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CASE REPORT

Robotic-assisted cytoreductive surgery with hyperthermic intraperitoneal chemotherapy (CRS-HIPEC)

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Abstract

Background Cytoreductive surgery with hyperthermic intraperitoneal chemotherapy (CRS-HIPEC) is an appropriate treatment for select patients with peritoneal carcinomatosis. While most commonly performed through an open incision, the laparoscopic approach has been reported and offers short-term benefits. A robotic-assisted approach for carcinomatosis of gastrointestinal origin, however, has not yet been described.

Methods We report our approach to robotic-assisted CRS-HIPEC for a patient with a perforated appendiceal mucocele. Our dynamic video highlights the advantages of this approach.

Results Our patient was a 57-year-old woman with minimal residual disseminated peritoneal adenomucinosis (DPAM), having a peritoneal carcinomatosis index (PCI) score of 1. She had a previous surgical history of a Roux-en-Y gastric bypass. A robotic-assisted approach was utilized using the Intuitive daVinci Xi robotic surgical system through 4 ports. No laparoscopic assistant port was required. The operative time was 426 min, and the estimated blood loss was 50 cc. The greater omentum, falciform ligament, bilateral ovaries, and two small areas of tumor implant were resected. The post-operative length of stay was 4 days, and the patient had regained bowel function by post-operative day 2.

Conclusions Our video demonstrates the feasibility of a robotic-assisted CRS-HIPEC in a patient with minimal, residual DPAM. Similar to a laparoscopic approach, the short-term outcomes are improved as compared to an open approach. An MIS approach to CRS-HIPEC, now with the first-reported robotic-assisted approach, is a viable option for select patients with peritoneal tumors.

Keywords Robotic assisted · Cytoreductive surgery · HIPEC

Introduction

Cytoreductive surgery with hyperthermic intraperitoneal chemotherapy (CRS-HIPEC) as a treatment for peritoneal tumors has been accepted as a recommended therapy for select patients according to the latest guidelines from the National Comprehensive Cancer Network [1–4]. Traditionally, CRS-HIPEC has been performed through an open, midline incision. Within the last few years, several groups have published small series utilizing the laparoscopic approach to CRS-HIPEC [5, 6]. Though the data are more limited, the minimally invasive surgical (MIS) approach to CRS-HIPEC offers several benefits, including less post-operative pain, decreased blood loss, and shorter post-operative length of stay (LOS) [7–9].

The use of a robotic-assisted approach for peritoneal tumors of GI origin has not yet been described. In this

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dynamic report, we describe our approach for the first-reported robotic-assisted CRS-HIPEC for a low-grade appendiceal mucinous neoplasm with limited disseminated peritoneal adenomucinosis (DPAM).

Methods

Pre-operative evaluation

Our patient was a 57-year-old woman with a previous history a laparoscopic Roux-en-Y gastric bypass performed approximately 12 years ago who had presented at an outside facility with generalized abdominal pain. Her body mass index (BMI) at presentation was 32.1 kg/m^2. A computerized tomography (CT) scan was consistent with early acute appendicitis (Fig. 1a). She underwent an uncomplicated laparoscopic appendectomy. Intraoperatively, there was a lesion located at the tip the appendix, which was described as a glossy, fluid-filled sac. The appendix was removed without gross rupture.

Final pathology showed a low-grade mucinous neoplasm with an area microperforation and extra-appendiceal acellular mucin. The proximal margin was negative. The patient was referred to our institution for consideration of CRS-HIPEC. She was seen 2 months after her appendectomy. An interval CT scan (Fig. 1b) did not show any evidence of residual disease. Following evaluation of the case at our multidisciplinary colorectal tumor board, the patient agreed to undergo CRS-HIPEC through a robotic-assisted approach.

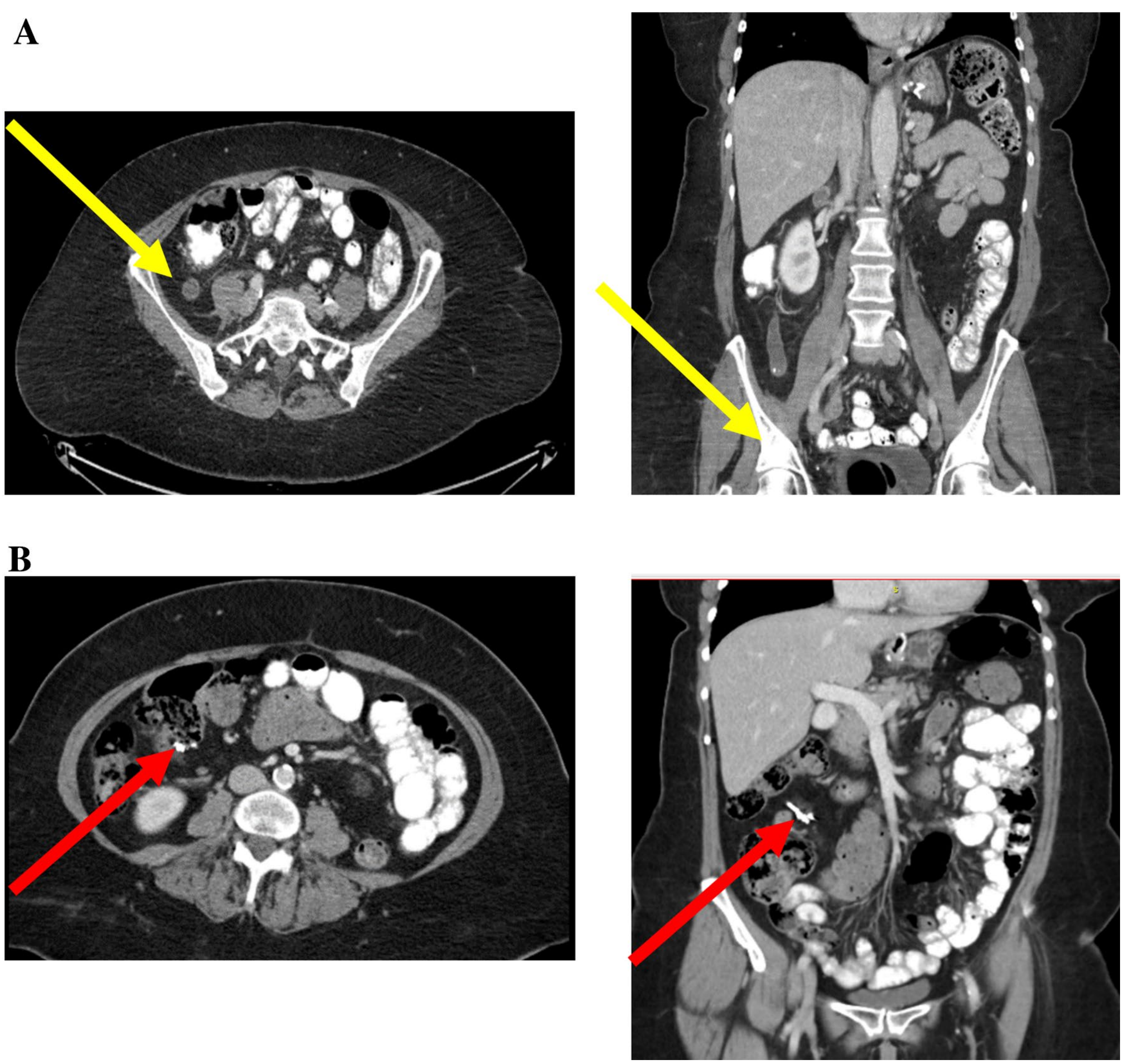

Fig. 1 **a** Pre-appendectomy CT scan showing the enlarged appendix (yellow arrows) concerning for a mucocele. Left images show the axial view, and right images show the coronal view, which also shows a small area of calcifications at the tip of the appendix that is consistent with a mucocele. **b** Post-appendectomy CT scan showing no residual disease (disseminated peritoneal adenomucinosis or DPAM) within the abdomen. The staple line reinforced with 5-mm clips (red arrows) can be appreciated

Operative description

The accompanying video demonstrates our surgical approach for the robotic-assisted CRS-HIPEC. Given her previous abdominal surgery, we elected to insufflate the abdomen through a left upper quadrant incision at Palmer's point using the Veress needle. A 5-mm Optiview trocar was then placed approximately 1 cm to the left and superior to the umbilicus. The additional robotic 8-mm trocars were placed at this level in a straight line across the abdomen from the right abdomen (mid-clavicular line just lateral to the rectus abdominus) to the left flank, with approximately 1 hand breath between each trocar. The Optiview trocar was exchanged for a robotic trocar.

Initial exploration was performed laparoscopically. A small mucinous implant measuring approximately 3 mm was identified along the mesentery to the cecum, and was removed. The rest of the peritoneal surfaces were investigated, and the small bowel and its mesentery were laparoscopically inspected in its entirety.

The Intuitive daVinci Xi robotic surgical system was then docked with the initial orientation to operate in the bilateral upper quadrants. The patient was noted to have a previous Roux-en-Y gastric bypass, thus distorting the omentum. Both limbs of the bypass appeared normal. The greater omentum had been divided into two sections from her previous surgery. Using the robotic vessel sealer, the omentum was dissected off both edges of the greater curvature to include ligation of the short gastric vessels. Similarly, the greater omentum was dissected off the anti-mesenteric surface of the transverse colon. Mobilization of the splenic flexure was performed to assist with this dissection.

The falciform ligament was then divided from the anterior surface of the liver and the peritoneal surface of the abdominal wall. The surface of the liver was inspected, and no peritoneal lesions were identified. All of the specimens were placed above the liver in the right upper quadrant for later extraction.

The next step in the CRS-HIPEC consisted of the bilateral oophorectomies. The daVinci Xi robotic surgical system was undocked, and the boom was rotated 180° to facilitate dissection in the bilateral lower quadrants. The placement of our robotic ports transversely across the abdomen at the level on the umbilicus facilitated this procedure. The bilateral oophorectomy was performed after placing the patient in steep Trendelenburg position.

The peritoneal surfaces in the pelvis and lower abdominal wall were carefully inspected. A small 2–3-mm mucinous lesion was found in the right lower quadrant and removed. In all, the patient had very minimal disease with small subcentimeter implants isolated to the right lower quadrant. Her peritoneal carcinomatosis index (PCI) score was 1 and her completeness of cytoreduction (CC) score was 0, highlighting the favorable patient selection for performing this robotic-assisted approach.

At this point in the procedure, we were ready to extract our specimens and perform the heated intraperitoneal chemotherapy using 30 mg of mitomycin C. The robotic system was undocked from the patient, and the left paraumbilical trocar was upsized to a 15-mm trocar. This trocar accommodated a large Endo-Catch bag, and all of the specimens were extracted through this incision after widening it 2.0 cm to accommodate their size.

The chemotherapy catheters were then inserted into the abdomen under laparoscopic guidance. The right paraumbilical trocar accommodated the inflow catheter, and the widened left paraumbilical trocar accommodated the outflow catheter. The looped outflow catheter was situated above the surface of the liver, while the single pronged inflow catheter was situated along the right lower quadrant abdominal wall. Heated chemoperfusion at 41 °C was performed for 90 min using standard techniques [10, 11].

After chemoperfusion, the trocar sites were closed either directly through open exposure or with the assistance of the Carter Thomason Endoclose device. Final incisions are shown in Fig. 2. Of note, no laparoscopic-assistant trocars were required or utilized during the procedure. Intraoperative estimated blood loss was approximately 50 cc. The operative time was 426 min.

Results

After completion of the robotic-assisted CRS-HIPEC, the patient was transferred to a regular hospital floor. Her nasogastric tube was discontinued on post-operative day 1,

Fig. 2 Locations of final incisions (highlighted by blue ovals) for the robotic-assisted CRS-HIPEC after all specimens have been removed and all incisions have been closed. Four incisions were placed in a transverse line just above the level of the umbilicus

and she regained bowel function on post-operative day 2. Consistent with previous reports for intraabdominal MIS [12, 13], she required very minimal intravenous narcotics for pain control, which was mostly managed with intravenous acetaminophen and ibuprofen. Specifically, she received two doses of 0.4 mg IV hydromorphone on post-operative day 3. She did not receive or request oral narcotic medication. The remainder of her post-operative course was unremarkable, and she was discharged on post-operative day 4. Final pathology showed that the small subcentimeter areas along the right colonic mesentery and the peritoneum of the right lower quadrant were consistent with mesothelioma hyperplasia and mucin. The remaining specimens were negative for a disease, confirming a PCI score of 1. She was seen 2 weeks later with no post-operative issues. An interval high-resolution MRI of the abdomen and pelvis was performed 8 weeks after surgery with no detection of disease. An additional surveillance MRI performed 6 months after surgery continued to be negative for recurrence.

Discussion

In this dynamic report, we show for the first time the feasibility of a robotic-assisted CRS-HIPEC for a selected patient with minimal disease from DPAM. Consistent with the laparoscopic approach as compared to the open approach, our patient had minimal blood loss, well-controlled pain without the routine use of intravenous narcotic pain medication, and a short post-operative LOS of only 4 days. In addition, only four robotic ports were required, and the surgery was performed without the use of an assistant port. Given the patient's previous gastric bypass, the robotic platform allowed ease of access to the patient's omentum, which had been sequestered in the left upper quadrant. As shown in the accompanying video, the robotic approach facilitated access high into the left upper quadrant for a prolonged portion of the procedure (approximately 1.5–2 h). While this can be accomplished through a laparoscopic approach as well, the robotic approach was more accommodating in this particular situation in the setting of the patient's increased BMI and previous gastric bypass.

There are additional benefits to the robotic approach, related to the stress placed on the surgeon, who can be more ergonomically positioned on the robotic console. The weight of the patient's abdominal wall rests on the robotic instruments as opposed to the surgeon via hand-held laparoscopic instruments. This is particularly relevant for long, complex cases such as CRS-HIPEC, and may contribute to the longevity of the surgeon, which has also been reported as a benefit of robotic surgery in gastrointestinal, urologic, and gynecological procedures [14, 15]. Furthermore, additional benefits of robotic surgery over laparoscopic surgery have also been reported, including lower rates of conversion to open, particularly in obese patients [16]. Taken together, the ability of the robotic platform to facilitate access to the distorted omentum or likewise complex anatomy, the high-resolution three-dimensional imaging, the potential to limit the number of ports, and the ergonomic benefits to the surgeon comprise the benefits of the robotic-assisted approach, all highlighted in this patient with an obese BMI as compared to the laparoscopic approach.

Additional benefits have been reported for MIS (mainly laparoscopic) in the setting of CRS-HIPEC, which can easily be translated to the robotic-assisted approach. Consistent with the general comparison of open surgery versus MIS, the latter results in the formation of fewer post-operative adhesions. This is of particular importance in the case of peritoneal malignancies, which have a high risk of recurrence. Thus, to facilitate re-entry into the abdomen, the MIS approach offers a distinct benefit compared to the open approach through the formation of less adhesive disease [17]. Moreover, the patient may develop a symptomatic recurrence of DPAM in the future, necessitating additional CRS-HIPEC procedures.

We recognize that this report has important limitations. First, we showed the feasibility of the robotic-assisted approach to CRS-HIPEC in a single, highly selected patient with minimal disease related to DPAM from a perforated low-grade appendiceal mucinous neoplasm. The follow-up of this patient is also currently limited to 6 months. Studies have shown that CRS-HIPEC can prolong the time to a symptomatic recurrence in this patient population [18, 19]. On the contrary, this approach is likely not to be acceptable for patients with more extensive disease requiring a more significant amount of debulking. In these cases, an open approach would be more advisable to manually strip disease from sites that would be difficult to address robotically, such as the surface of the small bowel or colon. Indeed, it is important to properly utilize pre-operative imaging to decide whether an MIS approach to CRS-HIPEC is feasible. When extensive disease is identified pre-operatively or intra-operatively, an open approach or conversion to open should be considered to inspect areas that may be more challenging to investigate during MIS, such as mesenteric surfaces. This may be even more pertinent to patients with higher BMIs. Moreover, as there is no tactile feedback through the robotic surgical system, it would be recommended to address extensive hollow organ disease through an open approach. Finally, since this is a single case report, a formal cost analysis could not be performed. However, emerging evidence suggests that the learning curve for robotic surgery may be lower than that for laparoscopic surgery, and with improvements in operative times, the robotic approach may offer an economically comparable option for patients undergoing complex intraabdominal procedures after the known initially higher costs [20].

Despite these limitations, we show that the robotic-assisted approach for CRS-HIPEC is a feasible option for the highly select patient. To our knowledge, this represents the first report of a robotic approach for CRS-HIPEC in gastrointestinal malignancy. Further prospective study will better characterize the benefits of robotic-assisted surgery for CRS-HIPEC. Given the relative novelty of this approach and the rarity of this disease, multi-institutional collaborative group analyses will be required to delineate the advantages of MIS for CRS-HIPEC, including both the robotic and laparoscopic-assisted approaches.

Compliance with ethical standards

Conflict of interest Drs. Gabriel, Elli, Bagaria, Wasif, Grotz, Stauffer, Kasi, and Asbun have no conflicts of interest or financial ties to disclose.

Informed consent Written informed consent was obtained from the patient for publication of this case report/any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

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