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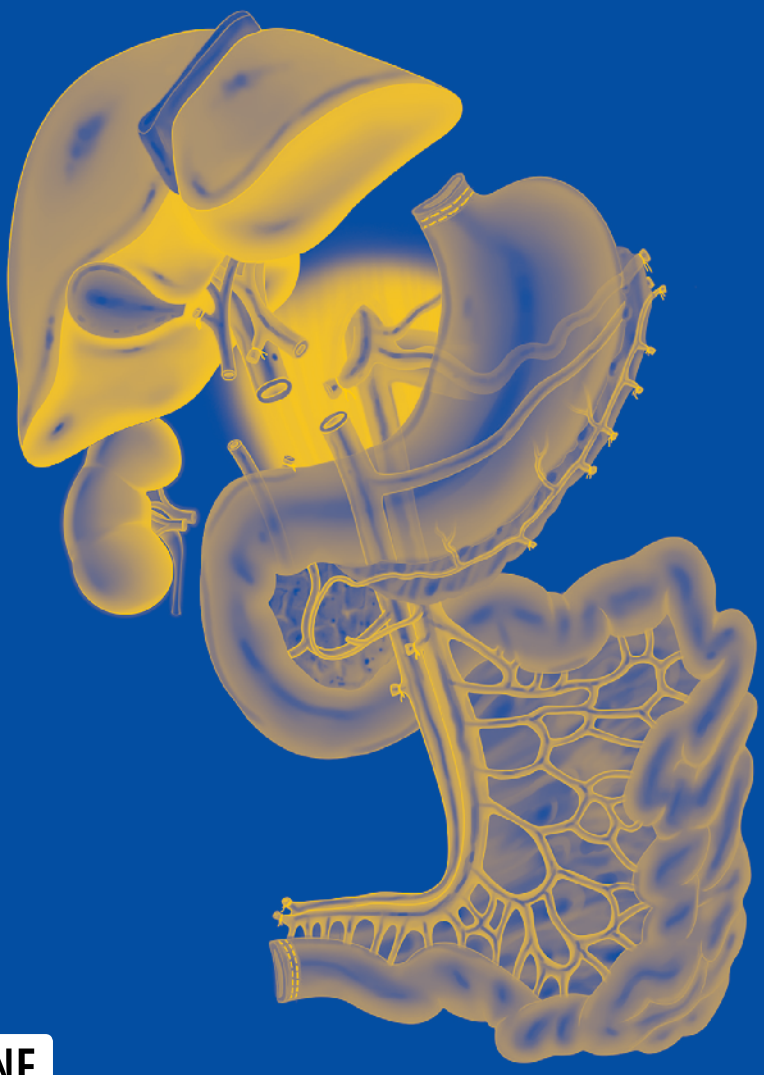
Transplantation Surgery



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Preface

In a very short time, transplantation has evolved from a quasi-experimental technique to a well-established treatment for end-organ failure. Whilst many factors played an important role, this rapid evolution was largely due to developments and refinements in surgical technique.

A successful transplant is underpinned by precise surgery. The complexity of transplantation surgery, be it kidney, liver, heart, intestine, or otherwise, requires detailed knowledge of anatomy and a mastery of a variety of techniques. Arguably, transplantation surgery is the epitome of surgery, as it encompasses aspects of all surgical specialties. Furthermore, transplantation is the only surgical field that requires the removal of organs in a perfect condition, to allow implantation and subsequent function in a different patient. This intricate correlation between donor and recipient surgery requires skills, knowledge, and, above all, a well-established transdisciplinary team.

This Atlas was developed with the above principles in mind and covers many aspects of transplantation surgery. Single-artist illustration ensures a cohesive approach throughout the chapters. Procedures are illustrated in a step-by-step fashion to allow the reader to visualise the techniques and the critical steps. Whilst it is difficult to capture every aspect and technical variation of all procedures, the book covers the principle aspects of organ retrieval and thoracic and abdominal transplantation. Separate chapters address specific technical issues in lung, heart, kidney, pancreas, and intestinal transplantation. Several chapters of the Atlas are dedicated to the developments in liver transplantation where innovative techniques such as split liver transplantation, auxiliary transplantation, or domino transplantation have increased access to transplantation to more patients than ever before.

The important contribution of living donation is acknowledged by several chapters illustrating living donor lung, liver, kidney, pancreas, and intestinal transplantation. Whilst the use of some of these approaches remains limited, there is no doubt that the advent of living donation has transformed transplantation surgery. Many of the innovative techniques developed for living donor transplantation have now been successfully transposed to deceased donor transplantation.

The *Atlas of Transplantation Surgery* is the result of a large collaborative effort, bringing together an experienced international team of authors who have pioneered many of the techniques described. As such, the book will be an ideal reference point for transplant surgeons, trainees, fellows, and other professionals involved in transplantation. The residents and fellows will find detailed descriptions of surgical procedures and additional recommended reading to consolidate the operative planning and knowledge. Equally, we hope that experienced surgeons will be able to benchmark their individual techniques against those described by the authors.

We believe that clinical transplantation is the best example of true transdisciplinary practice working in harmony. We wish to thank the patients and the whole clinical teams of the three editors and the authors. Without them, this book would have never been written.

Edinburgh, UK — Gabriel C. Oniscu
Bristol, UK — John L. R. Forsythe
Aurora, CO — Elizabeth A. Pomfret

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We are deeply indebted to all the authors for their enthusiasm for this project and for generously giving their time to see it to fruition.

We are grateful to Prof. John Lumley, Series Editor, for his encouragement to bring Transplantation Surgery to the family of Springer Surgery Atlas Series. We are also indebted to Mr. Lee Klein, senior editor at Springer, for his tireless assistance to the Editors and for being the critical link between the authors and the artist rendering the illustrations.

We would like to thank the patients and the clinical teams of the editors and authors for their support and for motivating us to complete this book.

As usual, none of this would have been possible without the tremendous support from our families.

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Part I

Abdominal Organ Retrieval

Abdominal Multiorgan Retrieval

1

John D. Terrace and Gabriel C. Oniscu

Organ transplantation has evolved from an experimental procedure to a well-established specialty, embracing advanced surgical techniques and cutting-edge technology. The transplantation pathway is now clearly established, starting with the identification of potential donors and the organ retrieval procedure through to transplantation and long-term follow-up of the patients who have undergone transplant procedures.

Organ retrieval is a fundamental part of this process and must be conducted in a sensitive and structured manner to respect the wishes of the donor and ensure a timely and safe recovery of organs for implantation.

Despite advances in other areas of organ transplantation, the technical aspects of abdominal multiorgan retrieval have seen very little change until relatively recently. With an increased utilization of organs recovered after circulatory death (DCD) or other extended criteria grafts from donation after brain death (DBD), organ retrieval techniques have evolved to ensure a rapid recovery of organs in order to minimize the damage associated with the functional warm ischemia (in DCD) or prolonged retrieval times for all organs in all types of donors. Furthermore, with the advances in organ perfusion and preservation such as the introduction of normothermic perfusion, surgeons being trained in transplantation require a structured approach to performing a safe abdominal multiorgan retrieval, focusing on excellence and the delivery of well-preserved, undamaged organs with the greatest chance of functional success. Although many aspects of the retrieval technique vary according to the surgeon's preference and experience (single versus dual perfusion, en bloc versus individual organ recovery, warm versus cold phase dissection), the principles of the technique are similar. This chapter focuses on the preoperative preparation and abdominal retrieval techniques in DBD and DCD donation and introduces some technical advances for DCD organ recovery.

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1.1 Preoperative Preparation

The structure of a multiorgan retrieval team varies across the world, but usually the retrieval is attended by an abdominal team, a cardiothoracic team, and in some cases a transplant anesthetist. The teams should be available for rapid mobilization 24 h a day, year round. On arrival at the donor center, the teams should liaise with the donor coordinator and agree on the planned sequence of organ procurement. It is the responsibility of the lead surgeon to check patient identification and the consent details and review the donor history. This includes the patient's blood group, blood tests, virology status, past history, and clinical progress to date and to exclude or consider any issues that might impact on organ procurement or implantation; if such problems are present, they must be discussed with the recipient surgeons. A careful review of confirmation of brain stem death documentation is a critical component for DBD donation, whereas the extent of supportive therapy and treatment withdrawal plans is important for setting the DCD retrieval.

1.2 Abdominal Multiorgan Retrieval in DBD Donors

There are two components to the retrieval procedure in a DBD donor: a warm phase and a cold phase dissection. The warm phase dissection takes place prior to aortic cross-clamping and perfusion with preservation solution. This allows the identification of anatomy and the dissection of

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organs in order to facilitate a rapid removal during the cold phase, following topical cooling with slush ice and intravascular cooling with a preservation solution.

The balance between the amount of warm and cold phase dissection undertaken during the retrieval depends on the expertise of the surgeon and the hemodynamic stability of the donor. Although cold phase dissection appears to be associated with better outcomes and less organ injury, the identification of vascular anatomy is more challenging in this dissection, particularly for the inexperienced surgeon.

The most commonly used preservation solution for the liver, kidney, and pancreas is University of Wisconsin (UW) solution. However, some centers favor histidine-tryptophan-ketoglutarate (HTK), particularly in DCD retrievals. Despite the fact that perfusion of the abdominal organs via the aorta alone is sufficient in most DBD patients, dual perfusion (aortic artery and portal vein) is preferred in DCD retrievals and extended criteria DBD donors.

There is still some debate regarding whether organs should be removed individually or en bloc (liver-pancreas). Although this is heavily influenced by surgeons' preference, there is evidence that a liver and pancreas en bloc retrieval provides a better initial organ function and is associated with fewer retrieval injuries.

1.2.1 Warm Phase Dissection

1.2.1.1 Patient Preparation, Incision, and Initial Assessment

The operative field is prepared with the patient in the supine position and draped to include the chest and abdomen for thoracolaparotomy from the suprasternal notch to the pubis (Fig. 1.1). The abdomen is opened first and, after dividing the ligamentum teres, a careful, comprehensive laparotomy is performed, including examination of the lesser sac through

Figure 1.1

With the patient in the supine position, the operative field is prepared and draped to include the chest and abdomen for thoracolaparotomy from the suprasternal notch to the pubis

the gastrocolic ligament, paying particular attention to any indication of neoplastic disease. Biopsies of any lesion should be undertaken at the donor center if possible and any peritoneal fluid sent for microbiological analysis.

A retrosternal tunnel is developed using blunt finger dissection and careful passage of a Roberts forceps along the bony undersurface of the sternum until the tip is visible at the suprasternal notch. Ventilation is temporarily disconnected to avoid lung damage, and a median sternotomy is performed using a Gigli saw or a power saw. The liver should be protected during this maneuver to avoid iatrogenic injuries. Bleeding from the bony surface is controlled by the application of bone wax before the pleural spaces are opened, the anterior portion of the diaphragm is partially divided on both sides, and a Finochietto retractor is placed (Fig. 1.2). The thoracotomy is completed by dividing the pericardium with scissors and placing a moist swab over the myocardium.

1.2.1.2 Organ Mobilization and Vascular Identification

The warm phase dissection is continued by three key steps that include visceral rotation using the Cattell-Braasch maneuver, identification of the superior mesenteric artery (SMA), and preparation of the aorta for cannulation. This latter step can be performed prior to opening the chest to ensure vascular control and rapid aortic cannulation and cold perfusion in the event of donor hemodynamic instability.

The left triangular ligament of the liver is mobilized over a swab placed under the left lateral section, taking care to avoid damaging the parenchyma or closely related left phrenic vessels. In order to limit any future traction injury, the posteroinferior peritoneal attachments of the right liver lobe should also be divided at this stage. The cecum and the distal small bowel are gently retracted in a cranial direction, and a Cattell-Braasch maneuver is performed to expose the retroperitoneal structures (Fig. 1.3). Taking care

Figure 1.1

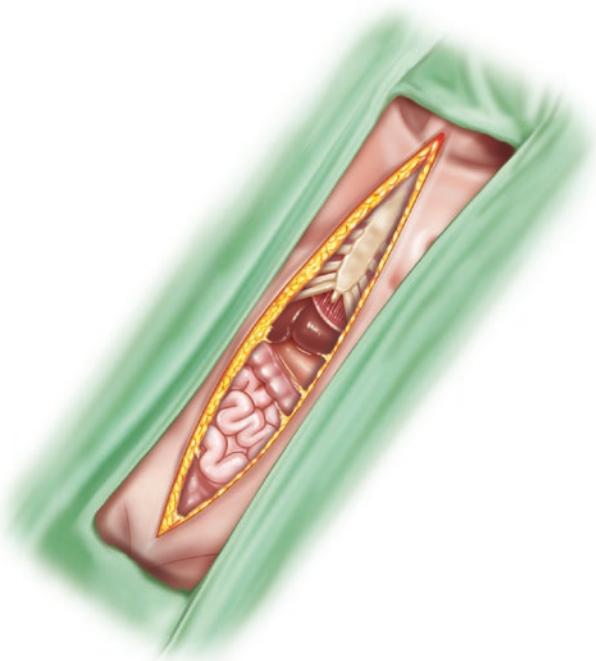


Figure 1.2

Bleeding from the bony surface is controlled by the application of bone wax before the pleural spaces are opened and prior to placing the Finochietto retractor

Figure 1.3

The cecum and the distal small bowel are gently retracted in a cranial direction, and a Cattell-Braasch maneuver is performed to expose the retroperitoneal structures

Figure 1.2

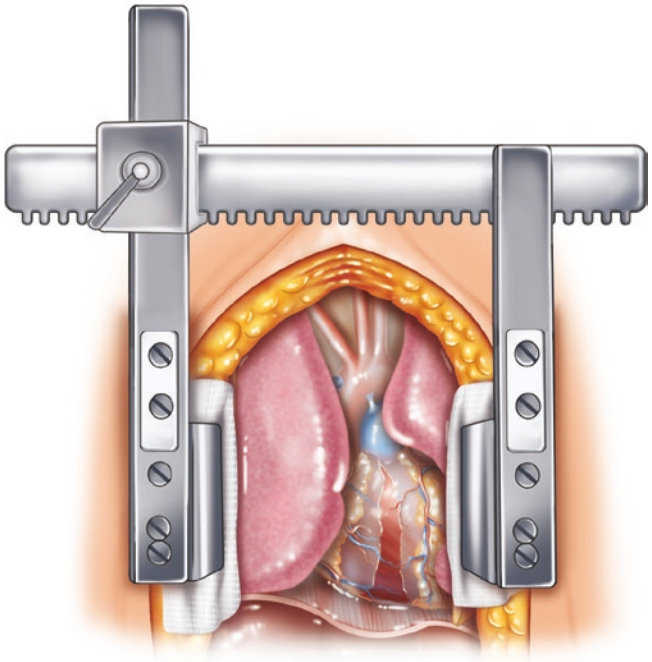
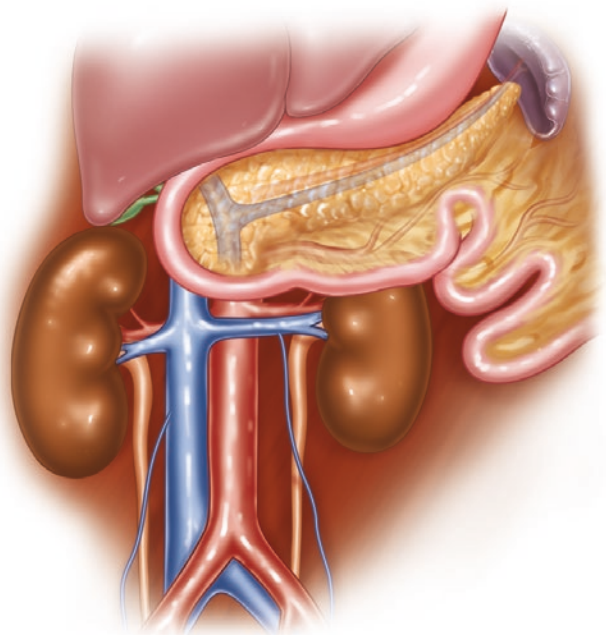


Figure 1.3



to identify and preserve the right gonadal vessels and the right ureter, the entire cecum, right colon, and small bowel are mobilized away from the retroperitoneal structures on the SMA pedicle. Dissection is developed cranially to include the hepatic flexure before carefully separating the colon from the duodenum. The duodenum can then be fully kocherized, exposing the infrahepatic inferior vena cava (IVC), the left renal vein, the aorta, and the ureters. Finally, the descending colon is mobilized medially to expose the Gerota fascia on the left side.

The SMA is palpated just above the superior border of the left renal vein and can be slung with a vascular sloop. This facilitates identification of any possible aberrant or replaced right hepatic artery, which typically arises from the SMA close to its origin.

The aortic bifurcation and common iliac arteries are dissected and exposed. The distal aorta just proximal to the bifurcation is dissected circumferentially, and two loose ties/vascular snuggers are passed around it (Fig. 1.4). The proximal tie will be used to secure the aortic cannula in place, whilst the distal one will prevent any iliac back-bleeding. An assessment of the distal aorta and common iliac arteries should be undertaken prior to this, and, if a lower polar renal artery arises from the common iliac artery, the contralateral

Figure 1.4

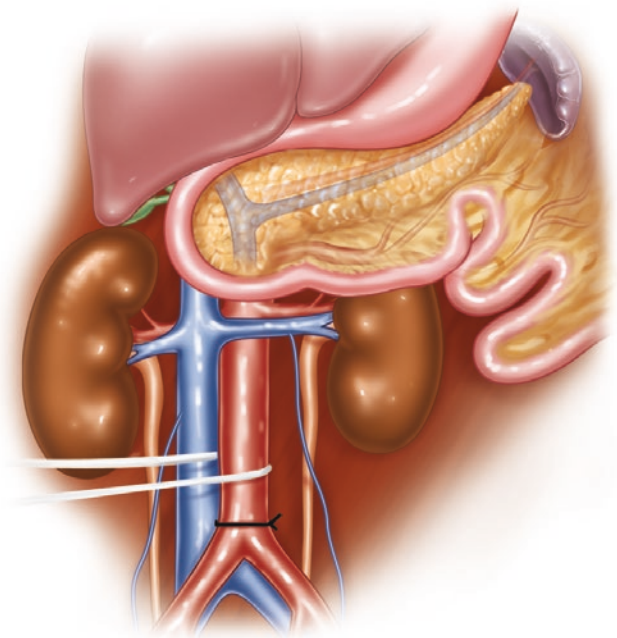
The distal aorta just proximal to the bifurcation is dissected circumferentially, and two loose ties/vascular snuggers are passed around it

common iliac artery is prepared for cannulation to preserve the aberrant renal vessel.

1.2.1.3 Dissection of Hepatoduodenal Ligament Structures

The next step is clarification of the vascular anatomy of the liver. Careful appraisal and palpation of the hepatoduodenal ligament and lesser omentum are required to ascertain the presence of any aberrant or replaced vasculature and must be performed prior to commencing dissection. Dissection takes place above the upper border of the duodenum from lateral to medial in order to minimize the risk of vascular injury. The anterior peritoneum and the small venous tributaries of the hepatoduodenal ligament are divided, and the distal common bile duct is encircled and transected, exposing the portal vein (Fig. 1.5). The gallbladder is opened and the extrahepatic biliary tree is flushed with saline. The hepatic artery proper is approached on the anteromedial side of the hepatoduodenal ligament, and dissection is continued proximally, identifying the origin of the gastroduodenal artery (GDA) from the common hepatic artery (CHA). The GDA is dissected toward but not into the pancreas and can be placed on a sling for easier identification. The course of the CHA is then dissected toward the celiac trunk, taking

Figure 1.4



care not to encroach on the superior border of the pancreas, until the origin of the splenic artery is encountered. This should be slooped and prepared over a 0.5 cm length without injuring the pancreas (Fig. 1.6).

1.2.1.4 Preparation for Pancreatic Retrieval

The previously opened gastrocolic ligament is further divided close to the greater curvature of the stomach, controlling the gastroepiploic vessels. The gastric antrum is

Figure 1.5

The anterior peritoneum and small venous tributaries of the hepatoduodenal ligament are divided, and the distal common bile duct is encircled and transected, exposing the portal vein

Figure 1.6

The course of the CHA is then dissected toward the celiac trunk, taking care not to encroach on the superior border of the pancreas, until the origin of the splenic artery is encountered. This should be slooped and prepared over a 0.5 cm length without injuring the pancreas

then identified and slooped. Similarly, the proximal jejunum is located and a window made in the adjacent mesentery, allowing the bowel to be slooped. These sites mark the proximal and distal extent of gastrointestinal division to allow the pancreas to be retrieved en bloc with the liver (Fig. 1.7).

Figure 1.5

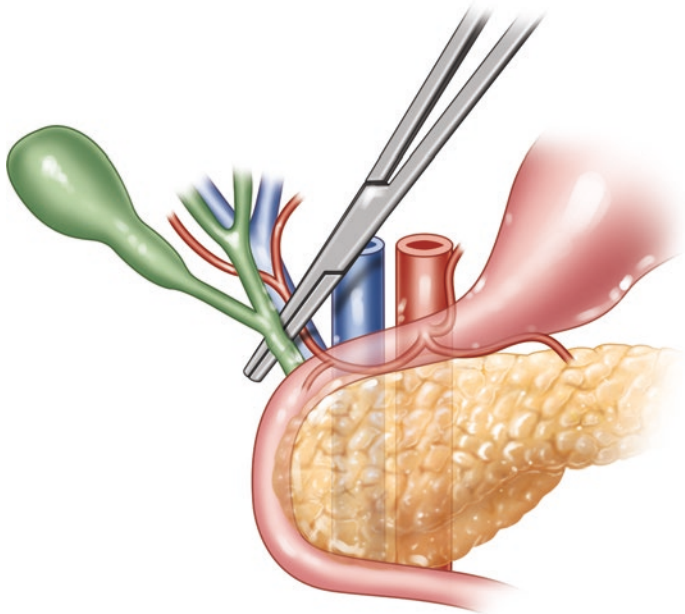
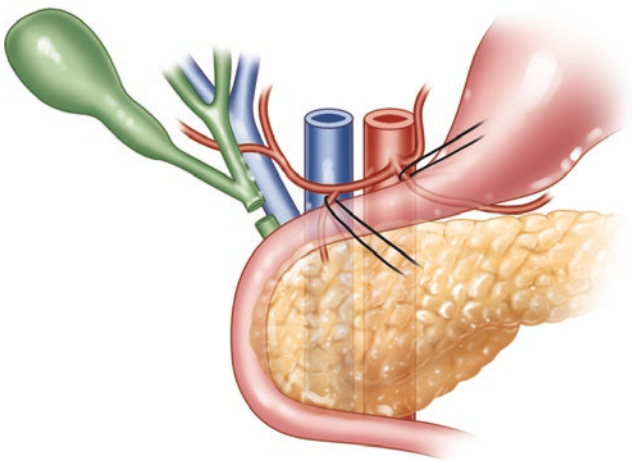


Figure 1.6



1.2.1.5 Preparation for Aortic Cross-Clamping

To ensure adequate perfusion of abdominal organs, proximal aortic occlusion is required. Although the authors favor a supraceliac location for aortic cross-clamping, the distal thoracic aorta is an alternative site. After gentle retraction of the left lateral segment, the diaphragmatic pillars are carefully separated in the midline over the aorta, and space is created on either side of the aorta until the index and middle fingers can be placed astride the aorta and the body of the 12th thoracic vertebra can be

Figure 1.7

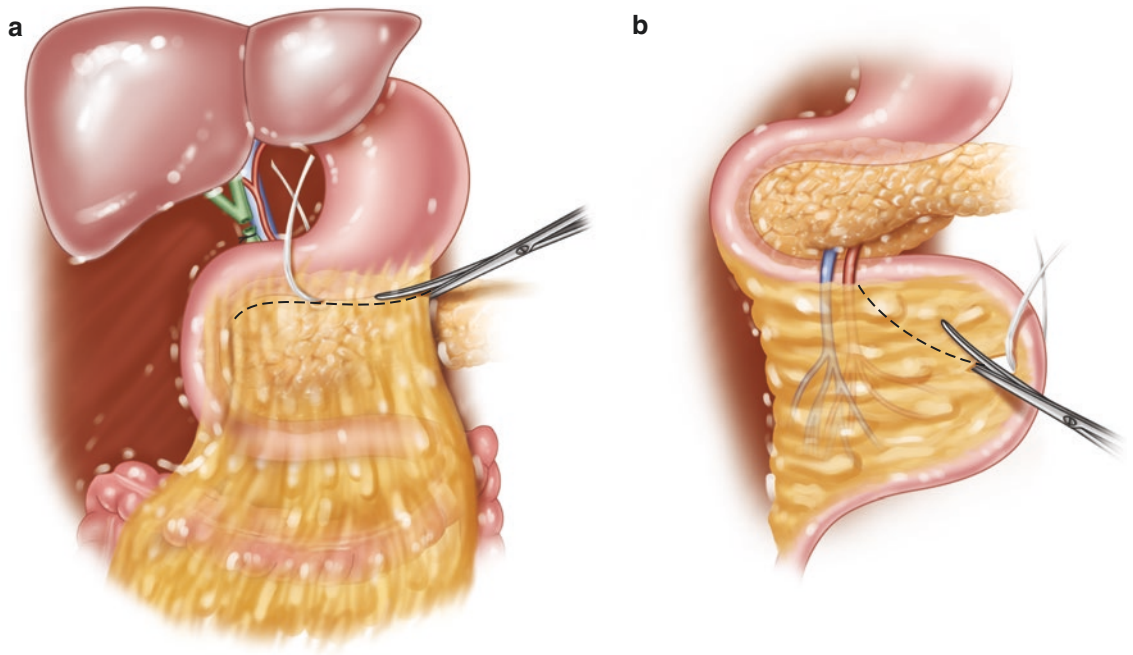
The pylorus is slooped (Fig. 1.7a), and the proximal jejunum is located, and a window is made in the adjacent mesentery, allowing the bowel to be slooped (Fig. 1.7b). These sites mark the proximal and distal extent of the gastrointestinal division to allow the pancreas to be retrieved en bloc with the liver

palpated. This will allow satisfactory placement of the aortic cross-clamp without circumferential aortic dissection, which could injure a lumbar vessel and lead to significant hemorrhage.

1.2.1.6 Aortic Cannulation and Organ Perfusion

Following systemic heparinization with 300 IU/kg for 5 min, the previously prepared distal aorta is ligated, and the corresponding proximal segment is prepared for cannulation. Complete agreement between the surgeon and assistant about

Figure 1.7



their respective roles prior to this maneuver is critical for safe insertion and securing of the cannula. The tie is held upward by the assistant, and the proximal aorta is occluded between the thumb and forefinger of the left hand (Fig. 1.8a). The anterior wall of the aorta is opened, and a check is made to ensure that the lumen is correctly identified, particularly when the aorta is atheromatous. A primed cannula, typically size 22 Ch/Fr or 24 Ch/Fr, is inserted for 2–3 cm, with care taken not to advance it past the origin of the renal arteries (Fig. 1.8b). The assistant then secures the tie firmly to the aorta just proximal to the arteriotomy and subsequently secures the ends of the tie several times around the cannula to prevent displacement.

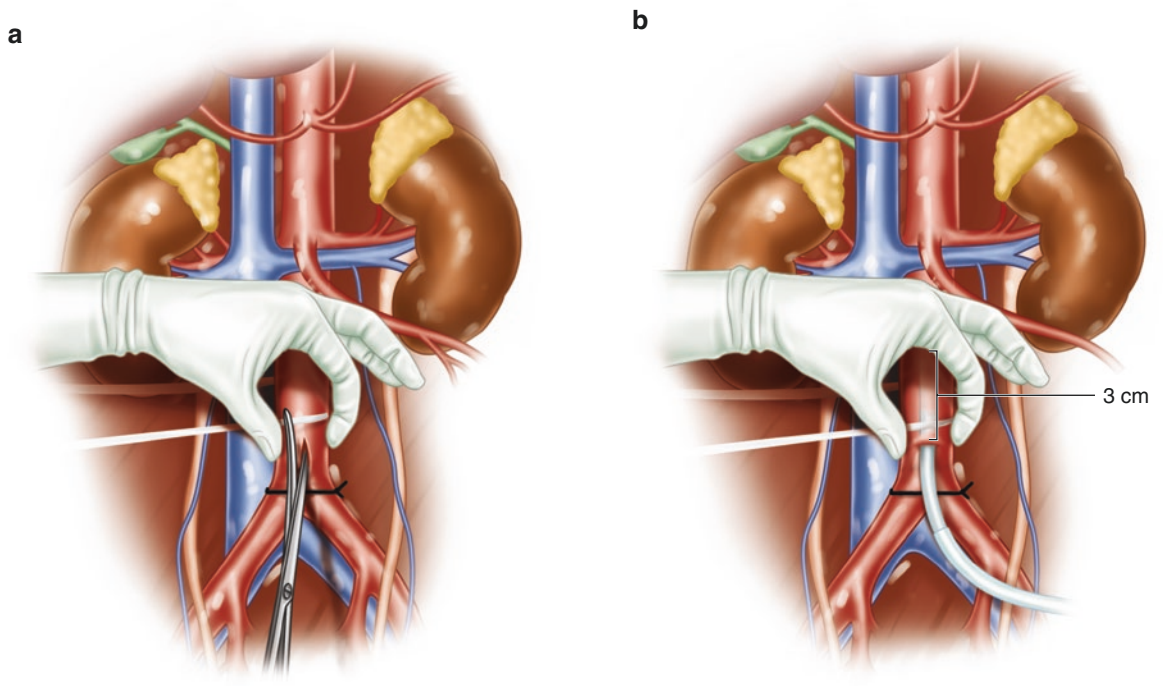
The abdominal contents are returned to their anatomical position, and the vascular sloops around the GDA and the

Figure 1.8

The tie is held upward by the assistant, and the proximal aorta is occluded between the thumb and forefinger of the left hand

splenic artery are slackened before the left lateral section of the liver is retracted and the previously prepared supraceliac aorta is cross-clamped. Attention is then turned to the right side of the heart and the IVC is incised for venting. Perfusion is then commenced immediately. In order to generate an appropriate length of suprahepatic cava with the liver for implantation, the assistant gently draws the liver downward so that the cavoatrial junction is clearly visualized before any incision is made. Suction is applied to evacuate the right side of the chest, and copious slush ice is applied to the liver, including above the diaphragm, around the kidneys, and the lesser sac and root of the mesentery (Fig. 1.9). Throughout the perfusion phase, ongoing dialogue between the surgeon and the perfusionist should take place to ensure that perfusion is running at the appropriate rate. The organs and caval outflow are continually inspected for adequacy of perfusion.

Figure 1.8



1.2.2 Cold Phase Dissection

1.2.2.1 Removal of the En Bloc Liver-Pancreas

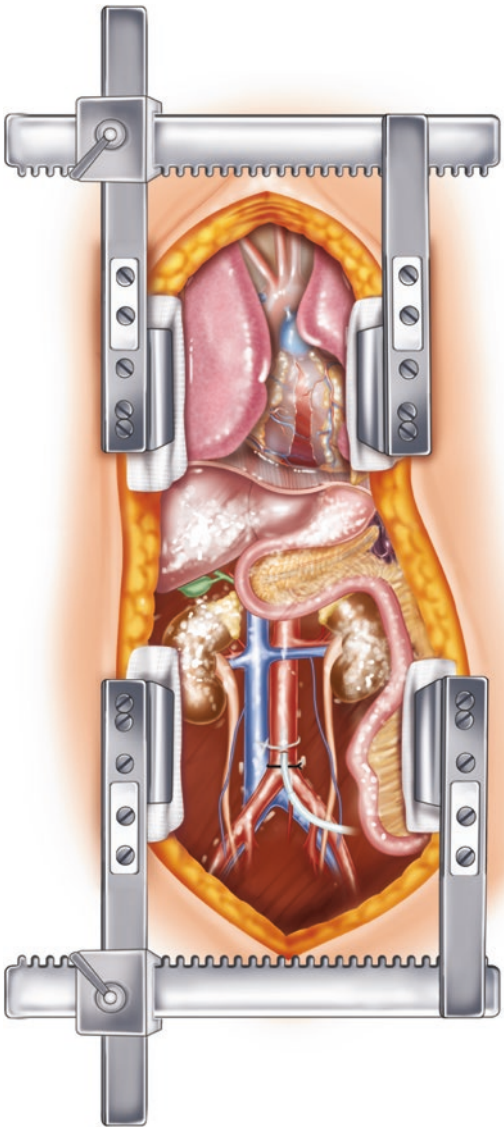
The gastric antrum and proximal jejunum are divided using a linear cutting stapler at the previously prepared sites (Fig. 1.7), and the greater and lesser curvatures of the stomach are fully mobilized, allowing the stomach to be rotated into the left side of the chest. Division of the gastrocolic ligament is extended to fully mobilize the hepatic and splenic flexures, drawing the transverse colon inferiorly and

Figure 1.9

Suction is applied to evacuate the right side of the chest, and copious slush ice is applied to the liver, including above the diaphragm, around the kidneys, and the lesser sac and root of the mesentery

completely opening the lesser sac, thereby exposing the pancreas. The root of the small bowel mesentery is divided using a linear cutting stapler, taking care not to encroach on the inferior border of the pancreas or uncinate process (Fig. 1.10). This division allows the colon and attached small bowel to be displaced in the left lower quadrant, exposing the retroperitoneal structures.

Figure 1.9



The anterior surface of the IVC is dissected, identifying the origin of the left and right renal veins. The vena cava immediately superior to the origins of the renal veins is transected. The left renal vein is divided at its confluence with the vena cava, dissected, and retracted to the left of the aorta (Fig. 1.11). The aortic cannula is removed, and the anterior wall of the aorta is opened in the midline, protecting the divided left renal vein. The incision is extended to the

Figure 1.10

The root of the small bowel mesentery is divided using a linear cutting stapler, taking care not to encroach on the inferior border of the pancreas or uncinate process. This division allows the colon and attached small bowel to be displaced in the left lower quadrant, exposing the retroperitoneal structures

Figure 1.11

The anterior surface of the IVC is dissected, identifying the origin of the left and right renal veins. The vena cava immediately superior to the origins of the renal veins is transected, and the left renal vein is divided at its confluence with the vena cava and retracted to the left of the aorta

level of the SMA, where the incision should be made obliquely (posterosuperiorly) to create the distal part of the future aortic patch, which will contain the SMA and the celiac trunk (Fig. 1.12).

The lienorenal ligament is divided and the spleen gently grasped and retracted anteromedially, exposing the retropancreatic tissue behind the pancreatic tail. Using the spleen as a handle to guide pancreatic mobilization, dissection is continued until the left lateral wall of the aorta is encountered and the inferior part of the aortic patch created earlier is seen (Fig. 1.13). During this dissection, great care should be taken to divide the tissue immediately superior and inferior to the

Figure 1.10

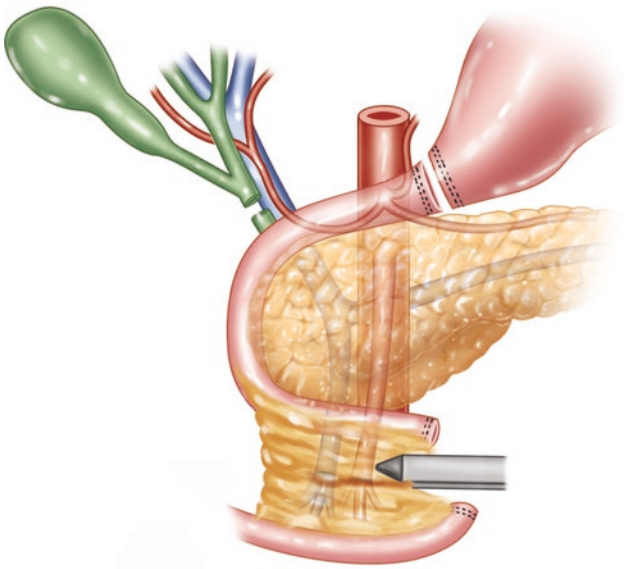
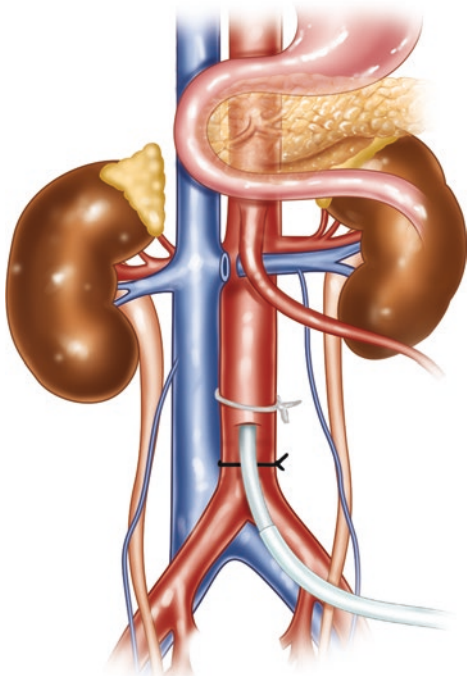


Figure 1.11



border of the pancreas no less than 1 cm from the pancreatic capsule to prevent any organ injury. At the level of the distal aortic patch, the retroaortic tissue is dissected superiorly, creating an aortic tube. The proximal part of the aortic patch is fashioned by dividing the left hemidiaphragm onto the proximal aorta at the level of the aortic clamp. The clamp is then removed, and the proximal aorta is divided to complete the aortic tube containing the SMA and celiac trunk.

Figure 1.12

The aortic cannula is removed, and the anterior wall of the aorta is opened in the midline, protecting the divided left renal vein. The incision is extended to the level of the SMA, where it should be made obliquely (posterosuperiorly) to create the distal part of the future aortic patch, which will contain the SMA and celiac trunk