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USE OF CRYOPRESERVED AORTIC HOMOGRAFT FOR SUBCLAVIAN ARTERIAL CANNULATION DURING EXTRACORPOREAL MEMBRANE OXYGENATION

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Extracorporeal membrane oxygenation (ECMO) is a vital tool in the treatment of patients with severe cardiovascular failure during heart surgery. The femoral artery is the most common access for veno-arterial ECMO in adults. Where there are contraindications to traditional cannulation techniques, the subclavian artery is an alternative access site, despite its many peculiarities. This paper presents a clinical case where peripheral ECMO connection with cannulation into the subclavian artery using a cryopreserved homovital abdominal aortic homograft was performed in a patient.

Keywords: extracorporeal membrane oxygenation, cannulation, subclavian artery, homograft.

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) is a life support system that temporarily takes over the function of a patient's heart and lungs by circulating their blood through a machine that adds oxygen and removes carbon dioxide, allowing the patient's own organs to rest and potentially recover from a reversible failure. According to the latest ELSO (Extracorporeal Life Support Organization) report, postcardiotomy syndrome patients have survival rates ranging from 25% to 50%. Additionally, 31% to 76% of patients are successfully weaned off ECMO [1].

Femoral artery cannulation (FAC) remains the most traditional and widely used approach for venoarterial ECMO (VA-ECMO) in adults. However, is associated with significant risks, such as arterial occlusion, limb ischemia, reperfusion injury leading to compartment syndrome, thrombosis, embolism, bleeding and hematoma formation [2]. In patients with peripheral artery disease, the risks of these complications are significantly higher and may be considered a contraindication to femoral artery cannulation.

Subclavian artery cannulation (SAC) is a viable alternative to FAC in patients with contraindications. However, it has technical peculiarities and usually requires surgical expertise [2]. Synthetic prostheses offer significant advantages over direct cannulation of peripheral vessels in VA-ECMO, particularly in reducing complications like damage to the artery by the cannula, vessel dissection, limb ischemia, and the need for post-decannulation arterial reconstruction. However, achieving hemostasis with synthetic prostheses in ECMO patients is challenging, especially in the setting of pronounced hypocoagulation. The porosity of synthetic grafts contributes to persistent bleeding from suture lines and puncture sites, leading to significant blood loss.

This article presents a clinical case in which ECMO was initiated via peripheral cannulation using a homovital cryopreserved abdominal aortic homograft. The homograft was obtained from a brain-dead donor during a multi-organ retrieval procedure. The retrieval and preservation technique ensured the absence of warm ischemia and included a controlled freezing protocol, preserving tissue viability, strength, and elasticity – critical factors for surgical manipulation [3]. According to available reports, cannulation using a homograft has not been previously performed.

CLINICAL CASE

Patient K., a 62-year-old man, underwent valve-sparing aortic root replacement (David procedure), radiofrequency ablation of atrial fibrillation zones, and coronary artery bypass grafting (CABG) as indicated. Following surgery, the patient was weaned from mechanical ventilation while receiving moderate doses of norepinephrine, epinephrine, and dobutamine. After extubation, transesophageal echocardiography revealed reduced contractility of both the left and right ventricular myocardium.

The early postoperative period was marked by worsening heart failure, a tendency toward hypotension, severe acid-base imbalances that were difficult to correct (metabolic acidosis, hypokalemia, hyperglycemia), and decreased urine output. Given the clinical deterioration, ECG changes, and overall negative dynamics, the

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patient underwent urgent CABG evaluation. No further deterioration was observed, and the coronary grafts remained patent.

On the second postoperative day, the patient's condition deteriorated significantly, with worsening heart failure, episodes of ventricular tachycardia, and an elevated lactate level reaching 20 mmol/L. Despite the use of inotropes at extremely high doses, hemodynamic instability persisted, necessitating VA-ECMO initiation. Due to the small diameter of the common femoral arteries and the presence of diffuse atherosclerosis, as confirmed by ultrasound, FAC was deemed unsuitable. Instead, a resternotomy was performed, with arterial cannulation of the ascending aorta and venous cannulation guided by ultrasound through the femoral vein. ECMO support led to stabilization of the patient's condition.

Given the anticipated need for prolonged mechanical circulatory support and the increased risk of infectious complications and bleeding associated with surgical diastasis of the sternum, a decision was made on the second day of ECMO to close the chest and transition to peripheral cannulation. Cannulation of the right subclavian artery was performed using a cryopreserved homovital abdominal aortic homograft, measuring 10 mm in diameter and 40 mm in length (Fig. 1).

Fig. 1. Cryopreserved homovital abdominal aortic homograft

Cryopreserved grafts are stored at temperatures ranging *from –150 °C to –170 °C, requiring approximately 1.5 to 2 hours for thawing.*

A 4 cm oblique incision provided access to the right subclavian artery, which measured 7 mm in diameter. The abdominal aortic homograft was prepared by suturing and clipping the lumbar branches. A proximal end-to-side anastomosis was then formed between the homograft and the subclavian artery using a continuous locking stitch with a 6.0 suture.

To ensure structural integrity, the distal end of the homograft was attached to a 3/8–3/8 connector, which was reinforced with a Dacron vascular prosthesis to prevent wall rupture. The connector was secured with a lavsan thread (Figs. 2, 3). The volumetric perfusion rate (VPR) achieved was 5.1 L/min, and activated clotting time (ACT) during ECMO was maintained between 160–190 seconds.

By day 9 of ECMO, progressive renal failure and oliguria necessitated the initiation of continuous renal replacement therapy (hemodialysis) via the ECMO circuit. By day 14, the VPR was gradually reduced to 2.2–1 L/min.

An attempt was made to gradually discontinue ECMO, but it was unsuccessful. Following ECMO cessation, the patient exhibited hypotension (BP 80/40–70/30 mmHg), paroxysmal atrial fibrillation, and required high-dose inotropic support. Given these hemodynamic instabilities, the decision was made to continue ECMO support.

On day 19 of ECMO, the arterial cannula became dislodged from the anastomosis site between the homograft and the subclavian artery. Immediate interventi-

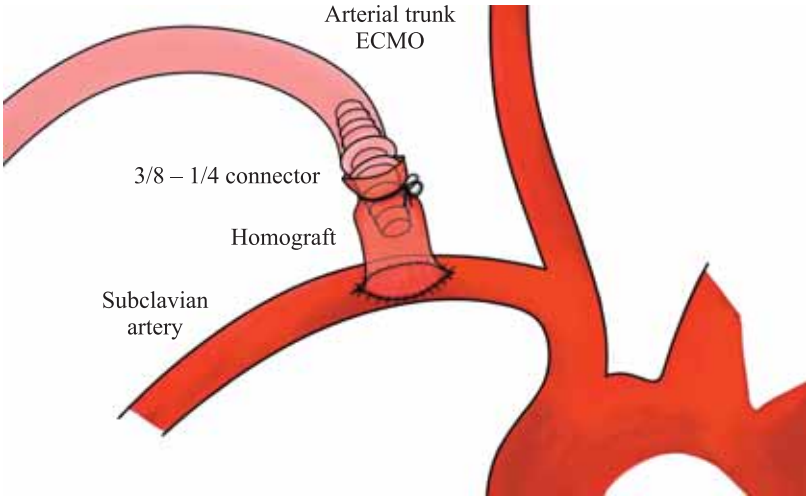

Fig. 2. Scheme of subclavian arterial cannulation using a homograft

on was required – a clamp was applied to the arterial ECMO line, and the surgeon performed re-cannulation into the homograft, securing it with a ligature knot. During ECMO cessation, cardiopulmonary resuscitation (CPR) was performed for 7 minutes before ECMO was successfully resumed. The patient's condition stabilized, with VPR restored to 4.3 L/min. Consciousness was regained, and treatment continued.

By day 27, mechanical circulatory support was reduced in response to stable systemic hemodynamics, with no signs of tissue hypoperfusion at a VPR of 1 L/min. A decision was made to discontinue ECMO and proceed with decannulation. The patient remained on ECMO for a total of 27 days.

After ECMO was discontinued, the patient continued to experience liver failure (blood bilirubin 261 mmol/L) and renal dysfunction. In response, hemodialysis with citrate anticoagulation was maintained. Despite the gradual reduction in inotropic therapy, there was no worsening of cardiovascular failure. The patient remained in the intensive care unit, receiving mechanical ventilation via tracheostomy.

It should be noted that throughout the entire ECMO support period, there were no complications related to arterial cannula patency, graft function, or bleeding at the cannulation site.

On day 14 after disconnection from ECMO, the patient succumbed to multiple organ failure.

Histological analysis of a fragment of the thawed cryopreserved homovital graft revealed moderate inflammatory changes in the intimal layer (Fig. 4).

Immunohistochemistry (IHC) analysis of the endothelial factor CD34, a well-known marker for blood vessel progenitor cells and stromal tissues, demonstrated a tendency for capacitive-type vessel formation in the adventitial layer (Fig. 5). Additionally, IHC staining with an antibody to ASM revealed positive expression of alpha-actin smooth muscle cells in the wall of the cryopreserved homograft, with focal absence observed in the middle layer.

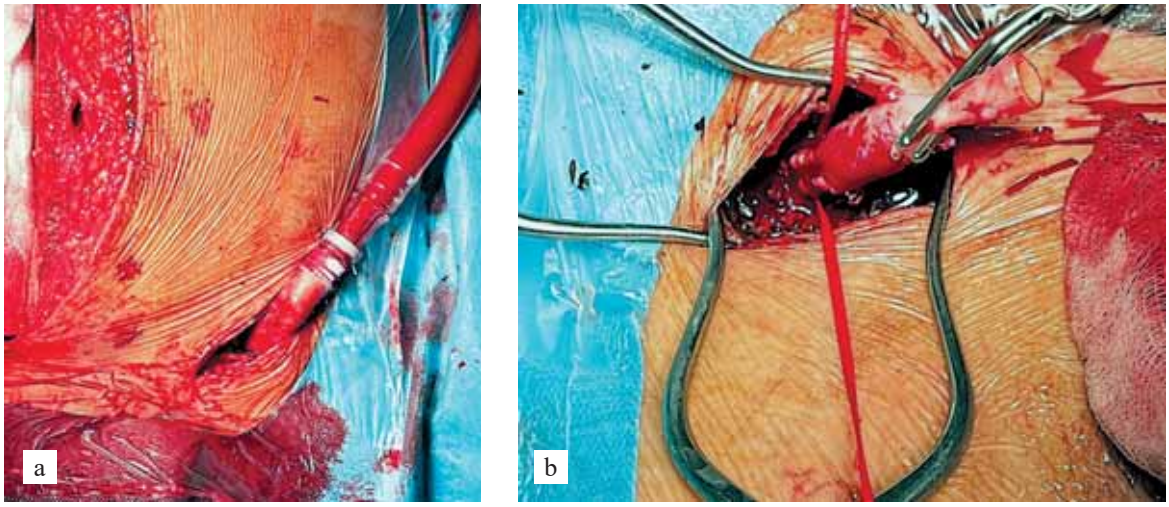

Fig. 3. Intraoperative photo: a, connection between the arterial trunk and homograft sutured to the subclavian artery; b, anastomosis between the subclavian artery and homograft

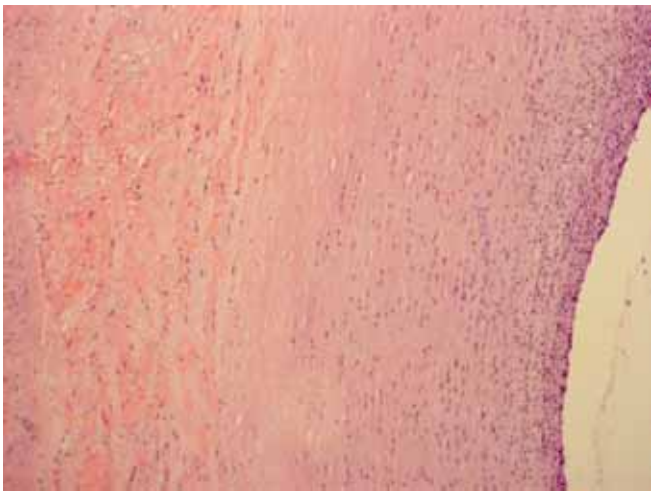

Fig. 4. Fragment of cryopreserved homograft. Inflammatory changes in the intima. H&E staining. ×400 magnification

DISCUSSION

ECMO plays a critical role in supporting patients with severe cardiovascular failure, especially during or after cardiac surgery [4, 5]. Cannulation in VA-ECMO can be central, or it can be peripheral [4]. The central cannulation technique is associated with a higher bleeding rate, increased need for blood transfusions, frequent reoperations, and surgical sternal diastasis, which requires delayed chest closure [6, 7]. When central cannulation is used for ECMO, the possibility of patient activation and mobilization is virtually nonexistent. According to

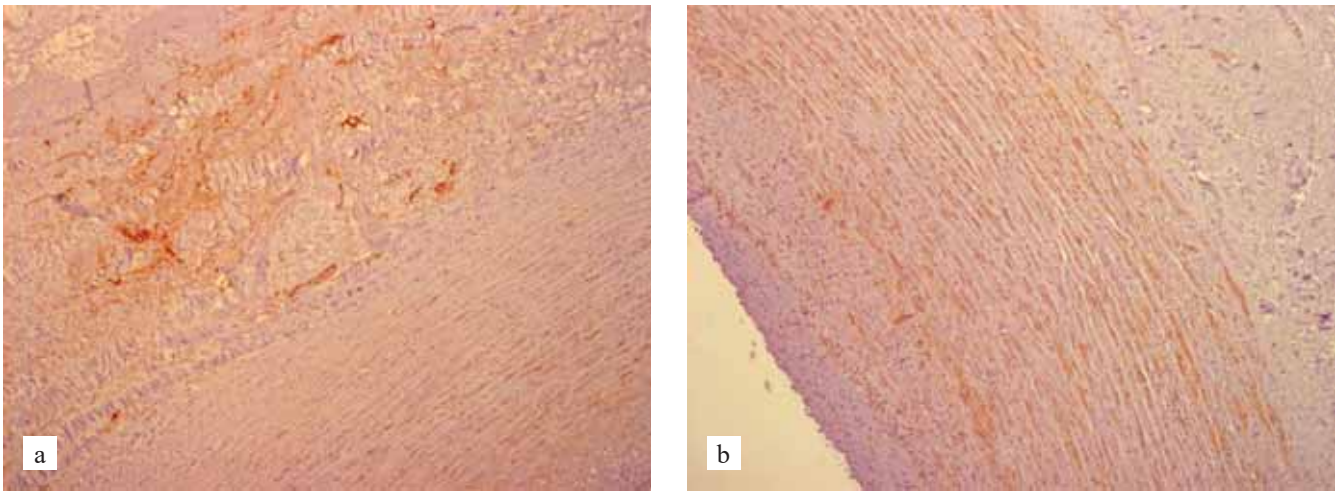

Fig. 5. Fragment of a cryopreserved homograft; a, formation of capacitance-type vessels, expression (CD34) in the adventitial layer; b, uneven positive actin expression (ASM). ×400 magnification. Immunohistochemistry

a multicenter registry analysis of 781 patients on ECMO and a meta-analysis, 30-day mortality was significantly higher in central ECMO compared to peripheral ECMO (72% *vs.* 61%, p = 0.004) [7].

Yes, peripheral VA-ECMO cannulation offers several advantages over central VA-ECMO, including less surgical trauma, quicker deployment, and greater potential for patient mobilization.

Peripheral VA-ECMO cannulation technique is able provides less surgical trauma, can be connected without the involvement of a surgical team, and has greater potential for patient mobilization [2]. At Meshalkin National Medical Research Center, over the past two years, peripheral VA-ECMO cannulation was applied in 61% of cases.

The common femoral artery and femoral vein are the standard vascular access points for peripheral VA-ECMO cannulation [2]. However, femoral cannulation has a unique challenge: its retrograde flow direction can, in some cases, increase left ventricular (LV) pressure, worsen LV dysfunction, promote pulmonary edema, elevate the risk of LV thrombosis, and significantly reduce the likelihood of myocardial recovery [9]. This scenario often necessitates additional interventions to unload the LV [10]. Various LV unloading methods exist, but they are generally invasive and may require supplementary mechanical support devices, depending on the chosen strategy [10].

When cannulating the subclavian artery, the most common approach involves inserting the arterial cannula through a vascular prosthesis (graft) that has been anastomosed to the artery. This technique preserves the integrity of the arterial lumen compared to direct cannulation through the arterial wall. It also simplifies the decannulation procedure, lowers the risk of limb ischemia, minimizes the chance of arterial dissection, and reduces the need for vascular wall grafting after ECMO discontinuation [11].

When cannulating the subclavian artery, the majority of nonpulsatile ECMO blood flow follows an antegrade direction through the aortic arch into the descending aorta. This approach is more physiologic and avoids increasing LV afterload, unlike femoral cannulation, where blood flow opposes the natural direction from the left ventricle [9, 12].

We have presented a clinical case of ECMO application in the peripheral venoarterial variant over 27 days, utilizing cannulation through a cryopreserved abdominal aortic homograft. The homograft was anastomosed to the subclavian artery, marking the first known clinical application of this technique. A review of literature databases (PubMed, Google Scholar, eLIBRARY) revealed no previously reported cases of homograft use for subclavian artery cannulation in ECMO procedures.

Cannulation into the homograft provided several advantages. First, it significantly reduced bleeding at the arterial cannula insertion site, even under high pressure (up to 250 mmHg) at the anastomosis level. This was due to the vascular graft's natural elasticity and the absence of anastomosis deformation. In contrast, synthetic prostheses, with their rigid walls and porosity, often present challenges in achieving satisfactory hemostasis – not only along the anastomosis line but also at puncture sites and due to prosthesis wall leakage. Second, the use of a homograft improved the positional maneuverability of the cannula.

The quality of a cryopreserved homograft is directly influenced by its preparation technique, with warm ischemia time before preservation being a critical factor. The term "homovital" refers to the preservation of viability in a significant portion of the endothelium, fibroblasts, and interstitial structures even after graft preservation.

It should be noted that the cryopreservation process itself does not cause significant damage to intact tissue. The strongest and most elastic graft walls are observed in homografts retrieved from brain-dead donors during multi-organ procurement, as these tissues experience no warm ischemia. In contrast, grafts obtained from cadavers hours or days after biological death have a significantly higher risk of structural failure and rupture due to degradation of vascular integrity [3].

Studies have demonstrated that cellular metabolism remains unchanged during cold ischemia for up to 24 hours and warm ischemia of no more than 12 hours. However, Yankah and Hetzer (1987) found that only 24% of endothelial cells survive after 2 hours of warm ischemia, and that prolonged warm ischemia of 12 hours results in cell apoptosis. The histological findings in this study align with previously published literature, confirming the preservation of a significant portion of the morphological structures in a homovital cryopreserved homograft.

The primary drawback of the presented technique is the inability to perform an emergency ECMO connection, as the graft thawing process (approximately 1.5–2 hours) and anastomosis formation require a certain amount of time. Additionally, in the context of organ shortages, maintaining a consistent stock of homografts with the required diameter may not always be feasible. From a legal perspective, the use of a homograft constitutes the transplantation of a "section of the vascular bed", necessitating compliance with all procedural and documentation requirements, which may be challenging to fulfill in enmergency cases.

CONCLUSION

The presented clinical case highlights the successful use of a cryopreserved vascular homograft for peripheral ECMO connection. Effective control of hemorrhagic complications during prolonged mechanical support is a crucial factor in achieving positive outcomes. This underscores the importance of accumulating further clinical experience with this technique to draw definitive conclusions regarding its effectiveness.

The authors declare no conflict of interest.

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