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Robo-Lap Approach for Anatomical Resections of Postero-Superior Liver Segments by Indocyanine Green Fluorescence: Intraoperative Navigation Based on Vascular Landmarks

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Rezumat

Abordul robotico-laparoscopic în rezecțiile anatomice ale segmentelor hepatice postero-superioare prin utilizarea verdelui de indocianină – navigarea intraoperatorie pe baza reperelor vasculare

Tehnicile chirurgicale de bază care permit realizarea unor rezecții anatomice robotice eficiente şi sigure ale segmentelor hepatice postero-superioare nu sunt încă suficient standardizate. În acest articol, vor fi descrise detalii chirurgicale cu privire la efectuarea rezecțiilor anatomice ale segmentelor hepatice postero-superioare (Sg7 şi Sg8) pe baza identificării reperelor vasculare şi a utilizării coloraţiei negative cu verde de indocianină. În segmentectomia Sg7, se recomandă abordarea dorsală a pedicului portobiliar, urmată de abordarea venei hepatice drepte de la origine către periferie de-a lungul liniei de demarcație colorată negativ de verdele de indocianină. În segmentectomia Sg8, abordarea venei hepatice medii de la rădăcină către periferie permite identificarea confortabilă a pedicului portobiliar Sg8. Abordarea venei hepatice drepte este facilitată de linia de demarcație colorată negativ. Abordul robotico-laparoscopic permite efectuarea acestor proceduri cu un nivel adecvat de siguranță şi reproductibilitate.

Cuvinte cheie: robotică, chirurgie hepatică, postero-superioară, navigație, verde de indocianină

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Abstract

Cornerstones elements of surgical technique to achieve a good

efficacy and safety profile in robotic anatomical resections of postero-superior segments have not yet reached an adequate level of standardization. In this technical note, surgical details to perform anatomical resections of postero-superior segments of the liver (Sg7 and Sg8) based on the identification of vascular landmarks and assisted by use of negative staining with indocyanine green (ICG) fluorescence will be described. In Sg7 segmentectomy, dorsal approach to portobiliary pedicle is suggested, followed by root to periphery approach to right hepatic vein along the negative staining demarcation line by indocyanine green. In Sg8 segmentectomy, root to periphery approach to middle hepatic vein allows comfortable indentification of Sg8 portobiliary pedicle. Approach to right hepatic vein is made easier by negative staining demarcation line. Robo-Lap approach allows to perform these procedures with an adequate level of safety and reproducibility.

Key words: robotic, liver surgery, postero-superior, navigation, indocyanine green

Introduction

The advantage of robotic approach in the field of minimally invasive liver surgery (MILS) is still under investigation and far from achieving a good level of scientific evidence. Data published so far suggest that robotic-assisted surgery allows to increase the feasibility of MILS by reducing the risk of conversion in settings of high technical complexity (1-3). On the other hand, however, cornerstones elements of surgical technique to achieve a good efficacy and safety profile have not yet reached an adequate level of standardization.

One of the most debated topics is the modality to carry out the phases of hepatic parenchymal transection: the portfolio of robotic instrumentation indeed does not currently include the availability of an ultrasonic dissector (4). Hence, the two available alternatives for liver dissection encompass either the use of the combination of robotic bipolar forceps and monopolar scissors (which reproduces the principles of kellykasia initially described in open surgery) or the alternating use of the laparoscopic ultrasonic dissector by the surgeon at the table with coagulation and section by robotic instruments (4-6).

This latter practice, named the Robo-Lap approach, combines the advantages of the two techniques, maximizing their performance and consequently exploiting their characteristics: on the one hand the dexterity and seven degrees of freedom in movements allowed by the robotic platform and on the other the efficacy and accuracy of parenchymal dissection with contemporary vascular structures preservation allowed by ultrasonic dissector (5).

In anatomical resections of the posterior segments performed by robotic approach, the availability of robotic technology and instruments - together with the Robo-Lap approach and improved performance of intraoperative navigation thanks to indocyanine green- allows to reach the desirable level of technical standardization in a context of high complexity, aiming to optimize perioperative outcomes (5-10).

In this technical note, surgical details to perform anatomical resections of postero-superior segments of the liver (Sg7 and Sg8) based on the identification of vascular landmarks and assisted by use of negative staining with indocyanine green (ICG) fluorescence will be described.

Instrumentation for Sg7 and Sg8 Anatomical Resections

Standard robotic instrumentation includes: prograsp forceps, Maryland bipolar forceps or long bipolar forceps, monopolar scissors and robotic clip applier.

Laparoscopic instrumentation includes: suction system, small vascular clamps, titanium clips, Hem-o-Locks, vascular stapler and ultrasonic dissector. For ultrasonic dissector, the choice may be based on surgeon's preference, taking into consideration its length, flexibility and efficacy.

OR setting and scrub nurse table including mixed instrumentation is reported in *Fig. 1.*

Anatomical Sg7 Resection

Position of the patient and configuration of trocars

The patient is placed in left lateral decubitus, reaching 45 degrees of inclination, with the left arm open outwards and the right along the ipsilateral side. The four robotic trocars are positioned along an oblique line running parallel to the costal arch, at a distance of at least 2-3 cm from it. The leftmost robotic trocar is positioned at the midsternal line. Two 10 mm laparoscopic accessory trocars are positioned in a more caudal position, respectively between robotic trocars 2 and 3 and between 3 and 4. The surgeon at the table is positioned to the left of the patient (*Fig. 2*).

Surgical technique

The dorsal approach - based on vascular landmarks - to perform anatomical resection of Sg7 includes:

- encirclement of the hepatic hilum on a tape which in then exteriorization out of the abdominal cavity for extracorporeal Pringle maneuver (the intracorporeal Pringle maneuver approach is not recommended due to the difficulty of clamping with the liver rotated towards the left hypocondrium with a patient positioned in left decubitus position);
- complete mobilization of the right hemiliver by sectioning the round, falciform, right coronary and triangular ligaments until the bare area of the liver, the anterior surface of the inferior vena cava and the right hepatocaval confluence confluent are exposed. Suspension of the right hepatic vein on a tape can be an option specifically for lesions located in proximity of the hepatocaval confluence;
- keeping the liver rotated towards the left hypocondrium, identification by ultrasound of the right dorsal portobiliary pedicle and then of the segmentary pedicle of Sg7, marking it position on the liver surface;
- hepatotomy parallel to the caval plane at

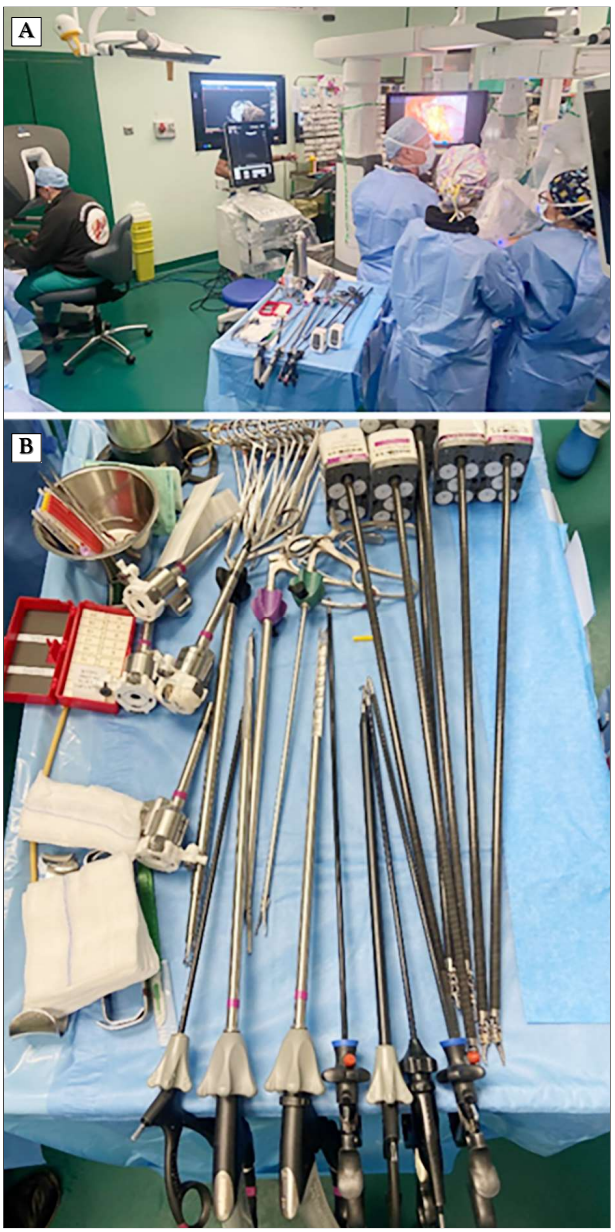


Figure 1. **(A)** Setting of the OR during robotic liver resection. **(B)** Scrub nurse table for robotic liver resection including mixed laparoscopic and robotic instrumentation.

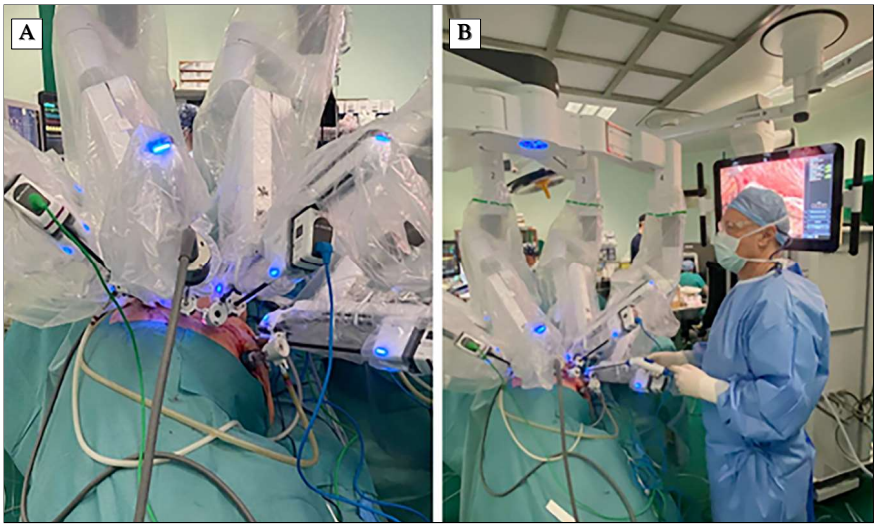


Figure 2. **(A)** Standard patient's and trocar positioning for anatomical Sg7 resection. (**B**) Table surgeon position during anatomical Sg7resection

the site identified as the topography of Sg7 pedicle to isolate the Sg7 pedicle;
- S7 pedicle encircling and suspension on vessel loop, then the pedicle is occluded until obtaining ischemic demarcation of segment 7. The tracer with indocyanine green fluoresce is intravenously injected to achieve negative staining of the segment to be resected;
- the path of the right hepatic vein is identified by ultrasound and hence exposed in a cranio-caudal direction through parenchymal dissection conducted with the combination of laparoscopic ultrasonic dissector and coagulation and section using robotic instruments along the demarcation line defined by ICG;
- identification and section of the previously isolated portobiliary pedicle;
- Conclusion of parenchymal transection phases with exposure of the caval plane and right hepatic vein.

See *Fig. 3* for details.

Anatomical Sg8 Resection

Position of the patient and configuration of trocars

The patient is positioned supine with arms and legs apart, in a reverse-Trendelenburg position. A laparoscopic 10 mm trocar is positioned in a right pararectal position, along the umbilical line. Four robotic trocars are positioned in a standardized configuration with one trocar in right flank, one along the mid-clavicular line, one along the midline and one in left hypocondrium and the robotic platform is docked to operating table coming from the head (Da Vinci X platform) or from the right side (Da Vinci Xi platform) of the patient. A second laparoscopic access is positioned on the right flank (between robotic arms 2 and 3): the second laparoscopic access should be positioned only after docking of robotic arms, to exclude conflicts among laparoscopic and robotic instruments and to improve ergonomy. The first surgeon seats at the console and the first assistant is located between patient's legs. See *Fig. 4*.

Surgical technique

The approach to anatomical segmentectomy of Sg8 through transparenchymal isolation of the portobiliary pedicle identified after cranio-caudal exposure the middle hepatic vein includes:
- partial mobilization of the liver by sectioning the round and the falciform ligament and the cranial portion of the right coronary ligament;
- encirclement of the hepatic hilum on a tape for extracorporeal Pringle maneuver or on Foley catheter for intracorporeal maneuver;

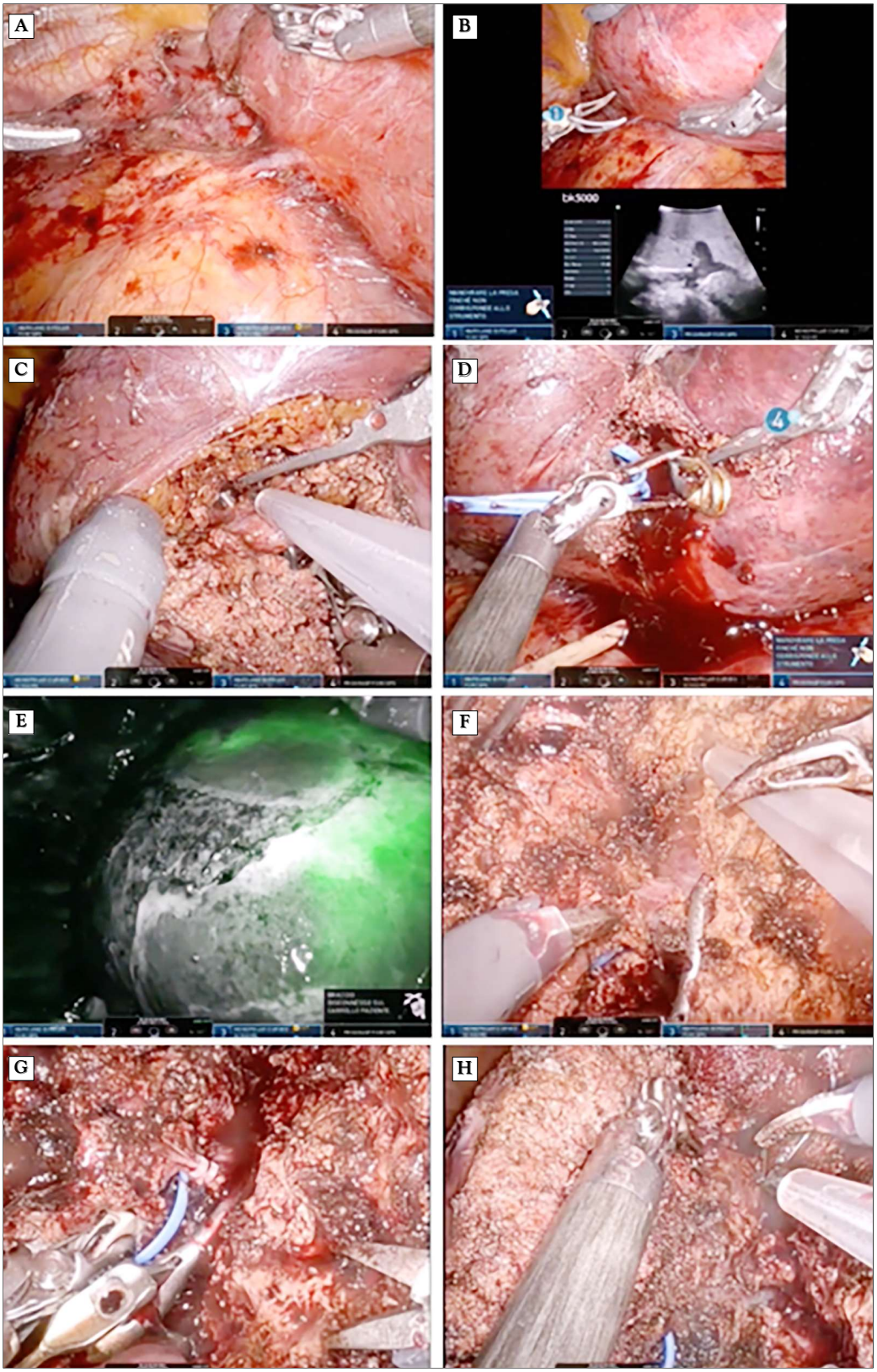


Figure 3. Anatomical Sg7 resection by Robo-Lap approach. **(A)** Liver mobilization. **(B)** Ultrasound to identify Sg7 pedicle. **(C)** Hepatotomy to reach Sg7 pedicle. **(D)** Clamping of Sg7 pedicle. **(E)** Negative ICG staining of Sg7 **(F)** Craniocaudal approach to right hepatic vein. **(G)** Section of Sg7 pedicle. **(H)** Final phases of liver transection by Robo-Lap approach.

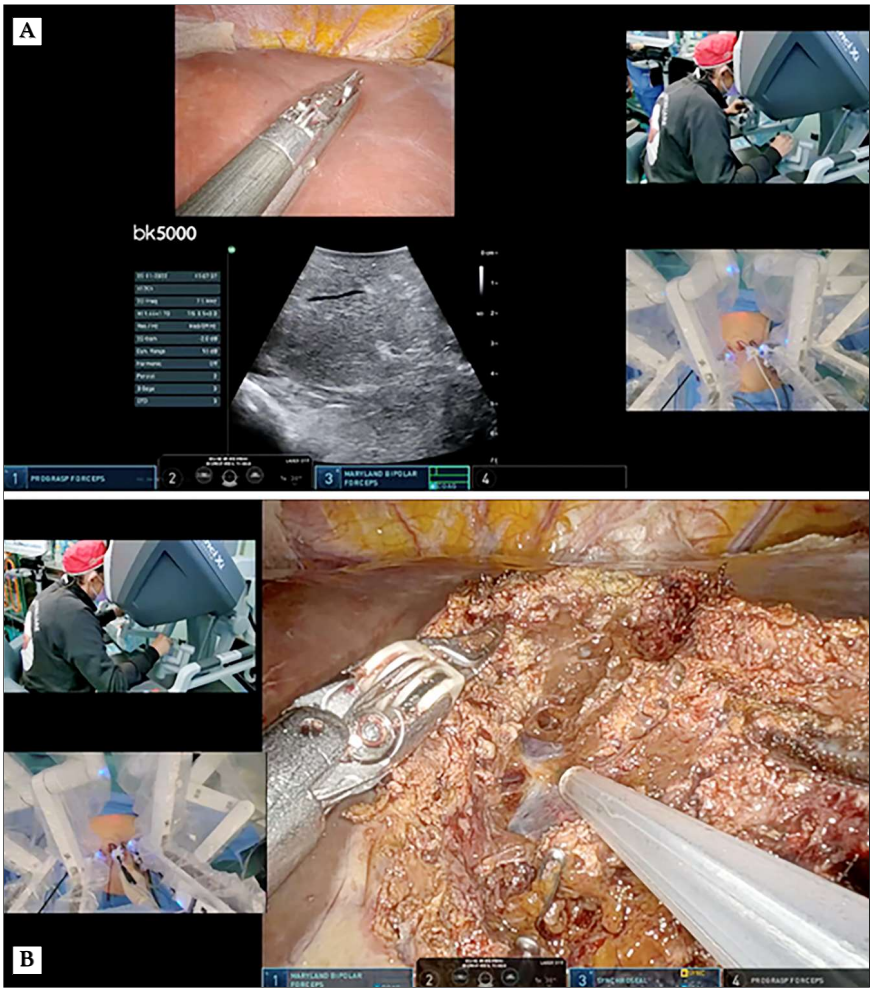


Figure 4. **(A)** Standard trocar and instruments positioning for anatomical Sg8 resection. **(B)** Setting for Robo-Lap approach to anatomical Sg8 resection with cranio-caudal approach to middle hepatic vein.

- ultrasound identification of the path of the middle hepatic vein and of Sg8 porto-biliary pedicle;
- approach from root to periphery to the middle hepatic vein with exposition of its anterior surface: middle hepatic vein is preserved through a sharp use of the ultrasonic dissector. The caudal landmark of root to periphery dissection is represented by the hepatic branch draining Sg5 which identifies the site of Sg8 pedicle (located dorsally to middle hepatic vein);
- identification and suspension on a vessel loop of Sg8 segmentary pedicle - identified by transparenchymal route - and clamping of segmentary pedicle until obtaining ischemic demarcation of segment 8. Intravenous injection of the tracer with indocyanine green for negative staining of the segment to be resected.
- approach from periphery to root to the right hepatic vein which is exposed and preserved representing the dorsal vascular landmark of the resection surface.

See *Fig. 5* for details. *Fig. 6B* represents the final view of the surgical field in Sg8 segmentectomy.

Discussion

The Robo-Lap approach is based on collaborative leadership between the surgeon at the console and the surgeon at the operating table. The synergy between the two members of the team in fact allows to maximize the benefit of the minimally invasive approach by combining

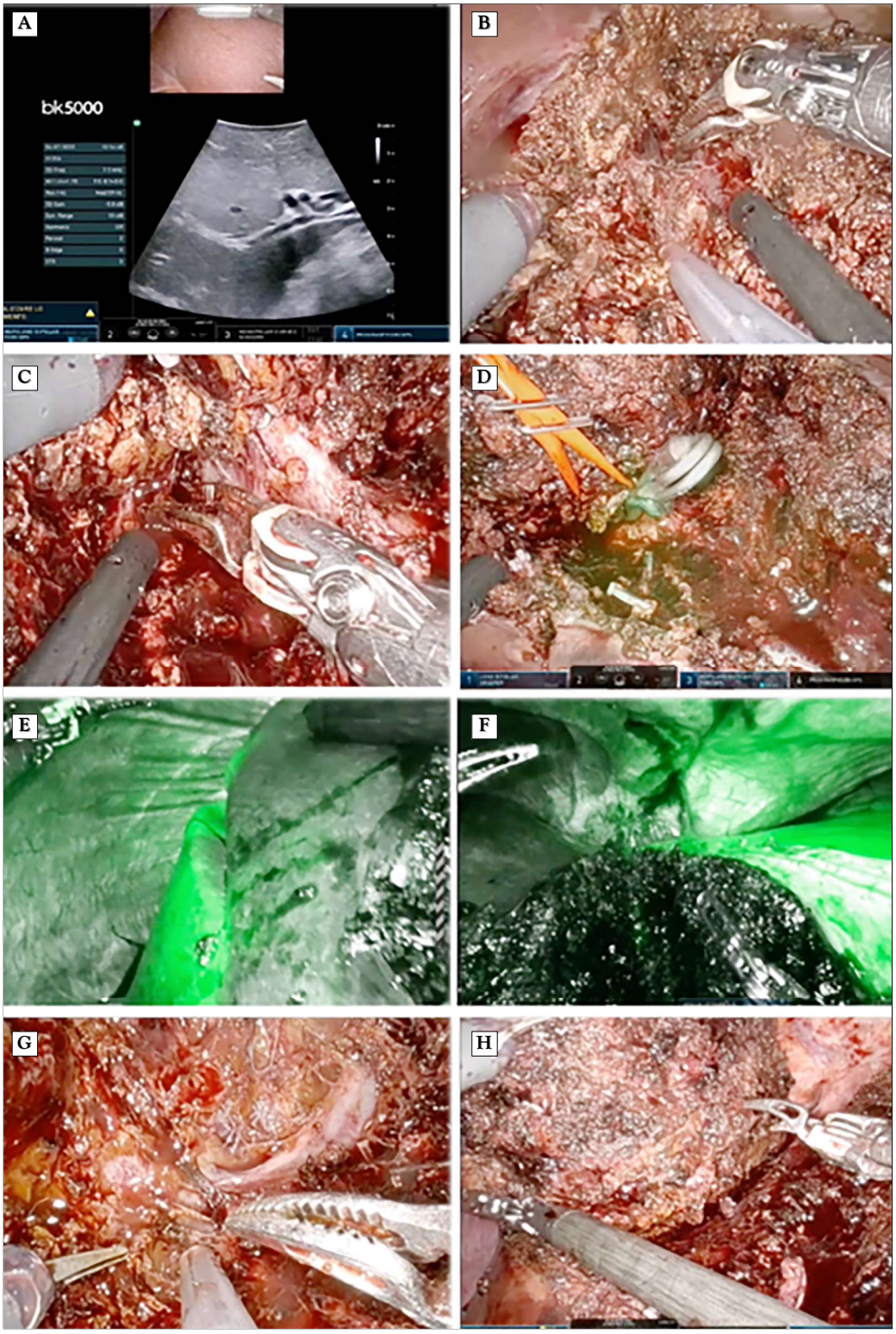


Figure 5. Anatomical Sg8 resection by Robo-Lap approach. (**A)** Ultrasound to detect middle hepatic vein and Sg8 pedicle. **(B)** Root to periphery approach to middle hepatic vein. **(C)** Transparenchymal approach to Sg8 pedicle. **(D)** Clamping of Sg8 pedicle. **(E)** Negative ICG staining of Sg8, demarcation between Sg7 and Sg8. **(F)** Negative ICG staining of Sg8, demarcation between Sg4a and Sg8. **(G)** Periphery to root approach to right hepatic vein. **(H)** Final phases of liver transection by Robo-Lap approach.

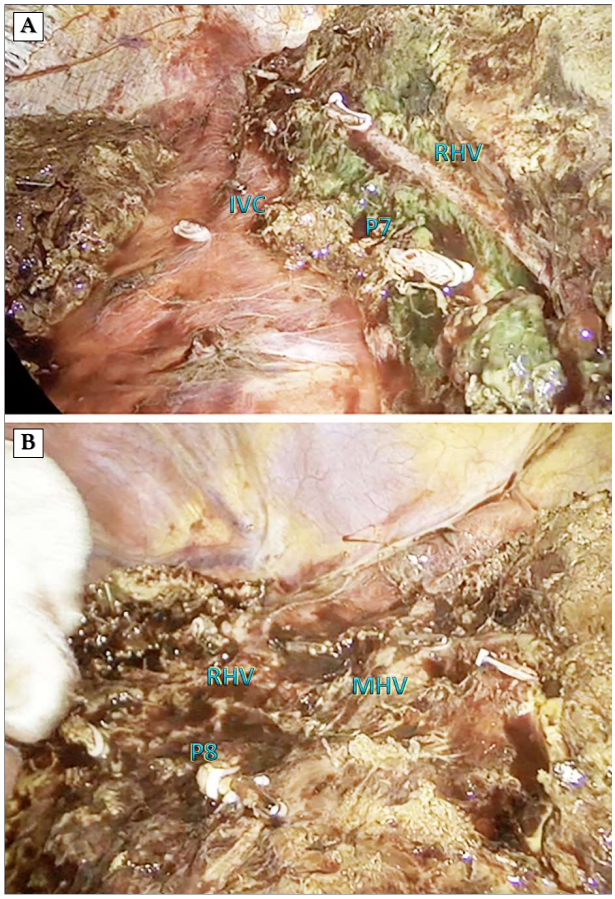


Figure 6. Final resection surfaces. **(A)** Sg7 segmentectomy. RHV, Right Hepatic Vein; P7, segmentary Sg7 Pedicle; IVC, Inferior Vena Cava. **(B)** Sg8 segmentectomy. MHV, Middle Hepatic Vein; P8, segmentary Sg8 pedicle; RHV, Right Hepatic Vein.

the dexterity of the robot and the possibility of conducting an accurate dissection as in laparoscopy (5,6).

Technical options to address challenges related to anatomical resections of postero-superior segments are a topic of current discussion in the setting of minimally-invasive liver surgery (11-14). Specifically, dorsal approach to segment 7 and trasparenchymal approach to segment 8 pedicle after cranio-caudal approach to middle hepatic vein seem to be the most widely used techniques in the setting of laparoscopic liver surgery. Despite this, this issue has been scarcely addressed in the area of robotic surgery.

Among the whole portfolio of liver resections, anatomical resections of postero-superior segments specifically have favourable characteristics to be the ideal field of application for combined approach of Robo-Lap technique: on the one hand indeed, the need for hepatic mobilization and accurate dissection of portobiliary pedicles benefits from the joint movements of the robotic wrist, paving the way for greater feasibility of minimally invasive complex procedures and for a reduction in operating times; on the other hand the transection line, allows an optimized use of the ultrasonic dissector by the surgeon at the table, increasing the accuracy of the dissection and the speed of the transection (5,6).

The crucial issue to be evaluated is the accessibility of the parenchymal transection plane by the ultrasonic dissector: in this perspective, anatomical resections based on the intraoperative navigation through vascular landmarks (i.e. portobiliary pedicles and hepatic veins) constitute an excellent field of application as the transection line (running longitudinally along hepatic vein paths and transversally along portobiliary pedicles paths) is generally in line with the eyes of surgeons and with the line of access of the ultrasonic dissector. Caution should be taken during laparoscopic ports positioning in order to optimize accessibility to the transection plane throughout the procedure.

The direction of the tip of the ultrasonic dissector should be optimized to obtain an effective transection without being limited in its movement by robotic arms outside and robotic instruments inside. Maintaining the principle of having the transection area in the center of the visual field of both operators, it is possible to use the ultrasound dissector and the robotic bipolar for coagulation at the same time. If the dissection field is particularly limited, a totally alternating use of the laparoscopic dissector and robotic instruments may be necessary. The surgeon at the console must be careful to bring the optics close enough to allow a good view to the bedside surgeon, without risking excessive fouling of the camera due to irrigation and dissection of the ultrasound instrument. Specific attention must be paid to phases of the procedure requiring the ultrasonic dissector working on

the wall of hepatic veins: the direction of access of the ultrasonic dissector - from bottom to top - could in fact be less favorable, and consequently more dangerous, than in laparoscopy. It is therefore advisable, in the proximity of hepatic vessels, to pay attention to avoid lesions of the lower and/or lateral wall of the vessel by first working on the anterior surface and eventually lowering the intensity of the ultrasound.

During preparation phases it is useful to take into consideration the length of the ultrasonic dissector and its possibility of reaching the furthest point of resection. If the abdominal cavity is wide or the resection area is cranial, the possibility to place laparoscopic trocars on the same line of robotic trocars should be taken into consideration and should be balanced with the risk of scarce possibility of movement of laparoscopic instruments due to lateral external conflict with robotic arms. It is important not to underestimate the space created due to distension from CO2 of the abdominal cavity (especially in obese and elderly patients), which considerably distances the trocars from the target site. This phenomenon has specific negative consequences especially on the accessibility of laparoscopic instruments to surgical field.

This robotic-laparoscopic technique offers the possibility of improving the expertise and level of training in complex hepatectomies for the surgeon at the table, allowing to deal with the challenges of the parenchymal transection phase in an "assisted" fashion. However, the first assistant should already have a good level of expertise to maintain the procedure within required level of safety. In particular, a good confidence with advanced laparoscopic technique is required, as well as an adequate level of partnership between the two surgeons, to carry out the transection phases in a synergistic way. It is in fact mandatory to have and excellent level of understanding, communication and collaboration between the two figures: unlike in the pure laparoscopic technique indeed, the first operator shares the surgical leadership in the parenchymal transection phase with the assistant. Furthermore, the assistant surgeon must have the expertise to timely and adequately manage any internal or external conflict among robotic instruments and must be able to manage an emergent conversion or other potentially life-threatening situations.

The integration of laparoscopic and robotic technologies, the improvement of intraoperative navigation techniques through the use of indocyanine green (integrated in the robotic platform) and the robotic ultrasound probe, together with the standardization of the technique to perform anatomical liver resections allows to reduce the risk of leaving ischemic areas and to optimize oncological results in the setting of most primary and secondary liver tumors, representing the future of modern liver surgery to optimize cancer treatment (15-21). The synergic favorable combination with the use of anatomical landmarks to navigate within the liver parenchyma allows to make these procedures reproducible and reduce the risk of blood loss and transfusions (22), as already described in laparoscopic surgery (23-25).

This technique is safe and reproducible in anatomical resections of postero-superio segments and – in general - in robotic resections with a high profile of technical complexity of parenchymal transection, if the accessibility of the resection site by laparoscopic instruments is guaranteed.

Conflicts of Interests

The authors declare no conflict of interest.

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