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Robot-Assisted Radical Antegrade Modular Pancreatosplenectomy Including Resection and Reconstruction of the Spleno-Mesenteric Junction

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robot, robotic, robot-assisted, minimally invasive, laparoscopy, laparoscopic, distal pancreatectomy, distal splenopancreatectomy, pancreatic cancer, radical antegrade modular pancreatosplenectomy, RAMPS

SUMMARY:

The robotic technique shown herein aims at faithfully reproducing the open procedure for radical treatment of cancer of the body-tail of the pancreas. The protocol also demonstrates the ability to master involvement of major peripancreatic vessels without conversion to open surgery.

ABSTRACT:

This article shows the technique of robot-assisted radical antegrade modular pancreatosplenectomy, including resection and reconstruction of the spleno-mesenteric junction, for cancer of the body-tail of the pancreas. The patient is placed supine with the legs parted and a pneumoperitoneum is established and maintained at 10 mmHg. To use the surgical system, four 8 mm ports and one 12 mm port are required. The optic port is placed at the umbilicus. The other ports are placed, on either side, along the pararectal line and the anterior axillary line at the level of the umbilical line. The assistant port (12 mm) is placed along the right pararectal line. Dissection begins by detaching the gastrocolic ligament, thus opening the lesser sac, and by a wide mobilization of the splenic flexure of the colon. The superior mesenteric vein is identified along the inferior border of the pancreas. Lymph node number 8a is removed to permit clear visualization of the common hepatic artery. A tunnel is then created behind the neck of the pancreas. To permit safe resection and reconstruction of the spleno-mesenteric junction, further preemptive dissection is required before dividing the pancreatic neck to bring in clear view all relevant vascular pedicles. Next, the splenic artery is ligated and divided, and the pancreatic neck is

divided, with selective ligature of the pancreatic duct. After vein resection and reconstruction, dissection proceeds to complete the clearance of peripancreatic arteries that are peeled off from all lympho-neural tissues. Both celiac ganglia are removed en-bloc with the specimen. The Gerota fascia covering the upper pole of the left kidney is also removed en-bloc with the specimen. Division of short gastric vessels and splenectomy complete the procedure. A drain is left near the pancreatic stump. The round ligament of the liver is mobilized to protect the vessels.

INTRODUCTION:

The incidence and mortality of pancreatic cancer are increasing, and the disease will soon become the second leading cause of cancer related death in Western countries[1]. The high fatality rate of pancreatic cancer is mostly related to the biological aggressiveness of this tumor type, with early and rapid metastatic dissemination[2]. For this reason, only approximately 20% of the patients are diagnosed with a seemingly localized disease. In these patients, radical tumor resection, in association with either neoadjuvant[3,4] or adjuvant chemotherapy[5], provides the only hope for a cure.

The diagnosis of pancreatic cancer located in the body-tail of the pancreas is often made when the tumor has already grown extensively or metastases are evident[6,7]. The few patients with a seemingly localized disease are those who could benefit from surgery, especially if negative resection margins are achieved[8] and an adequate number of lymph nodes is retrieved[9]. Patients meeting these criteria could actually attain long-term survival, as left-sided pancreatic cancers are associated with a less aggressive malignant phenotype when compared with pancreatic head cancers[10].

Radical antegrade modular pancreatosplenectomy (RAMPS), first described by Strasberg et al.[11], is a procedure that was specifically conceived to provide radical resection of pancreatic cancers located in the body-tail. Although laparoscopic RAMPS was shown to be feasible in well-selected patients[12], the complexity of this procedure and the high rate of margin negative resection reported after robotic procedures[13] suggest that robotic assistance could be rewarding in this operation. We herein describe the technique for robotic assisted RAMPS, that was developed in a center with experience in thousands of robotic procedures and in over 350 robotic pancreatic resections.

PROTOCOL:

The procedure described herein was conducted in compliance with the guidelines set out by the Ethics Committee of Pisa University Hospital for robotic operations, including regulations on research activity.

NOTE: The patient is a 70-year-old female with a 3 cm pancreatic ductal adenocarcinoma located in the body of the pancreas close to the neck of the gland. The patient presented with abdominal pain. Her past medical history demonstrated arterial hypertension and appendectomy. Total-body contrast-enhanced computed tomography (CT) showed a hypoenhancing pancreatic tumor strictly adherent to the spleno-mesenteric junction, with associated upstream dilation of the main pancreatic duct (**Figure 1**). No distant metastasis was identified making the tumor potentially resectable with curative intent.

1. Experimental pre-operation

1.1. Patient selection

1.1.1. Establish a diagnosis of pancreatic cancer, by either biopsy or unequivocal imaging findings.

1.1.2. Rule out distant metastasis by total-body contrast-enhanced CT scan. Perform the scan within 4 weeks of surgery[14].

1.1.3. Assay tumor markers (CEA and Ca 19.9).

NOTE: High preoperative levels of Ca 19.9 have prognostic implications[15], but low levels do not call into doubt the indication for surgery[16].

1.1.4. Ensure that the patient is fit for surgery and eligible for a minimally invasive approach[17,18].

1.1.5. Do not perform RAMPS during the learning curve[19].

1.1.6. Do not accept patients with tumors clearly involving the large peripancreatic vessels, until proficiency is achieved with standard RAMPS.

1.2. Patient preparation

1.2.1. Provide standard pre-surgical preparation.

1.2.2. Provide vaccination against encapsulated bacteria (*Streptococcus pneumoniae*, *Neisseria meningitidis*, *Haemophilus influenza* type B) to prevent overwhelming post-splenectomy sepsis[20].

1.3. Equipment

1.3.1. Ensure the availability of a robotic system.

NOTE: So far, only one robotic system (**Table of Materials**) has been used for pancreatic resections[18]. Herein a last generation robotic system is used. The docking technique and the targeting procedure are those specific to this system.

1.3.2. Ensure that standard laparoscopic equipment and the following robotic instruments are available: small and medium hem-o-lok clip appliers, Maryland bipolar forceps, monopolar curved scissors, harmonic shears, and large needle drivers.

1.3.3. In case of vein resection, ensure that the following instruments are available: robotic black diamond micro forceps and laparoscopic bulldog clamps.

1.3.4. Ensure that all necessary sutures and consumables (**Table of Materials**) are available.

1.3.5. Ensure that a laparoscopic stapler is available.

2. Surgical preparation

2.1. Anesthesia[17]

2.1.1. Assess operative risk by providing a grade according to the American Society of Anesthesiologists' (ASA) classification of Physical Health.

2.1.2. Place at least one large bore (14 G or 16 G) intravenous cannula in a peripheral vein. Place a central venous line in patients with limited possibility of peripheral vein cannulation.

2.1.3. Monitor electrocardiogram, arterial pressure (cannulation of radial artery), capnography, pulse oximetry, urinary volumes, and body temperature.

2.1.4. Provide general anesthesia.

NOTE: Both inhalation and intravenous anesthesia can be used.

2.1.5. Provide deep neuromuscular blockade (rocuronium bromide: 0.075–0.1 mg/kg).

2.1.6. Insert a nasogastric tube.

2.1.7. During surgery, perform blood gas analysis to verify blood gases and pH.

2.1.8. At the end of the procedure, reverse anesthesia and remove the nasogastric tube.

2.2. Operation setting

NOTE: A schematic view of the operating room setup is provided in **Figure 2**.

2.2.1. Have the main surgeon operate from the robotic console.

2.2.2. Have a laparoscopic surgeon (first assistant) stand between the patient's legs. He or she operates suction, introduces and withdraws sutures, helps with retraction, and fires staplers.

2.2.3. Have an assistant surgeon stand on the left side of the patient. He or she exchanges robotic instruments and assists the laparoscopic surgeon.

2.2.4. Have a scrub nurse stand on the right side of the patient.

2.2.5. Place the patient supine, with the legs parted (French position) on an operating table equipped with a thermic blanket (**Figure 3A**).

2.2.6. Place intermittent pneumatic compression cuffs around the legs (**Figure 3B**), for prophylaxis of deep vein thrombosis.

2.2.7. Secure the patient to the operating table with wide bandings (**Figure 3C**).

2.2.8. Prep the patient as to widely expose the abdomen (**Figure 3D**). Include the suprapubic region to permit a Pfannenstiel incision for specimen extraction.

NOTE: For all the other aspects the patients have to be prepared as for major laparoscopic surgery in cooperation with the anesthesia team[17].

3. Preparatory surgical maneuvers and docking of the robotic system

3.1. Establish a pneumoperitoneum, using either a Veress needle or an open technique. Maintain pneumoperitoneum at approximately 10 mmHg.

3.2. Place the 8 mm robotic camera port just below or just above the umbilicus, depending on individual abdominal configuration.

NOTE: The camera port should be approximately 10−15 cm from the closest boundary of the target anatomy.

3.3. Insert the robotic laparoscope and explore the abdomen searching for occult metastatic deposits. Biopsy any identified nodule and send it for frozen section histology. If no metastasis is discovered, place the other ports.

3.4. Place all ports along the transverse umbilical line. Place the 12 mm assistant port along the right pararectal line. Place the remaining robotic ports along the anterior axillary line, on either sides, and along the left pararectal line (**Figure 4**).

NOTE: Ideal port spacing is 6−8 cm. A minimum space of 4 cm can be accepted. Ensure 2 cm space between ports and bony prominences.

3.5. Adjust the operating table in reverse Trendelenburg position (15−20°) and tilt it towards the patient’s right side (5−8°) (**Figure 5**). Position the robotic tower where staff will not be walking or standing to maximize patient access from the bedside.

3.6. To begin docking, align the laser crosshair of the boom over the camera port (**Figure 6A**). Use robotic arm number 2 for the camera.

3.7. Direct the camera arm between L and E on the FLEX icon at the base of the robotic arm (**Figure 6B**).

3.8. Clutch and point the camera to target the operative anatomy (**Figure 6C**). Execute targeting by pressing the dedicated button on the camera head.

NOTE: Targeting automatically adjusts height, translation, and rotation of the overhead boom to maximize the range of motion of the robotic arms. The remaining arms are docked (**Figure 6D**), and the robotic instruments are inserted under vision.

4. Pancreatectomy

4.1. Open the lesser sac by dividing the reflection of colon and omentum. Do not go through the gastrocolic ligament as this could result in omental infarction[21].

4.2. Start dissection midway along the transverse mesocolon and extend to the right until the hepatic flexure of the colon is reached, and to the left until the splenic flexure of the colon is fully mobilized. Once the lesser sac is fully open, the pancreatic body and tail become clearly visible.

4.3. Begin dissection of the peritoneum along the inferior margin of the pancreas, to allow mobilization of the body-tail of the pancreas.

4.4. Identify the superior mesenteric vein.

NOTE: The superior mesenteric vein is a key landmark to proceed safely with further dissections.

4.5. In preparation for the creation of a tunnel behind the pancreatic neck, identify the common hepatic artery and the portal vein above the pancreatic neck. Resect lymph node number 8A to bring the common hepatic artery in clear view.

4.6. Seal as many lymphatic vessels as possible using either hem-o-lok clips or ligatures. Once the course of the common hepatic artery is clearly defined, dissect the lymphatic tissue laying between the artery and the superior margin of the pancreatic neck to bring the portal vein in clear view.

4.7. Tag the common hepatic artery with a vessel loop to increase visibility and facilitate handling of the vessel during the procedure.

4.8. Perform dissection around the major arteries using cold scissors as the use of energy devices may result in thermal injury to the vessel walls, thus potentially increasing the risk of delayed bleeding[22]. Peel off the common hepatic artery, the celiac trunk and the first portion of the splenic artery by the surrounding lympho-neural tissues to have a clear picture of the vascular anatomy.

NOTE: In the accompanying video, an injury occurs to the dorsal pancreatic artery. The bleeding was fixed with a 5/0 polypropylene suture. Ligature and division of the dorsal pancreatic arteru would have been required anyway as this maneauver improves exposure of the origin of the splenic artery and offers more room for safe ligature of this large artery.

4.9. Divide the splenic artery between ligatures or clips. Apply two ligatures proximally and divide the vessel between two hem-o-lok clips. Whenever possible, divide the splenic artery before dividing the splenic vein, as this prevents the occurrence of sinistral portal hypertension, thus reducing blood pooling in the spleen and the amount of backwards bleeding.

4.9.1. Alternatively, use a stapler, loaded with a vascular cartridge.

NOTE: A tunnel behind the neck of the pancreas is developed at this stage. However, as suspected at pre-operative imaging, the tumor was strictly adherent to the spleno-mesenteric junction, making it preferable to further mobilize the specimen in order to achieve wider control of all vascular pedicles, before proceeding with vein resection and reconstruction.

4.10. Identify the superior mesenteric artery, to the left side of the superior mesenteric vein. Peel off the superior mesenteric artery 180° on its left aspect.

4.11. Identify the inferior mesenteric artery and save to be used as a vascular patch at the time of vein reconstruction. During perivascular dissections, clip large lymphatics to reduce the amount of lymphatic leak.

4.12. Begin dissection medial to lateral in a posterior plane to remove a large amount of the retroperitoneal soft tissue en-bloc with the specimen. Identify the left adrenal gland during this stage. Further to the left, remove the Gerota fascia covering the upper pole of the left kidney en-block with the specimen, thus uncovering the anterior surface of the upper renal pole. The left renal vein and the left adrenal vein are clearly identified.

4.13. Divide the inferior mesenteric vein between clips. Spare a segment of the vein for vascular reconstruction. Dissect the splenic vein free proximal to the site of the tumor adherence to achieve upstream vascular control.

4.14. Place a transfix suture at the inferior margin of the gland to occlude the transverse pancreatic artery. Divide the neck of the pancreas. When enough room is available, use a laparoscopic or robotic stapler. Alternatively, divide the neck using harmonic scissors.

NOTE: For the patient shown in the video, the pancreas was divided using harmonic shears because of the limited space available.

4.15. Identify, dissect, and ligate the main pancreatic duct. Close the transection surface in a fish-mouth configuration using interrupted sutures of 4/0 expanded polytetrafluoroethylene (e-PTFE).

4.16. When possible, send the pancreatic margin for frozen section histology. Delay freezing the section of pancreatic margin after specimen extraction if the margin is perceived to be so close to the tumor that intracorporeal sampling appears troublesome.

NOTE: In this patient, the transection margin was assessed after removal of the specimen because of the proximity of the tumor to the neck of the pancreas.

4.17. Divide the splenic vein.

NOTE: The vein should not be divided now if tumor proximity to the spleno-mesenteric junction poses concerns about the radicality of the procedure. In these instances, vein resection and reconstruction are required to achieve an R0 resection.

5. Vein resection and reconstruction

5.1. Plan for the most appropriate type of vein resection and prepare accordingly for reconstruction. If needed, identify a vascular segment suitable for reconstruction.

5.2. Achieve control of all vascular pedicles.

5.3. Cross-clamp the splenic vein upstream to the site of the tumor involvement.

5.4. Cross-clamp the superior mesenteric artery to reduce the amount of blood pooling in the intestines during venous cross-clamping.

5.5. Cross-clamp the superior mesenteric vein and the portal vein.

5.6. Excise the involved venous segment en-bloc with the specimen. Carry out a side-wall resection of the portal-mesenteric junction. Harvest the inferior mesenteric vein. Place an e-PTFE suture between the inferior mesenteric vein graft and the upper corner of the vein defect.

5.7. If a vascular patch is needed for closure of the vascular defect, suture the vascular patch using two half-running sutures of 6/0 e-PTFE.

5.8. Before releasing the clamps, flush the vein with saline solution containing sodium heparin using a ureteral catheter connected to a syringe.

NOTE: The laparoscopic surgeon performs vascular flushing.

5.9. Remove the bulldog clamps. Remove first the bulldog on the portal vein to check for bleeding sites at a lower pressure.

6. Completion of dissection

6.1. Complete clearance of retroperitoneal vessels. Dissect along the periadvential plane of the superior mesenteric artery in a cephalad direction.

6.2. Skeletonize the right side of the superior mesenteric artery and remove the right celiac ganglion, if the tumor is located close to the neck of the pancreas, because of lymphatic drainage[23] and path for neural invasion[24].

6.3. Once the aortic plane is reached on the right side, perform the same dissection on the left side.

6.4. Complete the posterior dissection. Remove the left celiac ganglion en-bloc with the specimen. When using harmonic shears, pay attention to the active blade that is opposite to the artery. When finer dissection is required, use cold scissors.

6.5. Divide the short gastric vessels along the posterior surface and the upper margin of the pancreas.

6.6. Mobilize the spleen.

7. Protection of retroperitoneal vessels

7.1. Mobilize the round and falciform ligaments.

7.2. Cover the naked retroperitoneal vessels with round and falciform ligaments.

8. Specimen extraction and wound closure

8.1. Make a Pfannenstiel incision (~5 cm).

8.2. Extract the specimen and load in an endoscopic bag.

8.3. Close the incision in layer and insufflate the abdomen for final exploration.

8.4. Close the fascia of the 12 mm assistant port.

8.5. Place a 14 Fr pigtail catheter close to the pancreatic stump.

8.6. Deflate the pneumoperitoneum.

8.7. Close all incisions.

REPRESENTATIVE RESULTS:

The operation time was 6 h and 15 min with an estimated blood loss of 150 mL. The time required to complete the vascular suture of the patch applied to the sidewall defect of the portomesenteric junction was 11 min. The postoperative course was uneventful. Pathology demonstrated a moderately differentiated ductal adenocarcinoma of the pancreas (G2/3), with perineural invasion and involvement of the spleno-mesenteric junction. All the 56 resected lymph nodes were negative. Circumferential tumor margins, assessed at 1 mm, were also negative making the resection radical. The final pathology stage of this tumor was T3 N0 R0. At the longest follow-up of 30 months, the patient is alive, well, and disease-free.

At our institution, a robot-assisted radical antegrade modular pancreatosplenectomy was performed in 20 patients. Admittedly, during the same period of time, other patients suitable for a minimally invasive approach received the same procedure using a laparoscopic technique without robotic assistance. This was not due to patient selection or surgeon preference but to the fact that the robot was not always timely available at the time of planned surgery, because of competition with either other procedures performed by our group (e.g., pancreatoduodenectomy) or procedures performed by other groups (e.g., urologic procedures).

Briefly, all procedures were completed under robotic assistance, without conversions to open surgery, despite three patients required associated vascular procedures (**Table 1**). Namely, two patients required resection and reconstruction of the spleno-mesenteric junction, and one patient required resection of the celiac trunk (modified Appleby procedure). The mean operative time was 325 min ± 88.6 min. Post-operative complications developed in 12 patients (60%), being severe according to the Clavien-Dindo classification[25] in 3 patients (3a = 2; 3b = 1) (15%). There were no 90-day or in-hospital deaths. Grade B post-operative pancreatic fistula[26] developed in 5 patients (35%). There was no grade C post-operative pancreatic fistula. Pathology demonstrated ductal adenocarcinoma in 14 patients, malignant intraductal papillary mucinous tumor in 5 patients, and pancreatic neuroendocrine cancer in one patient. In a patient population with a mean tumor diameter of 34 mm ± 13 mm, circumferential tumor margins, assessed at 1 mm, were negative in 17 patients (85%). The mean number of examined lymph nodes was 39 ± 16.6.

FIGURE AND TABLE LEGENDS:

Figure 1: Preoperative computed tomography scan. (**A**) Basal; (**B**) Arterial phase; (**C**) Venous phase; (**D**) Parenchymal phase. A hypoenhancing pancreatic tumor, with upstream dilation of the pancreatic duct, is noted in the proximal part of the body of the pancreas.

Figure 2: Operating room setup.

Figure 3: Operation setting. (**A**) The patient is placed supine with the legs parted. (**B**) Intermittent pneumatic compression cuffs are placed around the legs. (**C**) The patient is secured to the operating table using wide bandings. (**D**) The abdomen is prepped widely.

Figure 4: Port placement and extraction site. (**A**) Abdominal landmarks. 1: right anterior axillary line; 2: right pararectal line; 3: midline; 4 left pararectal line; 5: left anterior axillary line; 6: transverse umbilical line; 7: suprabubic extraction site. (**B**) Pneumoperitoneum induction using a Veress needle technique. (**C**) Optic port placed immediately below the umbilicus. (**D**) Ports. I: robotic port for arm 1; II: assistant port; III: robotic port for arm 2 (optic); IV: robotic port for arm 3; V: robotic port for arm 4.

Figure 5: Operating table orientation. As highlighted in the square in the lower left corner, the operating table is oriented 15−20° in reverse Trendelenburg and tilted 5−8° to the patient's right side.

Figure 6: Docking of the surgical system for distal pancreatectomy. (**A**) Alignment of the laser crosshair of the boom over the initial camera port. (**B**) Direction of the camera arm (number 2) between L and E on the FLEX icon located at the base of the robotic arm. (**C**) Docking of the robotic arm 2 and insertion of the robotic camera. (**D**) After completion of targeting, the remaining arms are docked.

Table 1: Results of 20 consecutive robot-assisted radical antegrade modular pancreatosplenectomies.

DISCUSSION:

Radical antegrade modular pancreatosplectomy aims at increasing the rate of radical resection for tumors located in the body and tail of the pancreas, as well as to achieve radical lymphoneurectomy. Depending on the degree of tumor growth in the retroperitoneum, the left adrenal gland can be either spared (anterior radical antegrade modular pancreatosplectomy) or removed en-bloc with the specimen (posterior radical antegrade modular pancreatosplectomy). In all procedures the Gerota fascia covering the upper pole of the left kidney must be removed as well as all the lympho-neural tissues surrounding the common hepatic artery, the celiac trunk, and the left aspect of the superior mesenteric artery[11,27].

Overall radical antegrade modular pancreatosplectomy is a complex procedure even when using an open approach. Although radical antegrade modular pancreatosplectomy has also been performed using pure laparoscopic techniques[12,28], the use of a robotic system is thought to facilitate the procedure due to the enhanced dexterity offered by robotic assistance[29]. Indeed, Duouadi et al. found that robotic assistance reduced the rate of conversion to open surgery while increasing the number of resected lymph nodes and the rate of margin negative resections[13].

When the tumor is located close to the neck of the pancreas, involvement of the superior mesenteric-portal vein and/or the celiac trunk may occur, further complicating the procedure. Both arterial and venous resections have been performed using robotic assistance during radical antegrade modular pancreatosplectomy[30], but the safety and oncologic efficacy of these procedures remain to be established.

In the case presented here, we performed a sidewall resection of the portomesenteric axis. The defect was closed using a vein patch. We still consider overt vascular involvement a contraindication to robotic approach[18,31]. However, we have performed a few robotic pancreatic resections with associated vascular procedures when vascular involvement was limited, and operative conditions permitted the procedure to be safely completed under robotic assistance[32]. We have already performed over 500 of such procedures open and we have experience with both pancreatic[33] and renal[34] robotic transplants.

Not all pancreatic tumors located in the body-tail of the pancreas can be resected using minimally invasive techniques, including robotic-assistance. Although the contraindications to robotic resection are expected to vary with center and surgeon experience, it could be reasonable to accept that patients with truly locally advanced cancers, with portal hypertension secondary to superior mesenteric portal vein stenosis/obstruction, with severe central obesity, and/or requiring multivisceral resections are less likely to be safely resected robotically than open.

Although current guidelines recommend upfront resection for pancreatic cancers not meeting the criteria to be classified either “borderline resectable” or “locally advanced”[35], neoadjuvant treatments may also be beneficial in patients with immediately resectable tumors[36,37]. No evidence is currently available on the impact of the new neoadjuvant treatments on both the feasibility and safety of minimally invasive pancreatic resections. This issue is probably worth to be explored.

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The authors have nothing to disclose.

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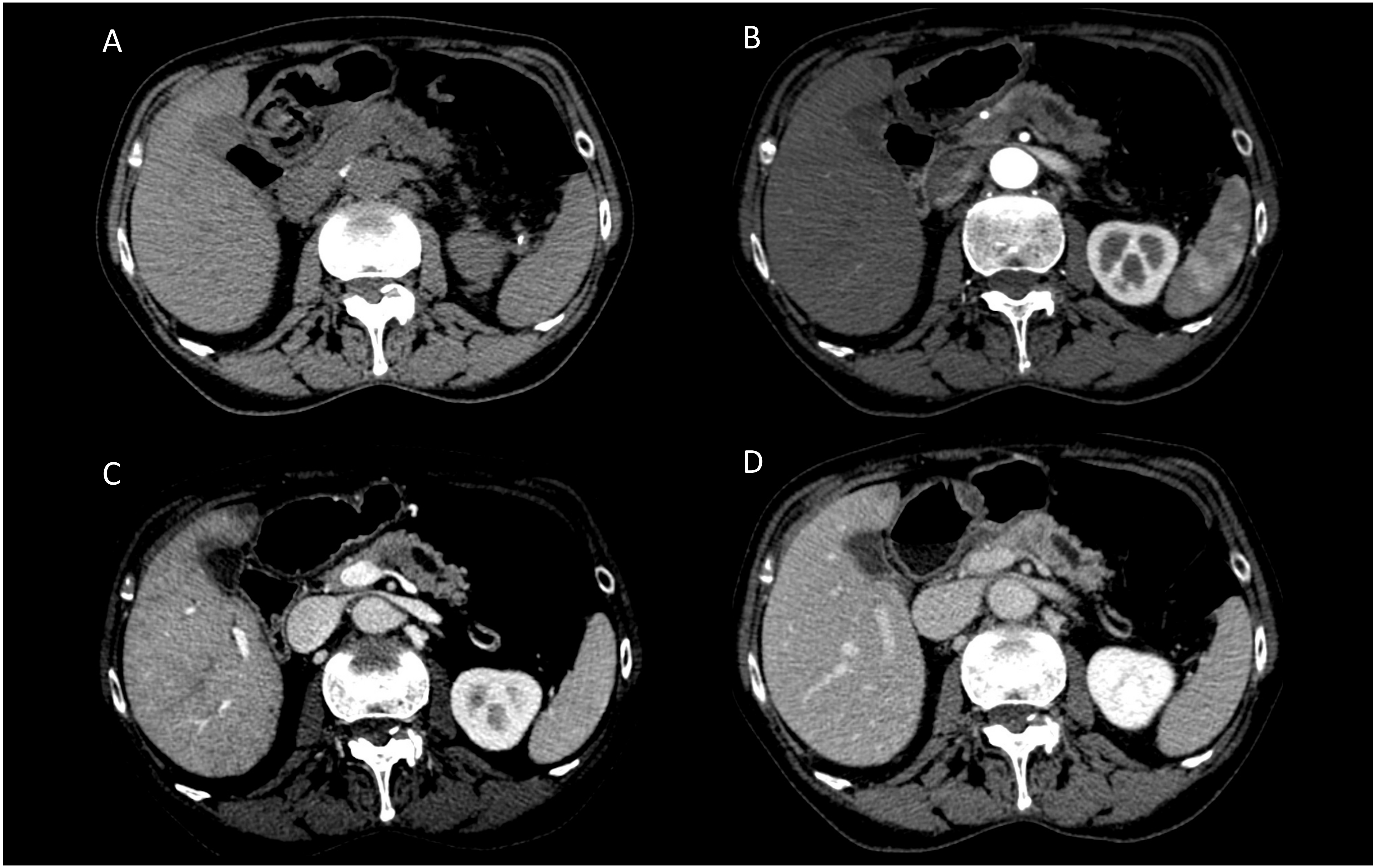

A
B
C
D

Figure 2

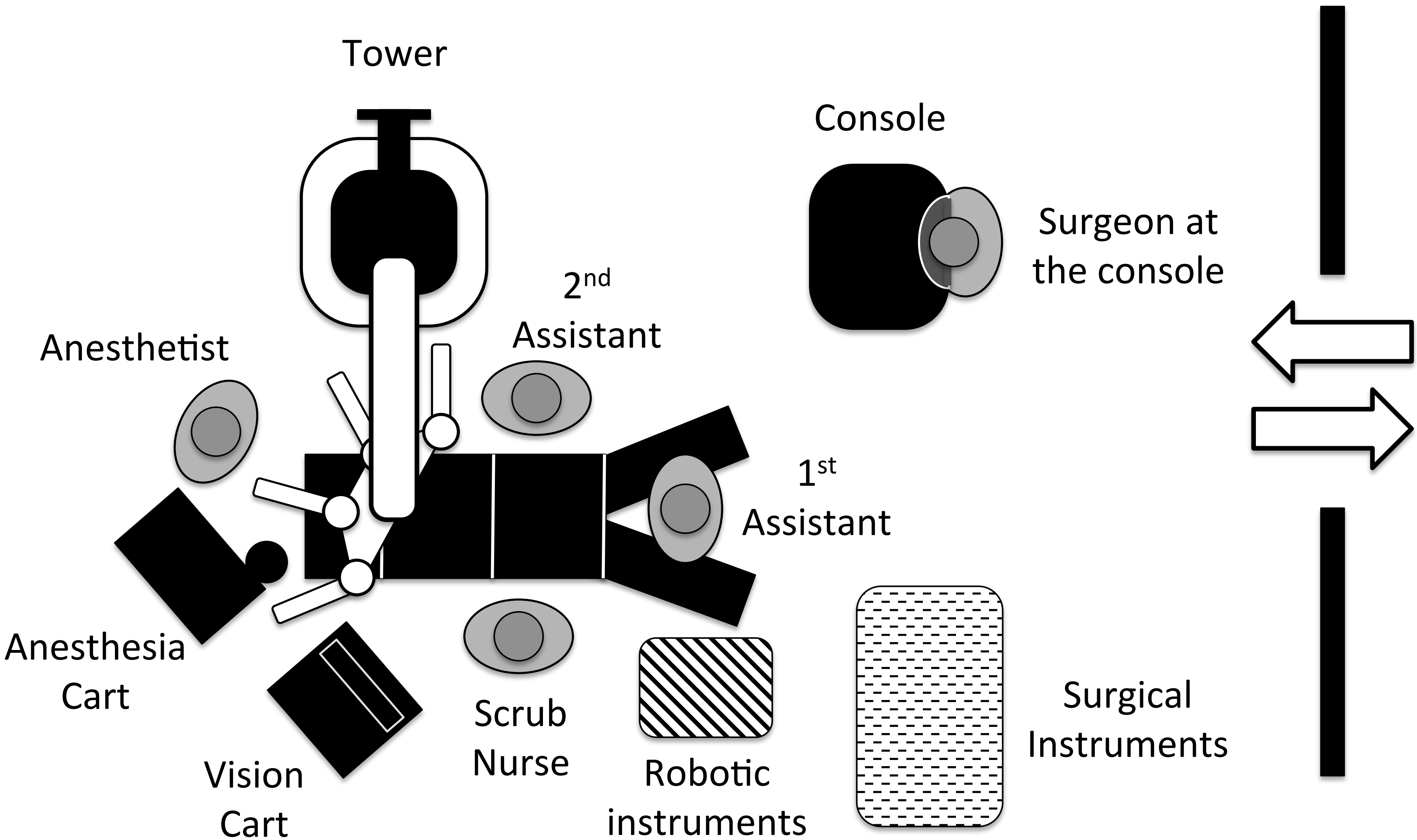

Tower
Console
Surgeon at the console
2nd Assistant
Anesthetist
1st Assistant
Anesthesia Cart
Vision Cart
Scrub Nurse
Robotic instruments
Surgical Instruments

Figure 3 Click here to access/download;Figure;Figure 3.pdf

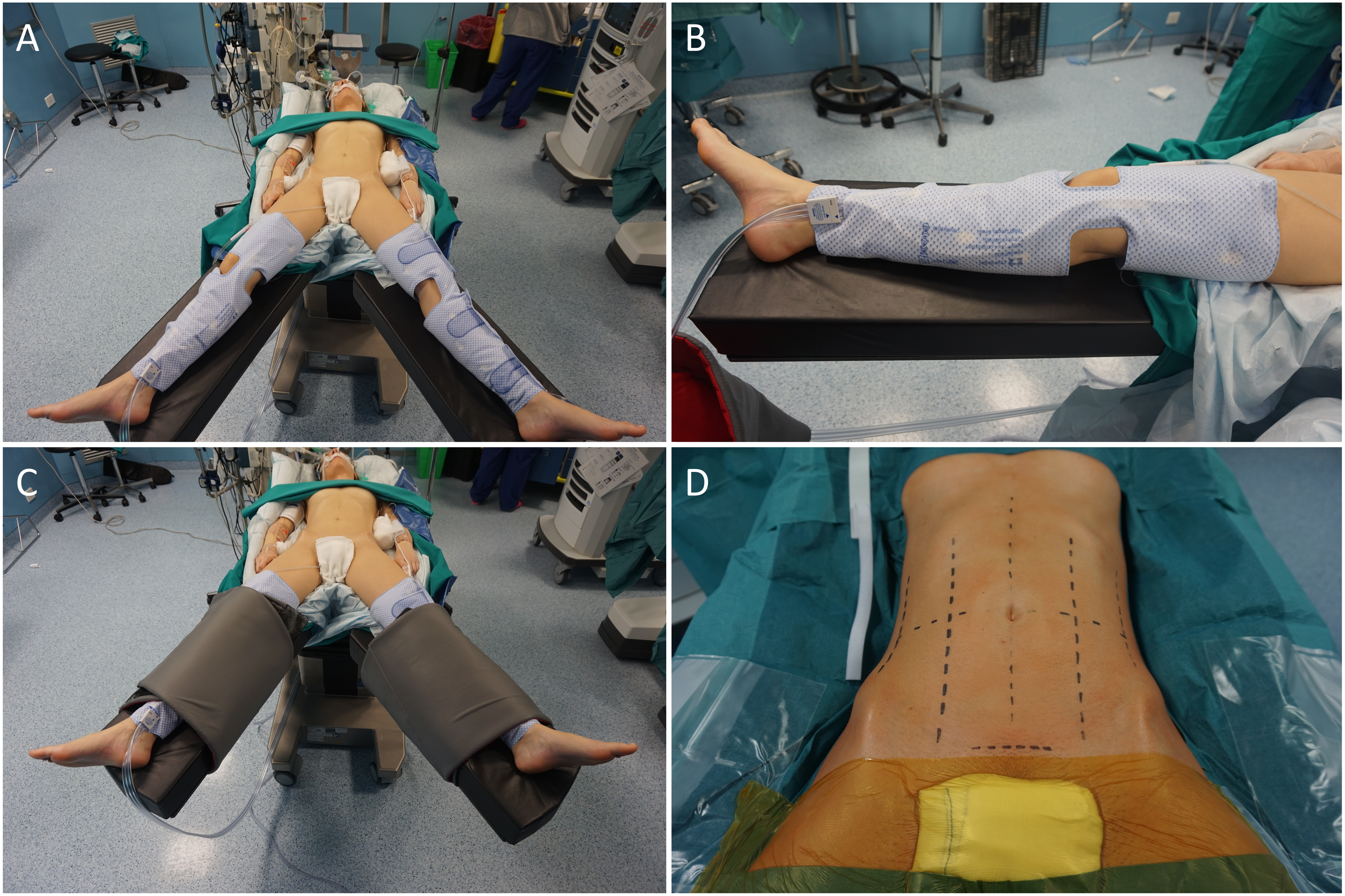
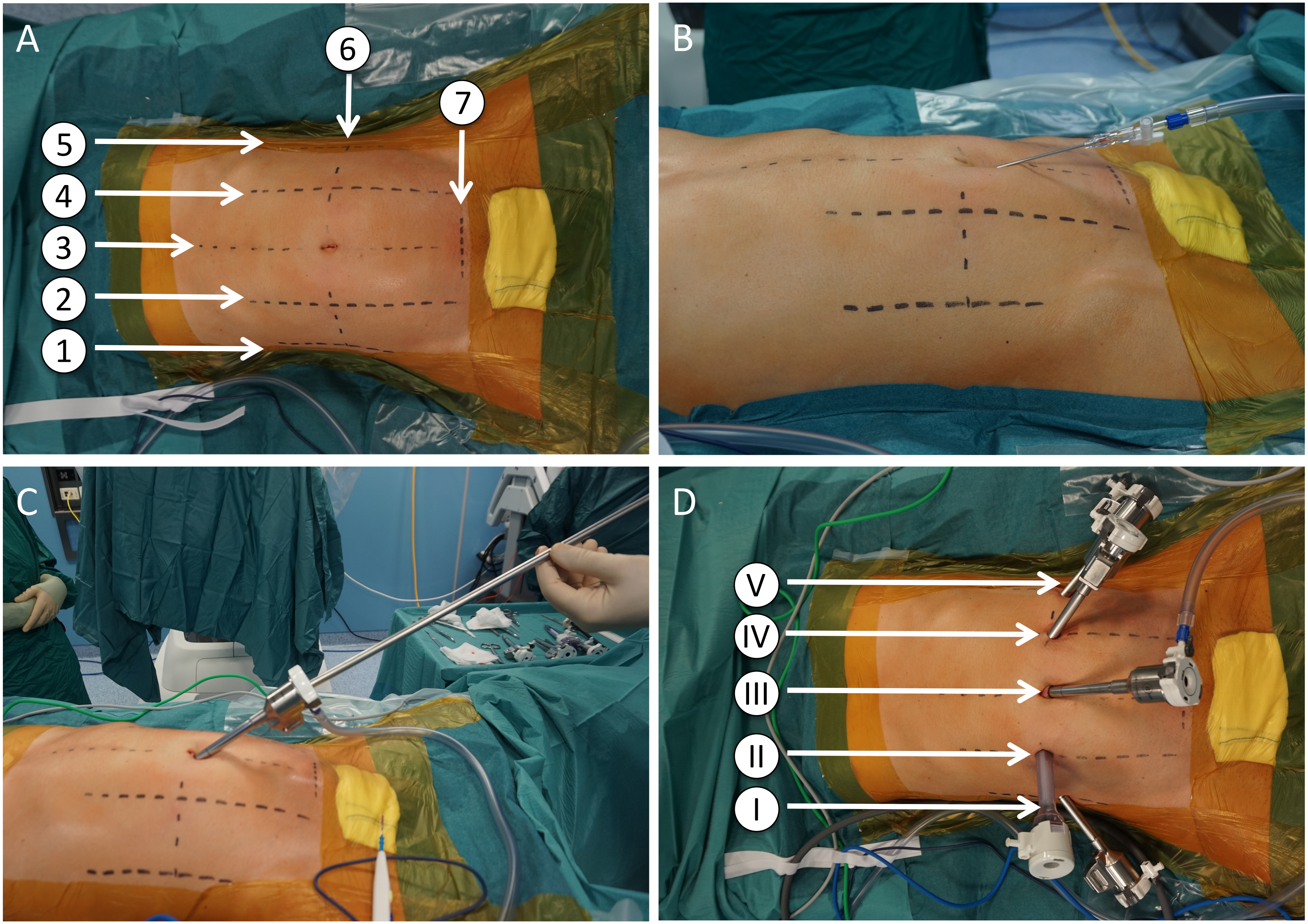


Figure 4



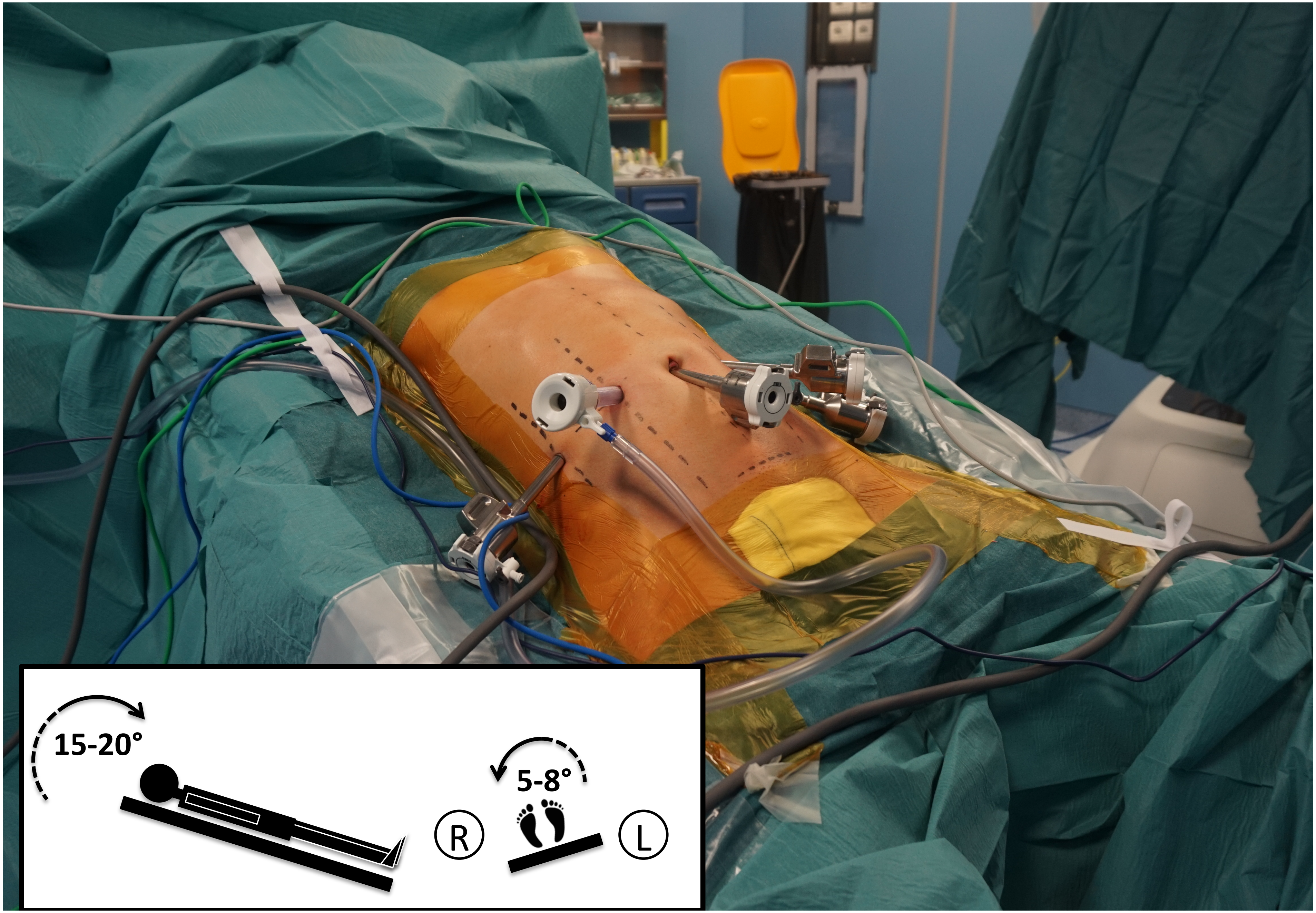

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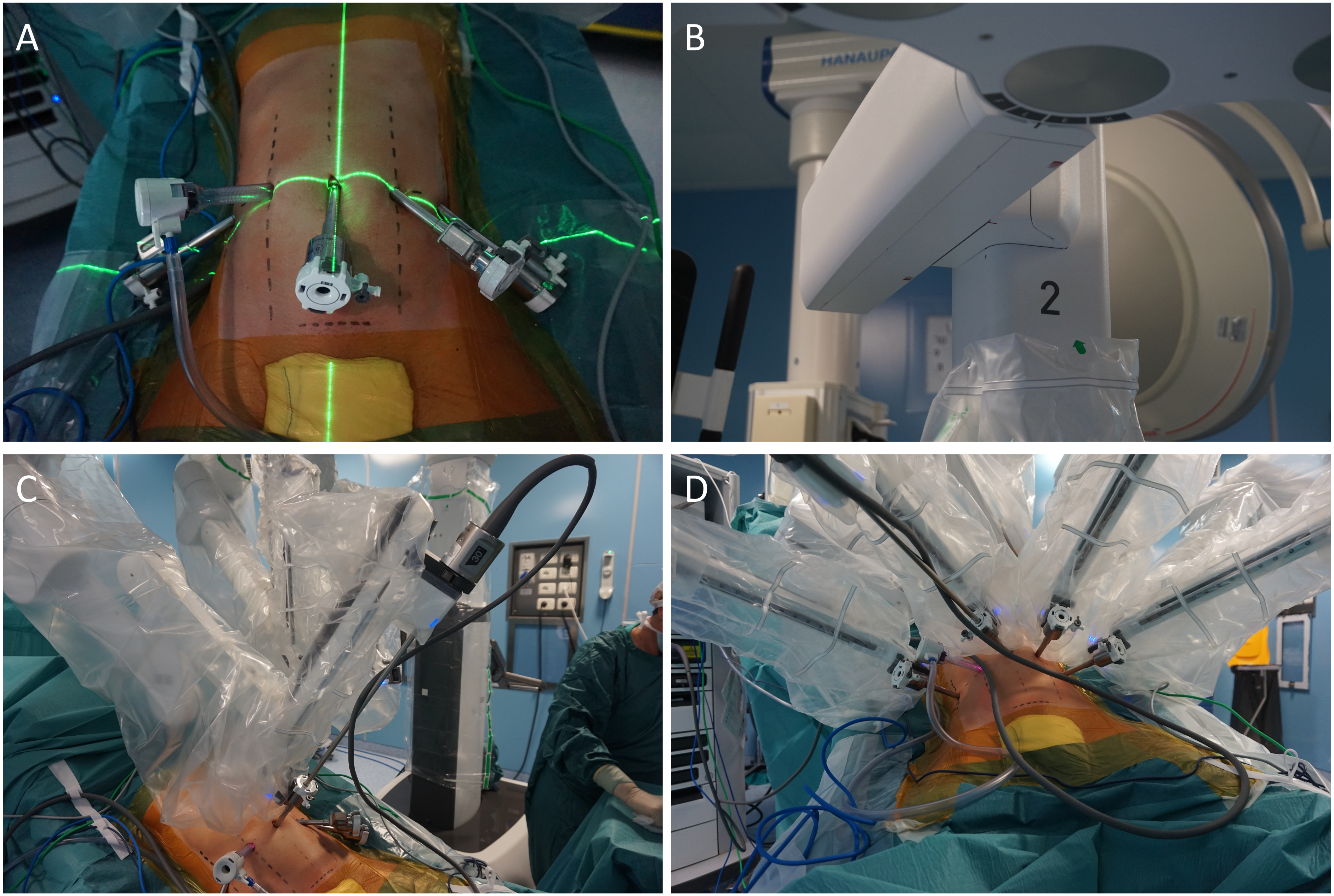
Figure 6



	Mean or number
Operative time (min)	325
Associated vascular procedures	3
Vein resection and reconstruction	2
Arterial resection (modified Appleby procedure)	1
Post-operative complications[25]	12
Severe post-operative complications (≥grade 3)	3
Clinically relevant post-operative pancreatic fistula[26]	5
Grade B post-operative pancreatic fistula	5
Grade C post-operative pancreatic fistula	0
90-day or in-hospital mortality	0
Tumor type	
Ductal adenocarcinoma	14
Malignant mucinous intraductal papillary tumor	5
Neurondocrine carcinoma	1
Tumor diameter (mm)	34
Tumor margins (assessed at 1 mm)	
Negative (R0)	17
Examined lymph nodes	39

Standard deviation or percentage
± 88.6
15%
10%
5%
60%
15%
25%
25%
-
-
70%
25%
5%
± 13
85%
± 16.6

Name of Material/ Equipment	Company	Catalog Number
0 ethylene terephthalate sutures, straight needle	Ethicon	PE6624
0 linen ligatures	LORCA MARIN	63055
0 Polysorb sutures	Ethicon	CL-5-M
12mm port	Kii	CTB73
2/0 linen ligatures	LORCA MARIN	63254
2/0 Polysorb sutures	Ethicon	GL-323
3/0 linen ligatures	LORCA MARIN	63515
3/0 linen sutures	LORCA MARIN	63146
3/0 Polysorb sutures	Ethicon	GL-322
4 robotic 8mm ports	Intuitive Surgical	470359
4/0 e-PTFE sutures	GORE	4N04
4/0 SH polypropylene sutures	Ethicon	8521
4/0 SH1 polypropylene sutures	Ethicon	EH7585
5/0 C1 polypropylene sutures	Ethicon	8720
5/0 e-PTFE sutures	GORE	5N04
5/0 SH1 polypropylene sutures	Ethicon	PEE5692
6/0 e-PTFE sutures	GORE	6M12
6/0 polypropylene sutures	Ethicon	8706
Belt for legs	Eswell	249100
Bioabsorbable staple line reinforcement	GORE SEAMGUARD	12BSGTRI45P
Black diamond micro forceps	Intuitive Surgical	470033
Bracci ureteral catheter 8Fr	Coloplast	AC4108
Cadiere forceps	Intuitive Surgical	470049
da Vinci Xi Surgical System	Intuitive Surgical	
Endo GIA articulating reload with tri-staple technology 60mm	Covidien	EGIA60AMT
Endocatch II 15mm	Covidien	173049
Endoscope with 8mm camera 30°	Intuitive Surgical	470027
Harmonic shears	Intuitive Surgical	480275
Hug-u-vac	Allen Medical	A-60001
Ioban	3M	6650EZ
Kendall SCD sequential compression comfort sleeves	Cardinal Health	74012

Laparoscopic stapler (Signia power handle)	Covidien	SIGSBCHGR
Large needle driver (n=2)	Intuitive Surgical	470006
Maryland bipolar forceps	Intuitive Surgical	470172
Medium hem-o-lok clip applier	Intuitive Surgical	470327
Monopolar curved scissors	Intuitive Surgical	400180
Pig-tail drain 14Fr	Cook	ULT14.0-38-25-P-6S-CLM-RH
Potts scissors	Intuitive Surgical	470001
Set of laparoscopic bulldogs clamps	Aesculap	
Signia power shell for signia power handle	Covidien	SIGPSSHELL
Small hem-o-lok clip applier	Intuitive Surgical	470401
Veress needle	Aesculap	EJ995
Vessel loops	Omnia Drains	NVMR61

Comments/Description

Polyethylene terephthalate is a braided non absorbable suture. 0 refers to suture size.

Linen is a sterile, non-absorbable, spun surgical suture material made of flax fibers of linen. Linen gives excellent knot security. 0 refers to

Polysorb is a braided absorbable suture armed with a single needle. 0 refers to suture size.

Conventional laparoscopic port, used by the laparoscopic surgeon. The 12 mm size is required to accept a laparoscopic stapler, if required.

Linen is a sterile, non-absorbable, spun surgical suture material made of flax fibers of linen. Linen gives excellent knot security. 2/0 refers to s

Polysorb is a braided absorbable suture armed with a single needle. 2/0 refers to suture size.

Linen is a sterile, non-absorbable, spun surgical suture material made of flax fibers of linen. Linen gives excellent knot security. 3/0 refers to s

Linen is a sterile, non-absorbable, spun surgical suture material made of flax fibers of linen. Linen gives excellent knot security. Linen sutures

Polysorb is a braided absorbable suture armed with a single needle. 3/0 refers to suture size.

Robotic ports are the specific type of cannulas that are docked to the robotic system and are used to introduce robotic instruments in the hu

Expanded polytetrafluoroethylene (e-PTFE) is non absorbable, microporous, monofilament material typically used for vascular sutures. Othe

Nonabsorbable, monofilament (polypropylene), suture typically used for vascular sutures and/or to fix bleeding sites. 4/0 refers to suture size

Nonabsorbable, monofilament (polypropylene), suture typically used for vascular sutures and/or to fix bleeding sites. 4/0 refers to suture size

Nonabsorbable, monofilament (polypropylene), suture typically used for vascular sutures and/or to fix bleeding sites. 5/0 refers to suture size

Expanded polytetrafluoroethylene (e-PTFE) is non absorbable, microporous, monofilament material typically used for vascular sutures. Othe

Nonabsorbable, monofilament (polypropylene), suture typically used for vascular sutures and/or to fix bleeding sites. 5/0 refers to suture size

Expanded polytetrafluoroethylene (e-PTFE) is non absorbable, microporous, monofilament material typically used for vascular sutures. Othe

Nonabsorbable, monofilament (polypropylene), suture typically used for vascular sutures and/or to fix bleeding sites. 6/0 refers to suture size

This device is used to prevent pressure injuries during surgical procudures.

The reinforcement consists ofa synthetic buttressing material meant to distribute the jaw closure stress on a larger surface.

Small needle driver suitable for fine sutures.

A Bracci catheter is a straight rubber hose with 6 side holes located close to an open distal tip. It has also with a radiopaque line. Bracci cathe

The da Vinci Surgical System is a telemanipulator that increases surgical dexterity during minimally invasive procedures. The system consists o

Cartridge for stapler reload

Bag for specimen extraction.

The robotic endoscope is a vision system providing HD and steroscopic vision to the surgeon working form the console.

This device is used to safely anchor the patient to the operating bed

3M is an incise drap that adheres securely to the skin thus reducing the risk of drape lift. It also provides wound protection, when placed to co

This device provides sequential, gradient, circumferential compression (to the leg, foot or both simultaneously) to help prevent deep vein thr

Signia is a laparoscopic, robotized stapler suturing and dividing tissues between three rows of titanium staples applied on each suture side.

A pig drain catheter is a rubber hose used to drain fluids from deep spaces in the human body. As compared with other catheters, the pigtail
Non-electrified scissors used mainly to incise, or unroof, vessels.
This set consists of several bulldog clamps (of different shape and size) with dedicated laparoscopic instruments to be used to apply and remo
Sterile cover for Signia power handle

A Verres needle is a particular type of needle that is used to puncture the abdominal wall in order to create a pneumoperitoneum. It consists
Disposable silicon rubber stripes, typically used to tag relevant anatomical structures

uture size.

uture size.
are armed with a single needle. 3/0 refers to suture size.

ıman body.
r properties of e-PTFE inculde low-friction and comprexibility. 4/0 refers to suture size.
e. SH refers to the range fo curvature of the needle (26 mm)
e. SH1 refers to the range fo curvature of the needle 22 mm)
e. C1 refers to the range fo curvature of the needle (12 mm)
r properties of e-PTFE inculde low-friction and comprexibility. 5/0 refers to suture size.
e. SH1refers to the range fo curvature of the needle (22 mm)
r properties of e-PTFE inculde low-friction and comprexibility. 6/0 refers to suture size.
e. 6/0 polypropylene comes with just one needle size.

ters have been designed for use in urology but can be used also to flush vessels during laparoscopic procedures. 8 Fr refers to the size of the

of three components: a patient side cart, a console, and a vision cart.

over the entire lenght of the surgical incision.
ombosis and pulmonary embolism.

ends with a curl, similar to the tail of a pig, that is thought to facilitare the anchoring of the catheter. 14 Fr refers to the size of the catheter i

ove the clamps

of an outer cannula, with a sharp tip, and an inner stylet, with a dull tip. The inner stylet is spring-loaded in order to protect viscera at the tin catheter in French.

n French.

ne of needle insertion, that occurs blindly.

VIDEO

Q1: Please revise the title of the video to match that of the manuscript.

Authors Reply 1: Seemigly, the title of the manuscript matches that of the video (Robot-Assisted Radical Antegrade Modular Pancreatosplenectomy Including Resection and Reconstruction of the Spleno-Mesenteric Junction).

Q2: As currently written the video is difficult to follow along with the written protocol. Please increase the homogeneity as much as you can. For instance, adding protocol section titles in the video (as those in the written protocol) might be helpful to guide the viewers.

Authors Reply 2: Protocol section titles were added in the video as requested. Please note that:
Not all sections presented in the protocol can be shown in the video, as they refer to general and basic principles. Presenting all this amount of information in the video would require much more time. It is quite similar to the materials (i.e. robotic instruments and sutures) that were shown in the first version of the video and the Editor asked to remove this part from the video since it was already shown in the table of materials.

Q3: Please note that all information in the video should be in the written protocol. Is a video script available? If so, I may help cross check to include all details presented in the video in the manuscript.

Authors Reply 3: To the best of our knowledge we have provided in the video the same information that are presented in the protocol. Because of the flow of the procedure and the practical difficulties in matching images with audio, information may be presented in a slightly different way but we believe that the contents are the same. We have included the text of the audio of the video for your reference.
Please note that for all surgical procedures a standard technique exists but this standard technique has to be adapted to individual (patient specific) circumstances. What is key is that the description of the technique clearly presents the golden principles of the procedure and that the video demonstrates these steps. All surgeons know that these golden principles must be respected but also know that the flow of the procedure has to be adapted to match the needs of the individual patient. Surgery, after all, remains a bit more art than science. This is why the flow of the video can be slightly discordant with the scholastic description provided in the text, yet all the information and steps described in the manuscript are clearly shown in the video, so that surgeons can promptly recognize them.

TEXT

Q1: What is the specimen?

Authors Reply 1: A specimen is the part of tissue or organ that is removed during surgery. Specimen is standard terminology for surgical procedures so that every surgeon exactly understands what it means without additional explanations.

Q2: How? (Deflate the pneumoperitoneum)
Authors Reply 2: During laparoscopic (o robotic procedures) the pneumoperitoneum is deflated by opening valves on surgical ports or simply by removing the ports. Again, it is a standard surgical maneuver so that no explanation is required for surgeons reading the manuscript or watching the video. The video, indeed, does not aim at teaching or showing laparoscopy but rather to demonstrate a procedure performed laparoscopically (under robotic assistance).

Q3: How? With what? (Close all incisions)
Authors Reply 3: Again it is a standard maneuver. We do not really need to specify how to close a small incision to surgeons. Everyone can use different materials and all will achieve the same result. It really does not matter.

Q4: Can this be presented in a table?
Authors Reply 4: Yes, it can (see table 1)

1. This video shows a robot-assisted radical antegrade modular pancreatosplenectomy including resection and reconstruction of the spleno-mesenteric junction. The procedure was performed to remove a cancer located in the body of the pancreas.

2. The procedure shown in this video was conducted in compliance with the guidelines set out by the Ethics Committee of Pisa University Hospital for robotic operations, including regulations on research activity

3. The CT scan demonstrates a hypoenhacing pancreatic tumor, with upstream dilation of the main duct. The tumor is located in the proximal part of the body of the pancreas and appears to be strictly adherent to the splenic vein, in close proximity to the spleno-mesenteric junction.

4. After induction of general anesthesia, The patient is placed supine with the legs parted and is safely secured to the operating table. Intermittent pneumatic compression cuffs are placed around the legs for prophylaxis of deep vein thrombosis. Next, a pneumoperitoneum is established and maintained at approximately 10 mm Hg.

5. Four robotic ports and one laparoscopic port are required. The laparoscopic port has to be 12 mm in size, and is used by the assistant at the table. One of the robotic ports is used for the endoscope while the three remaining ports are used for the robotic instruments.

6. The optic port is placed at the umbilicus. The endoscope is introduced and the abdomen is explored searching for occult tumor desposits.

7. Thereafter, the other ports are placed, on either sides, along the transverse umbilical line at the level of the pararectal line and the anterior axillary line. The assistant port is placed along the right pararectal line.

8. Before docking the robotic system the patient is placed in reversed Trendelenburgh position and the table is tilted to the right side. After reaching the desired position, the laser light originating from the overhead boom is pointed to the site of the optic port. Next, the appropriate arm is docked to the optic port and the endoscope is introduced.

9. The scope is oriented towards the surgical site to permit the targeting process that is triggered by pressing the dedicated button on the camera head. Targeting automatically adjusts height, translation, and rotation of the overhead boom to maximize the range of motion of the robotic arms. The remaining arms are docked and the robotic instruments are inserted under vision.

10. The procedure begins by detaching the omentum from the colon without division of the gastro-colic ligament. Dissection starts midway along the transverse mesocolon and extends to the right until the hepatic flexure of the colon is reached, and to the left until the splenic flexure of the colon is fully mobilized.

11. Once the lesser sac is fully open, the pancreatic body and tail become clearly visibile. Dissection begings with mobilization of the inferior margin of the pancreas. Early identification of the superior mesenteric vein provides a key landmark to proceed safely with further dissections.

12. In preparation for the creation of a tunnel behind the pancreatic neck, the common hepatic artery and the portal vein above the pancreatic neck must be clearly identified. Lymph node number 8A is resected to bring the common hepatic artery in clear

view. Lymphatic vessels are sealed by either hem-o-look clips or ligatures. Once the course of the common hepatic artery is clearly defined, dissection of lympatic tissue laying between the artery and the superior margin of the pancreatic neck brings the portal vein in clear view. The common hepatic artery is looped to increase visibility and facilitate handling of the vessels during the procedure.

13. Dissection around major arteries is prefentially carried out using cold scissors, as the use of energy devices at this level may result in termal injury to the vessel walls, thus potentially increasing the risk of delayed bleeding. Proceeding along the periadvential plane, and from bottom to up, the celiac trunk is naked from surrounding tissues.

14. Following identification of the celiac trunk, dissection proceeds along the origin of the splenic artery. During this stage the dorsal pancreatic artery was injured. The bleeding site was fixed with a 5/0 polypropylene suture. Ligature and division of the dorsal pancreatic artery would have been required anyway as this manoeuvre improves exposure of the origin of the splenic artery and offers more room for safe ligature of this large artery.

15. With the splenic artery in clear view, the vessel can now be safely ligated and divided. Two ligatures are applied proximally and the vessel is eventually divided between two hem-o-lok clips. Whenever possible, division of the splenic artery should occur before division of the splenic vein, as this manoeuvre prevents the occurrence of sinistral portal hypertension, thus reducing blood pooling in the spleen and the amount of backwards bleeding.

16. A tunnel behind the neck of the pancreas is developed at this stage. However, as supected at preoperative imaging, the tumor was stricly adherent to the spleno-mesenteric junction making it preferable to further mobilize the specimen in order to achieve wider control of all vascular pedicles, before proceeding with vein resection and reconstruction.

17. The main trunk of the superior mesenteric artery is hence identified to the left side of the superior mesenteric vein. The inferior mesenteric vein is also identified and spared to be used as a vascular patch at the time of vein reconstruction. During perivascular dissections, large lymphatics are clipped to reduce the aumount of lymphatic leak.

18. Dissection now proceeds medial to later in a posterior plane to remove en-bloc with the specimen a large amount of retroperitoneal soft tissue. The left adrenal gland is identified during this stage. Further to the left, the Gerota fascia covering the upper pole of the left kidney is removed en-bloc with the specimen, thus naking the anterior surface of the upper renal pole. The left renal vein and the left adrenal vein are also clearly identified.

19. The inferior mesenteric vein is divided between clips. A segment of the vein is spared for vascular reconstruction. The splenic vein is dissected free proximal to the site of tumor adherence to achieve upstream vascular control.

20. Before dividing the neck of the pancreas a transfix suture is placed at the inferior margin of the gland to occlude the transverse pancreatic atery. Division of the pancreas is often performed using an endoscopic stapler but in this patients, because of the limited space available, the gland was divided using harmonic shears. The pancreatic duct was identified, dissected off and selectively ligated. After completion of transection, the pancreatic neck was closed with interrupted sutures of 4/0 e-PTFE. When possible the neck margin is immediately sent for frozen section histology. In this patient,

because of the proximity of the tumor to the neck of the pancreas the transection margin was assessed after removal of the specimen.

21. To proceed with vein resection, vascular pedicles are cross-clamped. First, the splenic vein is clipped upstream to the site of tumor involvement. Second, the superior mesenteric artery is cross-clamped, to reduce intestinal congestion during venous occlusion. Third, the superior mesenteric vein and the portal vein are cross-clamped. A side-wall resection of the portal-mesenteric junction is carried out. The inferior mesenteric vein is harvested. An e-PTFE suture is placed between the inferior mesenteric vein graft and the upper corner of the vein defect. The graft is incised longitudinally to be used as a vascular patch. A stay suture is placed on the right margin of the vein defect, to improve exposure. Two half running sutures are used. Before releasing the clamps, the vein is flushed with saline solution containing sodium heparin.

22. Dissection now proceeds along the periadvential plane of the superior mesenteric artery in a cephalad direction. Because of the central location of this tumor also the right side of the superior mesenteric artery is skeletonized with removal of the right celiac ganglion.

23. Once the aortic plane is reached, the same dissection is performed on the left side. Also the left celiac ganglion is removed en-bloc with the specimen. When using harmonic shears attention is paid that active blade is opposite to the artery. When finer dissection is required, the use of cold scissors is preferred.

24. Dissection is now completed along the posterior surface and the upper margin of the pancreas. The spleen is also mobilized.

25. At the end the superior mesenteric vein, the superior mesenteric artery, the left adrenal vein, and the left renal vain are clearly visible.

26. Before completing the procedure, the round ligament is mobilized and is placed to protect the naked retroperitoneal vessels.

27. The specimen is now placed in an endoscopic bag and retrieved through a suprapubic transverse incision.

28. The procedure was completed in 635 minutes, with an estimated blood loss was 150 mL and no need for blood transfusions.

29. Final pathology demonstrated a G2 ductal adenocarcinoma of the pancreas, with perineural invasion and involvement of the spleno-mesenteric junction.
All the 56 resected lymph nodes were negative.
Circumferential tumor margins, were also negative.
Pathology stage of this tumor was T3 N0 R0.

30. At the longest follow-up of 30 months, the patient is alive, well, and disease-free.

31. In this video we have shown the feasibility of robot-assisted radical antegrade modular pancreatosplenectomy. En-bloc resection and reconstruction of the spleno-mesenteric junction was also shown.

32. Robotic assistance permits to perform oncologically correct dissections in the same planes followed during the open procedure.

33. We wish to underscore that the enhanced dexterity offered by robotic assistance cannot surrogate surgical competence.

We also believe that advanced laparoscopic skills are required to fully exploit the potential of robotic assistance in complex pancreatic resections.

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Author(s):	Niccolò Napoli1, Emanuele F Kauffmann1, Francesca Menonna1, Sara Iacopi1, Concetta Cacace1, Ugo Boggi1

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