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Tips and tricks for the robotic-assisted approach to colorectal cancer liver metastases

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Abstract

Colorectal cancer remains a leading cause of cancer-related morbidity and mortality, with liver metastases being a critical determinant of survival. The management of colorectal liver metastases (CRLM) has historically been challenging due to the complexity of hepatic resections and the need for precision to ensure patient safety and optimal outcomes. Recently, robotic hepatectomy has emerged as a pivotal evolution in minimally invasive surgery, offering a new tool in the treatment of CRLM. This article aims to share some tips and tricks accumulated by our surgical experience in robotic resections of CRLM that have been instrumental in optimizing both outcomes and safety. We explore the multifaceted approach required for successful robotic surgery. A meticulous preoperative evaluation sets the stage for successful robotic liver surgery, where we tailor anesthesia and patient positioning based on tumor location to complement the robotic platform. During surgery, the selection of specialized instruments along with nuanced parenchymal transection techniques is guided by a number of factors, including the quality of the liver and experience of the surgeon. Incremental progression from less to more complex hepatectomies is made possible by adherence to key principles of minimally invasive liver surgery, thoughtful preparation, and surgical precision. Ultimately, this article will contribute to surgeons' understanding of these principles and practical elements that can help to improve standards of patient care in the performance of robotic hepatectomies for colorectal metastases.

Keywords: Liver cancer, robotic surgery, colorectal metastases, minimally invasive

INTRODUCTION

The landscape of colorectal cancer management is continually evolving, particularly for liver metastases, which represent a significant milestone in disease progression and patient prognosis[1]. The advent of minimally invasive surgery has dramatically shifted the surgical paradigm, offering less invasive alternatives to traditional open surgery. Despite the complexities posed by colorectal liver metastases (CRLM), the proficiency in minimally invasive techniques has grown considerably[2]. However, the full potential of robotic hepatectomies within this field remains on the cusp of being fully realized.

Robotic platforms herald a new era of precision and dexterity, providing surgeons with enhanced capabilities when operating on the intricate anatomies involved in CRLM resections. Mirroring the success seen in other high-stakes procedures, such as surgeries for colorectal and pancreatic resections[3,4], robotic surgery has shown its ability to overcome some of the limitations encountered with laparoscopy in liver surgery[5], indicating a promising path forward in the management of CRLM.

This article delves into the intricacies of robotic hepatectomies for CRLM, aiming to arm surgeons with strategic insights that seamlessly integrate preoperative planning with intraoperative technicalities. Our collective experience is distilled into a pragmatic guide, intended to simplify the understanding and application of robotic surgery for CRLM. Through a meticulous journey from the drawing board to the operating room, we strive to enrich the body of knowledge and facilitate the safe utilization of robotics in liver surgery, fostering a results-driven approach to complex surgical challenges.

KEY CONCEPTS FOR PREOPERATIVE MANAGEMENT

The key concepts for preoperative management of patients undergoing minimally invasive hepatectomies for CRLM should encompass a strategy aimed at preserving liver parenchyma to potentially enhance overall survival, especially for those who may require repeat resections[6]. Hepatic recurrence after local treatment of CRLM is the rule rather than the exception, occurring in 70%-80% of cases[7]. Data have shown that in this scenario, the ability to offer local therapy again in combination with systemic therapy is associated with improved survival[8,9].

For this reason, one of the primary goals of local therapy for CRLM should be to preserve as much liver tissue as possible. This approach not only aims to avoid post-hepatectomy liver failure in the short term but also ensures that the liver can tolerate repeat local therapies in the long term. Our strong preference is to perform maximally parenchymal-sparing hepatectomy whenever possible, adhering to this principle rather than favoring expediency. For instance, we would opt to perform multiple partial hepatectomies for tumors in the right liver via an open approach if need be rather than a right hepatectomy via a robotic approach if it means preserving more liver tissue. That is not to say that a major hepatectomy is never indicated for CRLM - indeed, in the presence of numerous deep-seated tumors or those involving a central portal pedicle, a robotic right or left hepatectomy would be the procedure of choice.

To further refine the preoperative strategy, careful evaluation of cross-sectional imaging must be performed to clarify the relationship of the metastases to key vascular structures and facilitate measurement of liver volumetry to assess the need for future liver remnant volume augmentation. These steps are paramount to crafting a tailored surgical plan that prioritizes oncological clearance while safeguarding liver function[10].

It is also vital to communicate with medical oncology colleagues to minimize preoperative chemotherapy and reduce its hepatotoxic effects - particular caution should be exercised with agents such as oxaliplatin and irinotecan, which have been linked to sinusoidal dilation and steatohepatitis, respectively. These agents can also increase the rate of disappearing metastases[11,12], complicating surgical targeting and affecting patient outcomes.

In this context, for small lesions under 2 cm that are neither superficial nor subcapsular, and not located within the planned resection area, we recommend the placement of fiducial markers[13]. This is especially pertinent in instances of fatty liver disease where the contrast between tumor tissue and healthy parenchyma under ultrasonography may be compromised. By highlighting these preoperative considerations, we want to underline the importance of a tailored approach, optimizing visibility and precision during robotic hepatectomy to ensure clear margins and effective disease management.

These key preoperative considerations establish a robust foundation that supports the complexities of intraoperative navigation and sets the stage for favorable surgical outcomes.

ANESTHESIA CONSIDERATION AND PNEUMOPERITONEUM

In preparing patients for minimally invasive hepatectomies, anesthetic considerations such as fluid management, hemodynamic monitoring and pneumoperitoneum management are paramount and intricately linked to ensure optimal surgical conditions and patient safety[14].

A cornerstone of anesthetic management is maintenance of a low central venous pressure (CVP). This strategy reduces the pressure in the hepatic venous system and is critical for minimizing hemorrhagic complications during the procedure, although it does not necessarily translate to differences in postoperative outcomes[15]. It calls for lower airway pressures, which directly influence CVP, and a reduction of intravenous fluids leading up to and during hepatic parenchymal transection.

As for pneumoperitoneum pressure (PPP), the conventional wisdom of increasing PPP to control bleeding during hepatic resections may be questionable. Studies have shown that increasing PPP to control hepatic venous bleeding may not be effective under high airway pressures, as CVP can exceed PPP, compromising bleeding control. Findings suggest that reducing airway pressure can sometimes be more effective for bleeding management, though it increases the risk of CO_2 embolism when PPP is higher than CVP[16,17]. Instead, the strategy shifts towards decreasing airway pressure, which can sometimes necessitate disconnecting the ventilator temporarily, to effectively manage bleeding without escalating the risk of embolic events. We routinely limit our PPP to 12 mmHg.

These practices are supported by evidence suggesting that such nuanced approaches to anesthetic management and PPP manipulation can lead to better surgical outcomes, as they align with the enhanced recovery after surgery (ERAS) principles, where attention to such perioperative details is critical[18]. It is thus important to recognize that anesthetic management and PPP considerations are interdependent during robotic hepatectomies for CRLM, with each decision influencing the overall surgical experience and patient recovery trajectory.

PATIENT POSITIONING AND PORT PLACEMENT

Patient positioning and port placement are critical components of robotic hepatectomy. While the classic split-leg (often referred to as the "French") position is commonly employed in laparoscopic cases to accommodate surgeon positioning, in robotic surgery, a standard supine position is almost universally sufficient except for medially located tumors in segment 7 near the inferior vena cava (IVC) where a full left lateral decubitus position may be preferred. The arms do not need to be tucked, which is helpful for anesthesia. For right posterior tumors, placing a bump under the patient's right side, along with tilting of

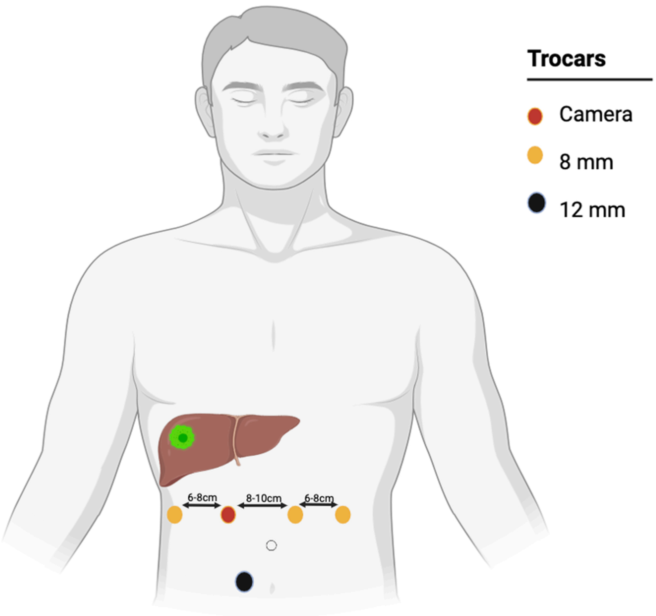


Figure 1. Trocar placement strategies for robotic liver surgery.

the bed right side up, may assist in optimizing exposure[19]. Adjusting the bed to place the flank over the break maximizes the space between the ribcage and iliac crest, which may be helpful in optimizing surgical access and maneuverability. Port placement is meticulously considered and executed, keeping in mind spacing to minimize collisions both inside and outside the abdomen [Figure 1]. Our routine practice is to use four 8-mm robotic trocars lined up across the abdomen, and a 12-mm assistant trocar located more inferiorly, either separately if we anticipate a smaller specimen or as part of a Pfannenstiel incision when a larger specimen needs to be extracted. This 12-mm assistant port will facilitate passage of the ultrasound (US), gauze, hemostatic agents, sutures, and appliances for inflow control.

INSTRUMENTS AND TOOLS

One must be familiar with the arsenal of instruments and tools on the robotic platform to safely execute successful robotic liver surgery. The use of robotic platforms in minimally invasive surgery offers unique advantages, including a magnified 3D view, improved ergonomics, and enhanced dexterity, which can facilitate complex procedures and potentially improve surgical precision and outcomes[20]. Additionally, these platforms reduce the natural limitations associated with laparoscopic instruments by providing seven degrees of freedom, allowing more refined and controlled movements during intricate procedures. The use of indocyanine green (ICG) may be helpful in outlining tumors. In the case of CRLM, injecting patients with ICG 48-72 h before planned hepatectomy can lead to a halo effect with ICG concentrating around the edges of the tumors and may assist in their intraoperative detection. This does present logistical and scheduling challenges. Adjunctive equipment is equally important to consider. For instance, it is our strong preference to use an insufflation system that maintains a steady pneumoperitoneum (even during suctioning) and automatically evacuates smoke. This stability is essential to ensure an unobstructed view and precise manipulation within the surgical field. However, because air embolisms are especially relevant and occur with such high regularity in hepatobiliary surgery[17,21,22], it is best to avoid systems that allow the entry of room air into the abdominal cavity as a means of maintaining pneumoperitneum since room air embolisms can be highly lethal.

As is the case in open surgery, intraoperative US is invaluable and can be achieved with either the 4-way laparoscopic US transducer or the robotic drop-in US transducer. Both require a larger-sized trocar (at least 10 mm) and provide high-resolution images that allow for accurate localization and characterization of liver lesions, a vital component of meticulous hepatectomy.

In the orchestration of surgery, the decision "To Pringle or not to Pringle" rests on the specifics of the case at hand. The Pringle maneuver, while traditionally favored for vascular control, may be skipped for superficial and peripheral tumors or in patients with extensive porta hepatis scarring from previous surgeries. Otherwise, we favor routine placement of an inflow control mechanism that can be used selectively. There are several options available for inflow control, including the use of a chest tube over the umbilical tape, a Foley catheter loop, an external clamp, or a short red rubber catheter with clip application, among others. Each method has its own advantages and can be chosen based on the specific requirements of the surgery and the surgeon's preference. Our preferred approach is a modified Huang's loop method which we have previously described[23,24].

The use of inflow occlusion is particularly advantageous for deeper tumors or those in proximity to major vessels as can be anticipated based on preoperative imaging and/or intraoperative US. This technique reduces blood flow to the liver, thereby minimizing blood loss during parenchymal transection. For the actual transection of the liver parenchyma various techniques have been described to transect the liver parenchyma. Our preference for normal and fatty livers is to use the clamp-crush technique using the Vessel Sealer Extend in combination with bipolar energy, where any sizable crossing vascular or biliary structures are controlled with clips and/or ties. When dealing with a firmer liver, the narrower profile of the Synchroseal more effectively advances into the liver and is used instead of the bulkier Vessel Sealer Extend[10].

Instrument selection may be influenced by the complexities of the surgical task, with a range of energy devices at our disposal. While numerous options exist for laparoscopic parenchymal transection, including sealing devices such as the Ligasure®, HARMONIC ACE®, and THUNDERBEAT, and ultrasonic dissector/aspirator such as the CUSA®, options on the robotic platform are more limited. However, what the robotic platform lacks in instrument options, it makes up for in the availability of wristed instruments (except for the robotic adaption of the Harmonic ACE®) that provide enhanced dexterity and control. In our practice, we use the ProGrasp and Cadiere forceps selectively based on tissue requirements, avoiding the ProGrasp on the bowel due to its stronger grip, which could risk crushing injuries. Both forceps, however, are suitable for handling sutures and catheters. We also rarely use monopolar energy devices such as the hook and scissors during hepatectomy, though other centers might. This approach aligns with our focus on preserving tissue integrity and minimizing injury risk.

The surgical mantra "meticulous dissection of vessels usually never leads to vascular damage" underlines the importance of technique over tools[25]. Energy devices, while efficient and reliable, cannot replace the fundamental skills of hepatic surgery: precise dissection, vascular control, and elective sealing. Thus, while the instruments and tools provide the means, it is the surgeon's skill that steers the course to a better surgical outcome.

TECHNICAL CONSIDERATIONS

Technical considerations begin with a thoughtful approach to the sequence of resections. In cases of multiple lesions, it is judicious to address the most technically challenging lesion first. This strategy not only allows for a more efficient use of resources and time but also ensures that the patient's physiology is at its most robust during the most difficult part of the surgery. It benefits from a surgical team that is at its most focused state, avoiding scrub or circulator turnover or breaks, while also ensuring that if conversion were necessary based on the most challenging resection, it would happen earlier rather than later.

Liberal use of intraoperative US is encouraged, particularly when disengaging from the Pringle maneuver. The US helps delineate the tumor margins and assess the local vascular anatomy, facilitating precise resection and minimizing the risk of positive surgical margins. In addition to minimizing blood loss during periods off Pringle, a hemostatic sheet on the parenchymal transection surface can also enhance its detection on US.

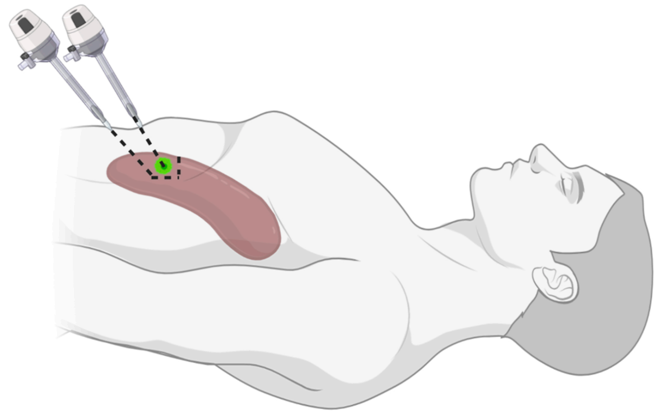
A crucial element to keep in mind is that while robotic instruments offer enhanced dexterity with seven degrees of freedom, they do operate differently from the human wrist. Therefore, incision planes must be aligned along the axis of the instruments to achieve the desired precision in resection. This may require starting the approach further out than the margin to account for the angle of entry and the natural skiving that occurs during robotic dissection [Figure 2]. While we do not routinely employ the diamond technique in our practice, it is important to recognize its role in enhancing precision during parenchymal transection. This method involves initiating the transection at a distance from the lesion, creating a diamond-shaped resection plane that facilitates clear margins and reduces the risk of positive margins. Incorporating such strategies can be particularly beneficial when dealing with nonperipheral liver lesions[26].

Finally, versatility in the use of the surgical toolbox for vessel control and hemostasis cannot be overstated. Mastery in various techniques and instruments, such as clips, sutures, and energy devices, allows the surgeon to adapt to the intraoperative findings and variations in anatomy, ensuring a safer and more effective hepatectomy. In particular, bipolar energy is an indispensable tool whose use must be mastered in the pursuit of safe minimally invasive hepatectomy. Finally, we very seldom use the stapler during robotic hepatectomy, saving its use primarily to divide the hepatic veins. Instead, a combination of Hemolock clips, surgical ties, and suture ligation can achieve outstanding control of critical vascular and biliary structures in narrow spaces such as the hilum.

By adhering to these technical concepts, surgeons can enhance the success of robotic hepatectomies, achieving favorable oncological outcomes while preserving liver function.

CONCLUSION

The advent of robotic technology in hepatic surgery represents a significant milestone in the treatment of CRLM. The precision, flexibility, and enhanced visualization offered by robotic systems have the potential to improve surgical outcomes and expand the capabilities of minimally invasive liver surgery. Despite these advantages, mastering robotic hepatectomy involves a notable learning curve, as indicated in recent studies[27,28], with a gradual progression in efficiency and safety observed over time. Understanding this learning curve is essential for surgeons to optimize their approach, balancing technical complexity with patient outcomes as they gain experience with robotic-assisted procedures. Ultimately, the robot platform is just a set of tools - albeit a very advanced one - that is intended to help surgeons provide safe hepatectomy for patients with liver tumors. The use of this instrument was carefully considered, balancing surgeon experience, complexity of the operation, and unique patient characteristics. Just as one should not jump straight to performing technically challenging hepatectomies such as extended hepatectomies or right posterior sectionectomies in the open setting, so should surgeons grow their robotic experience from straightforward, lower-complexity cases to more technically demanding operations over time. Our comprehensive guide underscores the importance of meticulous preoperative planning, tailored anesthetic



Demonstration of incision plane alignment and the approach at a greater distance from the margin to accommodate the angle of parenchymotomy during robotic dissection.

Figure 2. Incision alignment in robotic liver surgery.

strategies, and the judicious use of advanced instruments and tools that are unique to the robotic platform. The technical nuances detailed in this article, from patient positioning to the handling of parenchymal transection, aim to assist surgeons in navigating the complexities of robotic hepatectomies effectively.

We emphasize the surgeon's adaptability to fully leverage the capabilities of the robotic platform while adhering to the principles of sound surgical practice. As our experience grows and technological advancements continue to emerge, the role of robotic surgery in managing CRLM is poised to expand, potentially setting new benchmarks for patient care.

DECLARATIONS

Authors' contributions

Made substantial contributions to conception: Tran Cao HS, Haddad A, Acidi B
Performed data acquisition and provided administrative, technical, and material support: Tran Cao HS

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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