Thoracoabdominal normothermic regional perfusion—approaches to arch vessels and options of cannulation allowing donation after circulatory death multi-organ perfusion and procurement

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Since 2015, the use of hearts from controlled donation after circulatory death (DCD) donors for transplantation has steadily increased, with short-term outcomes shown to be comparable to those from donation after brainstem death (DBD) (1). Thoracoabdominal normothermic regional perfusion (TA-NRP) has emerged as an effective strategy to rapidly restore perfusion to and optimise the quality of thoracoabdominal organs *in situ* after circulatory death is confirmed (2). However, implementation of TA-NRP varies between countries and institutions due to differences in ethical considerations, regulatory policies, and legal frameworks surrounding DCD. A primary ethical concern focuses on the potential for blood flow to return to the brain during TA-NRP (3). This paper and associated video demonstrate the three most common approaches to arch vessels and cannulation for TA-NRP, that are adopted by the teams in the United States of America (USA), Spain, and the United Kingdom (UK) (4).

Clinical vignette

Case 1: 27-year-old male, hypoxic brain injury secondary to motorcycle accident, smoker, no past medical history (PMH). Echocardiography reported an ejection fraction (EF) of 60–65% and left ventricular (LV) septum 10 mm. Time from withdrawal of life support (WLS) to asystole was 71 minutes. The Colorado protocol was used.

Case 2: 16-year-old male, aneurysmal subarachnoid haemorrhage treated by craniotomy. No PMH, current smoker. Echocardiography reported an EF of 60–65%, LV septum 10 mm, and normal-sized ventricles and function. WLS to asystole was 10 minutes. The Spanish protocol was used.

Case 3: 39-year-old male who died from a cerebral bleed secondary to a traffic accident. No PMH, EF 65%, normal ventricle size and function, no valvular pathology. WLS to asystole for 17 minutes. The UK protocol was used.

Surgical technique

The Colorado TA-NRP technique

Using sharp dissection, the anterior table of the sternum is exposed and division of the sternoclavicular ligament at the sternal notch, followed by rapid median sternotomy is completed. After placing the sternal retractor, the innominate vein is bluntly encircled and divided using a stapler to enhance the exposure of the arch vessels. To avoid bleeding from the divided innominate vein, any lines, or devices within this vessel are withdrawn following confirmation of circulatory death. Next, the arch vessels are occluded with vascular clamps. The control of these vessels is communicated to the rest of the procurement team. The pericardium is then carefully opened with scissors to avoid injury to the distended right ventricle. Once the heart is exposed, the right atrium is directly cannulated to alleviate cardiac distension and facilitate venous drainage. The distal end of the innominate artery is directly cannulated with a flexible aortic cannula to avoid damage or haematoma to the aorta. The aortic cannula is fully deaired before initiating TA-NRP.

Once the heart is perfused, a pulmonary artery vent is inserted to reduce right ventricle afterload and left atrial preload before adequate ventricular contractility resumes. This vent remains in place during weaning from TA-NRP to prevent the negative impact of high pulmonary vascular resistance, especially in donors whose lungs are not procured. If the lungs are procured, the insertion point of this pulmonary artery vent is carefully selected at the level of pulmonary artery transection for heart and lung splitting. Once TA-NRP is terminated, the heart is fully loaded and expected to beat independently without the assistance of the circuit. Both during and after TA-NRP, the heart function is assessed using visual inspection. Some units would add further objective assessment in the form of transoesophageal echocardiography or right heart catheterisation.

The Spanish TA-NRP technique

In Spain, as selected pre-mortem interventions for donation are permitted, cannulation of femoral artery and vein is performed before the WLS (5). In the initial cases from 2020 to 2022, the three arch vessels were clamped first. Following the initiation of TA-NRP, the easily accessible arch vessels, usually the innominate and left carotid arteries, were individually cannulated and drained to the circuit. However, ethical concerns arose that simple cross-clamping of the arch vessels was insufficient in preventing blood from returning to the brain through collateral arteries and potential accumulation of cerebral perfusion pressure (3). To address this concern, since 2023, it has become mandatory to not only clamp the arch vessels but also divide them and open their cephalad ends to atmospheric pressure, before commencing TA-NRP. The blood drained from the cephalad ends of the arch vessels is then collected via a suction device and returned to the TA-NRP circuit. This refinement necessitated the use of an open circuit (extracorporeal circulation or modified extracorporeal membrane oxygenation device with a reservoir) capable of aspirating large volumes of blood.

The UK TA-NRP protocol

In the UK, no intervention is allowed before confirmation of circulatory death. Consequently, heparinisation and femoral or abdominal arterial and venous cannulation must be performed during procurement. Once arterial and venous cannulation are secured, a cross-clamp is applied to the thoracic descending aorta, and a venting cannula is inserted in the ascending aorta. Abdominal NRP is initiated first. In a process that is time-consuming, all three arch vessels must be individually cannulated, secured, and connected to the circuit under negative pressure. Only then, can the thoracic clamp be removed and TA-NRP commenced. Despite this additional precaution to preclude brain circulation, the use of TA-NRP was discontinued in the UK in late 2020 till further data is available to assess the existence of brain perfusion.

Comments

Although the cannulation strategies and approaches to the arch vessels vary between protocols, the primary principle of TA-NRP remains the same. The goal is to restore *in situ* normothermic perfusion to thoracic and abdominal organs as quickly as possible, minimizing the functional warm ischemic time to limit and mitigate ischaemia/reperfusion injury. It has been increasingly adopted by many centers in the world to expand the donor pool of DCD hearts for transplant. Compared to abdominal NRP, growing evidence suggests that TA-NRP is superior for perfusing abdominal organs. For hearts, TA-NRP offers a financial advantage over the method of direct procurement followed by *ex-situ* machine perfusion. Additionally, emerging literature supports the safety of TA-NRP for donor lungs.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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