"Non-Touch" Vena Cava Technique as an Improvement in Combined Lung and Liver Procurement in Controlled Donation After Circulatory Death

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ABSTRACT

The number of organs retrieved from donation after circulatory death (DCD) donors has continued to rise in recent years. The functional superiority of DCD organs is achieved when the lungs are perfused with cold perfusion and livers with normothermic regional perfusion (NRP). Thus, a precise surgical technique is required to combine thoracic and abdominal organ procurement.

The technique used at our center consists of a rapid laparotomy and middle sternotomy, then the abdominal aorta (Ao) and abdominal inferior vena cava (VC) are cannulated and the descending thoracic Ao is cross-clamped. NRP is started at that point. As a variation of previously described techniques, the thoracic vena cava is not initially clamped in order to improve the return of blood volume to the NRP circuit. The pulmonary artery is cannulated to flush the lungs and the left atrial appendage is opened for drainage. After 120 minutes, NRP perfusion is stopped and the organs are flushed with cold preservation solution.

In 2016, 3 livers and 6 lungs were harvested at our center using the technique described. After a minimum follow-up of 1 year, no evidence of biliary complications was observed. The combined procurement of lungs after room temperature perfusion and liver after NRP without initial clamping of the thoracic VC is feasible, with excellent function post-transplantation.

IN AN ATTEMPT to expand the donor pool for transplantation, the use of extended criteria for donors has increased in recent years, with donation after circulatory death (DCD) II and III being the most significant. However, liver grafts from these donors are associated with a higher incidence of primary nonfunction and ischemic-type biliary strictures [1]. These results stem mainly from the warm ischemia insult following the cessation of circulation. In contrast, outcomes in DCD lung transplantation have been consistently good [2], probably because lungs can be protected from hypoxemia by simple ventilation after death is established.

Normothermic regional perfusion (NRP) has been studied to minimize the warm ischemic damage and improve preservation of the livers with good applicability and results [3]. However, organ procurement in DCD may be complex when different organs are involved. When lungs are perfused with cold perfusion and livers recirculated with NRP, the technique employed needs to be precise and coordinated. The surgical technique for lung procurement with hypothermia and liver with normothermia in DCD II [4] and DCD III [5] has been described.

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The aim of this work is to describe a modified technique for multiorgan procurement from DCD III donors with abdominal NRP and simultaneous room temperature lung perfusion based on initial non-clamping of the VC.

MATERIALS AND METHODS

Surgical Technique

Withdrawal of life support and confirmation of death take place in the operating room. A total of 500–1000 units/kg of sodium heparin are administered before cardiac arrest. After the standard 5 minutes stand-off period, a rapid laparotomy is performed. The abdominal suprailiac aorta (Ao) is cannulated using a 20F-22F cannula and the abdominal suprailiac inferior vena cava (IVC) with a 28F cannula. Simultaneously, the donor is reintubated and the lungs are inflated with a recruitment maneuver. A rapid middle sternotomy is performed and the descending thoracic Ao is clamped. At that point, NRP is started at a flow >1.7 L/min and maintained for 2 hours. The abdominal Ao above the celiac trunk may be clamped for better delimitation of the abdominal NRP circuit and the intrathoracic VC is not clamped.

The main pulmonary artery is cannulated. Mechanical ventilation is started with fraction of inspired oxygen 50% and PEEP 8–10 mm Hg; perfusion of 4 L Perfadex (XVIVO Perfusion, Göteborg, Sweden) is then flushed through the pulmonary artery at room temperature (Fig 1). The left atrial appendage is opened for drainage. Unlike in standard donation after brain death (DBD), serum (neither cold nor room temperature) is not added to the thoracic cavity. After perfusion of Perfadex is finished, the IVC and superior vena cava (SVC) are clamped just at the entrance of the right atrium to preserve the azygos vein (Fig 1B). The thoracic IVC and SVC are then ligated and cut. The supra-aortic vessels and ascending Ao are sectioned. After dissection of the trachea and a Valsalva maneuver is performed up to 30 mm Hg, the trachea is stapled and sectioned. The lungs and heart are then removed in one piece. Bleeding points in the thoracic cavity are coagulated or ligated. Cold Perfadex is then used in the back-table surgery.

During the 2 hours of NRP of the abdominal cavity, meticulous liver dissection is performed as in a standard DBD. The common bile duct and gallbladder are opened to assess good perfusion with no ischemia. Liver function and preservation are evaluated every 30 minutes (pump flow > 1.7 L/min; temperature 37°C; pH 7.35–7.45; partial pressure arterial oxygen 100–150 mm Hg; hematocrit > 20%; Na, K, glucose, lactate normal values; initial aspartate transaminase/alanine transaminase < 3 times the upper normal limit; final aspartate transaminase/alanine transaminase < 4 times the upper normal limit). After the 2-hour period, if the liver is valid for transplantation, the abdominal organs are perfused with cold University of Wisconsin solution (Bel-Gen solution, Institut Georges Lopez, Lissieu, France) and recovered as in a standard DBD.

The whole procedure was approved by the Ethics Committee in our hospital.

RESULTS

During 2016, 3 donors underwent NRP for liver procurement simultaneously with room-temperature perfusion for lung retrieval. Donor characteristics and timings for NRP

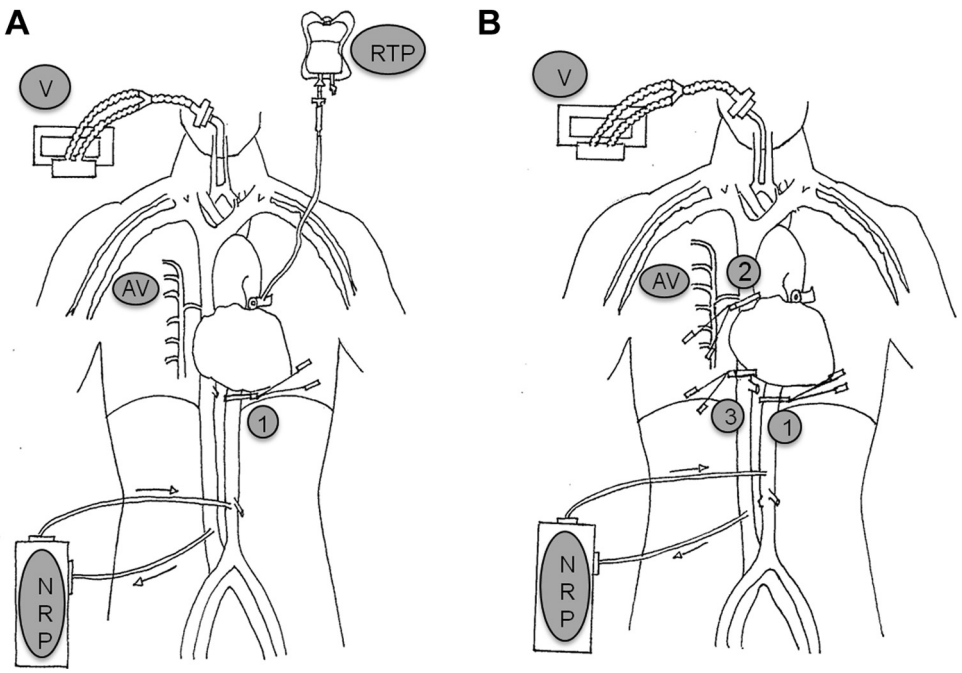

Fig 1. Abdominal normothermic regional perfusion circulation and lung perfusion. **(A)** After middle sternotomy, the descending aorta is clamped (1), mechanical ventilation is started, and room temperature Perfadex is flushed through the pulmonary artery. Simultaneously, abdominal normothermic regional perfusion is started through the suprailiac aorta and suprailiac inferior vena cava. **(B)** After the Perfadex perfusion is finished, lungs are still ventilated, the thoracic inferior vena cava (3) and superior vena cava (2) are clamped just at the entrance of the right atrium to preserve AV. The abdominal aorta remains clamped and normothermic regional perfusion is still working. AV, azygos vein; NRP, normothermic regional perfusion; RTP, room-temperature Perfadex; V, ventilation.

Table 1. Donor Characteristics, Timings for NRP, and Postoperative Liver Transplant Results

Age (years)	Underlying Disease	Withdrawal to Asystole (min)	Functional Warm Ischemia Time (min)	Cannulation Time (min)	Cold Ischemia Time (min)	Postoperative* AST/ ALT (UI) Peak	Postoperative* Hospital Stay (days)	Follow-up (months)	Liver Function
59	Anoxia	16	18	11	326	304/237	11	14.6	Normal
48	Anoxia	16	18	7	300	1902/1532	13	14.1	Normal
22	Anoxia	13	19	9	340	524/590	15	13.2	Normal

Abbreviations: ALT, alanine transaminase; AST, aspartate transaminase; NRP, normothermic regional perfusion.
*During hospital stay or within the first 30 days post-surgery.

are shown in Table 1. In all 3 donors, the addition of extra volume and blood to the circuit was required. No hemodynamic instability occurred during the NRP.

All allografts, lungs, and livers presented excellent immediate function. Postoperative results of livers are described in Table 1.

In the lungs cases, postoperative stays were 36, 45, and 330 days. The last patient had a prolonged postoperative stay owing to infectious complications. Lung function was good in all patients.

DISCUSSION

Taking into account that NRP is preferred for the abdomen and simultaneous cold perfusion followed by a rapid procurement technique for the lungs, a precise and combined technique is required in multiorgan DCD. Two surgical techniques combining thoracic hypothermia and abdominal normothermia have been described. "Bithermia preservation" [4] has been described in uncontrolled DCD and consists of a thoracic closed circuit connected to a roller pump that recirculates cold Perfadex and an abdominal normothermic extracorporeal circulation. Both circuits are kept working until consent is obtained. Sternotomy and lung procurement are then performed. One problem with this technique is that such a long cooling period in the chest may hinder maintenance of the temperature in abdominal NRP. For this reason, in the technique we describe, Perfadex at room temperature is used for perfusion and no serum (neither cold nor room temperature) is added, with good results. The "dual temperature multi-organ recovery" technique [5] has been described in controlled DCD. It consists of a rapid laparotomy, abdominal Ao and IVC cannulation and endo-clamping of the thoracic Ao with a balloon. While NRP is established, a routine sternotomy is performed, the ascending Ao clamped, and the main pulmonary artery cannulated for cold-flush perfusion. We present a variation of the latest technique based on initially avoiding clamping the VC and flushing the lungs with room-temperature perfusion.

One of the most important issues of any extracorporeal circuit is the lack of venous back flow. If the thoracic VC is ligated and sectioned just after cannulation of the abdominal Ao and the IVC, blood flow from both arms, head, and the area drained by the azygos will not be recovered for the extracorporeal circuit. For this reason, in our technique, the thoracic IVC and SVC are ligated and sectioned after lung perfusion is finished and just before the tissue around lungs needs to be cut to retrieve the lungs. By avoiding initial clamping of the IVC and SVC, there will be a greater venous back flow into the circuit (Fig 1A). It is also very important to identify the end of the azygous vein, which may vary, in order to ligate and cut the SVC just below the azygos takeoff, as Oniscu et al described previously [5]. If the azygos vein is not identified, it may remain open after retrieval of the lungs and significant blood loss may thus ensue (Fig 1B).

In the surgical technique described here, the lungs and heart are retrieved in a monobloc. A very interesting point to avoid blood loss in the chest in DCD donors under NRP would be to retrieve the lungs without the heart. The pulmonary artery would be cut just proximal to its bifurcation and the left atrium would be sectioned, leaving behind an adequate cuff for the lungs. By not retrieving the heart, the right cardiac circuit would remain intact and there would thus be no risk of damaging the azygos vein and causing chest bleeding. Although this procedure would theoretically be the best surgical approach, it requires a very precise technique and it may damage the lung grafts.

In conclusion, the simultaneous procurement of lungs after room temperature perfusion and liver after NRP without initial clamping of the thoracic VC is a feasible and safe procedure which improves venous back flow to the NRP circuit.

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