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ORIGINAL ARTICLE

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Standardized quick en bloc technique for procurement of cadaveric liver grafts for pediatric liver transplantation

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Abstract This paper describes a quick procedure for cadaveric liver graft retrieval during multiple organ harvesting. The technique is based on minimal preliminary dissection, absence of in situ direct portal perfusion, and en bloc removal of the liver and pancreas, with an aortic patch encompassing the coeliac trunk and superior mesenteric artery. The results of 110 pediatric liver transplantations with 109 organs harvested using this technique are reported. There were no graft harvesting injuries. The liver graft primary nonfunction rate was 4.5 % (5/110). The 3-month retransplantation rate was 10 %. The actual patient survival rates were 93 % at 3 months and 90 % at 1 year; actual graft survival rates were 85.5 % and 78 %, respectively. The technique described was at least as safe as conventional procedures. A major advantage of the procedure is its flexibility, which allows for the easily combined procurement of other organs (whole pancreas and intestine).

Key words Liver, procurement · Procurement, liver · Pediatric liver transplantation, en bloc procurement · En bloc procurement, pediatric liver transplantation

Introduction

The rapidly increasing number of various organ transplantations has led to the development of multiple organ harvesting. Procurement techniques have evolved [7, 8, 12, 14, 16] that allow for the safe removal of each graft. Although the en bloc procurement technique has already been proposed [7, 8, 12], numerous teams currently continue to do extensive dissection before organ perfusion and even during organ removal. Like others, we advocate a quick, en bloc technique that facilitates procurement. A standardized, new, simple, and safe method for liver graft retrieval was designed that has the additional advantage of great flexibility for combined en bloc organ removal.

Materials and methods

To assess the efficacy of a new, quick en bloc (QEB) technique, we retrospectively reviewed our data in pediatric liver transplantation. One hundred and nine liver grafts were procured by our team using the QEB technique. One liver graft was split between two children, thus allowing us to perform 110 transplantations. Donor and recipient charts were analyzed. The following parameters were looked for in the donor: age, weight, length of intensive care unit (ICU) stay, cause of brain death, episodes of donor cardiac arrest, procurement of other organs, arterial graft anatomy, and organ harvesting injuries. Recipient data consisted of: types of graft (full-size, reduced, or split), ischemic time, ABO compatibility, age, weight, pretransplant clinical condition [elective, urgent (hospital-bound), or highly urgent (ICU-bound)], and indication for liver transplantation. Postoperative morbidity, causes of graft loss, and patient death were reviewed. Primary graft nonfunction was defined as absence of hepatic function (PT < 20 %, no bile production, hyperlactacidemia, dependence on glucose intake) with progressive encephalopathy and progressive multiple organ failure. Initial poor function was defined as minimal hepatic function (PT < 20 %, minimal bile production, slowly decreasing hyperlactacidemia) but absence of progressive encephalopathy and of or-

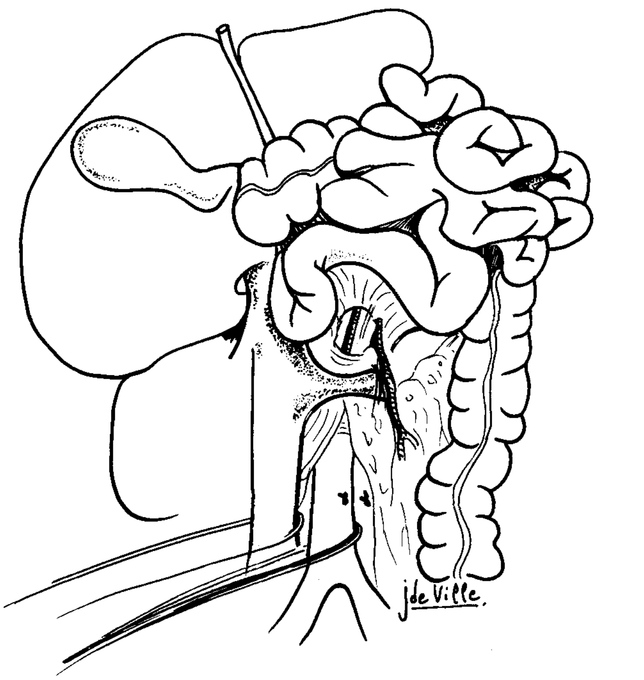


Fig. 1 Right colon and duodenum are reflected cranially and to the left. After identification of the superior mesenteric artery, abdominal aorta and inferior vena cava are dissected

gan failure. Overall, the actual graft and patient survival rates were calculated at 3 months ($n = 110$ and 98) and 1 year ($n = 101$ and 90), respectively. Numerical values were expressed as mean ± SEM.

QEB Graft procurement technique

Retrieval

After making a midline incision from the suprasternal notch to the pubis, the line of Toldt is incised and the entire right colon is reflected to the midline. Duodenum and bowel are mobilized using the Kocher maneuver and completed by dividing the peritoneal root of the mesentery from the iliac fossa to the ligament of Treitz. The distal abdominal aorta and the abdominal inferior vena cava (IVC) are dissected just above their bifurcation for later cannulation. Cranial reflection of the distal duodenum allows the surgeon to identify the left renal vein and the superior mesenteric artery (SMA). Dissection of this latter vessel is limited to its caudal and left part in order to avoid any trauma to a possible right hepatic artery (Fig. 1). After identification of a possible accessory left hepatic artery, the infradiaphragmatic aorta is identified and encircled. The fundus of the gallbladder is opened and the bile is flushed out with saline. When the other harvesting teams are ready, heparin is given and the aortic and caval cannulae are inserted. The latter cannula allows exsanguination by gravity when the cardiac team clamps the intrapericardic IVC. The infradiaphragmatic aorta is ligated and the aortic flush begins. For adult donors over 70 kg, we use 4 l of University of Wisconsin (UW) preservation solution.

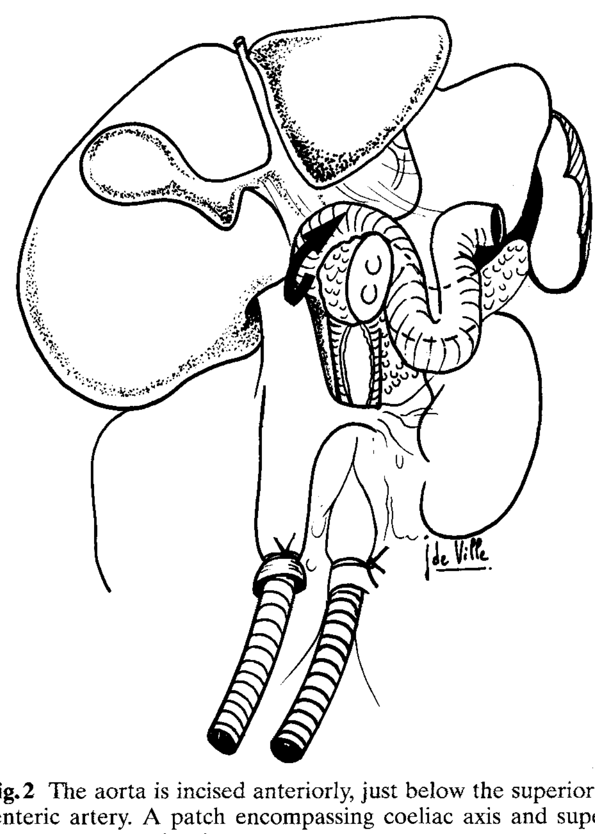


Fig. 2 The aorta is incised anteriorly, just below the superior mesenteric artery. A patch encompassing coeliac axis and superior mesenteric artery is taken

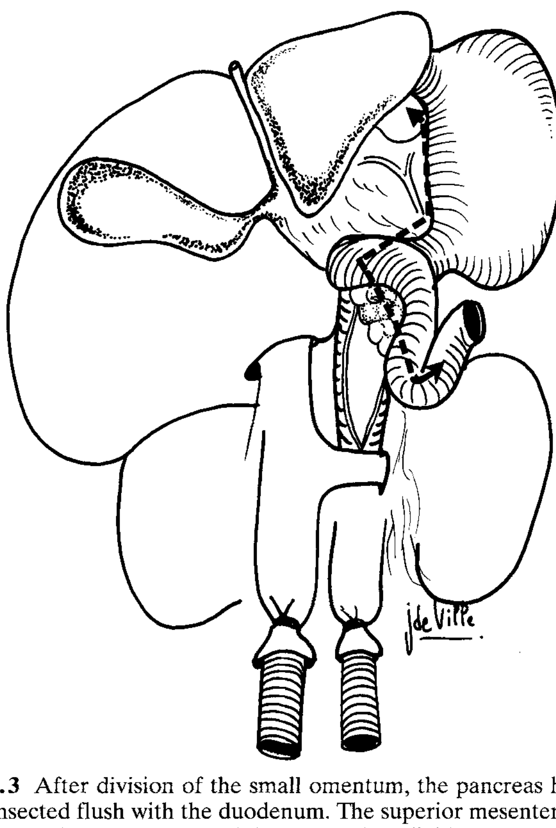


Fig. 3 After division of the small omentum, the pancreas head is transected flush with the duodenum. The superior mesenteric vessels and the retroperitoneal tissues are then divided

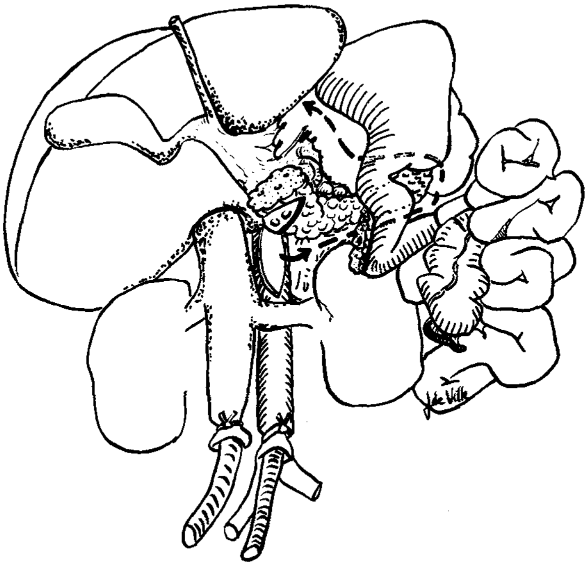


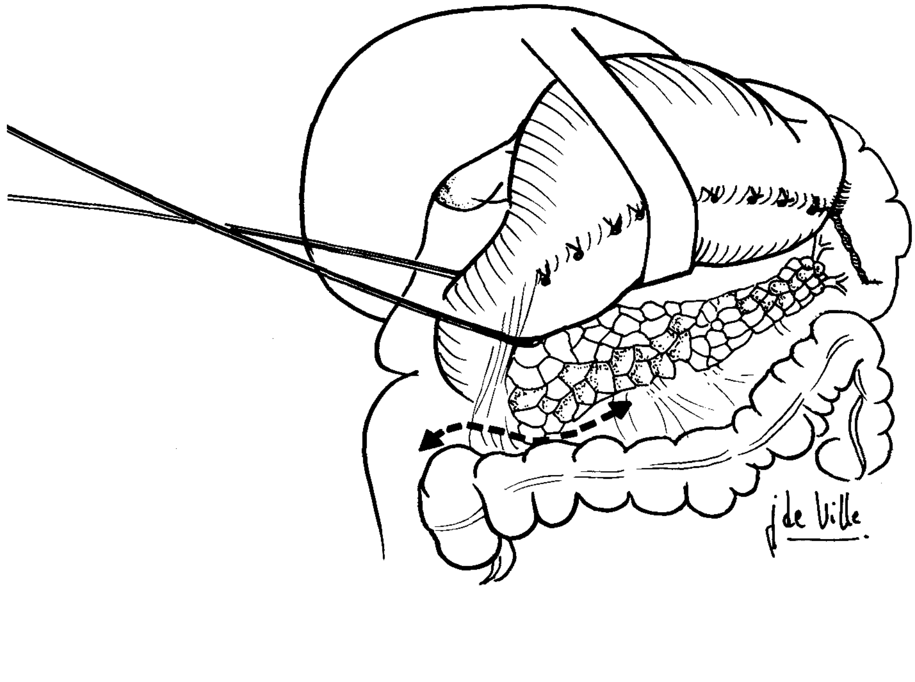
Fig. 4 The bloc with the pancreas tail is mobilized from the retroperitoneal tissues, dividing the splenic vessels at the hilum

When the weight is 40–60 kg, 3 l are used. For smaller donors, weighing 20–40 kg or less than 20 kg, we use 2 l or 1 l, respectively. Cooling of the abdominal organs is completed by generous topical irrigation with iced saline. The infradiaphragmatic aorta is then transected below the ligature. The entire bowel is reflected to the left and cranially in order to expose the SMA. After identification of the SMA and aorta, the dissection is continued to free the lateral aspects of the aorta. Then, by dividing the retroperitoneal tissue (retropancreatic lymphatics, solar plexus) between the IVC and the aorta from the left renal vein to the foramen of Winslow, the right side of the aorta and the SMA are fully exposed. The aorta is incised anteriorly, just below the SMA; a patch encompassing the coeliac axis is taken by bilateral prolongation of this aortic incision (Fig. 2). The remaining retroperitoneal tissue on the left is also divided. During this procedure, the orifices of the renal arteries are not approached. The intestine is replaced in the abdomen for the second maneuver, which consists of dividing the liver-pancreas bloc from the intestine. The lesser omentum is opened and the branches of the left gastric vessels are divided flush with the small curvature of the stomach (preserving an accessory left hepatic artery, if present) until reaching the cardia. Then, the duodenum is removed from the "bloc" by transection of the pancreas head (in which the common bile duct is cut), flush with the duodenum (Fig. 3). The superior mesenteric vessels and the ligament of Treitz are easily identified during this transection and divided below the pancreas. The bloc with the pancreas tail is then mobilized from the retroperitoneal tissue, dividing the splenic vessels at the hilum (Fig. 4). At the end of this step, the whole hepatic hilum, the aortic patch, and the pancreas are free. Next, the IVC is transected below the liver and the bloc (liver + pancreas) is removed with a large patch of diaphragm. The bloc is placed in an iced UW preservation fluid bath on the back table and the bile is again flushed out through the common bile duct. Usually, an ex vivo portal flush (200–500 ml) is performed by inserting a cannula through the superior mesenteric vein; this cannula is verified to lie in the portal vein and secured during flush by finger crossclamping of the hepatic hilum.

Bench work

The SMA is dissected first, in order to identify any accessory right hepatic artery; then, the coeliac axis and its branches are delineated. Next, the common bile duct and the portal vein, including the splenomesenteric junction, are dissected. This bloodless dissection facilitates the separation of the pancreas from the liver. Vascular anomalies are easily identified and long vascular patches can be procured for the liver graft. The part of the pancreas that has been removed is used for islet preparation.

Fig. 5 To retrieve the pancreaticoduodenal graft, the preparation can be somewhat extended: the omentum is divided flush with the stomach, as is the mesocolon with the pancreas



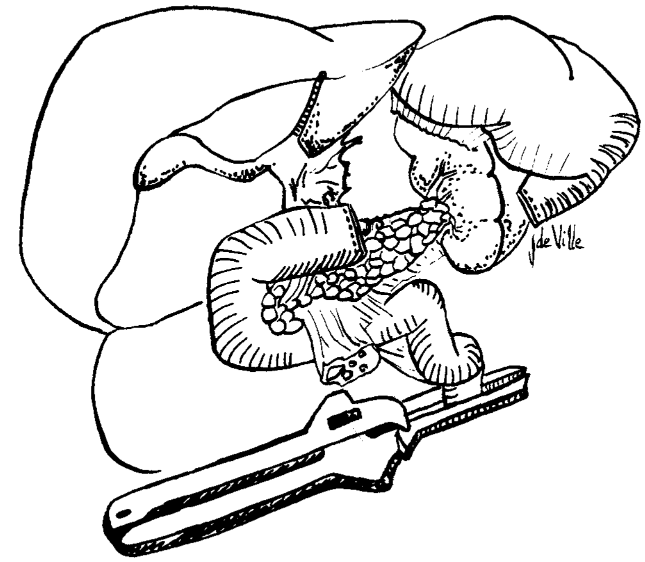


Fig. 6 Combined en bloc retrieval of liver and pancreaticoduodenal grafts (including preservation of the spleen "en bloc" with the pancreas): operative aspect of the bloc before removal

Pancreaticoduodenal graft

When the whole pancreas with the duodenum must be retrieved for clinical transplantation, the procedure is easily adapted. Experienced teams can use the same technique to retrieve the duodenum and spleen with the bloc. Others will prefer to extend the preparation before the perfusion somewhat in order to facilitate retrieval (Figs. 5, 6).

Results

Donor age and weight were 14.3 ± 1.1 years and 44.5 ± 2.8 kg, respectively. Thirty-one donors (28.4 %) weighed less than 15 kg at the time of the procedure (11 of them were less than 1 year old) and 42 donors weighed more than 55 kg. Duration of donor ICU stay was 3 ± 0.26 days (≥ 5 days in 20 cases). The causes of brain death were anoxia (n = 11), intracranial hemorrhage (n = 19), cerebral trauma (n = 71), acute hydrocephaly (n = 2), bacterial meningitis (n = 2), and primary brain tumor (n = 4). An episode of cardiac arrest was mentioned on 18 donor sheets. In addition to the liver grafts, 212 kidneys, 83 hearts, 11 cardiac valves, 11 whole pancreas for transplantation and 63 pancreas for islets procurement were also retrieved from the some 109 donors. A single hepatic arterial supply was present 79 times (72.5 %), 3 originating from the SMA. A second artery was identified in 23 donors (21.1 %) as a right accessory hepatic artery (n = 3) or a left accessory hepatic artery (n = 20). One of these latter donors had a common trunk for coeliac axis and SMA. Seven donors (6.4 %) had three hepatic arteries. All arteries were well preserved, uninjured during harvesting.

Recipient age and weight were 3.3 ± 0.3 years and 13.2 ± 0.8 kg, respectively. Twenty-eight recipients were less than 1 year old, and 46 weighed less than 10 kg at the time of transplantation. The ratio between donor and recipient weight was less than 2 in 43 cases, 2–4 in 22, 4–8 in 34, and more than 8 in 11 other cases. The donor/recipient ABO group match showed identity in 102 cases (93 %), mismatching in 7 others, and incompatibility in 1 case. The indications for liver transplantation were biliary atresia (n = 68), metabolic disease (n = 8), fulminant hepatic failure (n = 8), malignant liver tumor (n = 2), various cirrhoses (n = 6), and retransplantation (n = 18). The pretransplant clinical condition was elective in 64 recipients (58 %), urgent in 26 cases (24 %), and highly urgent in 20 recipients (18 %). Forty-three (39.4 %) donor liver grafts were used as whole liver grafts. Of the others, 56 (51.4 %) were used as partial liver grafts and 1 was implanted after left lateral segmentectomy. Nine liver grafts were split: 8 out of 18 split liver grafts were used for pediatric transplantation in this series. The cold ischemia time was 719.4 ± 17.2 min. It was less than 12 h in 57 cases (52 %), between 12 and 15 h in 32 others (29 %), and more than 15 h in 21 cases (19 %). Primary graft nonfunction occurred in five cases (4.5 %), two of which were correlated with long donor ICU stay (7 and 21 days) and 1 with a donor less than 1 year old.

Hepatic artery thrombosis was diagnosed eight times; it occurred as a delayed complication in two reduced-size grafts lost as a result of chronic rejection or poor function associated with massive sludge and multiple intrahepatic strictures. It was a primary complication in six full-size grafts retrieved from low-weight donors (all ≤ 17 kg), two of whom also had accessory arteries. Of these six latter grafts, five were lost due to ischemic sequellae; in the sixth case, thrombectomy, followed later by biliary revision, was successful, and the graft is functioning well 3.5 years after transplantation. When grafts were procured from donors weighing less than or equal to 15 kg, overall rates for hepatic artery thrombosis and graft survival were 16 % and 77.4 %; when the donors weighed more than 15 kg, the rates were 1.3 % and 74.7 %, respectively. When recipients weighing less than or equal to 10 kg were transplanted, these latter rates were 10.8 % and 78.3 %; when recipients weighed more than 10 kg, these rates were 1.6 % and 76.5 %, respectively. Nonischemic biliary complications were observed in 6 full-size grafts (14 %) and 12 technical variants (18 %). They consisted of nine biliary tract stenoses, seven anastomotic stenoses, and two leaks.

The actual patient survival rate was 93 % (91/98) at 3 months and 90 % (81/90) 1 year after transplantation. The actual graft survival rate was 85.5 % (94/110) and

78 % (79/101), respectively. Graft loss was not significantly correlated with ABO matching, ischemic times greater than 12 or 15 h, or with the pretransplant clinical condition in this series. Out of 31 grafts procured from donors weighing less than 15 kg, 25 (80.6 %) were functioning at 3 months. The causes of graft loss during the 1st postoperative year were primary nonfunction ($n = 5$), acute rejection ($n = 2$), chronic rejection ($n = 4$), hepatic artery thrombosis ($n = 4$), and patient death ($n = 9$). Graft loss due to patient death was secondary to sepsis ($n = 3$), brain death ($n = 1$), hemorrhage ($n = 1$), tumor recurrence ($n = 1$), and bone marrow aplasia ($n = 1$).

Discussion

During the last decade, an increasing number of donors have been considered for multiorgan procurement. As a consequence, the procurement time has become excessive when multiple operative teams successively perform "their" conventional preliminary dissections. In 1988, Miller et al. proposed a "Quick technique" in order to improve liver harvesting [7]. However, it is still not being used by all teams throughout the world, either for isolated liver or for combined liver and pancreas retrieval [5, 9, 10]. Although procurement of the liver and pancreas is competitive with regard to the vascular supply, the liver and whole pancreas can currently be obtained from every donor [5, 9, 10, 13] using the same preservation fluid and without any adverse effect on allograft function [1, 2, 11]. Most pancreas teams, however, still use conventional techniques, including extensive dissection of the hepatic hilar structures, coeliac axis, and superior mesenteric vessels. All of this is done in order to identify the vascular anatomy and, sometimes, to obtain selective portal cooling without pancreatic outflow hyperpressure.

Between 1984 and 1990, the procurement technique that we used gradually evolved from the "classic" to the "rapid" technique [14], then to en bloc harvesting using classic liver graft cooling, and finally to the current QEB technique. The latter was considered to be more of a logical evolution than a real innovation, and so an institutional review board was not consulted.

The simplified QEB technique described here is useful in retrieving liver grafts and can be easily modified to remove combined hepatic and pancreatic grafts. When the pancreas is not used for transplantation, its body and tail, which are procured with the liver graft, are used for islet preparation. The technique's major advantage lies in the fact that it requires no extensive dissection, either for the preparation or for the bloc retrieval. It is, thus, a real "non touch" technique, as reflected in this series by the absence of any graft-harvesting injuries. This contrasts highly with the results of another study of liver grafts procured and shipped to our center during the same period but harvested according to conventional techniques. This other study showed 23.1 % minor or major liver graft injuries [4]. Extensive dissection is well known to increase the risk of surgical errors in case of variations in the vascular supply [3, 15]. This was confirmed in our previous experience (1984–1990) with classic or rapid techniques: 115 grafts were procured and 10 grafts (8.7 %) presented with injury of an artery, mostly when a right hepatic artery arose from the SMA (7/10).

The QEB technique is of interest when a liver graft must be harvested from a small donor because a "no touch" technique is most appropriate. Although it may be unrelated to the technique, graft survival was equal in this series, whether or not the grafts harvested were from small donors. Hepatic artery thrombosis was, however, obviously related to the small caliber of arteries and mostly observed when full-size liver grafts harvested from small donors were implanted in small recipients [6].

Simplification of the cooling technique can also be done by flushing through an aortic cannula alone; we previously showed that this has no detrimental effect on graft function either in adult or pediatric patients [17]. The flow through the SMA provides rapid, bloodless, portal cooling, but also avoids any pancreatic outflow hyperpressure, something that is to be avoided during pancreas harvesting. The vascular anatomy is carefully identified on the back table where the two organs are separated. This allows for the most appropriate division of the common vascular supplies and for the realization of vascular reconstruction(s), as needed [5, 8–10, 13]. Not one pancreas planned for transplantation was lost.

Given the fact that 42 % of the transplantations were performed under urgent conditions and that 19 % of the grafts had more than 15 h of ischemia, one can say that the overall clinical results of this pediatric series were excellent. The low rates of graft loss, primary nonfunction, and hepatic artery thrombosis need to be stressed. The QEB technique is safe and makes abdominal organ procurement fast; the logical evolution of this technique would be the creation of a single abdominal procurement team that would remove all abdominal organs before shipping them to different recipient centers [8]. However, because not all donor centers are located in multiorgan transplant institutions, it is unlikely that the local teams would be fully trained for a total en bloc abdominal procedure [8]. A less complex procedure is, therefore, proposed that can easily be adopted by current harvesting teams. This would entail the standardization of harvesting techniques in order to enhance collaboration between transplant teams and to improve the acceptance rate for liver grafts harvested by other teams.

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