colectomy; hiatal hernia type I and II; Nissen fundoplication; ventral and inguinal hernia repair; low anterior resection with and without TME; rectopexy).

Exclusion criteria were age ≤16 years, BMI≥60, ASA IV. Patients demographics and characteristics are presented inside Table 1 The leading author (AG) has extensive experience in robotic surgery (mastery level); two surgeons had no prior robotic surgery experience (R.M. - P.G.) but are expert laparoscopic surgeons (>1000 and > 2000 cases respectively), the third surgeon (B.P.) had prior robotic experience (>50 cases on the daVinci™) in addition to laparoscopy () (>2500 cases) who transitioned more recently to robotics. All surgeons participating in the surgical procedures obtained certification for the use of Hugo$^{TM}$ RAS on 15 February 2023 at the training and certifying facility identified by Medtronic and located in Melle, Belgium (Orsi Academy) (G.A—R.M.—B.P.). The leading author was the console surgeon for 12 cases. The other two (R.M.—B.P.) surgeons transitioned from a bedside assistant to console surgeon for the remaining 5 cases (4 and 1, respectively) with the leading author sitting at the console side. All patients provided informed consent.

## 3 | OPERATING ROOM SET-UP

1. Surgeon Console:

To avoid a potential reason for disturbance or distraction for the surgeon using the pass of people moving inside the operating room (OR), the surgeon console is placed over one of the corners with its right side alongside the wall (Figure 1 - "*OR Setting* - *Cable disposition* … *a*, *b*, *c* and *d*"). This position allows the console surgeon to have a good view of the surroundings and facilitates communication with the rest of the OR team. Furthermore, the console power socket is located on the same corner of the OR and facing the back of the console surgeon, thus allowing shorter cable travel and preventing the console cables from being an obstacle for the surgical team or during the surgical cart repositioning.

Lastly, being the console close to the departure exit used to transition the patient to the recovery room after the procedure ended, the surgeon is not disturbed by the staff eventually accessing or exiting the OR through the main door that is located on the opposite side of the room.

2. Operating table:

The operating table is placed perpendicular to the imaginary line connecting the two OR doors (main entrance and departure), as we can see in Figure 1 "*OR Setting* - *Cable disposition* … *a*, *b*, *c* and *d*".

This position:

- facilitates the communication between the console surgeon and the staff assisting at the OR table whilst the console surgeon is maintaining a direct view of the surgical field;
- allows the anaesthesiologist to get rapid access to the medications stored inside the built-in cabinet facing the head-side of the OR table;
- frees up greater space on each side of the operating table for the robotic arms carts, the AirSeal® insufflation system cart, the robotic system tower, and the scrub nurse table.

3. cable disposition:

The manufacturer's directives indicate to place the power cables of the arm carts near the operating table as we can see in Figure 1 "*OR—Setting* - *Cable disposition* … *e*". However, we noticed with this type of disposition, the bedside assistant and the scrub nurse felt constrained and had difficulty in moving the surgical instrument table. Thus, we opted for a different configuration (Figure 1 "*OR Setting-Cable disposition* … *f*") as we have been placing the cables behind the robotic arm carts. This configuration opens the area around the operating table and enables the bedside assistant and the scrub nurse greater freedom of movement. We anticipate this configuration could also facilitate the undocking procedures in case of urgent open conversion as it frees up the field around the operating table from the presence of the arm carts' cables.

4. Scrub nurse and bedside assistant:

During our first procedure (Figure 1 "*OR Setting* - *Cable disposition* … *a*"), the scrub nurse and the bedside assistant were on opposite sides of the operating table facing each other. This configuration disturbed the exchange of surgical instruments. Thus, in the following procedures (see Figure 1 "*OR Setting* - *Cable disposition* … *b*, *c* and *d*"),

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**TABLE 1** Patient characteristics—Docking/tilting angles and operating room settings implemented for each surgical procedure - Surgical outcome.

| | Patient 1 - *Ileo-cecal Resection* | Patient 2 - *Ileo-cecal Resection* | Patient 3 - *Sleeve gastrectomy* | Patient 4 - *Cholecystectomy* | Patient 5 - *Ileo-cecal Resection* | Patient 6 - *Subtotal Gastrectomy* | Patient 7 - *Hiatal Hernia Repair + Nissen* | Patient 8 - *Sigmoidectomy* | Patient 9 - *Cholecystectomy* |
|---|---|---|---|---|---|---|---|---|---|
| **Age (years)** | 25 | 34 | 32 | 40 | 17 | 74 | 67 | 62 | 53 |
| **Sex (Male/Female)** | M | M | F | M | F | F | M | M | M |
| **Body Mass Index (Kg/m2 )** | 18.52 | 24.98 | 35.65 | 24.69 | 25.95 | 16.42 | 25.54 | 24.86 | 25.51 |
| **Comorbidities** | Chron's | Chron's | Morbid obesity | Tiroiditis | Chron's | Gastric Ca - HTN - Chronic Anemia | GERD - Hiatal hernia-HTN-BPH-MGUS | Diverticulitis-Prostate Ca | Cholelithiasis |
| **Previous Open Abdominal Surgery** | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **Docking time (min)** | 7 | 4 | 5 | 5 | 7 | 4 | 6 | 5 | 5 |
| **Tilt Arm #1 (°)** | +30 | +30 | -45 | -45 | +30 | -45 | -45 | -15 | -45 |
| **Tilt Arm #2 (°)** | +30 | +30 | +15 | +30 | +30 | +15 | +15 | -45 | +30 |
| **Tilt Arm #3 (°)** | -30 | -30 | +30 | +30 | -30 | +30 | +30 | -30 | +30 |
| **Tilt Arm #4 (°)** | -30 | -30 | -45 | -45 | -30 | -45 | -45 | +30 | -45 |
| **Docking Arm # 1 (°)** | 45 | 43 | 33 | 30 | 43 | 33 | 31 | 44 | 29 |
| **Docking Arm # 2 (°)** | 130 | 127 | 74 | 70 | 123 | 73 | 77 | 78 | 72 |
| **Docking Arm # 3 (°)** | 230 | 232 | 255 | 290 | 231 | 244 | 251 | 146 | 287 |
| **Docking Arm # 4 (°)** | 315 | 315 | 323 | 330 | 311 | 323 | 326 | 250 | 328 |
| **Number of docked robotic arms** | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **Console time (min)** | 140 | 100 | 38 | 48 | 160 | 240 | 150 | 147 | 75 |
| **Bedside Assistant** | Attending Surgeon | Attending Surgeon | Attending Surgeon | Attending Surgeon | Attending Surgeon | Attending Surgeon | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents |
| **OR Setting ( See the Figure.. Pg. ..)** | a | b | c | c | b | c | c | d | c |
| **Cable Disposition** | Facing Arm Carts, Next to the Operating table | Facing Arm Carts, Next to the Operating table | Facing Arm Carts, Next to the Operating table | Facing Arm Carts, Next to the Operating table | Facing Arm Carts, Next to the Operating table | Facing Arm Carts, Next to the Operating table | Facing Arm Carts, Next to the Operating table | Behind Arm Carts | Behind Arm Carts |
| **Skin-to-skin time (min)** | 166 | 135 | 67 | 80 | 205 | 305 | 175 | 267 | 111 |
| **Intra-operative complications (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **Arms collisions (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **Open conversion (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **EBL (ml)** | 50 | 30 | 20 | 10 | 30 | 75 | 40 | 50 | 20 |
| **Post-operative complications (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **Discharge home (POD)** | 9 | 5 | 3 | 1 | 7 | 15 | 4 | 7 | 1 |

| | Patient 10 - *Cholecystectomy* | Patient 11 - Ileo-cecal Resection | Patient 12 - *Cholecystectomy* | Patient 13 - *Cholecystectomy* | Patient 14 - Ileo-cecal Resection + Cholecystectomy | Patient 15 - *Cholecystectomy* | Patient 16 - Right Hemicolectomy | Patient 17 - *Cholecystectomy* |
|---|---|---|---|---|---|---|---|---|
| **Age (years)** | 31 | 69 | 47 | 52 | 60 | 77 | 83 | 60 |
| **Sex (Male/Female)** | F | M | F | F | F | F | M | M |
| **Body Mass Index (Kg/m2 )** | 23.03 | 21.97 | 28.23 | 24.61 | 27.91 | 31.25 | 31.38 | 29.54 |
| **Comorbidities** | IBD | Pseudo-obstruction, HPT, OSA, diverticulosis, angina, BPH | Mitral and Tricuspid Valve Prolapse, Uterine adenomyosis, Hepatic angioma | None | Chron's, Choledocholithiasis s/p ERCP, Hypothyroidism | TIA, BPCO stage I, Peptic ulcer, GERD | Moderately differentiated (G2) adenoca, AFIB | HPT |
| **Previous Open Abdominal Surgery** | NO | NO | NO | C-section | NO | NO | NO | NO |
| **Docking time (min)** | 5 | 8 | 9 | 7 | 7 | 9 | 7 | 6 |
| **Tilt Arm #1 (°)** | -45 | +30 | -45 | -45 | +30 | -45 | +30 | -45 |
| **Tilt Arm #2 (°)** | +30 | +30 | +30 | +30 | +30 | +30 | +30 | +30 |
| **Tilt Arm #3 (°)** | +30 | -30 | +30 | +30 | -30 | +30 | -30 | +30 |
| **Tilt Arm #4 (°)** | -45 | -30 | -45 | -45 | -30 | -45 | -30 | -45 |
| **Docking Arm # 1 (°)** | 34 | 45 | 35 | 31 | 47 | 31 | 45 | 29 |
| **Docking Arm # 2 (°)** | 80 | 130 | 79 | 70 | 131 | 75 | 130 | 70 |
| **Docking Arm # 3 (°)** | 287 | 229 | 285 | 290 | 231 | 289 | 231 | 290 |
| **Docking Arm # 4 (°)** | 330 | 328 | 330 | 329 | 315 | 331 | 317 | 330 |
| **Number of docked robotic arms** | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **Console time (min)** | 32 | 78 | 35 | 30 | 145 (Ileo-cecal Resection) 49 (Cholecystectomy) | 68 | 170 | 65 |
| **Bedside Assistant** | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents | Attending Surgeon + Residents |
| **OR Setting ( See the Figure.. Pg. ..)** | c | b | c | c | b | c | b | c |
| **Cable Disposition** | Behind Arm Carts | Behind Arm Carts | Behind Arm Carts | Behind Arm Carts | Behind Arm Carts | Behind Arm Carts | Behind Arm Carts | Behind Arm Carts |
| **Skin-to-skin time (min)** | 50 | 132 | 90 | 85 | 325 | 115 | 235 | 145 |
| **Intra-operative complications (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO |
| **Arms collisions (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO |
| **Open conversion (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO |
| **EBL (ml)** | 10 | 10 | 10 | 10 | 30 | 30 | 30 | 30 |
| **Post-operative complications (yes/no)** | NO | NO | NO | NO | NO | NO | NO | NO |
| **Discharge home (POD)** | 1 | 12 | 2 | 1 | 7 | 2 | 10 | 1 |


**FIGURE 1** - OR Setting - Cable disposition (A) Patient 1, (B) Patients 2, 5, 11, 12, 15 and 17, (C) Patients 3, 4, 6, 7, 9, 10, 13, 14, (D) Patient 8 and 16. The arm carts around the operating table are named per vendor recommendations (Medtronic) starting from the patient's head clockwise arm1, arm 2, arm 3 and arm 4. In green are represented the two overhead lights, the anaesthesia cart next to the anaesthesiologist and the cart to power the AirSeal insufflation system and the DS1.

the scrub nurse moved next to the bedside assistant, which facilitated the workflow. Digital plans, as presented in Figure 1 "*OR Setting-Cable disposition*", illustrating the OR set-up, were uploaded to the OR computer for easy access by the nursing staff during the set-up procedures.

## 4 | PORT SETTING

The port setting for ileocaecal resection, right hemicolectomy, sleeve gastrectomy, subtotal gastrectomy, cholecystectomy and sigmoidectomy as suggested by Medtronic is shown in Figure 2 "Port setting—Vendor, *a*,*b*,*c*,*d*".

The recommended port settings are generally provided by the vendor to the OR staff in a pdf or paper format. We decided to use the monitors of the OR to display the port setting (Figure 2 "Port setting—Vendor, *e*) to make them easily visible to the whole OR team and to use them as a didactic tool for the surgical residents present in the OR during the placement of the robotic trocars. In addition, having the port setting displayed on the monitors was more functional and practical instead of having it in a paper format.

In our institution, we employed a slight variance in the vendor recommendations for ileocaecal resection, right hemicolectomy, subtotal gastrectomy and sigmoidectomy. For sleeve gastrectomy and cholecystectomy (Figure 3 Port setting, *b* and *c*), the port setting was the same as recommended by the vendor.

In one of the ileocaecal resections (Figure 3 Port setting, *a*), the camera was moved caudally by 2 cm because the patient had a tight and long abdomen. The reserve arm ("R3") was also moved caudally as it was too close to the ribs.

In the subtotal gastrectomy (Figure 3 Port setting, *d*), the camera and right arm trocars were moved up and brought to the same line as the left robotic arm and the reserve arm trocars to better reach the stomach.

In the sigmoidectomy (Figure 3 Port setting, *e*), the right arm ("R1") trocar was placed along the same line as the left arm ("R2") and camera ("C") to get more effectively to the target anatomy.

## 5 | TILT AND DOCKING

The Hugo™ system consists of 4 independent arm carts, each arm requiring its own settings. Two main settings are required to configure each arm. One is the tilt angle, which is the vertical angle of the arm with respect to the flat operative bed (0°) and can be adjusted by lifting upwards or downwards the arm's nose. The other is the docking angle, which is the clockwise horizontal angle between the head of the patient (0°) and the arms direction. System docking and tilting of the robotic arms were straightforward and speedy processes for a properly trained surgical team, as shown in Table 1.

A key feature of the Hugo™ system is the modularity that allows for different tilt and docking angles.

In our setting, we changed the tilt and docking angles suggested by the vendor.

The variations were implemented trying to stay as much as possible within the tolerance range of +/−5° set by the vendor. However, the actual angles that were set at docking time for the various surgical procedures are indicated in Table 1. The modifications of the tilt and docking angles were employed to:

- increase the ability of the robotic instrument to reach out the target anatomy;
- optimise the workspace around the operating table for the bedside team (Figure 1 OR Setting - Cable disposition … *a*, *b*, *c* and *d*). For instance, during the sleeve gastrectomy, cholecystectomy, subtotal gastrectomy, and hiatal hernia repair with Nissen fundoplication, we increased the tilt angles of arms 1 and 4 (Figure 1 OR Setting - Cable disposition … *d*) from −30 to −45, to free some space for the anaesthesiologist who was standing in between these two arms;
- avoid instrument collision and clashing between the robotic arms outside the abdominal cavity. For instance, during the sleeve gastrectomy, cholecystectomy, and hiatal hernia with Nissen fundoplication, the arm 3 was used as the liver retractor, while the other three arms worked on the target anatomy. Thus, to prevent a collision between arm 3 and the other arms, the docking angle was reduced from 290° to 250°;

In the ileocaecal resection instead the docking angle of the camera arm was increased from 120° to 130° to allow the anaesthesiologist greater working space; In the sigmoid resection the docking angle of the left arm (R2) was decreased from 65° to 45° to better the reaching out of the splenic flexure whilst the docking angle of the camera arm was reduced from 105° to 90° to avoid collisions with the reserve arm; the docking angle of the right arm (R1) was instead increased from 240° to 250° to better the reaching out of the sigmoid colon.

## 6 | SURGICAL INSTRUMENTS

The surgical instruments used for the various procedures are presented in Table 2 - Surgical Instruments. Presently, the monopolar curved shears have a duration of 45 min. Thus, for the longer procedures, multiple robotic shears had to be used. Due to chain supply issues, the whole cholecystectomy of patient 10 had to be performed using only the robotic Maryland. Hugo's portfolio of robotic instruments currently does not include a robotic stapler, robotic hook, or any robotic energy device. The laparoscopic equivalent had to be employed instead (Table 2 "*Surgical instruments*").

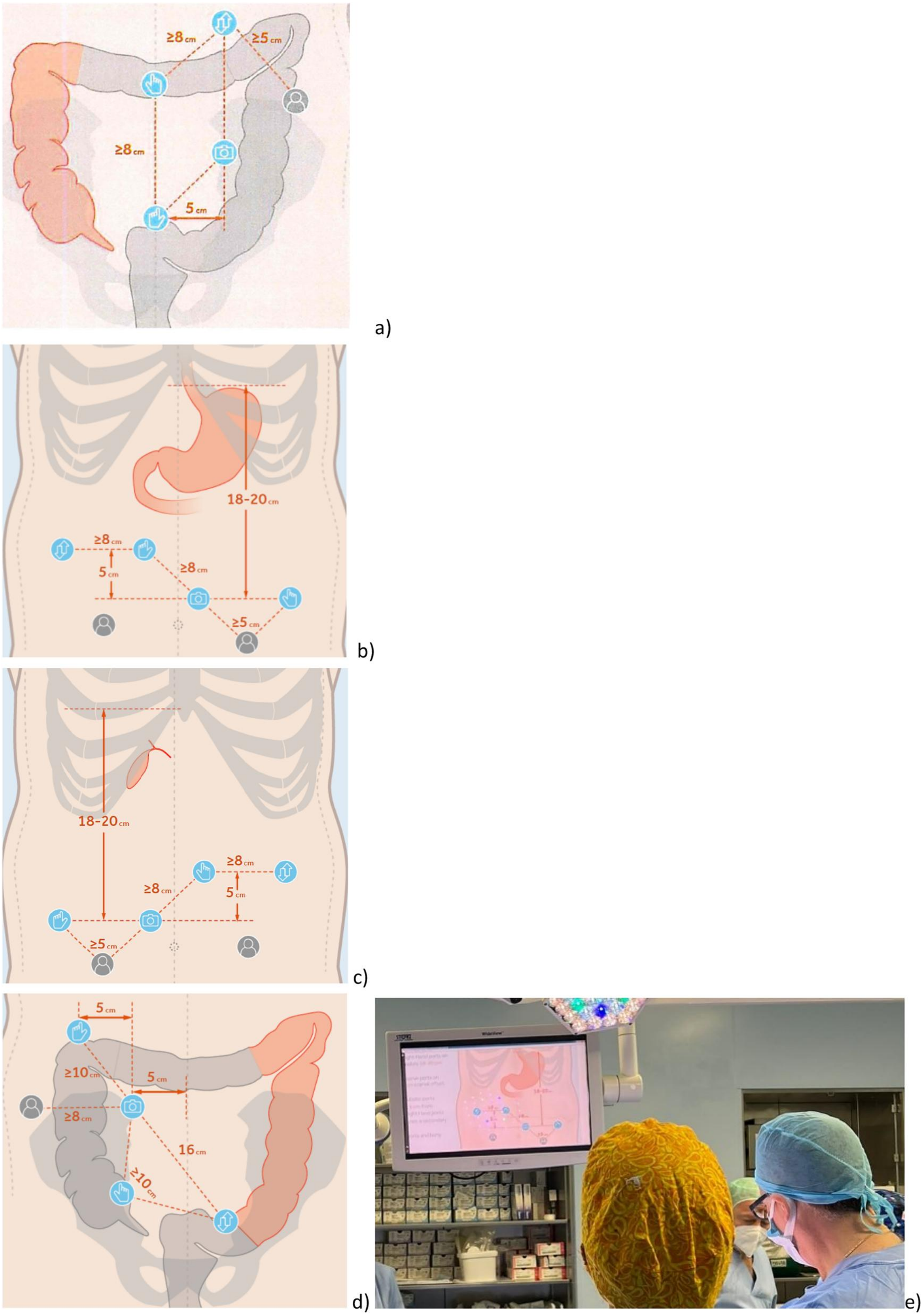


**FIGURE 2** Port setting—Vendor. Recommended port setting for (A) ileocaecal Resection and Right Hemicolectomy, (B) Sleeve gastrectomy, Subtotal Gastrectomy and Nissen, (C) Cholecystectomy, (D) Sigmoidectomy and Left Hemicolectomy. (Images authorised by Medtronic). The port setting suggested by Medtronic are provided in the pdf or paper format. We decided to use the monitors to display them (E).

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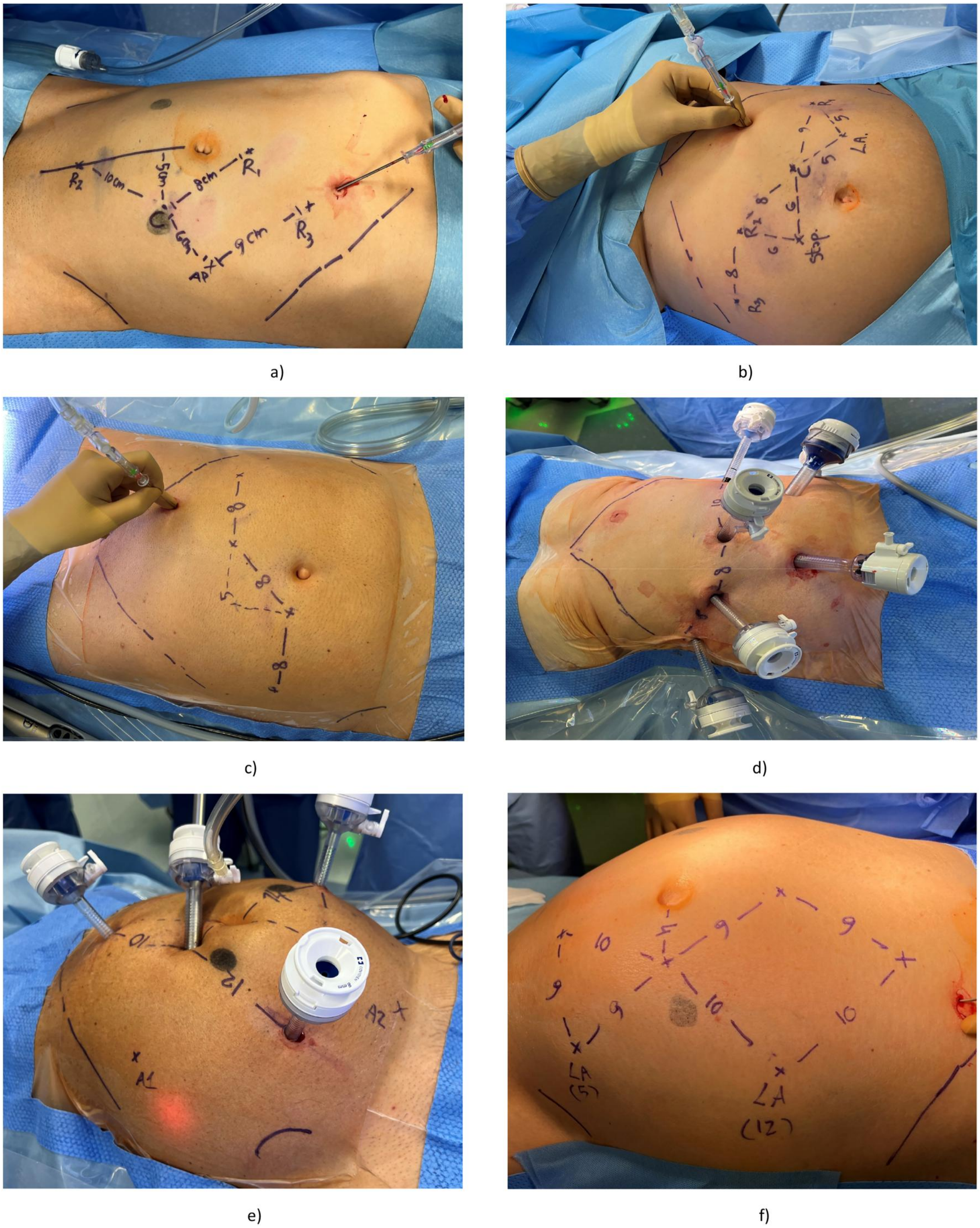


**FIGURE 3** Port Setting (A) Ileocaecal Resection, (B) Sleeve gastrectomy, (C) Cholecystectomy, (D) Subtotal Gastrectomy, (E) Sigmoidectomy, (F) Ileocaecal Resection + Cholecystectomy, blue circles in figure (A, E, F) are pre-operative identification for possible ostomy. "R1" and "R2" stands for surgeons' right- and left-hand robotic arm and "R3" for the reserve arm. "C" stands for camera port. "LA" stands for laparoscopic assistant trocar. "A1" and "A2" stand for laparoscopic assistant trocar n. 1 and n. 2. "Stap." indicates the laparoscopic assistant trocar identified for the placement of the stapler. Distances between adjacent trocars are marked in centimetres.

## 7 | SURGICAL TECHNIQUE

This study links the safety and feasibility of a novel robotic surgery platform to the surgical technique implemented by the authors to perform the presented surgical procedures. Thus, the specific surgical technique is being discussed in further detail. The pneumoperitoneum (pressure range 12–15 mmHg) was successfully established in all cases through the placement of the Veress needle over the Palmar's point. A 2 + 2 configuration (2 robotic carts with their respective arm coming from each side of the OR table) was used for

**TABLE 2** Surgical Instruments used for the various surgical procedures.

| | Robotic | Laparoscopic |
|---|---|---|
| Ileocaecal Resection, Right Hemicolectomy | Monopolar Curved Shears, Bipolar Fenestrated Grasper, Bipolar Maryland Forceps, Large Needle Driver, Cadiere Forceps, Double Fenestrated Grasper | Signia™Stapler (Medtronic), LigaSure™(Covidien) |
| Sleeve gastrectomy | Cadiere Forceps, Bipolar Fenestrated Grasper, Double Fenestrated Grasper | Signia™Stapler (Medtronic) |
| Cholecystectomy | Monopolar Curved Shears, Large Needle Driver, Cadiere Forceps, Double Fenestrated Grasper | Signia™Stapler (Medtronic) |
| Subtotal Gastrectomy | Monopolar Curved Shears, Bipolar Fenestrated Grasper, Bipolar Maryland Forceps, Large Needle Driver, Cadiere Forceps, Double Fenestrated Grasper | Signia™Stapler (Medtronic) |
| Hiatal Hernia Repair + Nissen | Monopolar Curved Shears, Bipolar Fenestrated Grasper, Bipolar Maryland Forceps, Large Needle Driver, Cadiere Forceps, Double Fenestrated Grasper | Sonicision™ (Medtronic), Signia™Stapler (Medtronic) |
| Sigmoidectomy, Left Hemicolectomy | Monopolar Curved Shears, Bipolar Fenestrated Grasper, Bipolar Maryland Forceps, Large Needle Driver, Cadiere Forceps, Double Fenestrated Grasper | Signia™ Stapler, Sonicision, (Medtronic) |
| Ileocaecal Resection + Cholecystectomy | Bipolar Fenestrated Grasper, Double Fenestrated Grasper, Monopolar Curved Shears, Cadiere Forceps, Large Needle Driver | Signia™Stapler (Medtronic), LigaSure(Covidien) |

all cases but the sigmoidectomy where a 3 + 1 (three robotic carts with their respective arm coming from the left side of the patient and one from right) configuration was instead implemented.

## 7.1 | Ileocolic resection

The patient is placed in the supine position and the OR table in moderate Trendelenburg and with a slight left tilt. The ileocaecal valve was then identified and the ileum was then run from distal to proximal until encountering grossly healthy-looking intestine and pertinent mesentery. A window was then created through the mesenteric border of the healthy-looking loop of the ileum with the robotic monopolar sears; the laparoscopic stapler was then inserted through the opening and fired (45 mm single bronze cartridge Signia$^{TM}$) to transect the ileum. The stump was then lifted up and the mesentery of the ileum transected in a proximal to distal direction until reaching the ileocolic junction. Here the ileo-colic pedicle was dissected and then transected in between 10 mm Hem-o-locks. The transection of the mesentery continued then from caudal to cephalad and from medial to lateral and until reaching the level of the proximal ascending colon. A phlegmon was identified for patient 1 and patient three involving the mesentery of the segment affected by the terminal ileitis and an adjacent loop of ileum in a far distant area of healthy intestine. The phlegmon was dissected with robotic bipolar forceps and sears. During this step, the laparoscopic energy device (Ligasure$^{TM}$- Covidien for the first two cases and then Sonicision-Medtronic for the third one) was used to achieve haemostatic control. A second window was then created with the robotic sears over the mesenteric border of the ascending colon and a second load of linear stapler was fired through it to transect the colon (60 mm single purple cartridge Signia$^{TM}$). The caecum was then mobilised from the parieto-colic gutter proceeding from lateral to medial and caudal to cephalad direction, paying attention to avoid accidental injuries of the ureter. Intestinal continuity was then re-established by creating an ileocolic anastomosis in a side-by-side and anti-peristaltic fashion by firing through the enterotomies created with the robotic sears on each stump a 60 mm load of linear stapler (single purple cartridge Signia$^{TM}$). The resulting common enterotomy was then approximated in a double layer with 3-0 polydioxanone (PDS) (continuous for the mucosal and interrupted with Lembert technique for the sero-muscular). A running suture was then applied to the free margin of the mesentery to reinforce it and thus decrease the likelihood of post-operative bleeding.

## 7.2 | Sleeve gastrectomy

A 36 Fr boogie was inserted orally by the anaesthesia team to use it as a guide in creating the stomach tube (sleeve) from the greater curvature to the lesser curvature.

Once the greater curvature of the stomach was completely separated using the laparoscopic energy device and the short gastric vessels controlled with the laparoscopic energy device and the fundus completely mobilised and the left crus fully visualised, sequential purple loads of laparoscopic stapler were used to transect the stomach vertically and create the gastric tube.

The haemostasis along the staple line did not require the application of any haemostatic stitches or agents.

A 15-Fr Jackson-Pratt drain was brought in through one of the trocars and its tip was left in the proximity of the GE junction.

The robot was then undocked, and the specimen was removed by extending the 11-mm trocar site fascia, which was then closed with 0-vicryl stitches under direct vision.

The drain was secured to patient's skin by using interrupted 3/0 Nylon stitch.

## 7.3 | Cholecystectomy

The patient was placed in the reverse Trendelenburg position. We grasped the fundus of the gallbladder with the double fenestrated forceps of the reserve arm ("R3") and pulled this cranially towards the diaphragm to expose the gallbladder neck and to lift the liver. The robotic bipolar forceps and monopolar sears were then used to dissect the hilum of the gallbladder for all cholecystectomies but the third one of the series where the bipolar Maryland had to be employed due to shortage of the robotic sears. We started by peeling off the superficial peritoneum layer covering the neck of the gallbladder to expose the cystic duct and the cystic artery. For our first cholecystectomy, we proceeded with suture ligation of the cystic duct and artery by using monofilament not absorbable sutures to prove the feasibility of Hem-o-lock free procedure and test at once the capabilities of the robotic instruments with fine suture ligation of small anatomical structures. For all the other cholecystectomies, after having verified the adequacy of Calot triangle exposure, we instead clipped the two structures with laparoscopic Hem-O-loks introduced through the "R1" trocar after having removed the robotic instrument on that side. Cystic duct and artery were then transected in between these Hem-O-loks with robotic shears or laparoscopic sears for the one case lacking the former. At this point, using the bipolar forceps and the robotic sears or the Maryland, we dissected the gallbladder from its liver bed. An endobag was deployed over the Mayo table of the scrub nurse and then pushed inside the peritoneal cavity manually with a laparoscopic grasper and through the "R2" robotic trocar to avoid the placement of an additional 12 mm laparoscopic trocar to deploy the bag inside the peritoneal cavity.

The gallbladder was then placed inside the endobag and removed outside the peritoneal cavity.

## 7.4 | Radical subtotal gastrectomy with billroth II anastomosis

An incision is made in the gastrocolic ligament just outside the gastroepiploic arcade on the body of the stomach. The gastro-colic ligament is divided parallel to and a few centimetres outside the gastroepiploic arcade towards the left gastroepiploic artery. The left gastroepiploic artery is identified, dissected, clipped and divided (n 4s node dissection). The gastrocolic ligament is divided along the same plane distally towards the right side (n 4 days node dissection). The right gastroepiploic vein and artery are dissected, clipped and divided (n 6 nodes dissection). The duodenum is retracted down, the hepatoduodenal ligament is incised and a window is created. The first part of the duodenum is mobilised and the gastroduodenal artery is identified and dissected. A linear stapler is inserted to divide the duodenum. The right gastric artery and vein are identified and divided (n 5 nodes dissection). The lesser omentum is divided laterally close to the liver towards the abdominal oesophagus. The peritoneum overlying the anterior surface of the pancreas is incised and the dissection progressed cranially until the common hepatic artery is reached and dissected (n 8a nodes dissection). The left gastric vein was found and divided anteriorly to the common hepatic artery (n 8p nodes dissection). The left gastric pedicle is retracted ventrally to facilitate dissection around the root of the left gastric artery that is clipped and divided (n 7 nodes dissection). The dissection is continued posteriorly along the anterior surface of the coeliac trunk towards the diaphragmatic hiatus (n 9 nodes dissection) and laterally along the splenic artery (n 11 p nodes dissection). The lesser curvature nodes (n 3) and right cardias nodes (n 1) are separated from the gastric wall. The stomach is transected with a linear stapler. The reconstruction is commenced (ante colic Billroth 2 with linear stapler plus Vlock 3:0).

The specimen is then removed through a Pfannestiel incision and a Jackson-Pratt drain left in the proximity of the anastomosis.

## 7.5 | Hiatal hernia repair + nissen fundoplication

We started the operation by opening the lesser omentum with the robotic monopolar sears over its most lateral aspect to avoid accidental injury of the vagus nerve termination reaching the lesser curvature and then incised with a caudal to cephalad and lateral to medial direction until reaching the caudal aspect of the right crus detaching the body of the stomach right below the cardiac region from the hernia sac and exposing the right crus. We continued the dissection in a circumferential fashion and therefore moved from the right to the left side and from the anterior to the posterior plane and therefore approached the phreno-oesophageal membrane first and then the body of the stomach right below the funding region and the left crus. Using electrocautery, the left crus was completely dissected, and the hiatus was then fully exposed. Down-traction with laparoscopic graspers was applied to the stomach by the surgeon assisting at the table whilst the dissection was continued inside the mediastinum. The mediastinal oesophagus was then circumferentially dissected alternating the robotic monopolar sears with the robotic Maryland to allow the viscus to reach the abdomen freely and with no tension. By following this proximal to distal strategy at some point, we fully exposed the oesophagus and could safely place a

Penrose drain around it. Every effort was made to preserve the anterior vagus nerve that was identified inside the mediastinum. The oesophagus and the herniated stomach were completely detached from the mediastinum, and both were successfully pulled back inside the abdomen. At this point, we could safely complete the posterior and distal dissection of the oesophagus and re-position the Penrose drain and fully expose the right and left crus over the posterior and caudal planes. We now had full and good exposure of the oesophagus, the stomach and the Nissen, and a hiatal defect that was found to be around 3–4 cm in size. We decided to close the hiatus posteriorly with interrupted 2/0 prolene sutures. The Penrose drain was then removed under camera vision through a 12 mm accessory laparoscopic trocar placed over the left abdomen. Then, attention was turned to the construction of the gastric fundoplication. The most posterior aspect of the fundus was grabbed behind the oesophagus and brought to the opposite site for the construction of the wrap. We made sure that the wrap reached into its position without excessive tension. The shoeshine manoeuver was also performed showing a floppy fundoplication. The fundoplication sits on the oesophagus and is 3 cm in length. Three gastrogastric sutures were performed using 2-0 prolene.

## 7.6 | Right hemicolectomy

Traction was applied to the caecum and the distal ileum with medial to lateral and cephalad to the caudal direction to tense up the mesentery of the right colon and facilitate the identification of the ileocolic pedicle. The peritoneum overlying the mesentery over this area was scored with robotic sears and the ileocolic artery was identified, dissected, and double clipped with Hem-o-Locks and then transected with robotic sears. The plan between the mesentery and the retroperitoneum was then opened with a combination of sharp and blunt technique and by using the robotic sears and bipolar forceps until reaching the hepatic flexure laterally and the point past the duodenum medially. The right branch of the middle colic artery was similarly identified, dissected, and clipped and transected between Hem-o-locks. The dissection continued in the medial to lateral direction until reaching the lateral margin of the entire right colon whilst sweeping down all associated nodal tissue with the specimen. At this point, we approached the right colon from the opposite direction and performed the dissection of the viscus along the line of Told from the caecum to the hepatic flexure. The homolateral ureter was identified and protected as was the duodenum. Points of transection were selected proximally and distally over the infra-hepatic flexure segment and the terminal loop of the right colon and ileum, respectively. A window through the mesentery of these segments was created in the proximity of the mesenteric margin of the bowel with the robotic sears and used to introduce the Signia™ that was then fired. The two stumps were brought together in iso-peristaltic fashion. Two stay sutures were applied proximally and distally to achieve greater juxtaposition and then enterotomies were created through each stump with robotic sears. A second load of Signia™ was fired and the anastomosis completed. The resulting "common" enterotomy was re-approximated in two layers with 3-0 PDS continuous suture for the inner and interrupted with the Lembert technique for the outer.

## 7.7 | Sigmoidectomy

Traction was applied to the descending and sigmoid colon with medial to lateral and caudal to cephalad direction to tense up the mesentery of the left colon and facilitate the identification of the left colic artery. The peritoneum overlying the mesentery over this area was scored with robotic sears and the left colic artery was identified, dissected, and double clipped with Hem-o-Locks and then transected with robotic sears. The plan between the mesentery and the retroperitoneum was then opened with a combination of sharp and blunt technique and by using the robotic sears and bipolar forceps until reaching the splenic flexure laterally. The inferior mesenteric artery was similarly identified, dissected, and clipped and transected near its origin in between Hem-o-locks. All the associated nodes were swept down with the specimen. The dissection continued in the medial to lateral direction until reaching the lateral margin of the entire left colon whilst sweeping down all associated nodal tissue with the specimen. At this point, we approached the left colon from the opposite direction and performed the dissection of the viscus along the line of Told from the junction with the rectum to the splenic flexure. The homolateral ureter was identified and protected. Points of transection were selected proximally and distally over the infra-splenic flexure segment and the sigmoid-rectal junction respectively. A window through the mesentery of these segments was created in the proximity of the mesenteric margin of the bowel with the robotic sears and used to introduce the Signia™ that was then fired. The specimen was removed through a Pfannenstiel incision protected by an Alexis® wound protector. The proximal stump was brought out through the Alexis and a purse string suture with prolene 2-0 was applied to its free margin and then tied around the anvil of the selected circular stapler and repositioned inside the peritoneal cavity. The circular stapler was introduced inside the rectum through the anus and fired after reaching out the anvil priory placed inside the proximal stump. The completed anastomosis was then checked with pneumatic leak test performed transrectally. A Jackson-Pratt drain was left near the anastomosis.

# 8 | RESULTS

17 patients underwent robotic-assisted (Hugo™ RAS system) ileocaecal resection for Chrons disease (two males and one female) and pseudo-obstruction of the terminal ileum (one male), cholecystectomy (three males and five females), subtotal gastrectomy with D2 lymphadenectomy (one female), sleeve gastrectomy (one female), hiatal hernia repair with Nissen fundoplication (one male), right hemicolectomy (one male) and sigmoidectomy (one male).

The median docking and console time were 6.23 (range: 4–9) and 104.12 (range: 30–240) minutes respectively. The port setting, the docking and tilting angles, the operating room (OR) setup are described. No conversion to open or laparoscopic approach was reported nor any arm collisions requiring corrective actions. Patient number 1 (ileocolic resection) required the transfusion of 2 packed red blood cells (PRBC) units for a self-resolved episode of haematochezia. In one patient, cholecystectomy was performed concomitantly to the ileocaecal resection by changing the position of only one robotic trocar. The median skin-to-skin time 158.12 min (range: 50–325), estimated blood loss 28.53 mL (range: 10–75), and length of hospital stay (LOS) were 5.1 days (range: 1–15) respectively. All patients completed their follow-up visit at 1 month after surgery.

## 9 | DISCUSSION

The results of our study investigating the safety and feasibility of the Hugo™ RAS for a broad range of surgical procedures of the alimentary tract, treating both benign and neoplastic diseases, prompt some interesting considerations. No hardware or software glitches were reported that could raise concerns about safety or cause possible harm to the patients.

Similarly, no intra-operative or peri-operative complications were reported except for an episode of haematochezia in patient 1 that required the transfusion of 2 units of PRBC and resolved without any other treatment. Among the other clinical outcomes, the reported LOS calls for some special considerations as 23.52% of our patients population were affected by a systemic disease (Chron's) with a local manifestation (terminal ileitis) that has been traditionally associated with a longer hospital stay after surgical intervention.[11] Patient 6, who underwent subtotal gastrectomy, could also be considered an outlier in terms of hospital stay (15 days). The advanced age (74), the presence of multiple medical co-morbidities, the low pre-operative BMI (16.42) and the status post neo-adjuvant therapy of this individual could have all affected this outcome. Lastly, our tertiary centre internal policy entails overnight admit for patients undergoing cholecystectomy which also contributed to inflate our median LOS.

Although the number of cases is limited, the variety of their nature and complexity support the overall safety of this novel robotic system.

Further considerations about the feasibility of the Hugo™ must account for the fact that this novel platform has been recently launched in the European market, and as such, is still under development. For instance, the present set of robotic instruments does not yet include the robotic hook cautery nor a robotic stapler or vessel sealer. Medtronic has already developed these additional robotic instruments, but they are not yet available in the market.

As a consequence, the console surgeon must rely on only two instruments for the dissection, the monopolar sears, and the bipolar Maryland. The former can be adapted by grabbing the tissue in between the two branches and slightly rotating the sear along its vertical axis whilst activating the monopolar pedal. This adaptation of the surgical technique is especially important during the dissection of vascular structures as the activation of the monopolar energy whilst the surgical instrument is touching a vital structure could cause inadvertent injury of its wall. It is worth noticing that the lifespan of the robotic sears is only 45 min, thus forcing the team to use multiple pairs in procedures requiring over 90 min of use. In one instance, we had to perform the whole cholecystectomy (patient 10) using only the Maryland dissector because of a shortage of the robotic surgeons. We do suggest our colleagues who are considering starting the Hugo™ RAS programme to plan well ahead of time the ordering of this specific instrument for the aforementioned reasons.

The present unavailability of the other two instruments (vessel sealer and stapler) implies a greater involvement of the surgeon assisting at the table. This could represent a possible limitation based on the laparoscopic skills and experience of the professional working at the table. Furthermore, a minimum of one accessory laparoscopic trocar of 12 mm size is required for every surgical procedure requiring the use of the stapler as the robotic camera at present requires an 11 mm trocar and thus cannot be switched to any of the robotic trocars used for the other 3 robotic arms that are all 8 mm size. Likewise, an additional 5 mm laparoscopic assistant trocar will have to be placed in addition to the 4 robotic trocars (one 11 mm e three 8 mm) if the console surgeon decides to use an energy device or suction and irrigation cannula and does not want to sacrifice one of the robotic instruments to allow insertion of the laparoscopic instrument through one of the robotic trocars.

The manipulators of the Hugo™ console perform well according to our preliminary experience. The upscaling of the wrist rotation is a feature unique of the Hugo system that we think could be beneficial in the future when for instance performing microvascular anastomosis. However, as of now, we did not have the opportunity to investigate this potential benefit as the structures we worked with did not require it.

The open console seems to facilitate the communication between the console surgeon and the rest of the OR team although further investigation will be required to confirm what -for now-is only a perception. Furthermore, this configuration enables multiple observers inside the operating room to watch the procedure over the same 3D screen used by the console surgeon by simply wearing the special 3D glasses. The quality of the 3D images is very good although the console surgeon did report some slight discomfort from wearing the 3D glasses over the "regular" prescription lenses.

The unavailability of indocyanine-aided fluorescent angiography and cholangiography has not halted the application of Hugo™ RAS for elective cholecystectomies and lymphadenectomies with oncological purpose, but the pilot nature of our feasibility and safety study and the very limited size of our sample cannot rule out potential negatives associated with this technical limitation. However, this specific limitation is of temporary nature as Medtronic is working on the development of this feature as well.

The Hugo™ RAS did not pose any technical issues in terms of maneuverability as all multi-quadrant procedures were completed without any collisions that required corrective actions or a change of the surgical plan.

However, it is worth noticing the robotic arms of Hugo ™ are longer than their daVinci™ counterpart and this implies potential greater likelihood of them colliding with the assistant at the table.

Nonetheless, the multi-modular nature of the Hugo™ RAS enables the operator to move away the separate carts from the surgical field individually.

Likewise, endless adjustments of cart position, tilt and docking angles can be implemented. These features enable the surgical team to virtually adapt the system to all sorts of different anatomies and patients' body shapes. For instance, we were able to carry on two distinct surgical procedures (ileocolic resection first and then cholecystectomy) in patient 14 by changing the position of only one port over the right upper quadrant (out of four that were initially placed for the ileocolic resection) by simply adjusting the carts position and their respective tilt and docking angles.

The drawback of this potential and greater versatility of the Hugo™ platform is the need to set the docking and tilt angles manually for every single procedure whilst the main competitor platform (daVinci®) allows automated adjustment of the docking and tilt angles based on the setting chosen over the control panel of the robotic cart (e.g. *Anatomy*: Upper Abdominal; *Cart Location*: Patient Left) and the targeting of the anatomy with the robotic camera at the bedside. In conclusion, our pioneering experience suggest safety and feasibility of the Hugo™ RAS for a quite wide range of surgical procedures to treat benign and neoplastic conditions affecting the alimentary tract. The small size of our patient population (17 patients for a total of 18 procedures) and the short follow-up (one month after surgery) are important limitations of our study and recommend caution in drawing any definitive conclusions.

Thus, further research and larger series including mid- and long-term follow-up data and clinical outcomes are required to confirm our initial findings.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

## DATA AVAILABILITY STATEMENT

The data are not publicly available due to privacy or ethical restrictions.

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