Anatomy and Surgical Procedures for Renal and Pancreas Transplantations

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Vikas Satyananda and Amit D. Tevar

Renal Transplantation

Introduction

The first renal transplant performed in the USA was performed at the Little Company of Mary Hospital in Evergreen Park, IL, on June 17, 1950. As no immunosuppressive agents were used, the graft subsequently failed 10 months later. Several other attempts at renal transplant were an operative success, but met with graft failure due to the lack of immunosuppression [1]. The first successful human renal transplant with long-term function was performed by Murray in 1954 between identical twins [2]. Understanding of immunosuppression and the use of immunosuppressive agents radically changed the field following Murray's 1962 renal transplant with azathioprine, which was the first nonidentical patient with long-term success [3].

The field has undergone major advancement in organ selection, organ preservation, organ allocation, patient selection, and short- and long-term immunosuppressive management. In 2012 in the USA the deceased donor graft failure rate was 1.8 % at 6 months and 2.7 % at 1 year. Currently there are 96,000 patients awaiting renal transplant in the USA, with 16,526 living and deceased donor transplants performed in the USA in 2012 [4]. Despite the massive strides the field has taken, the procedure of renal allograft implantation remains relatively unchanged for the past 40 years [5].

V. Satyananda, M.D. • A.D. Tevar, M.D. (✉)
Thomas E. Starzl Transplantation Institute, University of Pittsburgh Medical Center, E1540 Biomedical Science Tower (BST), 200 Lothrop Street, Pittsburgh, PA 15261, USA
e-mail: tevara@upmc.edu

Anatomy

Several different types of renal transplant allografts are procured for transplantation in the adult patient. These include pediatric en bloc, cadaveric donor, and live donor. Each graft has its own anatomical considerations in the implantation process.

The human kidneys lie in the retroperitoneal space between T12 and L3 with their long axis parallel to the body. The kidneys themselves are encased in perinephric fat, which may differ in quantity reflecting the body mass index and sex. Each kidney is ovoid in shape with an indented medial border that gives rise to the renal pelvis and renal hilum resulting in a bean-shaped appearance. There is no significant difference in size of the right versus left kidney and patient height, width, or weight does not predict size of the graft.

The kidney is covered by a fibrous renal capsule with fibroareolar tissue called the renal fascia. Surrounding this is the perinephric fat. The kidney itself lies on the psoas muscle on both the right and left side. The right kidney abuts superiorly the R lobe of the liver. The duodenum will cross the hilum and the right colon hepatic flexure will often abut the medial border of the inferior pole of the right kidney. The left kidney will have abutting the hilum, the anterior border of the stomach, spleen, pancreas, and splenic flexure of the colon.

The arterial supply of each kidney arises directly from the aorta between L1 and L2. The right renal artery is usually longer as it passes underneath the inferior vena cava. The left renal artery arises slightly lower on the aorta. The renal artery usually divides close to the hilum into five segmental arteries. The venous outflow from each kidney is also very different. Renal veins are direct outflow to the systemic system. The right kidney most commonly has a very short renal vein as it sits adjacent to the inferior vena cava. The left renal vein most commonly passes anterior to the aorta as it drains to the inferior vena cava and drains serve as

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a tributary for the adrenal vein (superior edge), gonadal vein (inferior edge), and lumbar vein (posteriorly). The left renal vein is most commonly longer in length, in comparison to the right, and is most commonly the preferred organ for procurement, as the transplantation and anastomosis of the renal vein can potentially be technically easier with a significantly longer vein.

Arising from the hilum on both kidneys is a single ureter, which is a thick-walled, muscular duct which carries urine from the renal pelvis to the posterior bladder. Each ureter is approximately 13 cm long and 5 mm wide, with a muscular layer, which has frequent peristalsis. The course of each ureter is generally the anterior surface of the psoas muscle and crossing the external iliac artery. The arterial supply to the ureter comes from the renal artery and gonadal artery proximally. Preservation of this proximal blood supply remains crucial as the medial and distal arterial supplies will be divided with procurement of the kidney.

Procurement from the cadaveric donor will be described in detail elsewhere in the text. Briefly after organs are flushed with a preservation fluid through a cannula placed in the distal aorta, with a vascular clamp placed at the level of the supraceliac aorta. The fluid is vented through an incision in the distal vena cava or the right heart, until all of the abdominal organs are completely evacuated of blood. After this is completed, the kidneys are generally the last of the solid organs to be removed after the liver and pancreas. The kidneys are most commonly removed en bloc with the segment of aorta and vena cava with ureters cut well beyond the level of the external iliac artery. Once removed from the body the kidneys are separated on the back table. Adrenal glands or partially cut adrenal glands are excised with each kidney. The right kidney vasculature is excised from the en bloc configuration with a renal artery with aortic cuff and renal vein and entire segment of vena cava. This segment of vena cava can later be fashioned to extend the renal vein if needed either with a hand-sewn technique or with a stapled technique. The left kidney on the other hand will include the renal artery with aortic cuff and no vena cava on the renal vein. The procured organ from a laparoscopic or open live donor is different in that the renal veins and renal arteries do not contain cuffs of vena cava or aorta and the adrenal gland is most commonly completely preserved in the donor and not taken with organ. Ureter length in the live donor is often less.

Preoperative Considerations

As the wait time for cadaveric renal transplantation can often extend to 3–7 years depending on blood grouping, antibodies, age, and region, patients' cardiac and perioperative risk factors can dramatically change from their initial listing evaluation. This does require close scrutiny by all members of the transplant team including surgery, medicine, and anesthesia immediately upon the patient's arrival to the hospital. The University of Pittsburgh KP team has a separate Waitlist Clinic to monitor patients on the waitlist and performs yearly cardiac testing to optimize perioperative risk. Frequency of testing and waitlist clinic visits is dictated by patient's age, medical complexity, and functional status. Transplant program's waitlist management varies by center.

The UNOS criteria for listing for a cadaveric renal transplant specify that the patient has eGFR of <20 ml/min. As a result, a patient may or may not have initiated dialysis, which results in a wide range of functional volume and electrolyte status for these patients. ESRD patient undergoing hemodialysis often have this on an alternating day schedule and cadaveric renal transplants performed on Mondays may have patients that have not undergone hemodialysis since the previous Friday. In addition to preoperative testing, rapid assessment of the patient's volume status, electrolytes, and need for preoperative dialysis must be done immediately upon the patient's arrival to the hospital to ensure that preoperative hemodialysis does not impact the cold ischemic time of the organ.

End-stage renal disease patients have a variety of hemodialysis options and entry points including by way of tunneled hemodialysis catheter, arteriovenous fistula creation, and arteriovenous graft insertion in upper or lower extremities. As it is commonplace, many patients will have multiple fistulas, previous catheters, and central venous stenosis. As all patients will undergo central venous and arterial line placement prior to surgery, it is important that all team members obtain a detailed history and physical examination of all functional and nonfunctional access.

Anesthesia Considerations

After determining adequacy of perioperative testing and dialysis, the patient may be brought back to the operative room for general endotracheal intubation and central venous line placement and arterial line placement. The CVL should be placed using a modified Seldinger technique, with the use of ultrasound guidance. Again, prior to this thorough investigation must be performed of previous catheters, prior imaging demonstrating central venous stenosis, evidence of failed AVF or AVGs, and evidence of central venous varices in the superficial chest and neck. If the guide wire does not easily pass into the right atrium, consider injection of a small amount of dilute contrast under direct fluoroscopy to identify central venous stricture or thrombosis.

Arterial line is usually placed in the wrist or upper arm. Avoid using the ulnar artery in a wrist with a functioning or nonfunctioning radiocephalic fistula as this may represent the only arterial supply to the hand.

Bench Preparation of Renal Allograft

The back table preparation of the renal graft is done prior to skin incision or after start of the case based on staff, graft, and OR availability. The process involves dissecting fat around the renal capsule and mobilization of the renal artery and vein. In addition the ureter is identified and great care is taken to avoid devascularization by minimal dissection and avoidance of dissection of the lower pole of the kidney and the ureter. In preparation for the anastomosis of the renal artery and vein, the renal vein is carefully examined. In the case of the right donor kidney, with a known shorter vein, several options exist to allow for a safe and tension-free anastomosis to the external iliac vein. One option exists of mobilizing the external vein completely and in some cases dividing the internal iliac vein to allow for a tension-free anastomosis. The second involves extending the renal vein by creating a vena caval conduit by oversewing both ends of the cadaveric vena cava after it has been divided above and below the insertion point of the right renal vein. The opposite side of the vena cava can then be opened for anastomosis.

Renal Transplant Operation

The operation begins after appropriate general endotracheal anesthesia, central venous line placement, and invasive arterial line placement, described previously. Prior to skin incision of vital importance is the operative timeout with identification of the patient, procedure, cadaveric, or live donor organ with laterality and UNOS ID number.

As the heterotopic transplant is performed in the retroperitoneum, the skin incision is curvilinear and extends from 2 cm above the pubis symphysis to a point 2 cm medial to the anterior superior iliac spine. In the event that a simultaneous renal and pancreas transplant is being performed or the patient has previous transplant in both the right and left iliac fossae, a lower midline incision can be used. Surgeons usually prefer the right iliac fossa as the artery and vein are more superficial there. The layers of the abdominal wall are opened in sequence to expose the retroperitoneal space and avoid violation of the peritoneum. This begins with division of the subcutaneous tissue, Scarpa's fascia, external oblique aponeurosis, internal oblique muscle, and transversals fascia. The epigastric artery and veins are identified during the exposure and are initially preserved for possible inflow to a lower pole accessory vessel. If there is no lower pole vessel or the artery is calcified, they can be ligated and divided without consequence. The spermatic cord is also identified and preserved. In rare instances it may be ligated and divided as it impedes with the operation; this is the exception rather than the rule. In female patients the round ligament is ligated and divided.

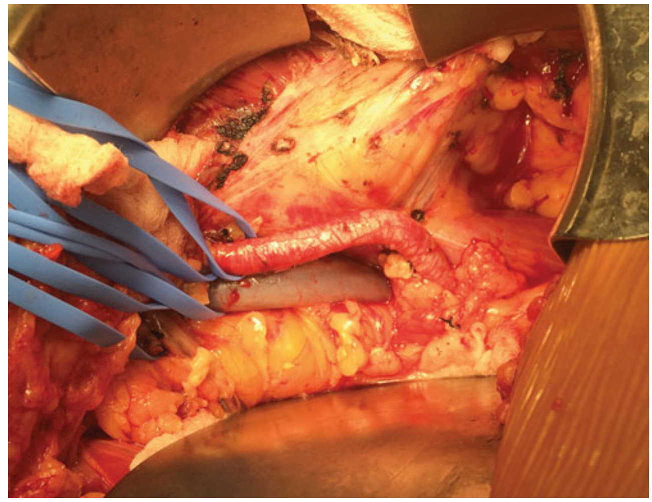

Fig. 21.1 Exposure of the vessels for renal transplantation in the right iliac fossa. Visualized is the external iliac artery and external iliac vein

At this time a retractor system based on surgical preference or availability is put into place. Dissection is then performed of the external iliac artery and vein circumferentially with ligation of any lymphatic structure as to avoid lymphocele formation post-transplantation (Fig. 21.1). Depending on the level of arterial disease or donor graft anatomy the dissection of the iliac artery can be taken proximally to the level of the common iliac artery. The venous dissection can also be taken to the distal vena cava if needed.

It should be noted that the renal graft should be kept cool from the time of cross clamp of the arterial inflow in the donor to reperfusion in the recipient. The kidney is packaged in iced preservation fluid during transport and should be maintained in a similar cool solution during the benching process. Throughout the time of the vascular anastomosis the kidney is packed in ice and wrapped in a cool laparotomy sponge.

Prior to initiation of the vascular anastomosis and reperfusion induction agents should have been started and the patient must be hemodynamically stable. Systemic heparin is usually given to patient approximately 3 min prior to the clamping of the iliac artery and vein. The surgeon then proceeds with complete vascular clamping of the external iliac artery and vein. The venous anastomosis is usually completed first. A venotomy is fashioned with an #11 blade and then extended using Potts scissors. The graft renal vein to recipient external iliac vein anastomosis is then completed in a running fashion with 5-0 or 6-0 synthetic, permanent, monofilament suture (Prolene). Care is taken to avoid purse string narrowing of the anastomosis and/or back wall narrowing. If a graft extension is required and no donor vena cava is attached (as is the case with all L kidneys), stored cadaveric vein can be used. Synthetic graft is not recommended due to the very high thrombosis rate.

Next the arterial anastomosis is performed. This is done after vascular clamps are placed on the proximal and distal external iliac artery. After a small arteriotomy is made, it is extended using Potts scissors or a 4 or 6 mm cardiac punch. The anastomosis is done in a running or an interrupted fashion with 5-0 or 6-0 synthetic, permanent, monofilament suture (Prolene). Several options exist with multiple arteries including separate implants on the external iliac artery, creating a common patch prior to implantation.

The time for completion of the arterial and venous anastomosis is approximately 30–50 min depending on the complexity on the anastomosis. Prior to vascular clamp removal and reperfusion of the graft, the patient is usually given a diuretic (Lasix and/or mannitol) and assessment of appropriate volume status and systolic blood pressure. Clamps are then carefully removed, venous followed by arterial. The renal graft then will quickly regain turgor and a pink color. Deliberate and quick assessment of the renal anastomoses and hilum is undertaken to assess and repair suture line or hilar open vessel bleeding and investigate for thrombosis. This is the most likely time that surgeons will encounter brisk bleeding. In the event that there is thrombosis or uncontrollable bleeding, the option of reclamping the vessels and removing the graft and flushing on the back table does exist.

After the kidney has demonstrated good perfusion, hemostasis has been maintained, and the patient is hemodynamically stable, attention can be focused on the ureter-to-bladder anastomosis. Prior to skin incision a three-way catheter is inserted into the bladder. At this point in time, the Foley catheter tubing to the urine collection bag is clamped and the bladder is distended with antibiotic irrigation until distended adequately. Keep in mind that patients will have different volume of complete bladder distention depending on the amount of urine that they make. Over-distention can result in an extra- or intraperitoneal bladder rupture. The peritoneum is then reflected away from the bladder, and the serosal and detrusor are then divided for a length of 3 cm. The bladder is then entered with an #11 blade or Potts scissors and for 2 cm. The irrigation is aspirated and the Foley catheter clamp removed (Fig. 21.2). The ureter is cut to the appropriate length and the spatulated to match the bladder incision length. The ureter is then anastomosed to the bladder mucosa with 6-0 absorbable suture (Fig. 21.3). A 6 Fr × 12 cm double J closed-tip stent may be placed in the ureter to the pelvis and bladder prior to completion of the anastomosis. The detrusor is gently re-approximated over the anastomosis with interrupted 4-0 absorbable monofilament, with great care taken to avoid compressing the anastomosis.

At this time thorough inspection of the operative field is undertaken to ensure hemostasis and appropriate positioning of the renal graft to avoid tension, torsion, or pressure on the renal artery or vein. A drain may be left if desired. The external oblique and anterior rectus sheath fascia is then closed in a running fashion. Subcutaneous layer is closed with absorbable suture and the skin with clips.

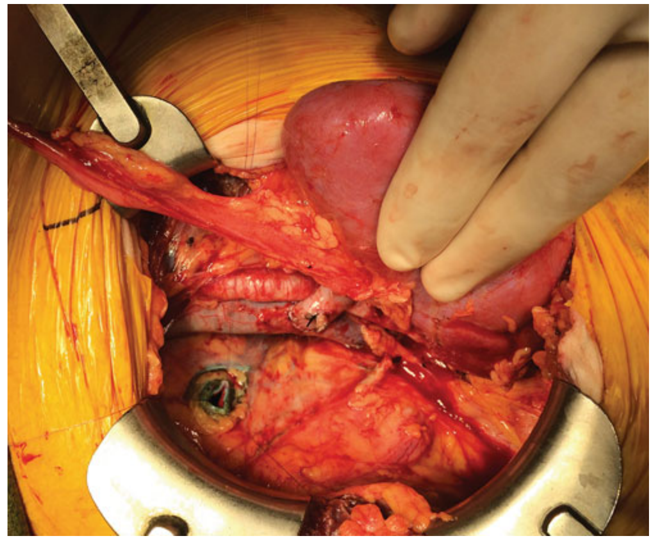

Fig. 21.2 Reperfused renal allograft with visualization of the venous anastomosis. The bladder has been opened in preparation for ureteral implantation

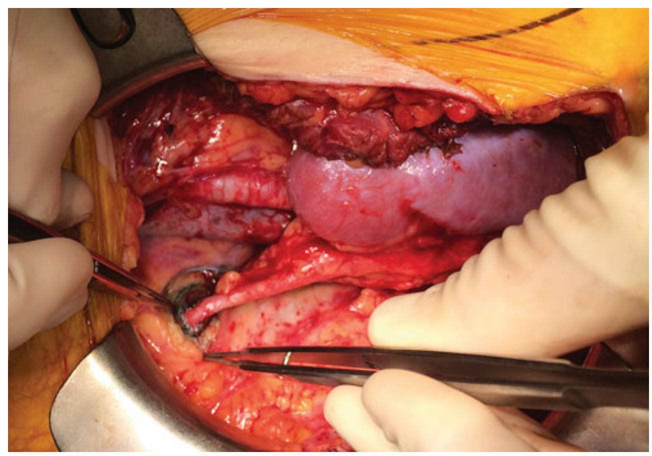

Fig. 21.3 Reperfused renal allograft with completed ureteral anastomosis

Pancreas Transplantation

The cadaveric whole-organ pancreas transplant is done as a simultaneous pancreas and kidney transplant, pancreas after kidney transplant (pancreas after previous successful cadaveric or LD renal transplant), or pancreas transplant alone. The transplant is done most commonly through a midline incision. The first successful whole-organ pancreas transplant was performed at the University of Minnesota on December 16, 1966, by William Kelly and Richard Lillehei [6].

Fig. 21.4 Cadaveric pancreas allograft prior to bench preparation. The staple lines are noted at the borders of the duodenum and the mesentery

Fig. 21.5 Cadaveric pancreas allograft with bench preparation completed. The vascular clamps are on the portal vein. The ends of the duodenum are oversewn and the extension Y-graft has been fashioned to the splenic artery and superior mesenteric artery. The spleen has also been removed and the splenic vessels have been suture ligated

The benching of the cadaveric pancreas graft remains one of the most crucial aspects of the transplant. The organ is inspected thoroughly for evidence of trauma, fatty infiltration, or fibrosis. If any of these are found the graft should be discarded. The graft generally comes with duodenum and spleen attached (Fig. 21.4).

The spleen is first carefully dissected off the tail of the pancreas and splenic artery and vein and branches are ligated. Next the proximal and distal duodenal cuff staple lines are inverted with interrupted permanent suture. The root of the mesentery is oversewn with permanent suture in a running locking fashion. Next the superior mesenteric artery (SMA) and splenic artery are then prepped for anastomosis. A Y-graft is then made from the donor common, external, and internal artery. The external and internal iliac arteries of the Y-graft are then anastomosed in an end-to-end fashion with the splenic artery and SMA, respectively. This allows for a single-inflow connection to perfuse the entire pancreas and duodenum. The graft is then tested with iced heparinized preservation fluid and any small venous or arterial branches are ligated (Fig. 21.5). The pancreas is now ready for implantation.

After appropriate prep and drape, the operation is started with a long midline incision. This is taken through to the fascia and carefully into the peritoneal cavity. Implantation of the kidney in the SPK is performed first if there is minimal cold ischemic time to be placed on the pancreas. The sigmoid colon is mobilized and exposure of the common iliac vein and artery is performed. The renal graft is then anastomosed to the L common iliac artery and vein as described above with permanent monofilament. The ureter is then anastomosed to the bladder in a fashion similar to the isolated renal transplant.

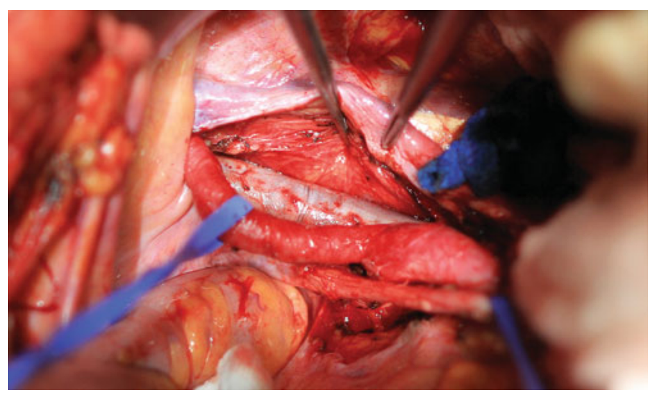

Fig. 21.6 Visualization of the right common and external iliac vein prior to ligation of the internal iliac vein and lateralization

The implantation of the pancreas starts with mobilization of the cecum and the right colon. The distal vena cava and the right common and external iliac vein are identified and dissected free of surrounding tissue (Fig. 21.6). The right internal iliac vein is often ligated and divided to allow for further mobility of the right common and external iliac

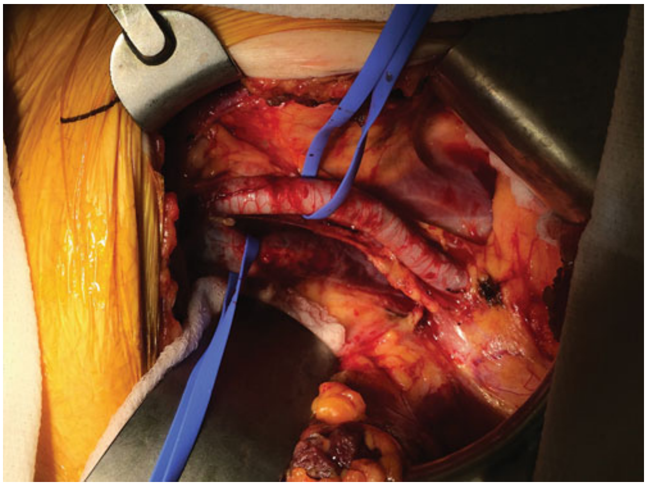

Fig. 21.7 Preparation and lateralization of the right common iliac and right external iliac vein after ligation of all branches of the right internal iliac vein

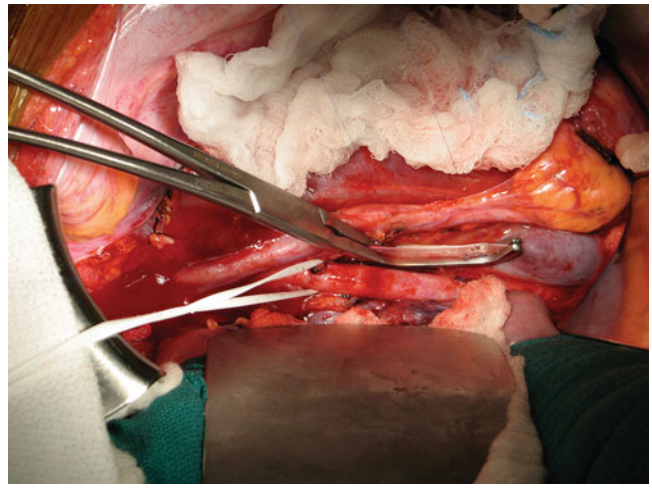

Fig. 21.8 Venous clamping with a partial occlusion clamp of the common iliac vein with 6-0 Prolene proximal and distal corner sutures in place in preparation of the portal vein to common iliac vein anastomosis

vein (Fig. 21.7). The distal iliac artery is then dissected. The preferred site of implantation of the pancreas is the graft portal vein to external iliac vein or to distal vena cava and graft Y-conduit to common or external iliac artery. Clamps are placed proximal and distal to the implantation site and most commonly the venous anastomosis is completed first with 6-0 permanent monofilament (Fig. 21.8). In the event of use of the distal vena cava a partial occlusion vascular clamp is placed to allow for adequate venous return. The arterial clamps are then placed and arteriotomy is fashioned and the Y-graft is anastomosed to the R common iliac artery with running 6-0 monofilament permanent suture. Clamps are then removed, arterial after venous. Careful inspection of the anastomoses and the entirety of the pancreas are then undertaken. Suture line bleeding and body and tail bleeder are suture ligated. This portion of the case in general results in the most bleeding if there is going to be any.

The exocrine secretions of the graft are then drained by connection of the graft duodenum to the small bowel of the recipient. The bowel anastomosis can be performed in a hand-sewn fashion or with a stapler. With a hand-sewn technique, a two-layer anastomosis is done, using a nonabsorbable suture for the outer layer and an absorbable suture for the inner layer. Both layers can be performed with a simple running suture technique.

After meticulous inspection for hemostasis as the patient will likely be started on anticoagulation, drains are placed alongside the pancreas and kidney. Fascia is then approximated with running suture. Skin is closed with staples.

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