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Definitive management of giant duodenal (D1 – D2) perforations in Acute Care and Trauma Surgery, made simple: "Pancreas-sparing & ampulla-preserving duodenectomy".

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Background:

Ideal surgical treatment for acute duodenal injuries should guarantee a definitive treatment, with reasonably low morbidity and mortality, but also simple and easily reproducible by acute care surgeons in emergency setting. Duodenal injury due to major perforated or bleeding peptic ulcers or iatrogenic/traumatic perforation, represents a surgical challenge, with high morbidity and mortality. Our aim was to review management of these injuries and assess the outcomes of a definitive surgery with a pancreas-sparing ampulla-preserving duodenectomy.

Methods:

Pancreas-sparing ampulla-preserving D1-D2 duodenectomy was used for patients presenting with major duodenal injuries over a 5-years interval (March 2012-November 2017) The ampulla was identified and preserved by using a transcystic/transpapillary tube. The outcomes were recorded.

Results:

Ten patients were treated with this technique: seven with perforated or bleeding peptic ulcers, two iatrogenic perforations and one with blunt abdominal trauma. Mean age was 78 years (range 65-84). Four patients were haemodynamically unstable. The location of the duodenal injuries was always D1 and/or D2, above or in close proximity to the ampulla of Vater. The surgical approach was open in nine patients and laparoscopic in one. The mean duration of surgery was 264 min (range 170-377'), all patients were post-operatively transferred to ICU (mean ICU stay 4.4 days, range 1-11), and overall mean hospital stay was 17.8 days (range 10-32). Six patients developed major postoperative complications: cardiorespiratory failure in 5 patients, gastrointestinal complications in another 4. Surgical re-operation was needed in one patient for postoperative necrotizing and bleeding pancreatitis. No leaks from duodenal stump, gastro-jejunal anastomosis or bile duct strictures were observed. 30-days mortality rate was 20%.

Conclusions:

Pancreas-sparing ampulla-preserving D1–D2 duodenectomy for emergency treatment of 'major' duodenal perforations is feasible and associated with satisfactory outcomes.

Definitive surgical management of major duodenal (D1 – D2) perforations.

Comment [DSSI]: Just a question for you, whatever you prefer: should we keep just this part of the title describing the technique and what are its characteristics?
So should we make the title be ?
Definitive surgical management of major duodenal (D1 – D2) perforations:
“Pancreas-sparing & ampulla-preserving duodenectomy”

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The technique described in here, has been partially shown within a Video Case accepted by the the Committee on Video-based Education for presentation at the American College of Surgeons Clinical Congress 2017, during the Session: VE22 General Surgery III - Foregut, held on October 25, 2017

KEYWORDS:

Authors' Contribution:

SDS, ES, conception and design, SDS thought about and developed the novel technique, SDS is the operating Attending Surgeon in the video and for all the 9 patients, ST has manually drawn the figures, SDS, ES, AB, ST, GT, VT, AR, MP drafting the article or revising it critically for important intellectual content; SDS, ES, AB, ST, GT, VT, AR, MP final approval of the version to be published.

TWEET: The difficult duodenum, KEEP IT SIMPLE! How to do a “Pancreas-sparing & ampulla-preserving duodenectomy @BJS @salo75

INTRODUCTION AND BACKGROUND

Urgent surgery for duodenal perforation is a major challenge for surgeons. This is due to the intrinsic difficulty of repairing large duodenal perforations with major loss of tissue by simple surgical measures (e.g. primary repair, omental patch). Alternatively, diverting/excluding procedures (pyloric exclusion, proximal gastric disconnection, serosal or jejunal patch etc) often result in poor outcomes and high rates of persistent duodenal fistula¹. The disappointing results achieved by conservative and simple surgical strategies can be overcome by definitive, major resection such as pancreaticoduodenectomy, however, this requires advanced hepato-biliary expertise and carries risks associated with technical complexity. Arguably the most definitive outcome would be achieved by formal duodenal resection, including the large perforation and area of duodenum. This type of duodenectomy could be quick and technically straightforward, and easily reproducible by surgeons of varying skill levels. The pancreas the ampulla of Vater and common bile duct should be preserved, thus avoiding the morbidity and mortality associated with emergency Whipple's procedure. There are a number of causes of major duodenal perforation including perforated peptic ulcer or bleeding duodenal ulcer², traumatic perforation (blunt or penetrating), and iatrogenic/endoscopic perforations (SDC1–SDC2). Also duodenal leak after initial conservative management or of primary repair can be a cause. The size of a perforation is the most relevant prognostic factor influencing the choice of surgical treatment, but there is controversy in what constitutes major or giant duodenal perforation. The traditional definition of giant duodenal ulcer is size greater than 2 cm^{3 4}; these are associated with much higher morbidity and mortality⁵. Gupta et al proposed that duodenal perforation can be classified into three main groups (1) small perforation (less than 1 cm in size); (2) large perforation (between 1 cm and 3 cm); (3) giant perforation (exceeding 3 cm in size)⁶. Aim of this study is to review the current management of the major duodenal injuries and to identify which major duodenal injuries are not safely manageable by primary repair alone and/or other non-resectional surgical strategies, requiring a definitive resection of the diseased duodenum and therefore classify the indications for a duodenectomy (Tab 1-SDC). Further aim is to describe in an educational step-by-step fashion a safe and reproducible technique for performing a D1-D2 pancreas-sparing and ampulla-preserving duodenectomy (Video 1); Fig. 1 illustrates what type of "major" duodenal perforation is the ideal candidate for such definitive D1-D2 duodenectomy and analyse the clinical outcomes in our series of patients treated with this technique.

METHODS

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6 Ten patients (7 M/3 F) were treated by a single Consultant surgeon over a 5 year interval, between March
7 2012 and November 2017 (Tab. 2-SDC). The mean age of the patients was 78 years (range 65-84).
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9 Preoperative haemodynamic shock was present in four patients and ASA scores ranged from III-E to V-E.
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11 Seven patients had perforated or bleeding peptic ulcers, two had iatrogenic perforations (one post lap chole
12 and the other after endoscopic duodenal stent insertion), and one patient had blunt abdominal trauma. The
13 location of the injuries was always D1 and/or D2, above or close to the ampulla of Vater on the anti-
14 mesenteric border.
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18 SURGICAL TECHNIQUE (Video 2): The procedure can be performed either open or laparoscopically,
19 depending on the patients hemodynamic status⁷, aetiology and location of the perforation, skills and
20 experience of the operating surgeon. Initial assessment includes identification and localization of the exact
21 site of the duodenal injury. In the case of bleeding duodenal ulcer, duodenotomy may be required for
22 locating the exact site of the ulcer and assessing if the bleeding can be effectively controlled with a simple
23 overrun or if definitive management and a duodenal resection are needed. In case of giant perforated ulcers
24 or iatrogenic perforations, especially if the lesion is posterior or retroperitoneal, identification and
25 localization may be difficult and opening the retroperitoneum for evacuation of large periduodenal
26 collections may be necessary. This manoeuvre can be challenging and potentially dangerous since the planes
27 of dissection are adherent to the extraluminal collection, increasing the risks of duodenal tears or of enlarging
28 the defect. Incision of the peritoneal reflection and entering the collection with careful blunt dissection and
29 medial mobilization of the entire C-shaped duodenum, is the key (Step 1a- 1b). Second step is performing
30 the cholecystectomy and identifying the cystic duct by cannulation with a trans-cystic drain (Step 2). The
31 trans-cystic tube is pushed into the CBD, progressed through the papilla into the duodenal lumen to identify
32 precisely the location of the ampulla and its anatomical correlation to the site of the duodenal perforation.
33 This allows a thorough assessment of the feasibility of a proximal duodenectomy with preservation of the
34 ampulla. The transcystic tube is then retrieved allowing to precisely assess whether the staple line on the
35 supra-ampullary duodenum is falling on healthy tissues and if the whole perforation and devitalised margins
36 are entirely comprised within the resected duodenal tract. After carefully locating the ampulla, the next step
37 is to disconnect the gastric antrum and pylorus from the gastric body. The duodenal resection should start
38 proximal to the pylorus, where less inflamed. Gastrocolic ligament is opened. The lesser sac is entered and
39 the posterior wall of the gastric antrum is mobilized. This step continues with division of the lesser omentum.
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6 Pyloric vessels are ligated, the antrum and pylorus are mobilized and gastric distal resection can be
7 performed with a linear stapler (Step 3). Disconnecting the gastric antrum allows one to flip over the
8 specimen and permits easier dissection of the posterior aspect of the antrum and D1 from the head of the
9 pancreas. The next step is proceeding downwards with dissection of the first part of the duodenum and the
10 superior duodenal flexure from the head of the pancreas (Step 4). This step is facilitated by having already
11 disconnected the antrum, which can be flipped over to stay on a correct dissecting plane between the duodenal
12 wall and pancreatic parenchyma. The small vessels connecting the medial duodenal wall to the head of the
13 pancreas can be safely controlled with bipolar forceps, haemoclips or fine ties. Following this plane, the
14 pancreatic head can be spared and preserved, whilst the duodenum is detached. The division of the second
15 part of duodenum from pancreatic head is continued downwards, below the superior duodenal flexure,
16 staying on a plane between the duodenal wall and the upper and lateral border of pancreatic head, until
17 reaching the level of insertion of the ampulla onto the medial side of duodenum (Step 5). The trans-cystic
18 tube is left trans-papillary, to mark for a safe, ampulla-preserving, resection. This also helps avoid iatrogenic
19 injury to the ampulla and/or CBD and avoid accidental detachment of the ampulla from the medial wall of
20 the duodenum during separation of the supra-ampullary duodenum from the pancreatic head. The next step is
21 to place an articulating stapler tangentially across healthy margins of the mid-duodenum, just above the
22 ampulla. Use of a flexible endo-stapler makes this step easier, because endostaplers can be articulated and
23 angled to reach a sharp oblique orientation (Step 6). In fact, the perforation site is usually located on the
24 lateral side of the duodenal wall. Such oblique stapling can achieve a nearly-total resection of D2 with
25 complete closure and full stapling of the remaining distal duodenum, over healthy margins and, at the same
26 time, avoid injuries to the orifice of the ampulla within the lumen of the medial duodenal wall (SDC3). We
27 recommend that the trans-cystic tube is retracted back into the CBD, before stapling across the duodenum, to
28 prevent its entrapment (Step 7). After stapling and completion of the D1-D2 resection, a good tight seal of
29 the entire duodenal staple line can be verified with a leak test using methylene blue injected from trans-cystic
30 or T-Tube drain (SDC4). Trans-cystic drain is then left at the level of distal CBD for the purpose of external
31 bile diversion. In selected cases, biliary external diversion can be achieved more effectively by a T-tube in
32 the CBD. Finally, GI continuity is restored by a Roux-en-Y gastrojejunostomy (Step 8). Postoperative
33 imaging of the remaining duodenum can be obtained via trans-cystic cholangiogram or CT cholangiography
34 to rule out leaks from the duodenal stapled stump and/or the patency of the CBD and ampulla (SDC5).

RESULTS

Nine patients underwent open surgery, either via midline laparotomy or rooftop incision; one who was haemodynamically stable was treated laparoscopically. In all patients, a D1 or a D1 + D2 duodenectomy was performed. Cholecystectomy and transcystic T-tube insertion for identification of the location of the ampulla and for postoperative biliary external diversion was used in all patients except the laparoscopic one. GI tract continuity was restored by Roux-en-Y reconstruction in 8 cases. Major associated surgical procedures were spleno-pancreasectomy of the body-tail in one case due to 10 cm neuroendocrine gastrin-secreting carcinoma of the pancreatic body. Median operative time was 241 minutes (mean 264 min, range 170-377). N-J tube for postoperative enteral feeding was added in 6 cases. Mean postoperative ICU stay was 4.4 days (median 3.5 days, range 1-11). Overall mean duration of postoperative hospital stay was 17.8 days (median 16.5 days, range 10-32). Postoperative morbidity was common and occurred in nine patients; six major, three minor. Complications included cardiorespiratory (major in 2, minor in 3) which required critical care. Four patients developed gastrointestinal complications including a bleeding from the gastrojejunal anastomosis managed by endoscopic haemostasis; a postoperative necrotizing and bleeding pancreatitis requiring multiple re-laparotomies; a peripancreatic stump collection managed by percutaneous CT-guided drainage and finally a biliary leak around the T-tube insertion in a patient who had surgery for iatrogenic perforation after endoscopic placement of a palliative biliary-duodenal stent (SDC1-2-3). There were no leaks from the peri-ampullary stapled duodenal stump or strictures of the common bile duct. Two patients died, one for severe necrotizing pancreatitis and the other for cardiorespiratory failure (30-days mortality 20%). Final histology of the duodenal resected specimen was in all cases free of malignancy.

DISCUSSION

Major perforated and/or bleeding duodenal ulcers as well as duodenal traumatic injuries are not common, and their management can be technically demanding. Postoperative morbidity and mortality rates are extremely high, especially when a postoperative leak occurs after initial attempt of primary repair. Choosing rapid and easily reproducible techniques such as simple closure with omental patch (Cellan Jones or Graham) or a derivative antrectomy with reconstruction but without definitive resection of the affected tract of the duodenum, often have disappointing outcomes in patients having major duodenal ulcer perforation and poor preoperative general conditions. Re-operation for gastric disconnection due to postoperative leakage and bleeding has been often reported in such cases¹. Despite its high morbidity and consequences on quality of

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6 life, gastric disconnection was recommended with the aim of bailing out definitive surgery and deferring
7 restoration of GI continuity to a later stage⁸. Lal in 2009 reported a 70% rate of postoperative leakage after
8 primary repair of 20 cases with perforation >2cm, with 8 patients (40%) requiring re-exploration and more
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life, gastric disconnection was recommended with the aim of bailing out definitive surgery and deferring restoration of GI continuity to a later stage⁸. Lal in 2009 reported a 70% rate of postoperative leakage after primary repair of 20 cases with perforation >2cm, with 8 patients (40%) requiring re-exploration and more invasive delayed procedures such as duodenal exclusion, partial gastrectomy, jejunal serosal patch or jejunal pedicled graft, free omental plug, gastric disconnection and triple tube ostomy⁵. The intrinsic problem with all these strategies is that the diseased duodenum is not addressed by definitive surgical treatment in a timely fashion. Ultimately, this delay in obtaining a definitive source control by duodenal resection resulted in high mortality rates, reaching 65% in the group of patients with large and giant perforation who underwent initial primary closure with Cellan-Jones or Graham omental patch. Other authors reported a lower postoperative mortality rate with simple closure and vagotomy than with simple closure alone (12.5% vs 26.7%) and lower recurrence rate (38.1% vs 63.6%)⁹. Nonetheless five years postoperatively, the cumulative recurrence rate after simple closure (41.2%) was significantly higher than that after resection (15.9%) and the authors recommend gastric resection. The choice of procedure must be tailored to the nature of the defect, the amount of tissue lost and amount of peritoneal contamination¹⁰. Risk and consequences of a leak are exacerbated by the high intraluminal pressures, extrusion of duodenal mucosa through the closure and autodigestion by pancreatic enzymes and bile. Therefore, an adjunctive external biliary diversion should be strongly considered. There is increasing agreement that when facing a “giant” perforated ulcer (>2 cm), both the Graham patch and primary closure of the ulcer are less successful and a more definitive operation (eg, vagotomy with pyloroplasty or partial gastrectomy) is usually recommended¹¹. Particularly challenging cases may occur especially when a retroperitoneal abscess is found, as these are associated with posterior perforation of a duodenal ulcer. In such cases kocherization of the duodenum, visualization of the ulcer and primary repair of the ulcer can be difficult to achieve. Therefore, partial duodenectomy with a duodeno-jejunal anastomosis was described with successful outcome¹². Some authors have attempted a pancreas-sparing complete duodenectomy but detachment and re-implantation of the duodenal ampulla represents a significant technical challenge, resulting in higher postoperative leakage and complication rates¹³. A pancreas-sparing partial or subtotal/total duodenectomy with translocation of ampulla and distal CDB has been described for certain types of benign duodenal tumors¹⁴, premalignant or early malignant duodenal lesions¹⁵ or infra-ampullary lesions including selected malignancies^{16 17}. Elective pancreas-sparing duodenectomy has also been described as an emergency procedure for duodenal trauma, major bleeding

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6 peptic ulcers or duodenal diffuse ischemia with 20% mortality and no GI-related postoperative complications.
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8 Paluszkiwicz et al. reported five cases with complex and extensive duodenal injuries¹⁸. Two patients
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10 required resection of the entire duodenum (D1 to D4) while three had the distal duodenum (D2 to D4)
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12 resected. The reconstruction described here is technically challenging and time-consuming, requiring an
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14 anastomosis between isolated ampulla or surrounding mucosal patch to the side of a jejunal loop, leading to
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16 increased risk of leakage, pancreatitis and pancreatic fistula. For duodenal trauma, Ivatury suggested that
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18 most duodenal penetrating injuries may be treated effectively by primary repair¹⁹. Pyloric exclusion has been
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20 advocated for complex traumatic injuries, but associated with longer hospital stay and ultimately no survival
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22 or outcome benefits compared to primary repair only²⁰. Complex duodenal injuries, those diagnosed and
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24 treated late, and those associated with major destruction of adjacent structures require careful consideration
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26 of the physiologic stability of the patient, severity of injury, extent of local inflammation and experience of
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28 the surgeon²¹. Recent studies suggested that a decrease in the use of damage control laparotomy in trauma is
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30 associated with decreased use of resources, without increasing morbidity and mortality²². The present
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32 technique may represent an easily reproducible surgical strategy for definitive management of moderate-
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34 severe grade duodenal traumatic injuries, which cannot be satisfactorily managed with simple repair or
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36 exclusion/derivative techniques and not necessarily requiring an emergent trauma-Whipple's. This technique
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38 also has the advantage of being easily reproducible by most surgeons, although tube duodenostomy and
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40 damage control might be safer in small centers and in absence of hepatobiliary expertise.
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12 **Videos available as Supplementay ONLINE only material**

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14 Video #1: Massive digestive haemorrhage due to bleeding duodenal ulcer treated with a duodenectomy
15 <https://www.youtube.com/watch?v=ymtVTg7pP6w&feature=youtu.be>

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17 Video #2: Duodenectomy – Surgical technique described Step by Step
18 <https://www.youtube.com/watch?v=juWr70ruyjU&feature=youtu.be>

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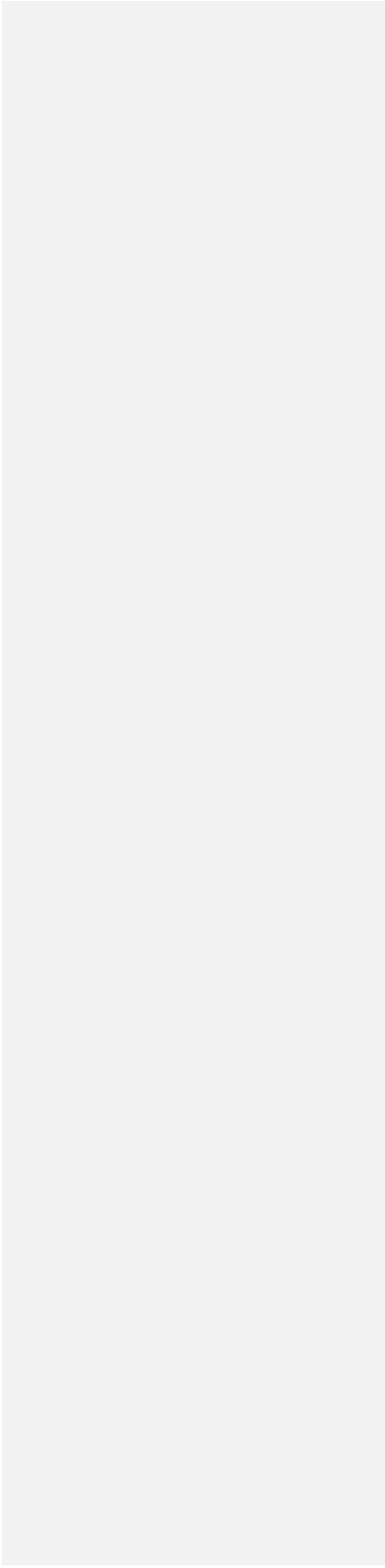
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TABLES available as Supplementary ONLINE only material

Table 1: (ONLINE ONLY SUPPLEMENTARY MATERIAL)
Practical indications for a "Pancreas-sparing ampulla preserving duodenal resection"

TABLE 2: (ONLINE ONLY SUPPLEMENTARY MATERIAL)
Patients data and clinical outcomes

FOR REVIEW ONLY

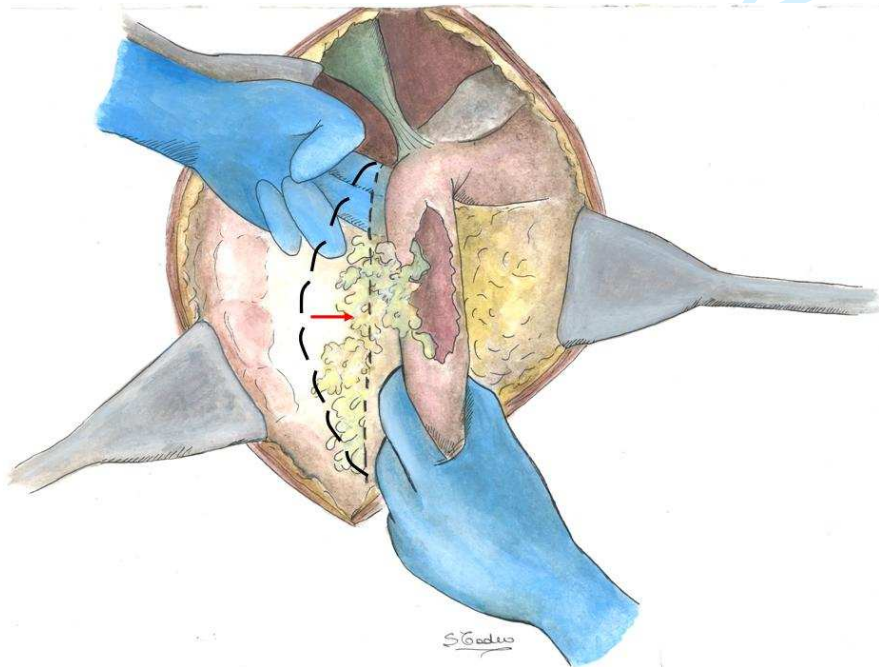
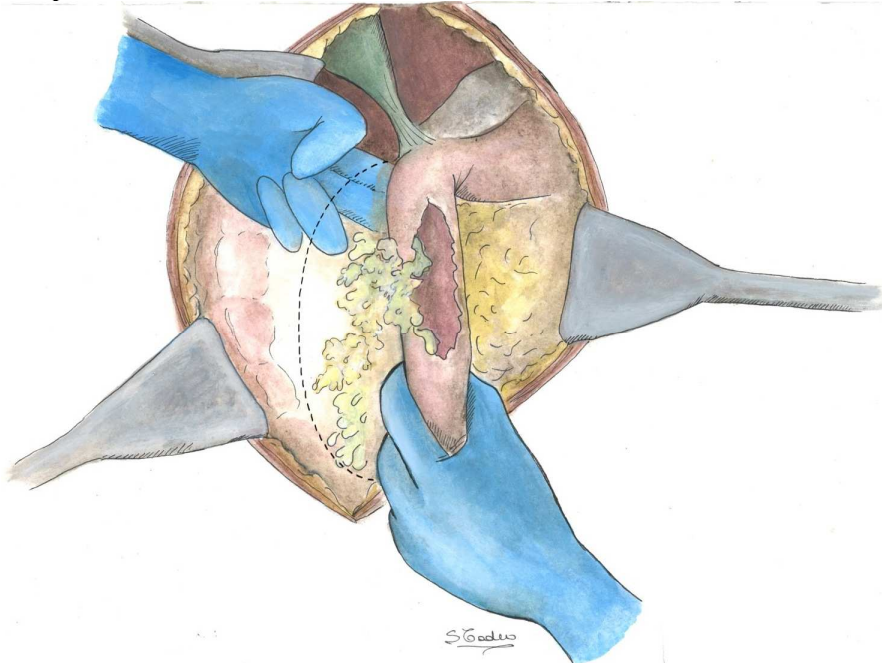


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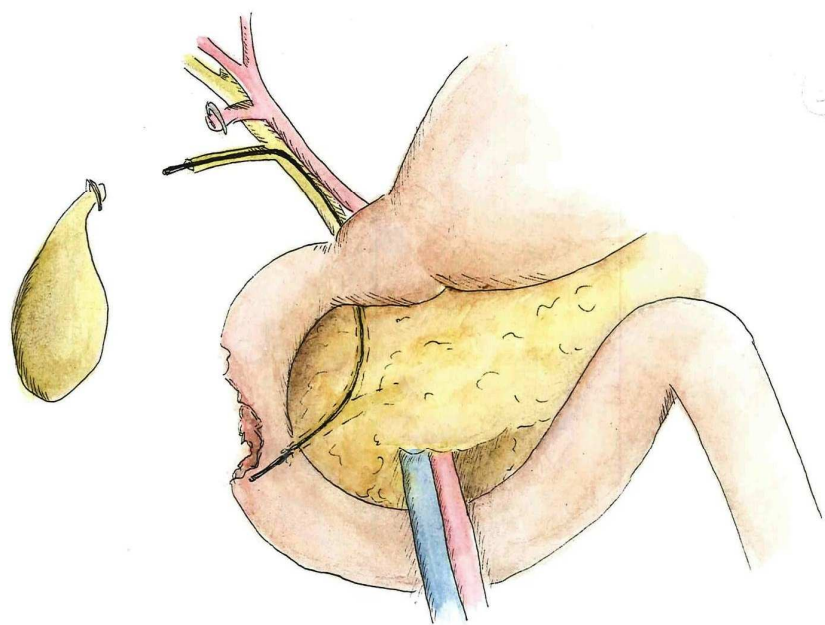
LEGENDS OF THE 6 FIGURES SELECTED FOR PRINTED VERSION:

Fig. 2: *STEP 1a-1b* - Kocher manoeuvre with medial mobilization of the duodenum, evacuation of retroperitoneal collection and full visualization of the of the location and extension of the lesion



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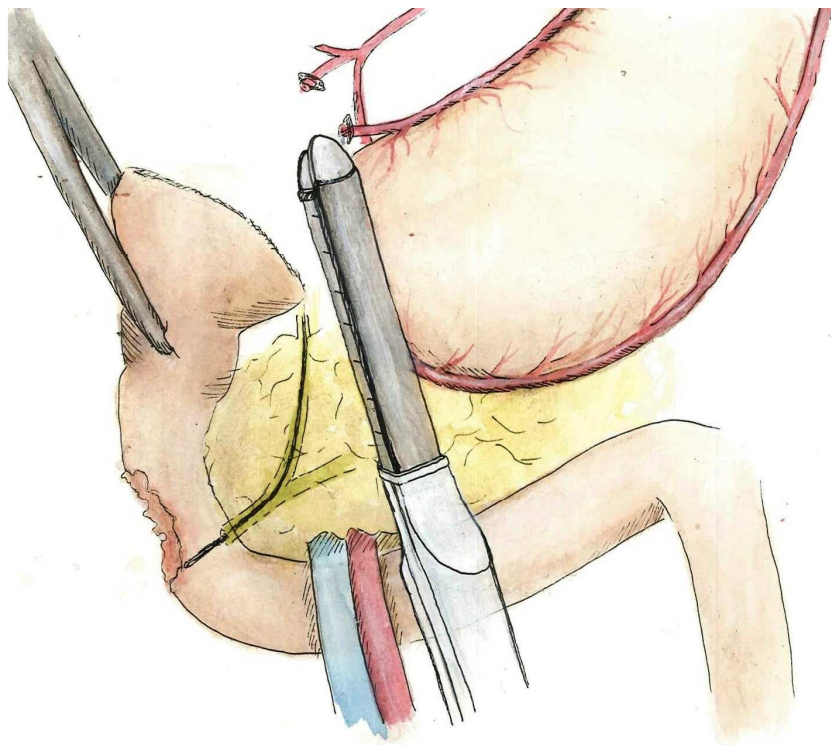
Fig. 3: STEP 2 – Cholecystectomy and insertion of a transcystic tube in the CBD, pushed further until its exit transpapillary in order to identify and precisely locate the ampulla



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Fig. 4: STEP 3 – Division of the gastric antrum and gastric distal resection



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Fig. 6: STEP 5 - Division of the second part of the duodenum from the pancreatic head continued downwards, using bipolar forceps and selective vessel ligation, on a plane between the duodenal wall and upper and lateral borders of pancreatic head, until reaching the level of the insertion of the CBD and the ampulla on to the medial side of the duodenal wall

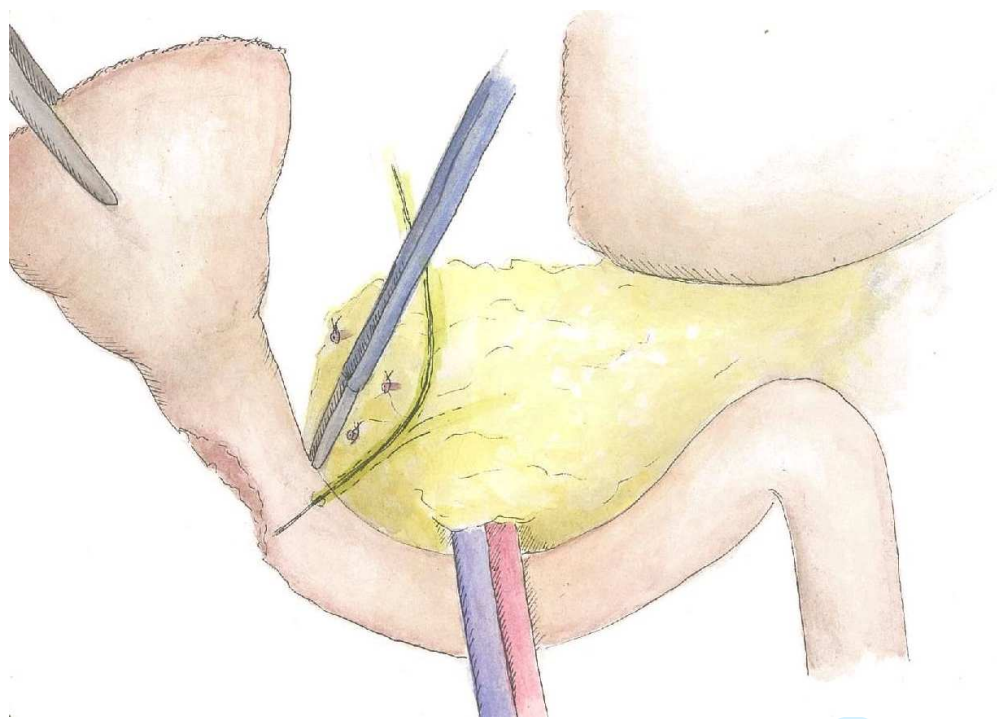
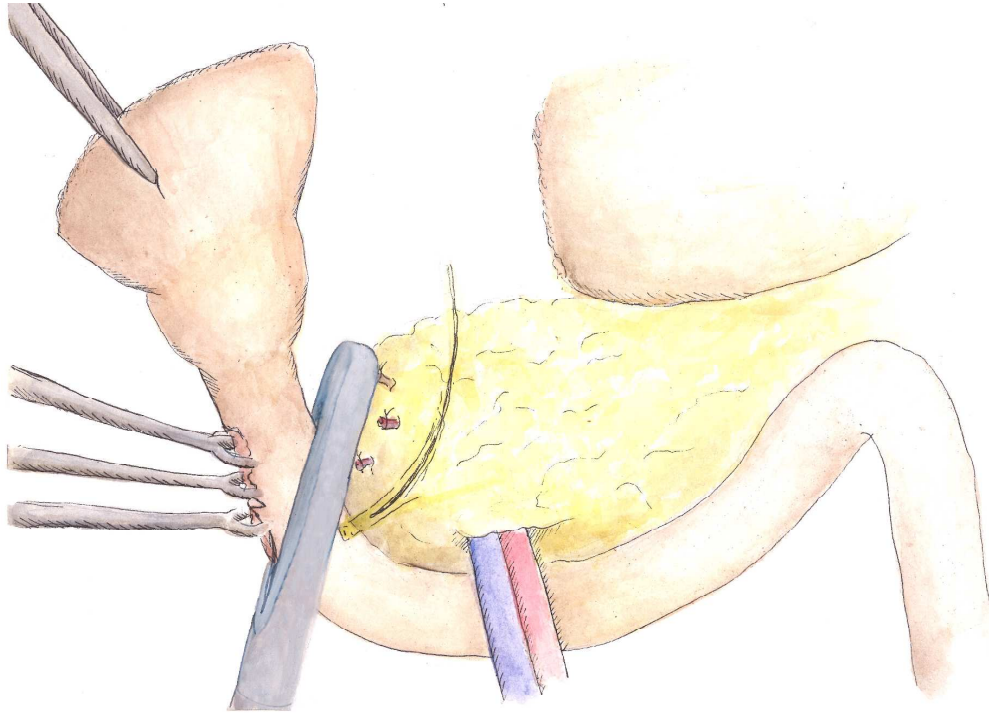


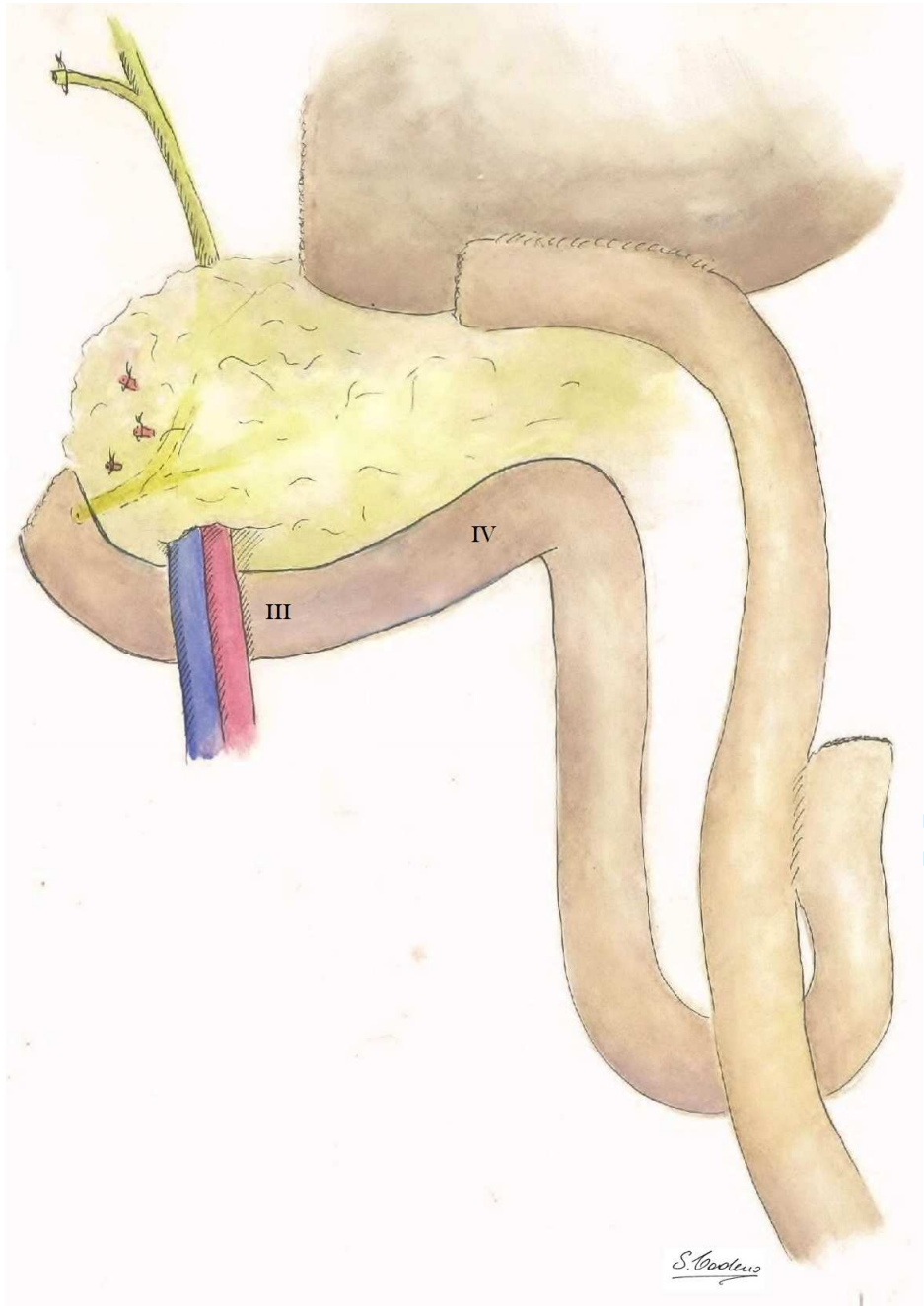
Fig. 7: STEP 6 – Placement of an articulating flexible endostapler tangentially across healthy margins of the mid-duodenum, just above the ampulla, and complete the resection of D1 and proximal D2



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Fig. 9: STEP 8 - GI continuity is finally restored by performing a Roux-en-J gastrojejunostomy. Ampulla is preserved and the normal flow of bile and pancreatic juices into D3 and D4 is preserved



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3 **Figures and Table list and Captions (in bold the Tables and Pics to stay for the printed**
4 **version, all other figs and pics will be for [ONLINE ONLY SUPPLEMENTARY](#)**
5 **[MATERIAL](#)**);
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9 **Table 1: Practical indications for a “Pancreas-sparing ampulla preserving duodenal**
10 **resection”**
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15 *TABLE 2: Patients data and outcomes ([ONLINE ONLY SUPPLEMENTARY MATERIAL](#))*
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18
19 *Fig. 1 ([ONLINE ONLY SUPPLEMENTARY MATERIAL](#)): Location of a typical giant*
20 *duodenal perforation (either PPU or Trauma) best candidate for such pancreas-sparing*
21 *ampulla-preserving D1-D2 duodenectomy*
22

23
24 **Fig. 2: STEP 1a-1b - Kocher manoeuvre with medial mobilization of the duodenum,**
25 **evacuation of retroperitoneal collection and full visualization of the of the location and**
26 **extension of the lesion**
27

28
29 **Fig. 3: STEP 2 – Cholecystectomy and insertion of a transcystic tube in the CBD,**
30 **pushed further until its exit transpapillary in order to identify and precisely locate the**
31 **ampulla**
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34 **Fig. 4: STEP 3 – Division of the gastric antrum and gastric distal resection**
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38 *Fig. 5 ([ONLINE ONLY SUPPLEMENTARY MATERIAL](#)): STEP 4 - Dissection of the first*
39 *part of the duodenum and of the superior duodenal flexure from the head of the pancreas on*
40 *the plane between the duodenum and the pancreatic gland*
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42
43 **Fig. 6: STEP 5 - Division of the second part of the duodenum from the pancreatic head**
44 **continued downwards, using bipolar forceps and selective vessel ligation, on a plane**
45 **between the duodenal wall and upper and lateral borders of pancreatic head, until**
46 **reaching the level of the insertion of the CBD and the ampulla on to the medial side of**
47 **the duodenal wall**
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49
50 **Fig. 7: STEP 6 – Placement of an articulating flexible endostapler tangentially across**
51 **healthy margins of the mid-duodenum, just above the ampulla, and complete the**
52 **resection of D1 and proximal D2**
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3 *Fig. 8 (ONLINE ONLY SUPPLEMENTARY MATERIAL): STEP 7 – Completed*
4 *duodenectomy. Be careful to retract the transcystic tube back into the CBD, before stapling*
5 *across the duodenum. Methylene blue test can be accomplished to verify the tight seal and*
6 *complete closure of the duodenal stump*
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9 **Fig. 9: STEP 8 - GI continuity is finally restored by performing a Roux-en-J**
10 **gastrojejunostomy. Ampulla is preserved and the normal flow of bile and pancreatic**
11 **juices into D3 and D4 is preserved.**
12

13
14 *Fig. SDC1 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
15 *Large duodenal iatrogenic endoscopic perforation*
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18 *Fig. SDC2 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
19 *Large duodenal iatrogenic endoscopic perforation*
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21 *Fig. SDC3 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
22 *Final view of the operative field after completed resection of D1-D2 with pancreatic head*
23 *sparing*
24

25 *Fig. SDC4 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
26 *Tight seal of the entire duodenal staple line can be verified with a leak test using methylene*
27 *blue injected from the transcystic or T-Tube drain*
28

29 *Figure SDC5 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
30 *Intraoperative or postoperative Imaging can rule out leaks from the duodenal stump and*
31 *evaluate the good seal of the staple line and the patency of both the CBD and ampulla*
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34 *Figure SDC6 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
35 *Intraoperative findings of a Giant D1-D2 circumferential perforation of a duodenal ulcer*
36 *with nearly complete disconnection of D1 from the gastric remnant (antrum)*
37

38 *Figure SDC7 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
39 *Step 2 in the case of the patient described in SDC6: insertion of a transcystic tube in the*
40 *CBD, pushed further until its exit transpapillary in order to identify and precisely locate the*
41 *ampulla*
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44 *Figure SDC8 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
45 *Steps 4 and 5 in the case of the patient described in SDC6: the gastric antrum has been*
46 *divided & distally the dissection of the first part of the duodenum and of the superior*
47 *duodenal flexure from the head of the pancreas is carried out on the plane between the*
48 *duodenum and the pancreatic gland. The shattered duodenal margins are grasped and lifted*
49 *up with Ellis clamp or similar round tip clamp.*
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51 *Figure SDC9 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
52 *Steps 6a in the case of the patient described in SDC6: An articulating flexible endostapler is*
53 *placed tangentially across healthy margins of the mid-duodenum, just above the ampulla*
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55 *Figure SDC10 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*
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4 *Steps 6b in the case of the patient described in SDC6: The resection of D1 and proximal D2*
5 *is completed with an oblique orientation over D2, in order to preserve the orifice of the*
6 *ampulla on the medial side of the duodenum. Distal to the stapler, D3 segment and the*
7 *inferior duodenal flexure can be seen.*
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9 *Figure SDC11 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*

10 *Operative specimen view from the case of the patient described in SDC6: the definitive*
11 *surgical resection of the distal antrum and pylorus (on the right side) and of D1 and D2 (on*
12 *the left side) can be appreciated. The duodenal margins are shattered and non viable and*
13 *such cases are not good candidates for tube (malecot) duodenostomy, being the*
14 *duodenectomy a viable alternative for a rather definitive resection, pancreas sparing and*
15 *ampulla preserving*
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17 *Figure SDC12 (ONLINE ONLY SUPPLEMENTARY MATERIAL)*

18 *Step 7 in the case of the patient described in SDC6: Final view of the operative field, after*
19 *D1-D2 duodenectomy has been completed. From the right side of the picture, going*
20 *anticlockwise, the stump of the D3 segment can be seen, the head of the pancreas looking*
21 *skeletonized after the removal of the duodenum, the transcystic tube for biliary external*
22 *diversion and finally on the upper part of the picture the gastric distal stump and the jejunal*
23 *loop which has been anastomosed to the gastric remnant.*
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Table 1: Practical indications for a "Pancreas-sparing ampulla preserving duodenal resection"

Condition	Comments
Large (1-3 cm) Perforated Peptic ulcer of the duodenum D1 and/or D2 AND not safely amenable to primary repair	Large Perforated Peptic ulcer of the duodenum (>1 and up to 3 cm according to the definitions from the literature) involving the bulbar tract of the duodenum/superior duodenal flexure and/or involving both D1 and D2 in the supra-ampullary tract or reaching the peri-ampullary segment in the antimesenteric border AND not safely amenable to primary repair
ANY giant PPU (>3 cm) involving D1/D2 in their supra-ampullary tract or reaching the peri-ampullary segment on the antimesenteric border	Even if the lower edges of the perforation, extend to D2 and reach the level of the ampulla, the perforated duodenal wall is usually on the lateral duodenal wall and opposite to the ampullary region and to the pancreatic head. Therefore, provided this side of the duodenum is viable and the ampulla is not involved in the process, a linear stapler can be articulated and angled with a sharp oblique orientation (staying just above the ampullary region on the medial side of the duodenum adjacent to the pancreatic head, whereas the resection margin can be well below this region on the lateral side of the duodenum) in order to achieve a complete closure and full stapling of the remaining distal duodenum, over healthy margins.
Large iatrogenic perforations with devitalised / non viable tissue and/or shattered margins	E.g. iatrogenic perforations after lap cholecystectomy or post-endoscopic especially after endoscopic stents placement, ERCP or after EUS procedures.
Large traumatic injuries (blunt or penetrating of the duodenum involving D1 +/- D2 with shattered/devitalized margins and/or not amenable to primary repair	Large traumatic injuries of the duodenum involving D1 +/- D2 with shattered/devitalized margins and/or not amenable to primary repair or other conservative strategies, in absence of massively destructive involvement of the head of the pancreas/CBD/Ampulla and/or of the inferior flexure / sub-ampullary segment of the duodenum [AAST grade II - Laceration: Disruption <50% of circumference of D1-D2 (above the ampulla) not safely amenable to primary repair AAST grade III - Laceration: Disruption 50%-100% of circumference of D1 and/or Disruption 50%-75% of circumference of D2 (above the ampulla)]
Bleeding large duodenal ulcer, AFTER failed endoscopic attempt of hemostasis and not controllable by over-run	Open surgery is recommended when endoscopic treatments failed and there is evidence of ongoing bleeding +/- hemodynamic instability. Most of DUs arriving to surgery for persistent bleeding are usually big and posterior lesions and the bleeding is often from gastro-duodenal artery. Duodenotomy and over-run can be first attempted,

	however Billroth-II resection with distal gastrectomy might be needed if D1 is fully shattered by a large duodenal ulcer. Nonetheless, even with such distal gastric resection and gastric content diversion, the risk of postoperative leak from the duodenal stump is consistent if the shattered and weak duodenum is not removed and definitively resected.
Definitive Surgical Treatment of Persistent postoperative large duodenal leaks after failed conservative, endoscopic or surgical (e.g. primary repair) management	Definitive Surgical Treatment of persistent postoperative large duodenal leaks with non-viable/shattered duodenal margins after primary repair of a perforation / iatrogenic injury / traumatic injury / duodenotomy to control bleeding and after failed further attempts of conservative or endoscopic management

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Pt #	Age	Sex	ASA	Associated comorbidities/ associated diseases	Preoperative shock	Underlying duodenal lesion (ACS vs Trauma)	Location (D1/D2)	Surgical approach (Open/Lap)	Procedure performed	Cholecystectomy and type of biliary external diversion (transcystic vs T-tube)	Type of GI continuity restoration (Roux en Y vs BII)	Associated surgical procedures
#1	81	M	IV E	High blood pressure; obesity BMI=34,2 ; constipation; occasional atrial fibrillation	No	large iatrogenic perforation post-cholecystectomy with thermal injury or surrounding margins , already primarily repaired with persistent leak	D1, thermal injury and ischemia up to proximal D2	Bilateral subcostal Laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy	Transcystic tube for identification of the ampulla and postoperative biliary external diversion (cholecystectomy done at another institution)	Roux en Y	None
#2	72	M	VE	Thoraco-Abdominal trauma	Yes, Septic shock with severe metabolic acidosis and ventricular tachicardia	Blunt Thoraco-Abdominal trauma with large grade IV duodenal injury (Disruption >75% of circumference of D2 but not involving the ampulla), bleeding and perforation	D1/D2	Median Xifo-pubic Laparotomy	D1 Duodenectomy and distal gastrectomy with Billroth II gastrojejunostomy	Cholecystectomy + transcystic tube	BII	Cholecystectomy
#3	79	F	III E	Multinodular goiter; hysterectomy; right inguinal repair; chronic constipation, malnourishment and recent weight loss, bedridden	No	ACS - perforated duodenal diverticulum	D1/D2	Bilateral subcostal Laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy	Cholecystectomy + Transcystic tube	Roux en Y	Cholecystectomy
#4	81	F	IV E	High blood pressure; Diabetes mellitus II; Chronic renal failure	No	ACS - postoperative leak after initial laparoscopic primary repair of a Large perforated D1 posterior ulcer	D1/D2	Bilateral subcostal Laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy	Cholecystectomy + definitive T-tube; transeystic for identification of the ampulla.	Roux en Y	Cholecystectomy; partial gastrectomy; Choledochotomy

						eroding into pancreatic head						
#5	83	M	VE	Alzheimer Disease, Liver Cyrrhosis	Yes, Hemorrhagic Shock	ACS - Giant (5 cm) bleeding ulcer of D1 eroding into pancreatic head and not amenable to over-run, already failed endoscopic hemostasis	D1	Bilateral subcostal Laparotomy	D1 Duodenectomy and distal gastrectomy with Billroth II gastrojejunostomy	Cholecystectomy + transcystic tube	BII	Cholecystectomy
#6	81	M	IV E	CHD with previous MI and coronary stents, Chronic Atrial Fibrillation with OACs; previous mild cerebral stroke without major residual impairment, recent onset of Distal CBD obstruction and jaundice	Yes, Septic Shock	Iatrogenic perforation after positioning of CBD-Duodenal derivative Stent	D1/D2	Bilateral subcostal Laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy	Cholecystectomy + T-tube; transcystic for identification of the ampulla.	Roux en Y	Cholecystectomy; Choledochotomy
#7	71	M	III E	High Blood Pressure. Allergic Rhinitis; Neuroendocrine Tumor G2 (WHO2010) body-tail of pancreas	No, severe sepsis	ACS - Giant perforated ulcer of passage D1-D2 eroding into pancreatic head with large posterior leak and retroperitoneal collection	D1/D2	Bilateral subcostal Laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy	Cholecystectomy + transcystic tube	Roux en Y	Spleno-Pancreasectomy body-tail; cholecystectomy;
#8	65	M	VE	Heavy Smoker; Chronic Alcoholic, Chronic Leg Edema with cutaneous ulceration; diabetes mellitus; peripheral	Yes, Hemorrhagic Shock	ACS - Giant bleeding ulcer of passage D1-D2 eroding into pancreatic head and not amenable to over-run, already failed endoscopic	D1/D2	Bilateral subcostal Laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy	Cholecystectomy + transcystic tube	Roux en Y	Cholecystectomy;

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				vasculopathy; Deafness		hemostasis						
#9	84	M	III E	Diabetes mellitus type II; Peripheral vasculopathy;	No	ACS - Large perforated D1 posterior ulcer	D1	Laparoscopy	D1 Duodenectomy and distal gastrectomy with B-II gastrojejunostomy	No	BII	None
#10	83	F	IVE	Severe COPD, chronic respiratory failure on intermmitent oxigen therapy at home, hypertension, chronic cardiac failure, normotensive hydrocephalus, admitted in hospital one month before for acute respiratory failiure, two weeks later emergent laparotomy for Hinchey IV perf diverticulitis, with sigmoidecotmy and end colostomy, again two weeks later re-laparotomy for PPU	No, severe sepsis	ACS - Large perforated D1 ulcer with complete disruprion of D1 and disconnection from the pylorus	D1	Median re-laparotomy	D1-D2 Duodenectomy and distal gastrectomy with Roux en Y gastrojejunostomy, extensive adhesiolysis	Cholecystectomy + transcystic tube	Roux en Y	Cholecystectomy, estensive adhesiolysis, re-fashioning of detached colostomy

Pt #	Op time (min)	Feeding NJ Tube	ICU stay (days)	Postop LOS (days)	Postop complications	Postop duodenal leaks	Re-operation	Need of Postop Percutaneous drainage	Other managements of post-op complication	30-days mortality	Histopathology
#1	332	Nasojejunal tube for enteral feeding	1	15	Yes, postoperative bleeding from GastroJJ	No	No	No	Endoscopic clipping of a bleeding postoperative	No	Benign iatrogenic perforation with ischemia from thermal injury of

					anastomotic line				anastomosis ulcer of the gastroJJ anastomosis		the surrounding tissues
#2	170	Nasogastric tube	11	11	Cardiac and Respiratory Failure	No	No	No	Critical care: vasopressors, broad spectrum antibiotics, mechanical vent	Yes	Destructive Traumatic Duodenal injury
#3	240	Nasojejunal tube for enteral feeding	2	12 d - 50 d in long term care	No	No	No	No	No	No	Benign - perforated duodenal diverticulum
#4	360	No	1	10	Postoperative necrotizing pancreatitis (6th POD), uncontrollable hemorrhage from the pancreatic head (10th POD)	No	Yes, on 6th POD and 10th POD	No	Relaparotomy, toilette, drainage and hemostasis on the head of the pancreas (6th POD), abdominal packing (10th POD)	Yes	Benign - Giant Bleeding Duodenal Ulcer (3 cm) of passage D1-D2, dehiscence of primary repair
#5	195	Nasogastric tube	3	17	Yes, respiratory failure and pleural effusion	No	No	None	Respiratory Failure treated with NIV and bronchoscopy for toilette of secretions, thoracentesis of pleural effusion	No	Benign - Giant Bleeding Duodenal Ulcer (5 cm) extending on D1
#6	189	Nasojejunal tube for enteral feeding	4	20 d + long term palliative care	Yes, Biliary leak around the T-tube insertion due to the distal CBD malignant obstruction	No	No	None, surgical drains left in situ	Biliary leak around the T-tube insertion due to the distal CBD malignant obstruction, managed conservatively	No	Benign Large iatrogenic perforation of the passage D1-D2, well differentiated adenocarcinoma of the distal

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									by leaving the abdominal drains		CBD, invading the head of the pancreas, without invasion of the duodenal wall
#7	377	Nasojejunal tube for enteral feeding	3	22 d + 25 d in long term care	Yes, peripancreatic stump collection, postop-pancreatitis	No	No	Yes x2 to drain the peri-pancreatic stump collection	Medical management of pacnreatitis	No	Benign Giant perforated Duodenal Ulcer (6 cm) of passage D1-D2, pancreatic head showed 10 cm well diff neuroendocrine gastrin producing tumor G2 T3N0, 20 lymphnodes negatives
#8	296	Nasojejunal tube for enteral feeding	4	32	Yes, aspiration pneumonia	No	No	None (no postop collections)	Mechanical Ventilation, Antibiotics	No	Benign - Giant Bleeding Duodenal Ulcer (3 cm) of passage D1-D2
#9	242	None	5	16	Respiratory Failure in ICU	No	No	None	Respiratory Failure treated with NIV and bronchoscopy for toilette of secretions	No	Benign - Large Duodenal Ulcer (3 cm) of D1
#10	238	Nasojejunal tube for enteral feeding	11	23 d - 28 d in long term care	Respiratory Failure in ICU	No	No	No	Respiratory Failure treated with NIV and repeated bronchoscopy for toilette of secretions	No	Benign - Giant Duodenal Ulcer of D1 with complete pyloric-duodenal detachment

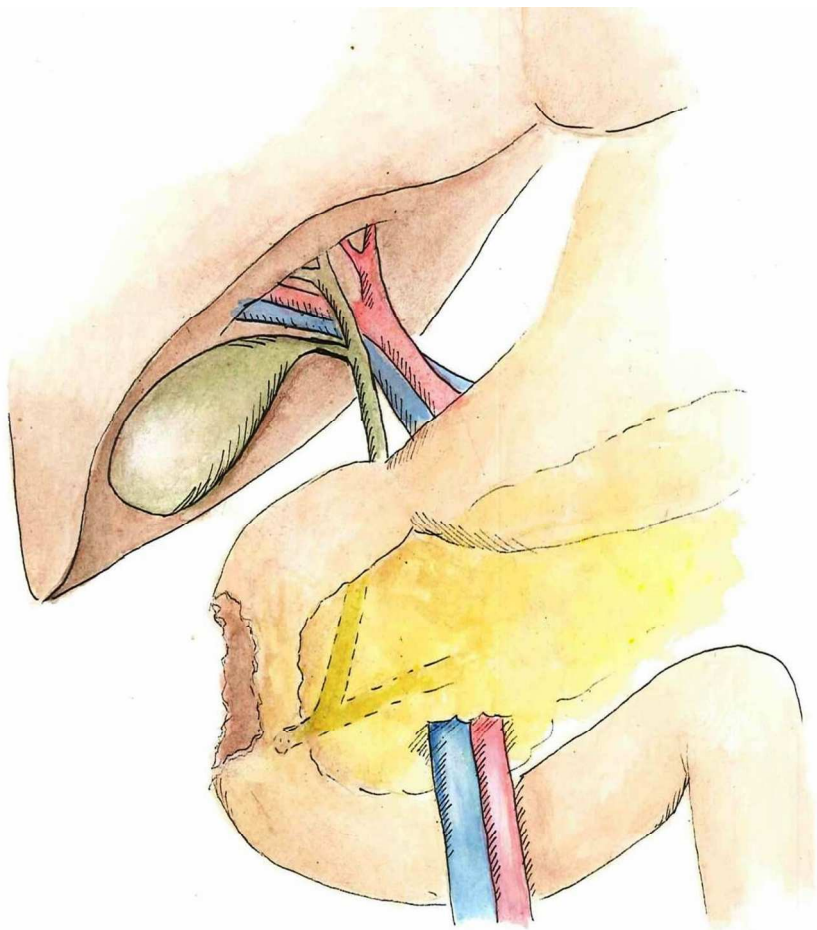
1 Videos privately available for Editor's and Peer Reviewers vision ONLY at the following link on
2 YouTube personal account of Dr. Salomone Di Saverio MD FACS FRCS
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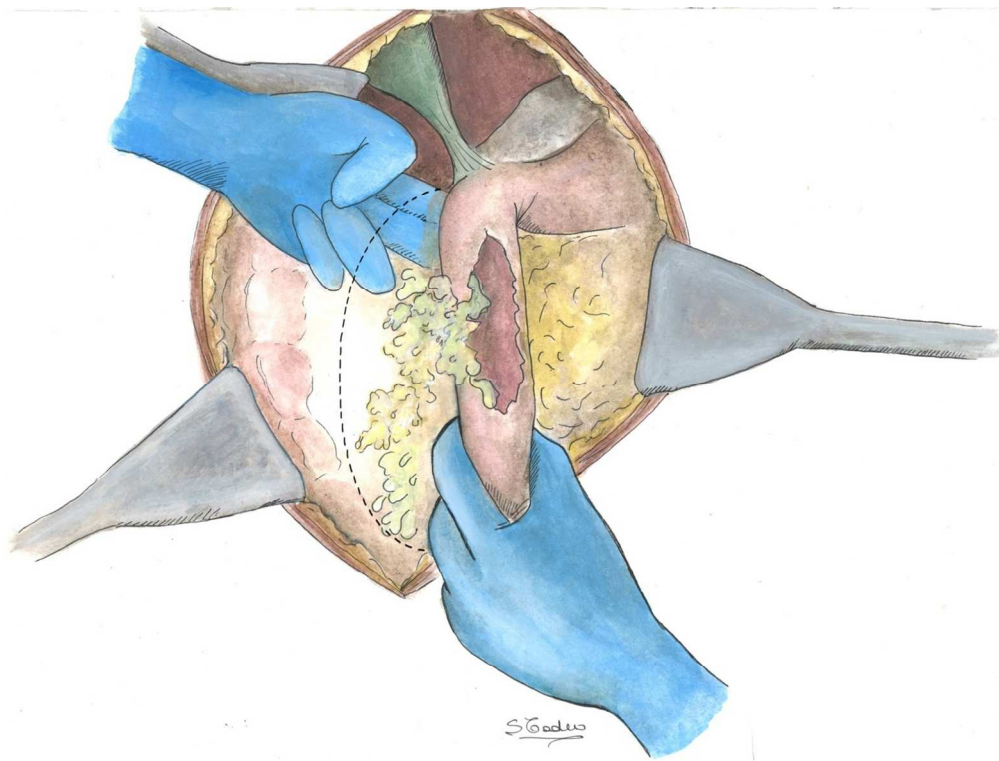
4 Video #1: Massive digestive haemorrhage due to bleeding duodenal ulcer
5 <https://www.youtube.com/watch?v=ymtVTg7pP6w&feature=youtu.be>
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8 Video #2: Duodenectomy –Surgical technique described Step by Step
9 <https://www.youtube.com/watch?v=juWr70ruyjU&feature=youtu.be>
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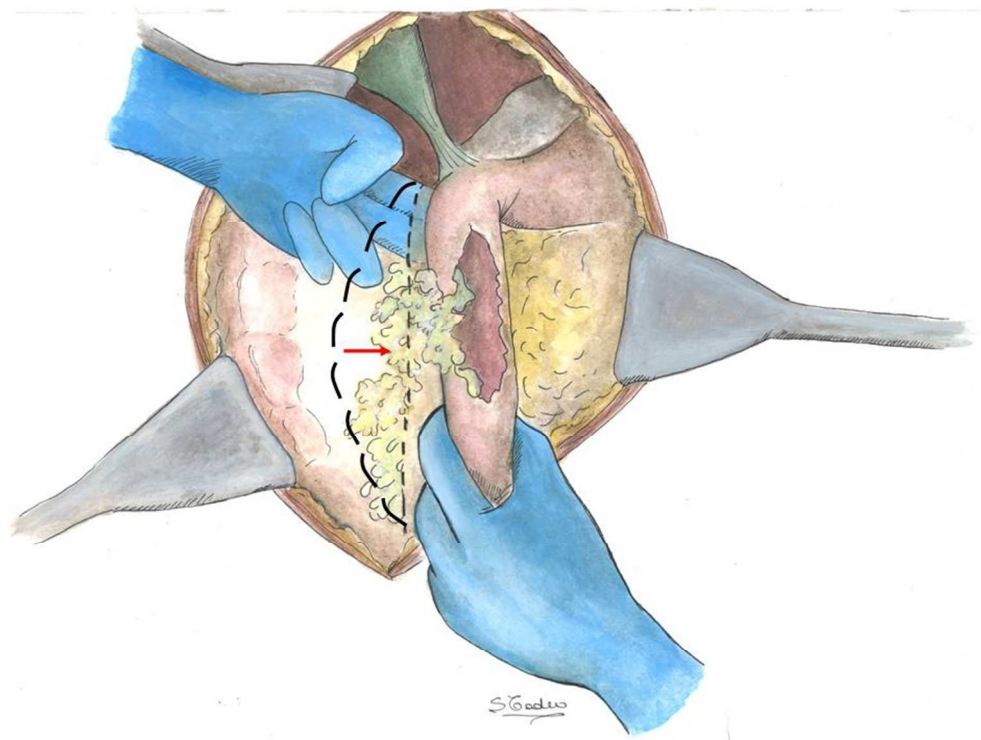


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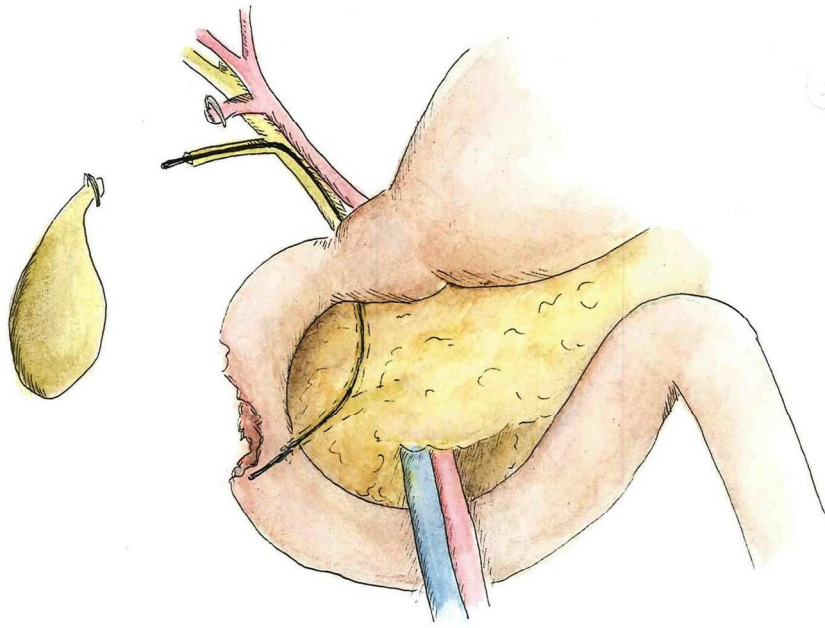
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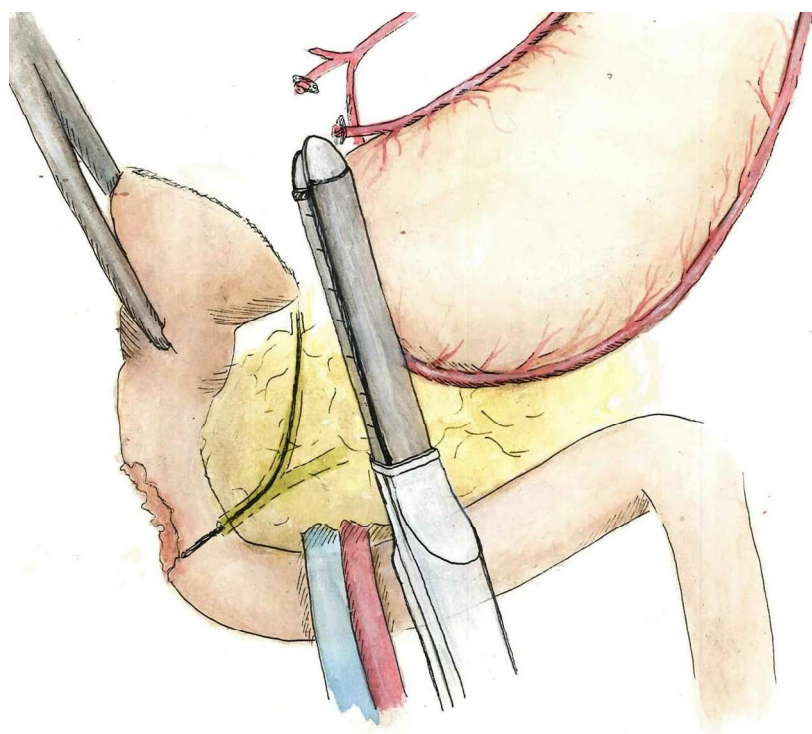
254x190mm (96 x 96 DPI)

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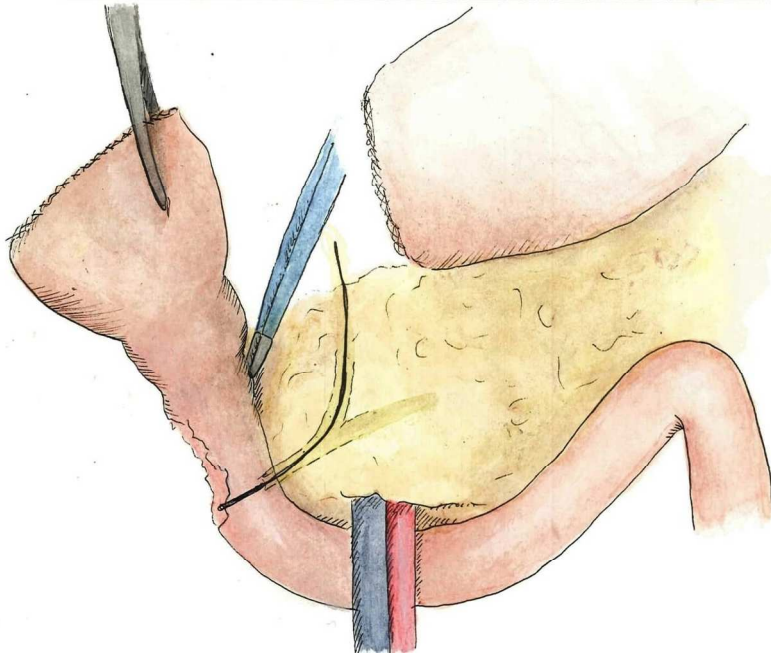
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464x334mm (96 x 96 DPI)

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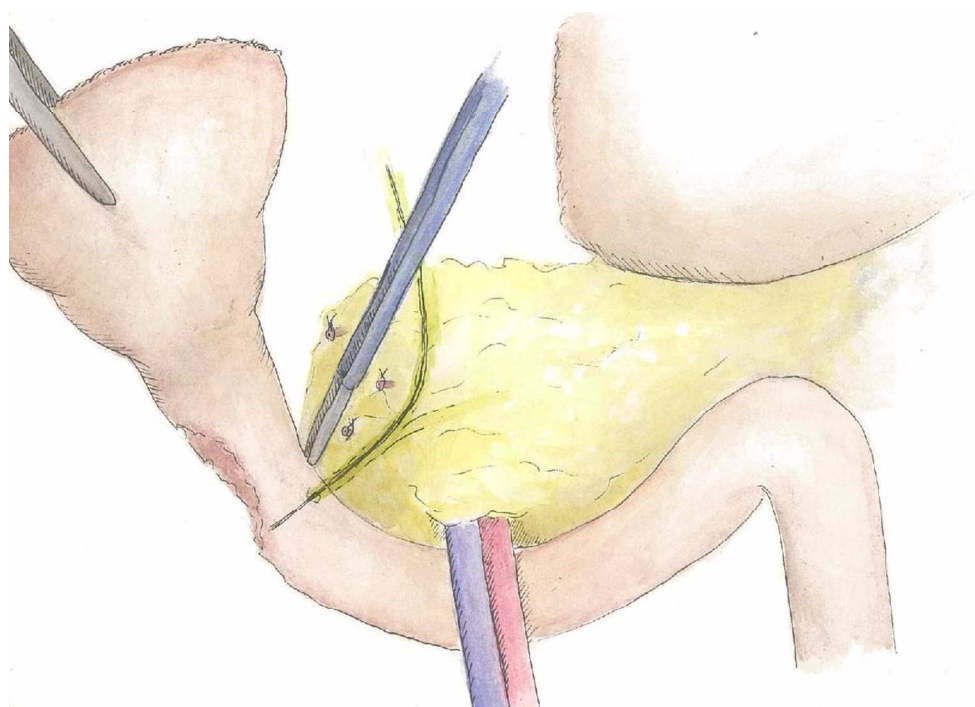
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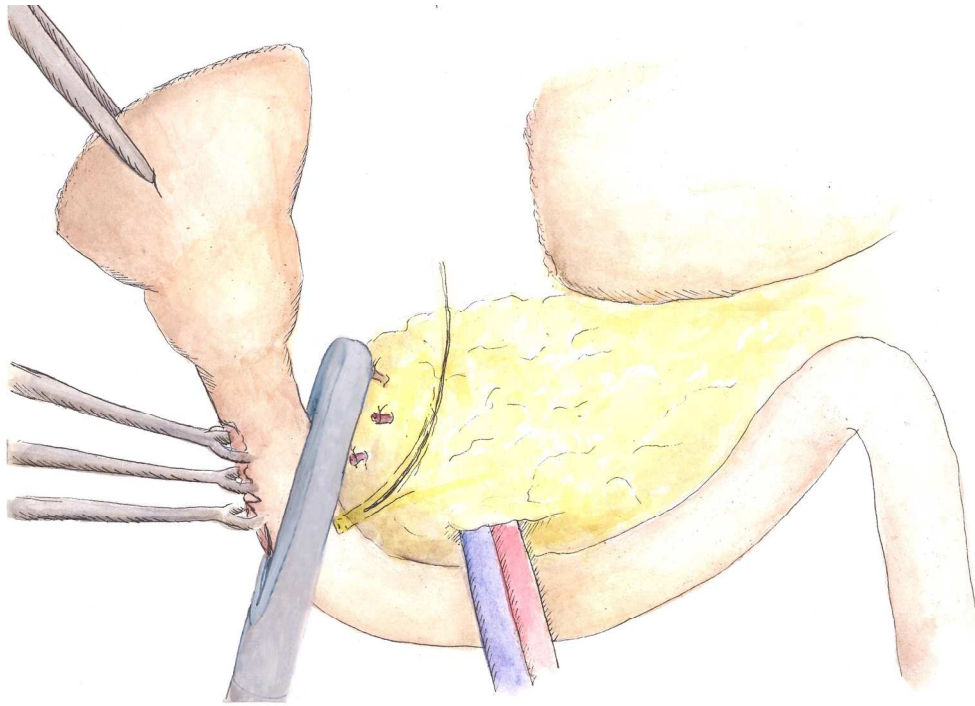
474x309mm (96 x 96 DPI)

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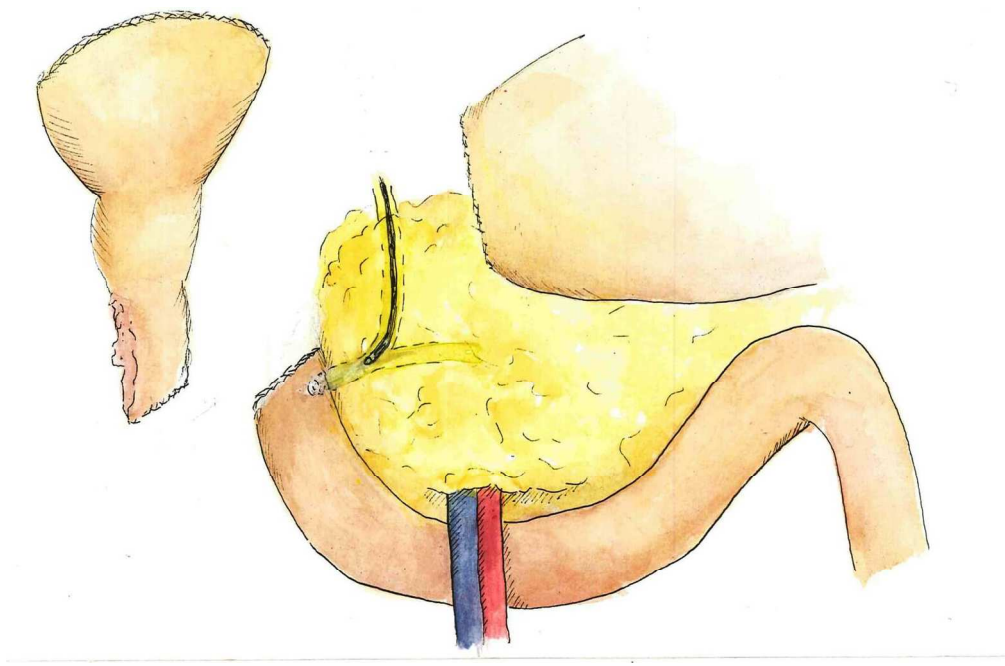


169x120mm (300 x 300 DPI)

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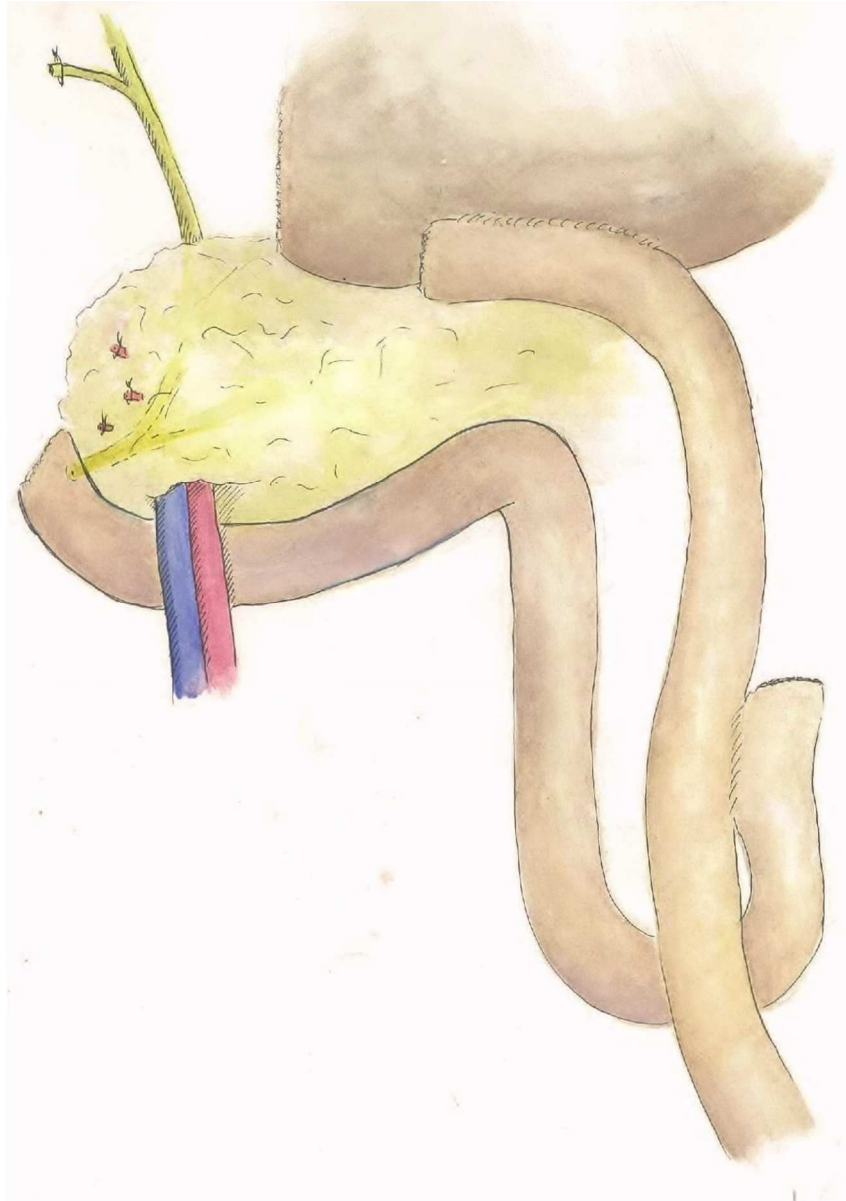
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477x312mm (96 x 96 DPI)

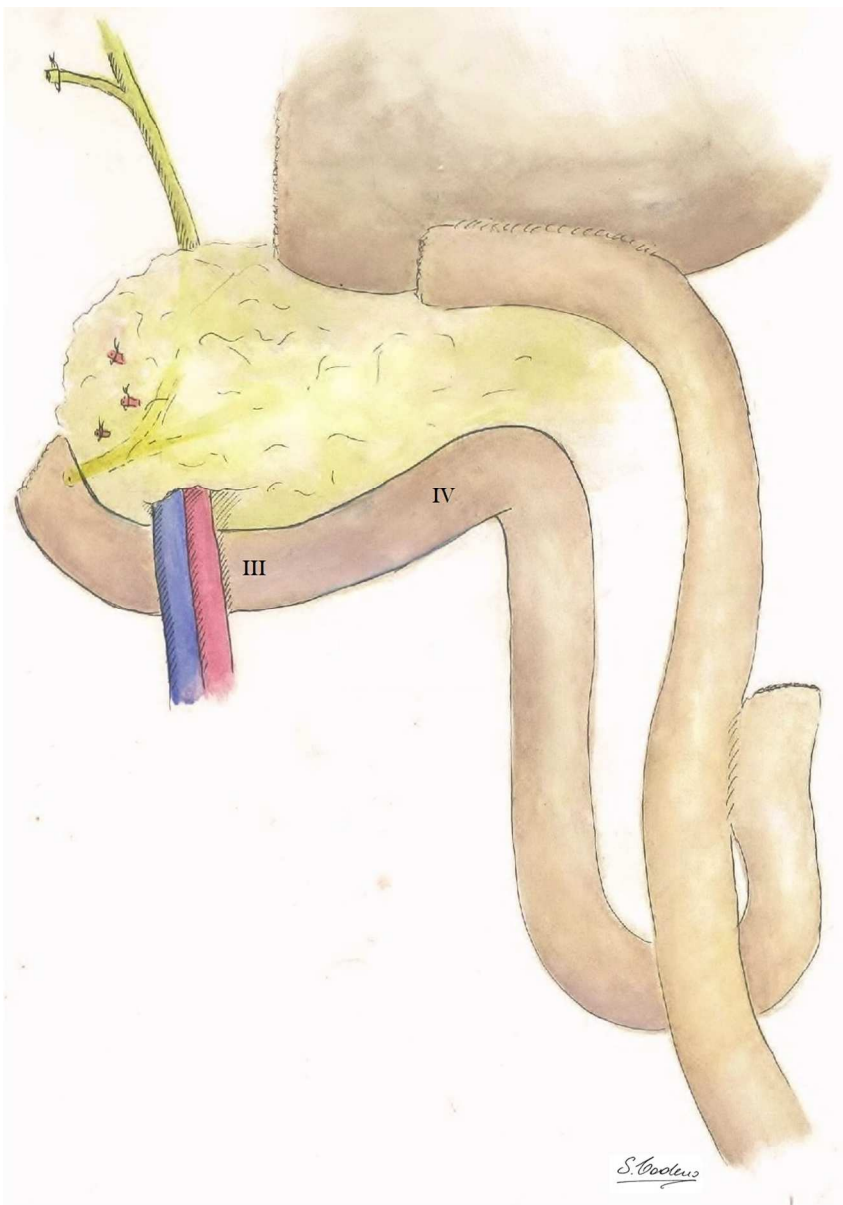
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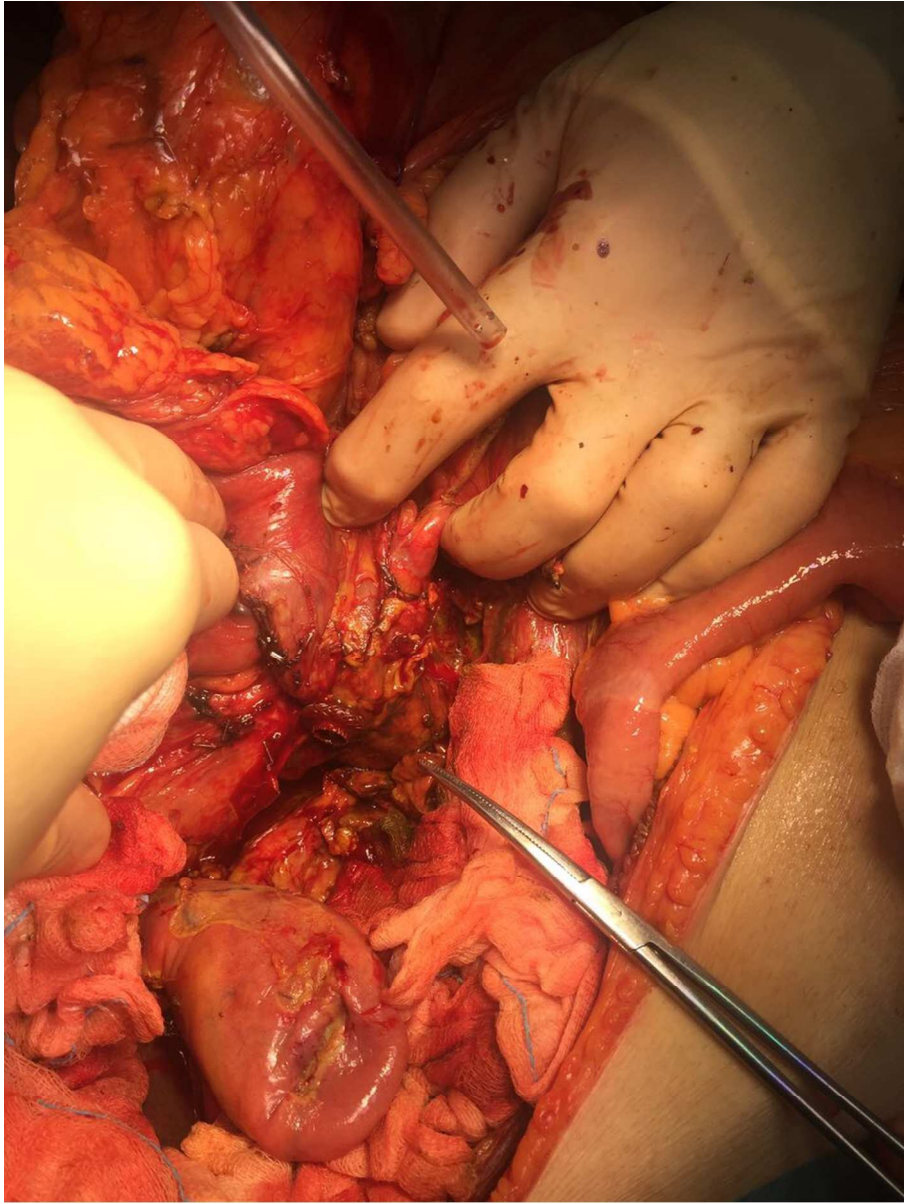
308x438mm (96 x 96 DPI)

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197x280mm (150 x 150 DPI)

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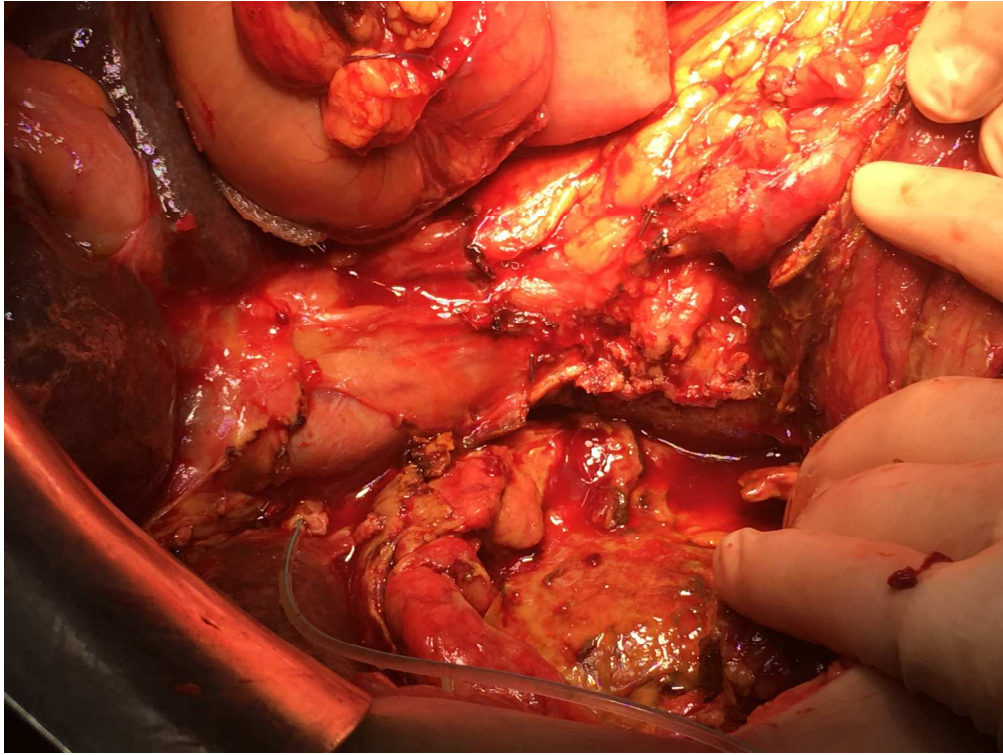
338x451mm (72 x 72 DPI)

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338x451mm (72 x 72 DPI)

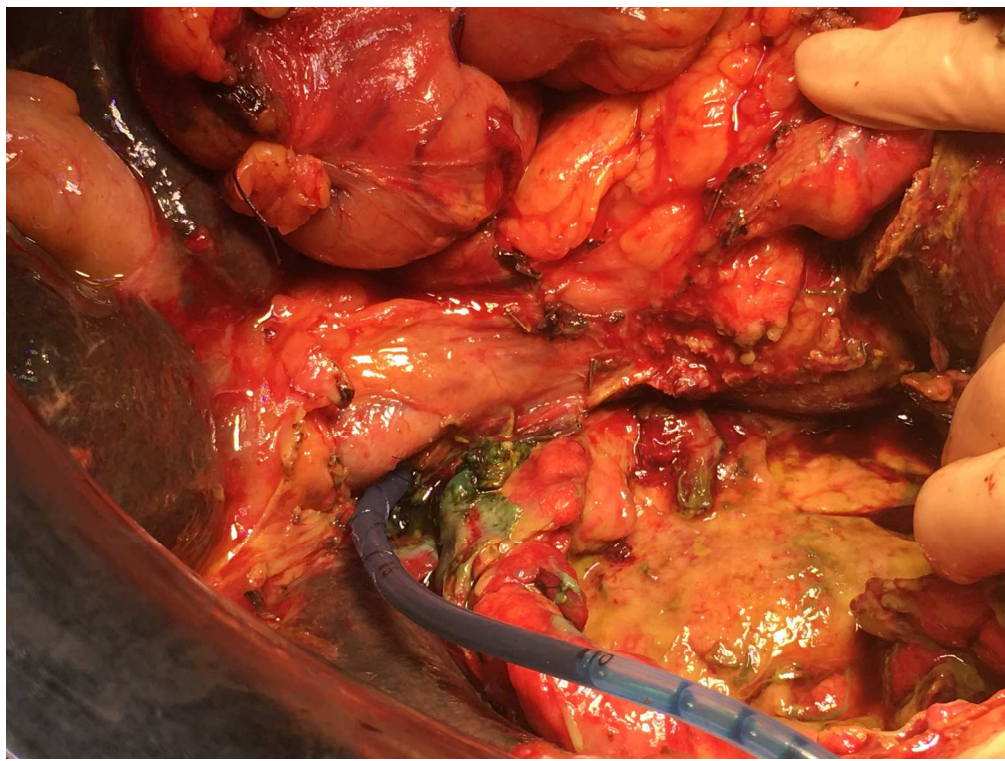
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1422x1066mm (72 x 72 DPI)

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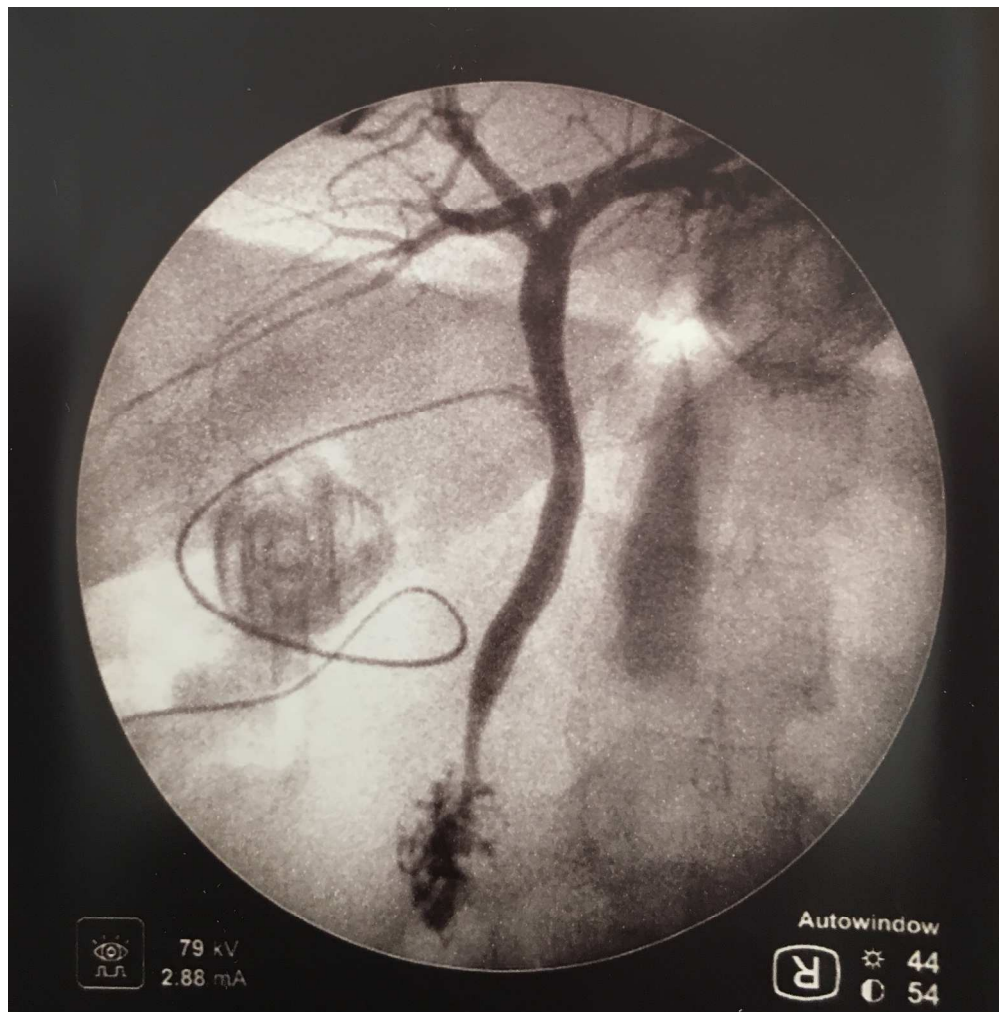
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1422x1066mm (72 x 72 DPI)

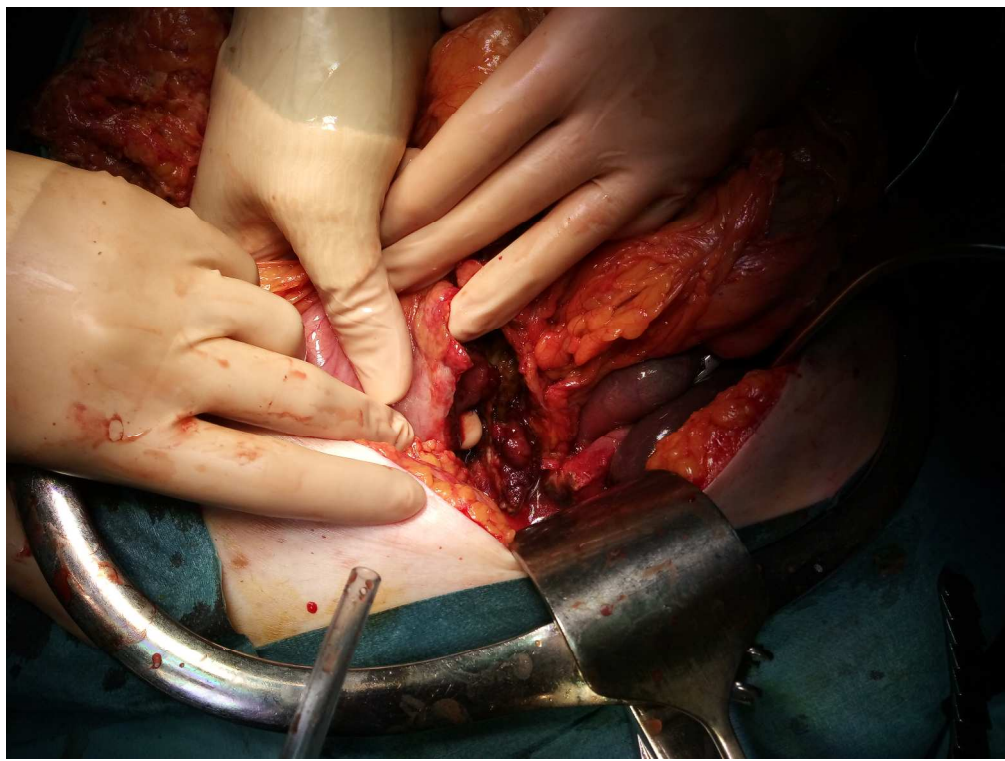
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1065x1077mm (72 x 72 DPI)

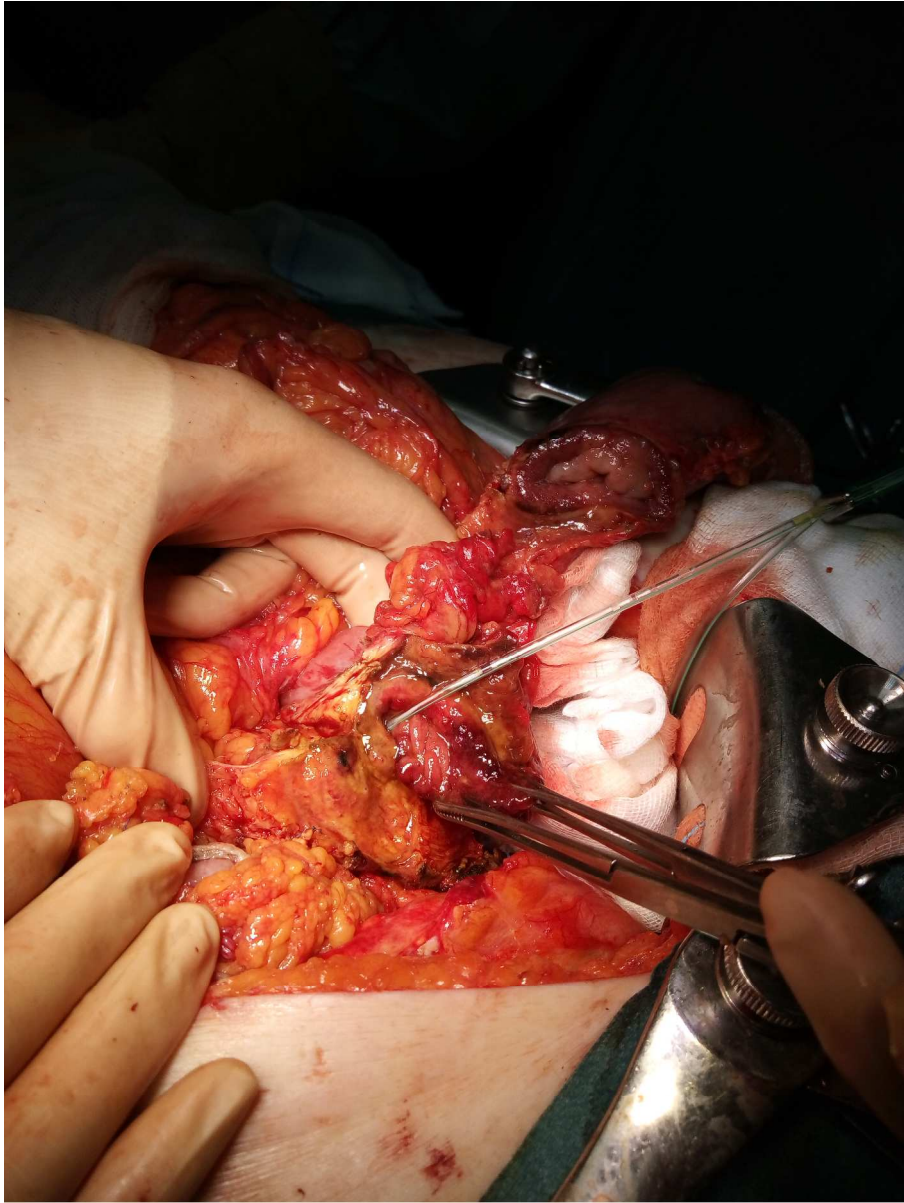
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1467x1100mm (72 x 72 DPI)

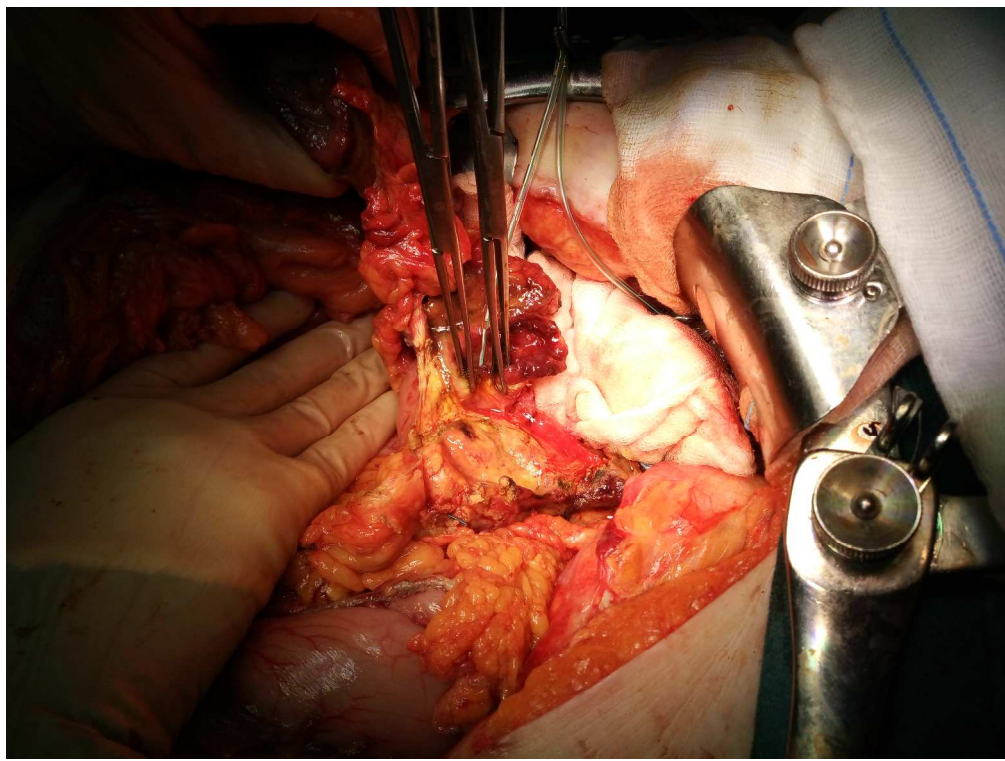
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1100x1467mm (72 x 72 DPI)

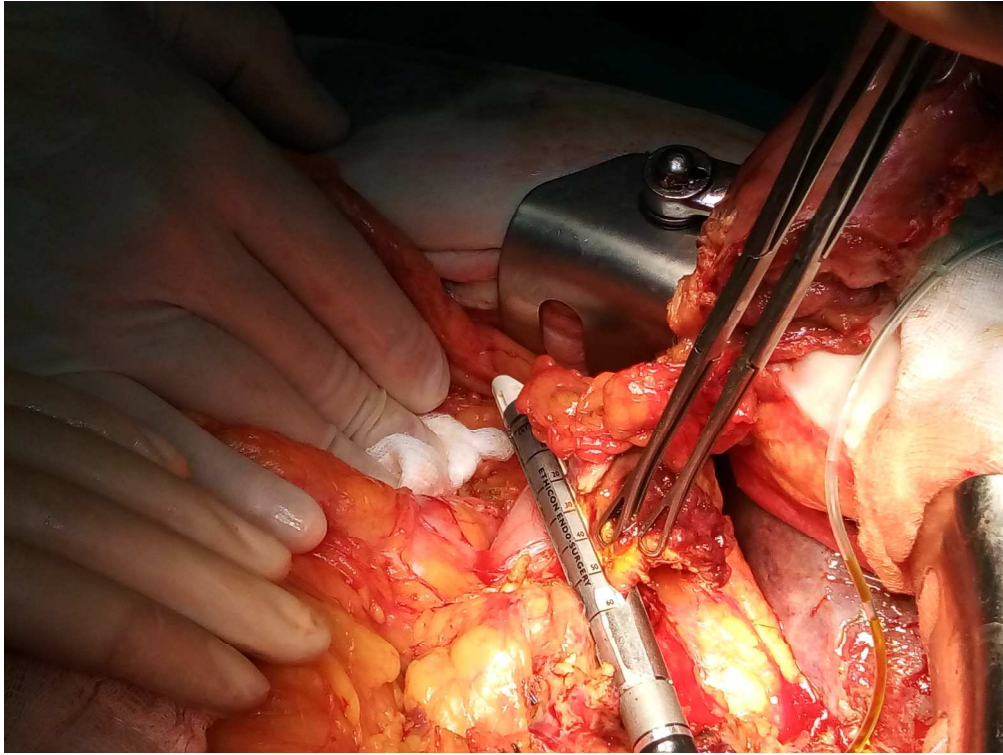
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1467x1100mm (72 x 72 DPI)

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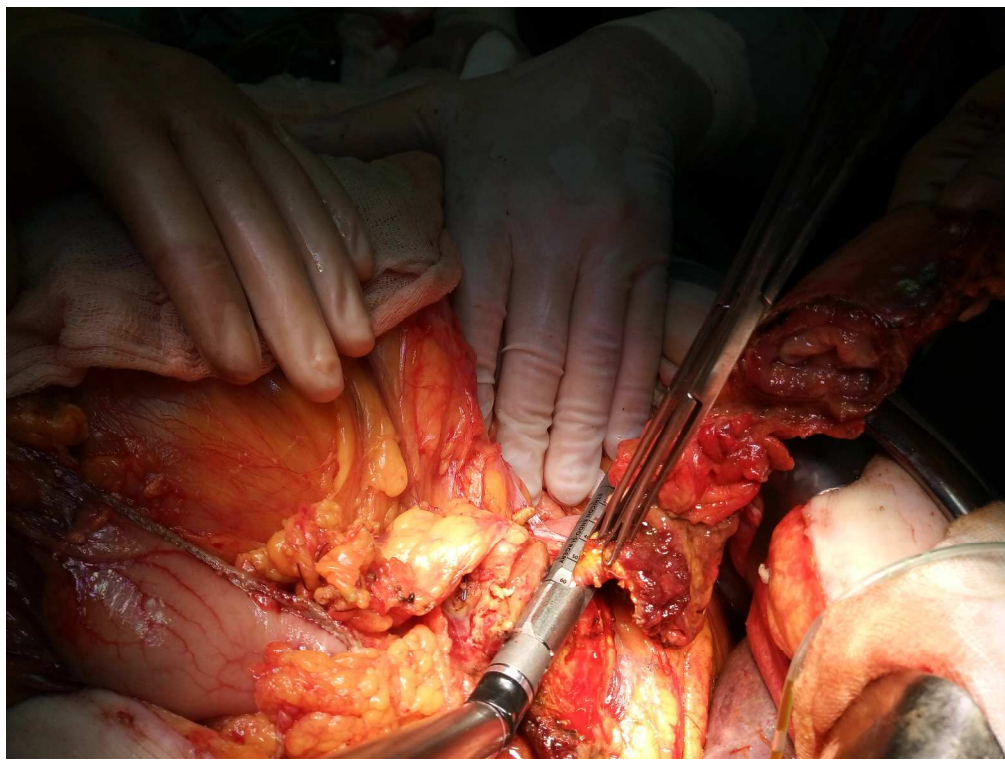
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1467x1100mm (72 x 72 DPI)

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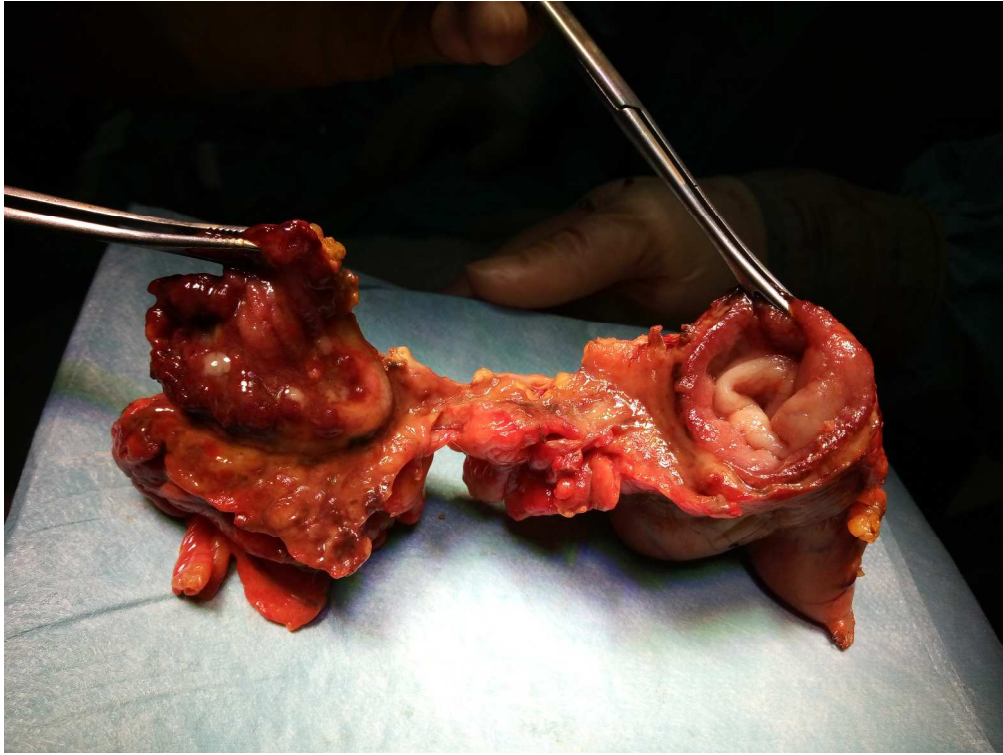
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1467x1100mm (72 x 72 DPI)

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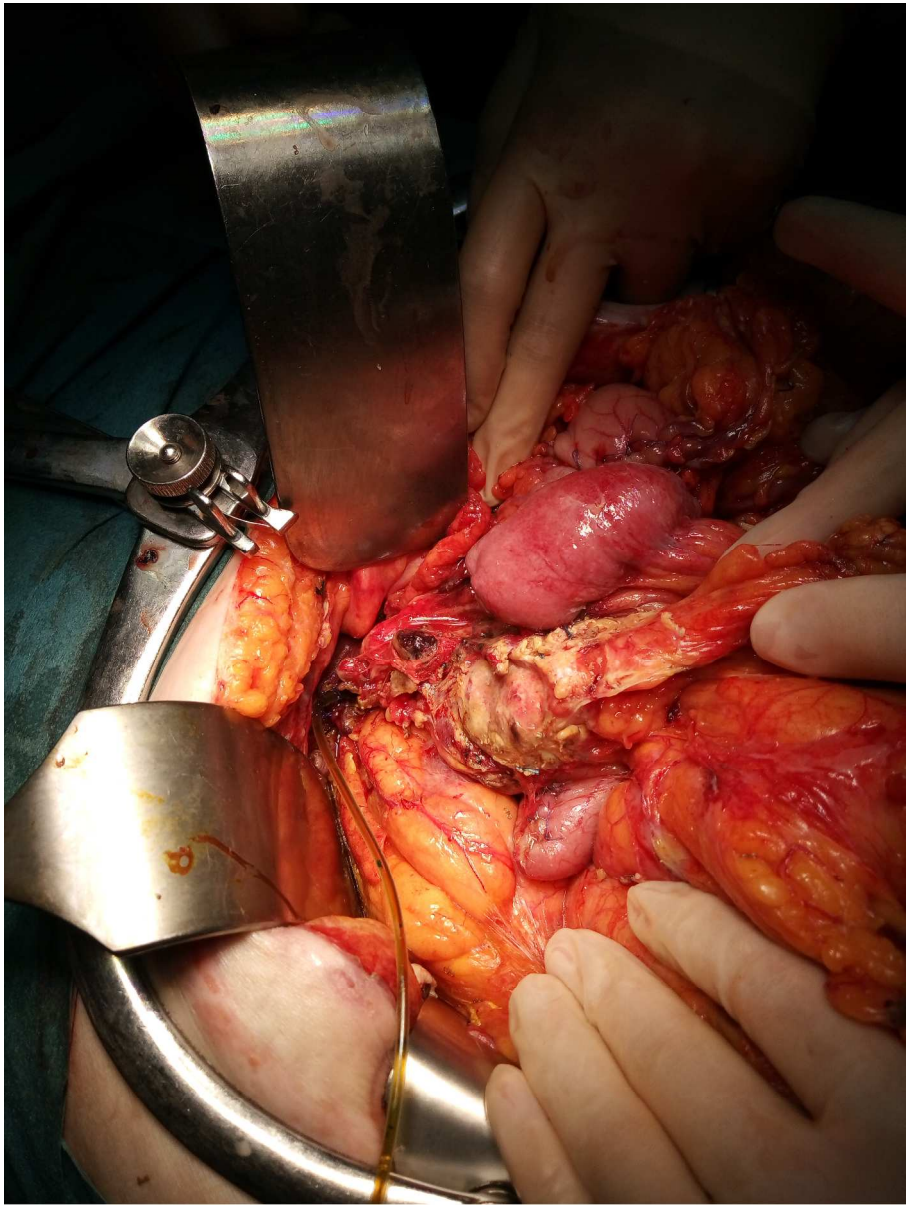
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1100x1467mm (72 x 72 DPI)