



## Robotic ALPPS

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### ABSTRACT

**Background.** The associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) procedure is a useful strategy to treat patients with advanced liver tumors and small future liver remnants. This video presents a robotic ALPPS procedure to treat synchronous colorectal liver metastases.

**Methods.** A 71-year-old man with liver metastases from sigmoid cancer was referred. A multidisciplinary team decided on chemotherapy followed by liver resection (first), then colon resection. After four cycles, objective response was observed and the multidisciplinary team then chose the ALPPS procedure. The future liver remnant (segments 3 and 4 and the Spiegel lobe) was 24%. A robotic approach was proposed. Colon resection was performed after the ALPPS procedure, also using the robotic approach.

**Results.** The duration of the first stage was 293 min, and the technique used in the first stage was partial ALPPS (parenchymal transection deep to 2 cm above the inferior vena cava) with preservation of the right hepatic duct. The patient was discharged on the fourth day. The second stage of the procedure took 245 min. Recovery was uneventful and the patient was discharged on the fourth day. Finally, the patient underwent robotic resection of the primary colorectal neoplasm. The surgery lasted 182 min, recovery was uneventful, and the patient was discharged on the fifth

postoperative day. Final pathology disclosed a T3N1bM1 adenocarcinoma. Liver pathology confirmed colorectal metastases with partial response. All surgical margins were free. Currently, the patient is well, with no signs of disease 5 months post-procedure.

**Conclusions.** Robotic ALPPS is feasible and safe. The robotic approach may have some advantages over the laparoscopic and open ALPPS approaches. This video may help oncological surgeons to perform this complex procedure.

The associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) procedure is a useful strategy to treat patients with advanced primary or metastatic liver tumors and small future liver remnants.<sup>1,2</sup> This technique induces greater liver hypertrophy, although initial reports indicated that it results in significant morbidity and mortality.<sup>1,3</sup> Since then, better patient selection and precise indications have led to better results.<sup>4–7</sup> Simultaneously, important technical modifications<sup>8–13</sup> have reduced complications, and today the ALPPS procedure is established and accepted worldwide.<sup>7</sup> The use of minimally invasive surgery (in our view) is an excellent way to reduce surgical severity, and we have been using this approach since 2012.<sup>8,13</sup> The aim of this video is to present a robotic ALPPS procedure as a treatment for synchronous colorectal liver metastases. The treatment was completed by robotic resection of the colorectal primary tumor.

### METHODS

A 71-year-old man with synchronous multiple liver metastases from a sigmoid cancer was referred for surgical treatment. The tumor marker carcinoembryonic antigen (CEA) was elevated (35 µg/L) and magnetic resonance imaging (MRI) revealed multiple and bilateral metastases that occupied all liver segments, except the caudate lobe.

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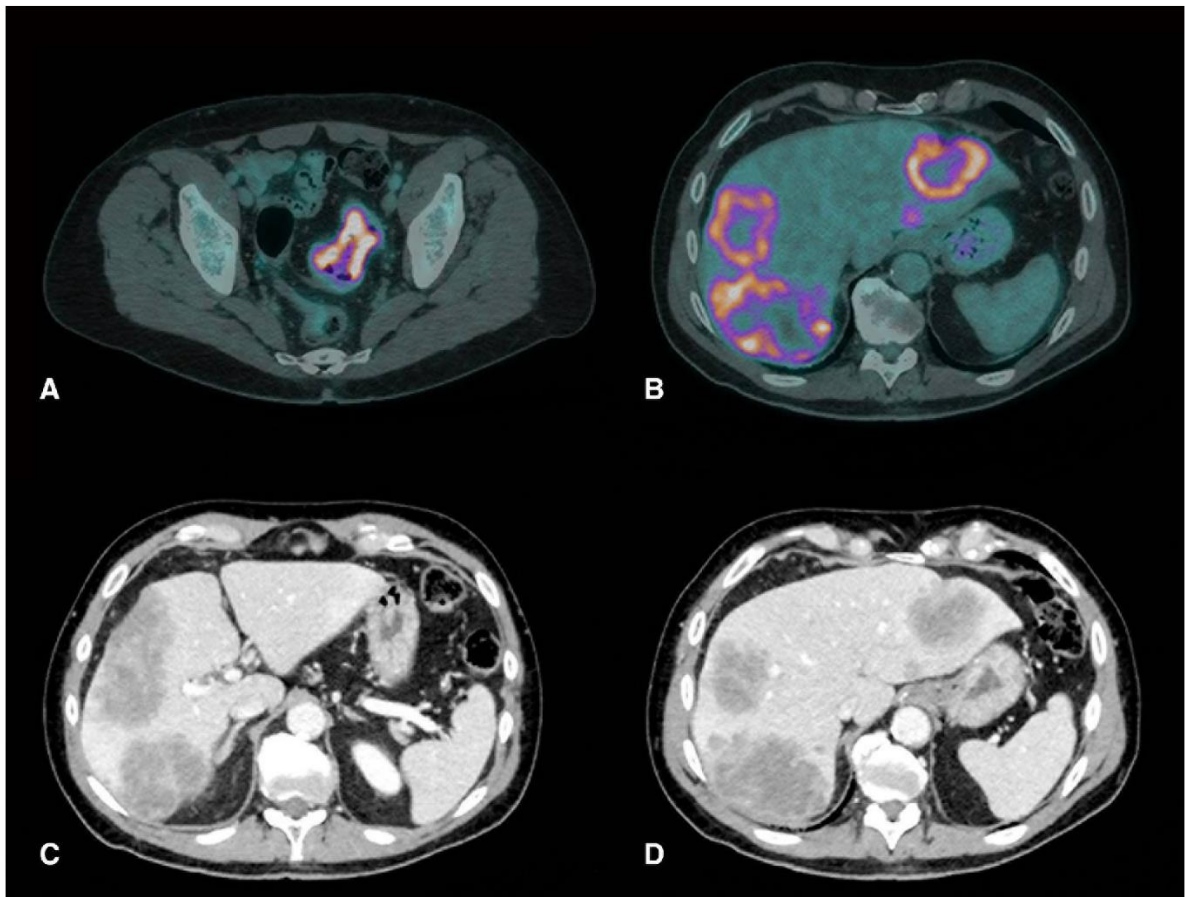
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Position emission tomography/computed tomography (PET/CT) showed no evidence of disease, other than in the colon and liver (Fig. 1). A multidisciplinary team decided on chemotherapy followed by liver resection (first), and then a subsequent colon resection, as a treatment strategy if an objective response is achieved. The patient then received four cycles of FOLFOXIRI, and was found to have reduced tumor marker ( $7.5 \mu\text{g/L}$ ) and objective response in the primary and liver metastases during imaging studies (Fig. 2). The multidisciplinary team decided to use the ALPPS procedure. The future liver remnant will include segments 3 and 4 and the Spiegel lobe, and was calculated to be 24%. A robotic approach was proposed after obtaining informed consent for the procedure. Colon resection was scheduled to be performed after the ALPPS procedure, also using a robotic approach. This study was approved by the review board of the Department of Surgery from our institution.

## SURGICAL TECHNIQUE

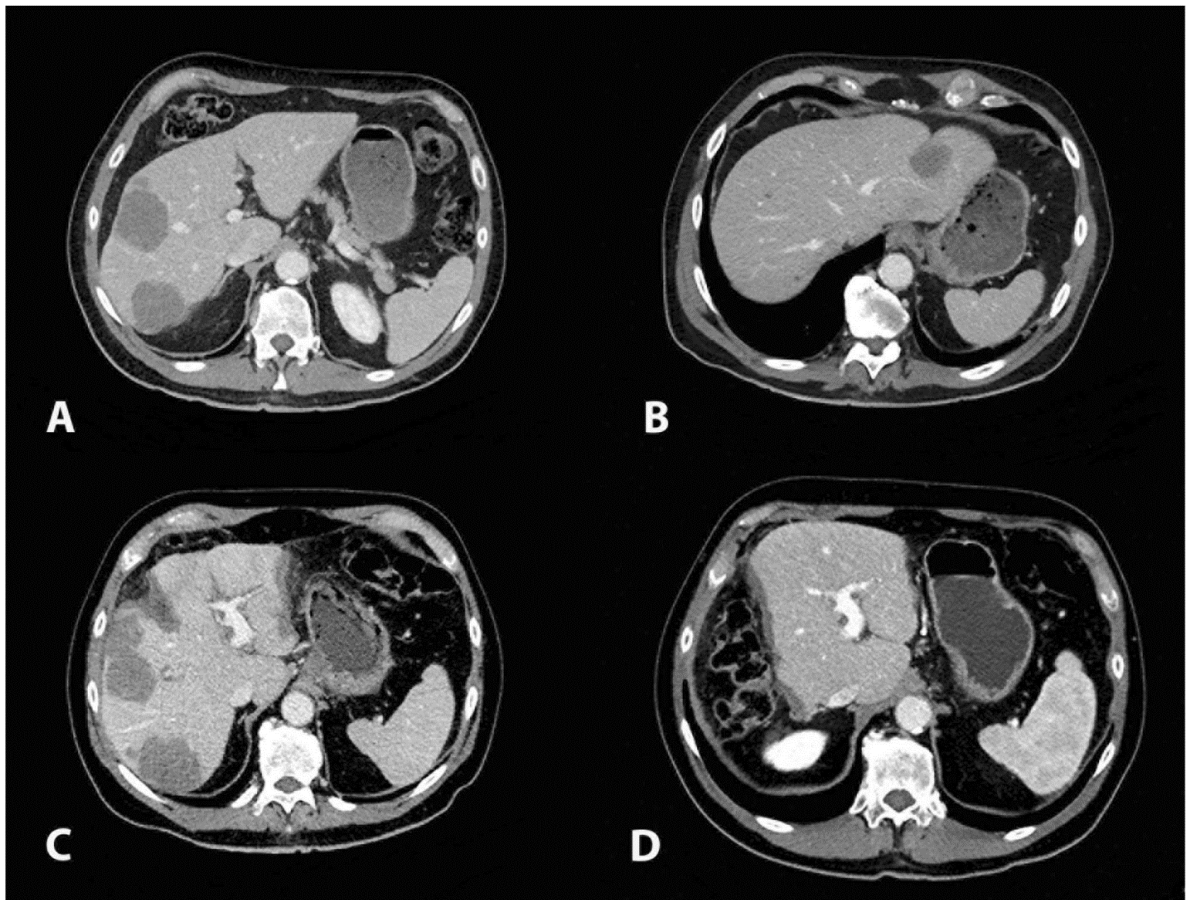
### *Patient Positioning and Port Placement*

The patient was placed in the supine position and 30° reverse Trendelenburg position. Robotic surgery was performed using the da Vinci Xi robotic platform (Intuitive Surgical Inc., Sunnyvale, CA, USA). This technique used five trocars (Fig. 3). A pneumoperitoneum was created using an open technique in the supra-umbilical port (A in Fig. 3), and the pneumoperitoneum was established at 14 mmHg. The remaining trocars were inserted under direct vision (Fig. 3). During this technique, the surgeon is seated at the robotic console and the assistant surgeon stands on the patient's left side. The assistant surgeon performs retraction, suction, clipping, and stapling, and changes the robotic instruments.



**FIG. 1** Robotic ALPPS. Imaging studies before neoadjuvant chemotherapy. PET/CT imaging shows (a) a large tumor in the rectosigmoid junction and (b) multiple liver metastasis. CT scan shows (c) multiple lesions in the right liver and (d) multiple metastases in the

right liver and in segment 2. ALPPS associating liver partition and portal vein ligation for staged hepatectomy, PET/CT position emission tomography/computed tomography



**FIG. 2** Robotic ALPPS. Imaging studies after neoadjuvant chemotherapy and after the first and second stages of the ALPPS procedure. CT scan after neoadjuvant chemotherapy shows (a) a marked reduction in the size of the metastases and (b) objective radiological response. (c) CT scan after the first stage shows

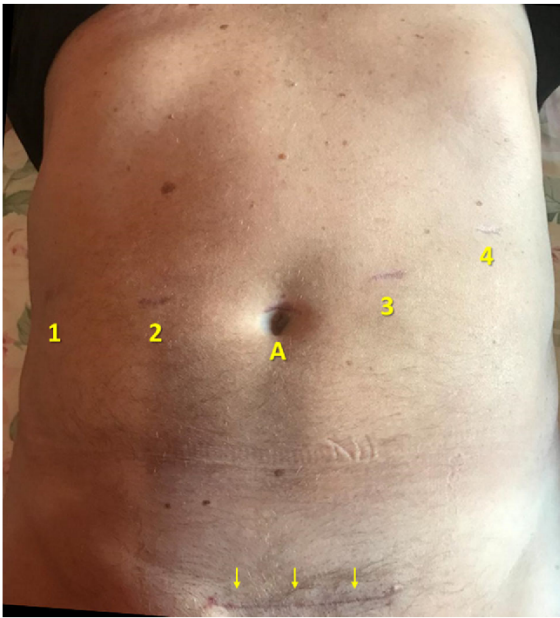
hypertrophy of the future liver remnant. (d) CT scan after the second stage shows hypertrophy of the liver remnant. ALPPS associating liver partition and portal vein ligation for staged hepatectomy, CT computed tomography

### First Stage

The first stage consisted of non-anatomical resection of segment 2, resection of liver metastases in segments 4 and 3 (found intraoperatively), followed by right portal vein ligation and liver bipartition at the Cantlie's line.

The left liver was completely mobilized by dividing the round, falciform, coronary, and left triangular ligaments. Intraoperative ultrasound confirmed two lesions in segment 2 and one lesion in segment 4, and found another small lesion in segment 3. Ultrasound was important for demarcation of the line of the future liver transection, sparing the segment 3 branch from the left hepatic vein. The next step included resection metastases from segments 3 and 4. In this procedure, using selective hepatic artery clamping instead of the Pringle maneuver, segment 2 is resected using a combination of robotic bipolar forceps and scissors

under saline irrigation. After completion of segmentectomy 2, the right portal vein is dissected. The caudate lobe portal vein branch is spared. A cholecystectomy was subsequently performed. The right portal vein is ligated, resulting in ischemic discoloration of the right liver. Fluorescent imaging after infusion of indocyanine green disclosed the Cantlie's line, which was marked with cautery as the future line of the liver transection. The last step was liver bipartition, which was accomplished using a combination of robotic bipolar forceps and scissors under saline irrigation. The bipartition was performed at the level of the hepatic hilum and about 2 cm above the level of the retrohepatic vena cava. This strategy is known as partial ALPPS. The procedure is completed with removal of the specimen and drainage of the abdominal cavity.



**FIG. 3** Robotic ALPPS. Postoperative photograph of the abdominal wall showing incisions for the robotic arms (1–4), auxiliary port (A), and suprapubic incision (small arrows) used for the retrieval of surgical specimens. ALPPS associating liver partition and portal vein ligation for staged hepatectomy

#### *Second Stage*

A CT scan performed after 7 days showed a great amount of hypertrophy (46%) of the future liver remnant, representing 41% of the total liver volume (Fig. 2). The second stage was performed with the da Vinci Xi robotic platform using the exact same number and location of trocars as the first stage. During the operation, there were no adhesions other than those encountered at the partition area. Adhesions were divided and the partition area was exposed with blunt dissection. Fluorescent imaging revealed residual indocyanine green at the partitioned area. The right liver was then fully mobilized. The next step was to approach the right Glissonian pedicle, which could be seen after removal of the liver tissue around the pedicle. The right pedicle is divided with a stapler, resulting in ischemic discoloration of the right liver. Fluorescent imaging after infusion of indocyanine green showed adequate perfusion of the future liver remnant. Right hepatectomy begins with division of the right portion of the caudate lobe and insertion of an umbilical tape around the right liver on the right side of the inferior vena cava, a modified hanging liver maneuver. The tape is pulled upwards to expose the liver partitioned area. The liver is carefully divided using a combination of robotic bipolar forceps and scissors under saline irrigation, towards the

right hepatic vein. Finally, the hepatic vein is divided using a stapler and the second stage is completed. The procedure is completed with removal of the specimen through suprapubic incision and drainage of the abdominal cavity.

#### *Robotic Colon Resection*

The strategy for this patient was liver first, then resection of the primary. The surgical treatment was completed by robotic anterior resection with the da Vinci Xi robotic platform using the exact same number and location of trocars as the first stage. After mobilization of the splenic flexure of the colon, ligation of the inferior mesenteric vein and artery, and lymphadenectomy, the left colon was divided at the level of the upper rectum and brought to the suprapubic incision. Finally, colonic mechanical anastomosis was performed. The Robotic platform was reinserted and additional seromuscular sutures were applied and the leak test was negative. The procedure was completed and the abdominal cavity was not drained.

## **RESULTS**

The operative time for the first stage was 293 min. The patient's estimated blood loss was 420 mL, with no need for intraoperative or postoperative transfusion. Selective hepatic artery clamping was used for 40 min. The patient's recovery was uneventful and the patient was discharged on the fourth postoperative day. The drain was removed on the sixth postoperative day. The second stage took place 3 weeks after the first stage and the operation time was 245 min, with blood loss estimated to be 270 mL. Recovery was uneventful and the patient was discharged on the fourth postoperative day. Finally, the patient underwent robotic resection of the primary colorectal neoplasm. The operative time was 182 min, recovery was uneventful, and the patient was discharged on the fifth postoperative day. Final pathology disclosed a 3.3 cm T3N1bM1 adenocarcinoma of the sigmoid colon, with three of 27 positive lymph nodes resected. Liver pathology confirmed colorectal metastases with partial response (tumor regression grade 3 according to the Rubbia–Brandt classification). All surgical margins were free. Currently, the patient is well, with no signs of disease 5 months after the procedure. A CT scan showed complete regeneration of the remnant liver (Fig. 2).

## **DISCUSSION**

The first minimally invasive ALPPS procedure was published in 2012.<sup>8</sup> A totally laparoscopic first- and second-stage ALPPS has been described in a letter to the

editor.<sup>8</sup> Since then, only a few cases have been reported.<sup>13–15</sup> In a recent systematic review of the literature on this subject, only 27 cases were identified.<sup>16</sup> Minimally invasive ALPPS, in accordance with this review, appears to be safe, with lower morbidities and mortalities when compared with its counterpart open procedure. One possible explanation, according to these authors, was better selection of patients and underlying pathology treatment, with predominance of colorectal liver metastases.<sup>16</sup> However, the predominance of colorectal metastases is explained by the first analysis from the ALPPS registry. Here, better results were found in this subgroup of patients and a relative contraindication in some types of pathology, such as biliary tumors.<sup>3</sup>

In a study from our team, in which 10 laparoscopic ALPPS procedures were compared with 20 open cases, we observed better results in the laparoscopic series.<sup>13</sup> There are several reasons for this improved result. Patient selection is one reason because not every patient is suitable for a minimally invasive approach. Another reason that has been neglected is the longer interval between the two stages that minimally invasive procedures allow, by reducing adhesions that can be extremely hazardous after an open procedure. Indeed, a longer interval has been associated with better results after ALPPS,<sup>17</sup> indicating that the great hypertrophy of the future liver remnant may take some time to reflect actual liver function; this has already been discussed by other authors.<sup>18</sup> Another reason is that the liver partition performed by laparoscopy is usually partial due to the difficulty in performing the classic hanging maneuver by laparoscopy. Partial ALPPS<sup>11</sup> and other techniques such as the Mini-ALPPS<sup>12</sup> have recently been described to reduce the surgical trauma from the first stage and to increase the safety of ALPPS, as well as reducing the number of patients who could not undergo the second stage due to complications. We were probably performing partial ALPPS without even noticing, whenever a minimally invasive approach was chosen. In the systematic review, all minimally invasive cases of ALPPS resulted in adequate hypertrophy of the future liver remnant, and the second stage was possible in every case.<sup>16</sup>

Robotic surgery has gained growing acceptance in recent years and has expanded to liver resection.<sup>19,20</sup> ALPPS is one of the most complex procedures in surgery and may be associated with increased rates of morbidity.<sup>1,3,4</sup> Different techniques and a large set of skills are needed to perform a safe robotic ALPPS. There are only two reports of robotic ALPPS in the literature. In the first report, only the second stage was completed using the robotic approach, while in the second report, only the first stage was completed using the robotic platform.<sup>21,22</sup> To our knowledge, this is the first case of robotic ALPPS in which both stages were completed using the robotic approach.

Moreover, resection of the primary was also performed using the robot. The newest robotic platform, the da Vinci Xi, has the advantage of interchangeable cameras between the four robotic arms. Therefore, we could complete the entire treatment for synchronous colorectal liver metastases, including the primary, with the same trocars and without increasing surgical difficulty. Different techniques and approaches used in liver surgery were employed in this case and were useful to safely complete a robotic ALPPS, such as liver first,<sup>23</sup> selective hepatic artery clamping,<sup>24</sup> partial ALPPS,<sup>11</sup> the Glissonian approach,<sup>25</sup> and the modified liver hanging maneuver.<sup>26</sup> After adequate experience with both open and laparoscopic ALPPS, and with robotic liver resection, an evolution towards robotic ALPPS seemed natural. As anticipated by some authors,<sup>27</sup> we are also “convinced that robotics represents a valuable option to widen the application of minimally invasive surgery, even for highly demanding surgeries like the ALPPS procedure”.<sup>27</sup>

## CONCLUSIONS

Robotic ALPPS is feasible and safe. The robotic approach may have some advantages over the laparoscopic and open ALPPS approaches. This video may help oncological surgeons to perform this complex procedure.

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