Operative Techniques in Thoracic and Cardiovascular Surgery

Tips and Tricks of Peripheral ECMO Cannulation and Management for Postcardiotomy Shock

Charles Juvin-Bouvier,* Pascal Leprince,*,† and Guillaume Lebreton*,†

Postcardiotomy cardiogenic shock is a severe and feared complication of open-heart surgery. Even if the frequency seems low, the mortality is very high. The use of an extracorporeal membrane oxygenation device in this context can save up to a third of patients, but its implantation and management must be carried out by specialized teams; proper cannulation technique will help prevent many complications and facilitate weaning from the device. For this, all steps and preventive measures must be known and respected, which may include the coexistence of other circulatory assistance devices.
Operative Techniques in Thoracic and Cardiovascular Surgery 28:158–174

KEYWORDS ECMO, cardiac surgery, cardiogenic shock, postcardiotomy shock

Central Message

Protocols for implantation and management of percutaneous ECMO with distal limb perfusion, bilateral cannulation, and left ventricle unloading can improve results in postcardiotomy cardiogenic shock.

Introduction

Cardiogenic shock is a possible complication after open heart surgery that accounts for approximately 1% of the patients[1] with a mortality rate that can reach 40% according to published datas.[2,3] After optimal medical treatment, extracorporeal membrane oxygenation (ECMO) support is increasingly used in the context of postcardiotomy cardiogenic shock as a bridge to recovery, bridge to decision, bridge to bridge or bridge to transplantation[2]; its ease and quick implantation by experienced teams, its cost and its results have favored the diffusion of this therapy in the context of postcardiotomy shock, which remains the main indication for ECMO in the United States,[4] concerning between 0.4 and 3.7% of patients undergoing cardiopulmonary bypass surgery.[1,2]

Some patients seem to be more at risk of receiving a postcardiotomy ECMO: advanced age, renal insufficiency, recent myocardial infarction, main left coronary artery disease, left ventricular dysfunction, and prior cardiac surgery appear as risk factors in studies.[2,5]

ECMO initiation must be early, even preoperatively if required, in any patient where myocardial recovery or, if necessary, long-term assistance and/or heart transplantation can be envisaged; the only absolute contraindication is uncontrollable bleeding[6] but risk factors for a poor prognosis must be taken into account (advanced age, arterial level of lactates, renal insufficiency, female sex, prior cardiac surgery, preoperative neurological events, surgery of the aortic arch[6,7]) at the time of decision-making.

The operating theater is the most common site of implantation, but ECMO is also sometimes set up in an intensive care unit. Despite the possibility to perform central cannulation because of the presence of a sternotomy, peripheral access is still preferred in order to reduce infections, renal failure, bleeding, and re-sternotomy,[2] except in cases where there is a contraindication for peripheral access (thrombosis or malformation of the inferior vena cava, peripheral artery disease, presence of other devices, surgical issues, etc.). Although in studies surgical peripheral cannulation is preferred, percutaneous implantation (using the Seldinger technique[8]) of ECMO has shown many benefits[9] (fewer local infections and better 30-day survival); vascular complications related to percutaneous access are mainly related to decannulation techniques which, thanks to new post-closing devices, are improving day by day.

Placement of a reperfusion cannula distal to the limb is strongly recommended to reduce the risk of ischemia[6,10]; limb perfusion monitoring, such as Near-Infrared

Conflicts of interest: Authors have no conflict of interest relative to this article.
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
*Department of Cardio-Thoracic Surgery, Pitié-Salpêtrière Hospital, Sorbonne University, Paris, France
†Institute of CArdiometabolism and Nutrition (ICAN), UMR 1166, Sorbonne University, Paris, France
Address reprint requests to: Guillaume Lebreton, Department of Cardio-Thoracic Surgery, Institut de Cardiologie, Pitié-Salpétrière Hospital, 47-83 Boulevard de l'Hôpital 75013 Paris, France. E-mail: guillaume.lebreton@aphp.fr

1522-2942/$–see front matter
https://doi.org/10.1053/j.optechstcvs.2023.03.003

Spectroscopy (NIRS), can be used as a diagnostic resource. In addition, the use of ultrasound guidance for the cannulation of the femoral vessels allows to know vascular anatomy, helps in the choice of cannulas, and has demonstrated a reduction in complications and attempts as well as in access time to the vessels; it's therefore strongly recommended.[11-13] This is a particularly important point: a correct cannulation and a targeted puncture of the vessels facilitates decanulation without complications. Another tip is to perform a bilateral cannulation (venous drainage and arterial reinjection in different sides); there is a possibility of reducing distal limb congestion or ischemia even if, in this case, no statistical significance was found out.[10]

Myocardial dysfunction and increased afterload related to ECMO make left ventricular unloading and aortic valve opening difficult; this will increase intracavitary pressures and the risk of pulmonary edema, increase myocardial oxygen consumption, promote intracavitary stasis and the formation of thrombi. Even if the results of the studies are variable, it seems logical to think of the benefit of combining ECMO with an intra-aortic balloon pump to promote pulsatility while reducing ventricular afterload; in case of failure, the placement of a transvalvular axial pump like Impella (Abiomed, Danvers, MA) or surgical unloading of the left cavities is necessary.[2,6,14–19]

Regarding anticoagulation, mechanical circulatory support in postcardiotomy is a special situation with high-risk of bleeding concerns. In our center, we wait for 6 hours postoperatively and if bleeding is controlled, intravenous heparin is started at 100 U/kg per day to reach a 0.2-0.25 antiXa value at our laboratory. After 24 hours, and if bleeding is still controlled, heparin dose is increased to 200-300 U/kg per day to reach an antiXa of 0.3. In case of postoperative bleeding, anticoagulation can be avoided for 24-48 hours.

In the next sections, we present the ultrasound-guided percutaneous cannulation technique which aims to minimize the difficulty of implantation and the complications related to ECMO (Figs. 1-14).

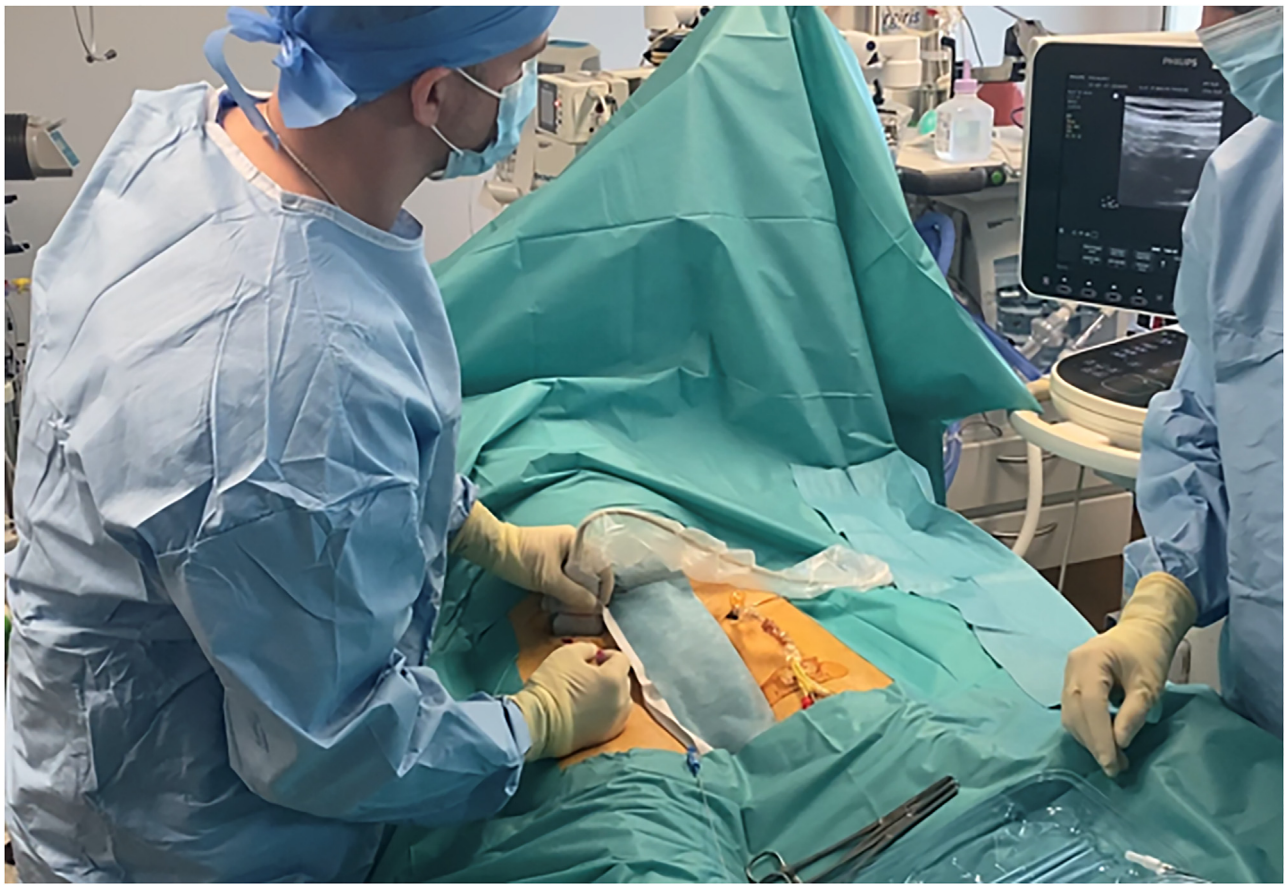

Figure 1 Echography-guided identification of the femoral vessels. Analysis of the anatomy and calcifications of the femoral artery to choose the ideal puncture point on the anterior wall of the common femoral artery, between the inguinal ligament and the femoral bifurcation. The measurement of the diameter of the vessel will help to choose the most suitable cannula for the vascular anatomy of the patient. On the image, the intra-aortic balloon pump being already in place on the left common femoral artery, the arterial cannulation of the ECMO will be performed in the right common femoral artery. (Color version of figure is available online at www.optechtcs.com.)

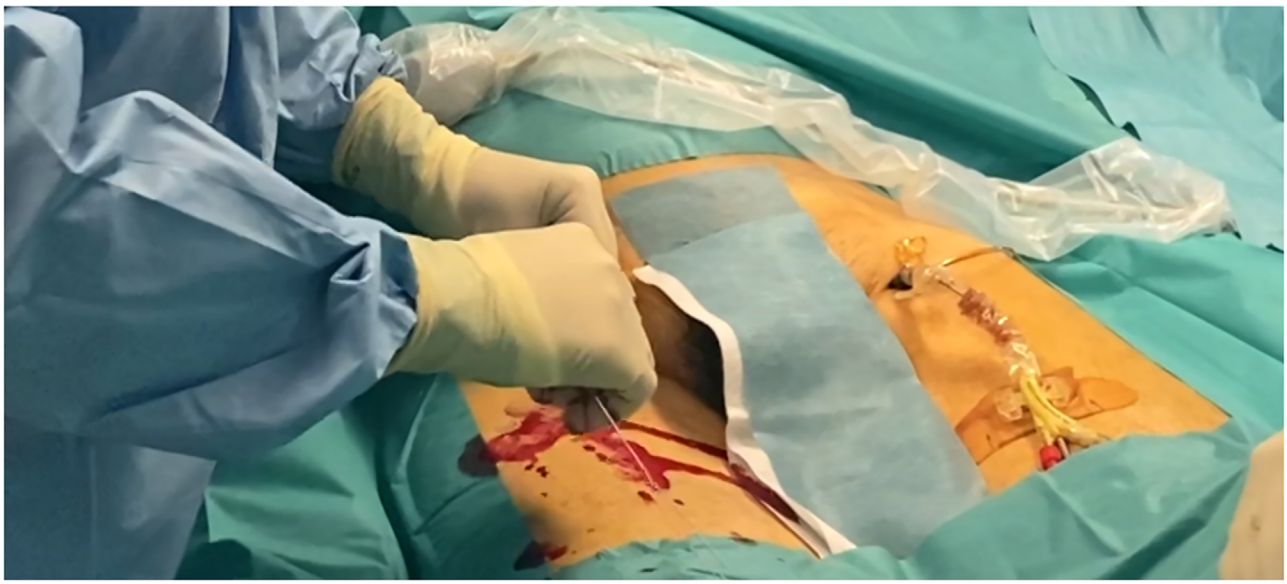

Figure 2 Ultrasound-guided arterial puncture and introduction of a 0.038″ (0.97 mm) 100 cm guide wire through the 18 Ga needle. (Color version of figure is available online at www.optechtcs.com.)

Figure 3 Ultrasound-guided analysis of the left common femoral vein. It is important to properly locate the arch of the greater saphenous vein to avoid puncturing through it. Bilateral cannulation, venous drainage on the left and arterial reinjection on the right in this case, seems to reduce the risk of distal limb ischemia. The first placement of the arterial and venous guidewires before the guide of the distal reperfusion arterial cannula makes possible, in case of a sudden worsening of the patient's clinical condition, to cannulate quickly and start assistance. (Color version of figure is available online at www.optechtcs.com.)

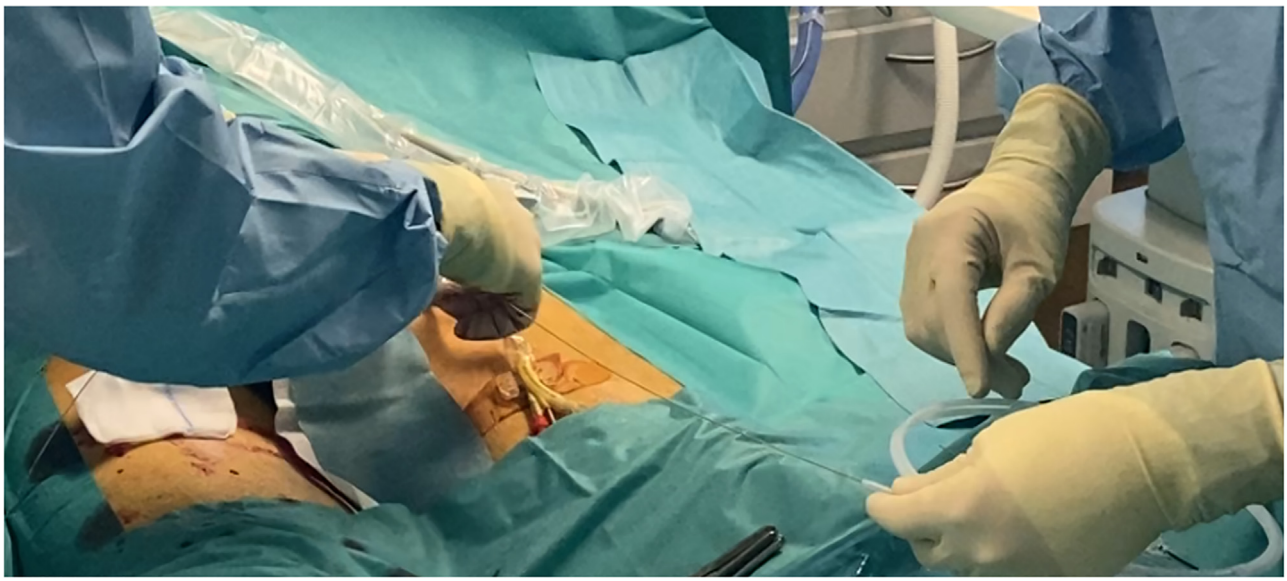

Figure 4 Ultrasound-guided venous puncture and introduction of a 0.038″ (0.97 mm) 150 cm guide wire through the 18 Ga needle. The guidewire must reach the right atrium and this can be find out by transthoracic (or transesophageal if possible) echocardiography control and/or appearance of extrasystoles on electrocardiogram. (Color version of figure is available online at www.optechtcs.com.)

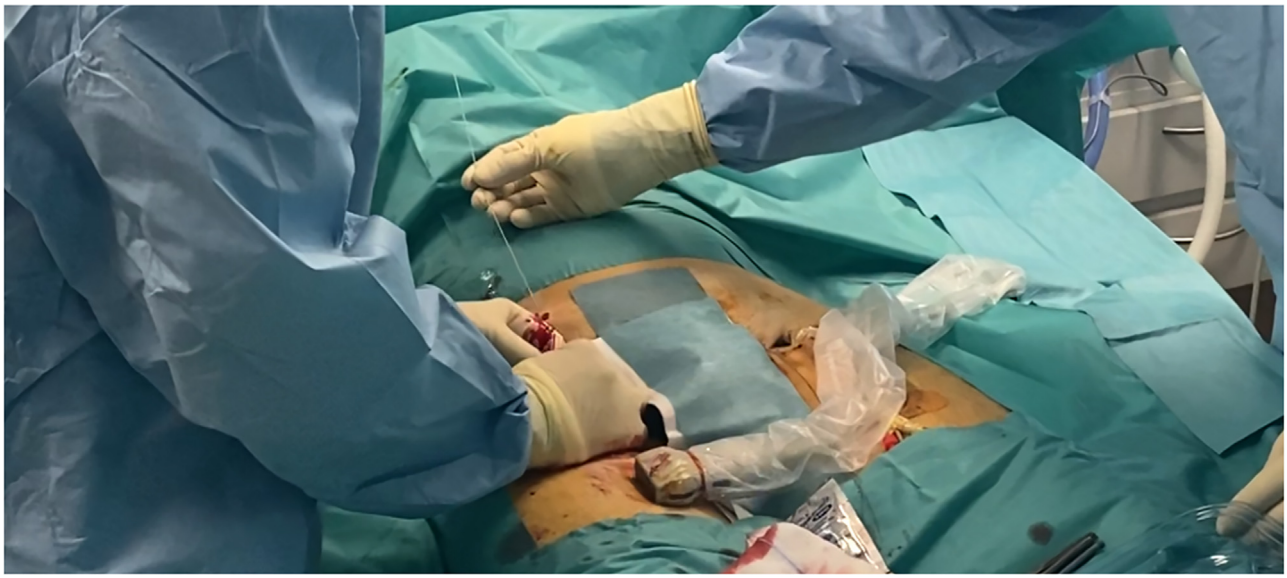

Figure 5 Antegrade ultrasound-guided arterial puncture of the right common femoral artery and introduction of a guide wire through the 18 Ga needle for distal reperfusion cannula. The guidewire enters through the common femoral artery but must be placed in the superficial femoral artery. If an obstacle is encountered during guidewire introduction, it will be most likely placed in the deep femoral artery. The adequate placement of the distal reperfusion cannula is essential to prevent distal limb ischemia during ECMO support; once more, vascular echography and echocardiography could be useful to verify the intravascular position of the different guidewires. (Color version of figure is available online at www.optechtcs.com.)

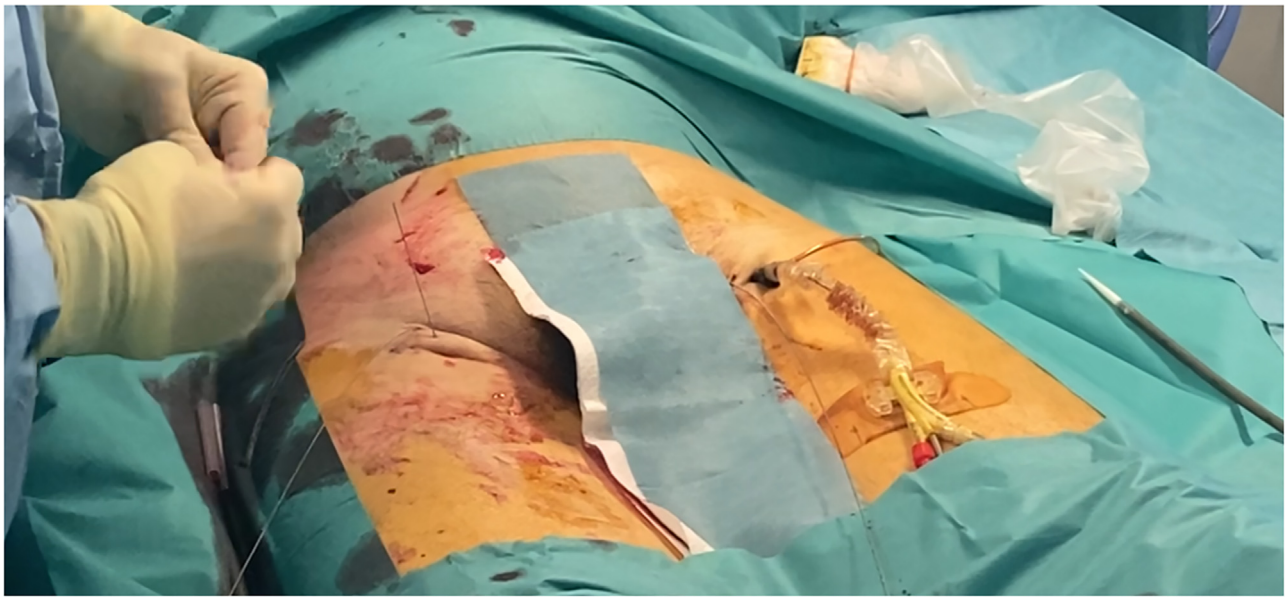

Figure 6 The three guidewires are in place: one in the left common femoral vein, one in the right common femoral artery and one antegrade in the superficial femoral artery through the common femoral artery. (Color version of figure is available online at www.optechtcs.com.)

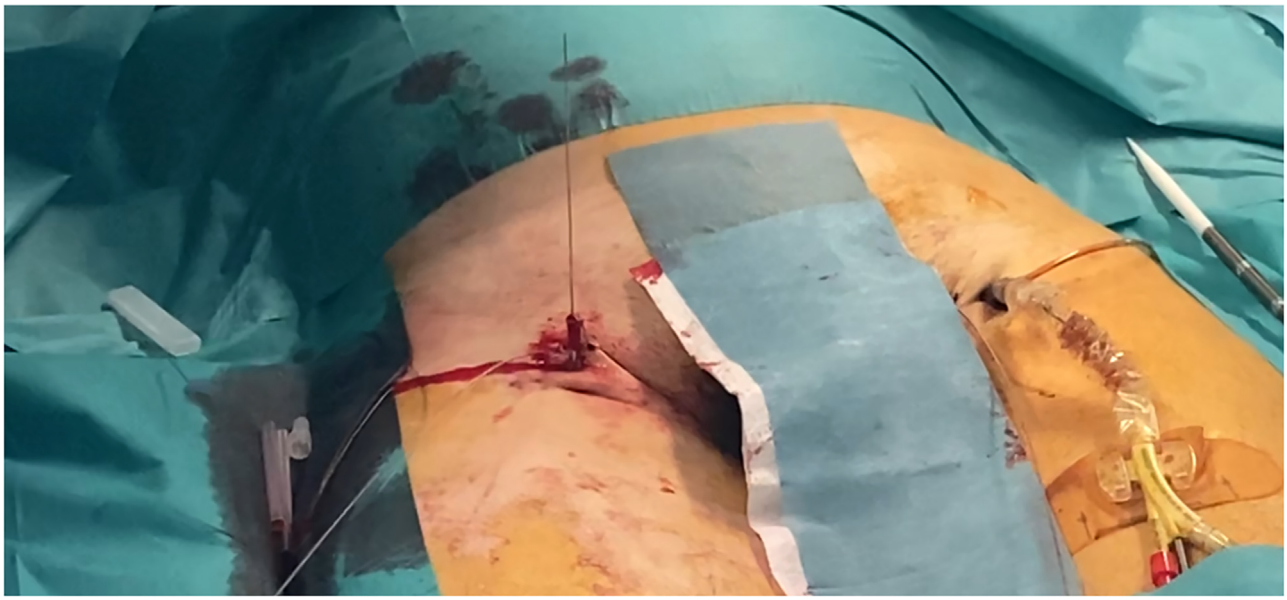

Figure 7 After an intravenous bolus of 5,000 IU of heparin, placement of the distal reperfusion cannula on a guidewire in the right superficial femoral artery. In the present case it is an arterial catheter of 5 Fr and 11 cm. Ideally, reperfusion should be placed before arterial cannulation to check the arterial blood return through it, which will ensure its intravascular position; once the ECMO arterial cannula is in place, the backflow of blood into the reperfusion line may be reduced or absent due to the induced obstruction. The final location could be checked by echography. (Color version of figure is available online at www.optechtcs.com.)

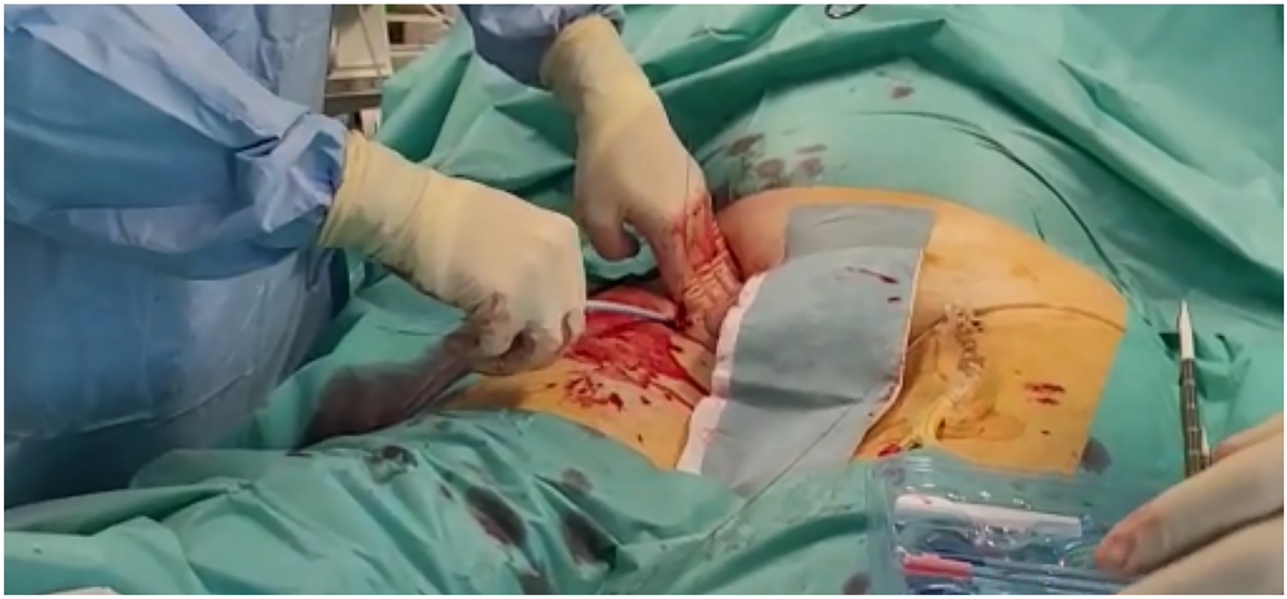

Figure 8 After a small incision in the skin, progressive dilation of the path and the femoral artery with dilators of increasing size. The fixed point on the guide is fundamental to avoid kinking, false paths and any vascular complication. The maximum size of dilators should never exceed the size of the cannula. Pictured is a 16 Fr dilator for a 17 Fr arterial cannula. (Color version of figure is available online at www.optechtcs.com.)

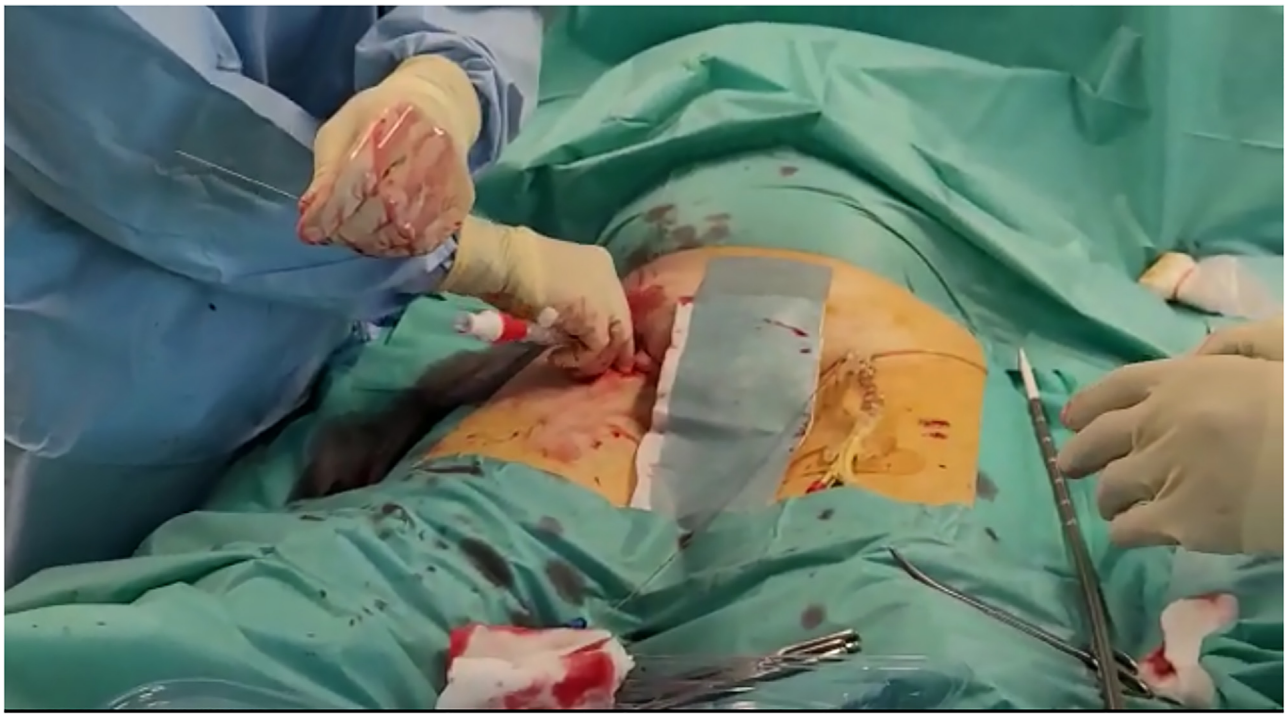

Figure 9 After correct dilation, on-guide cannulation of the common femoral artery, in this case with a 17 Fr and 23 cm cannula. Remove the internal stylet and clamp the non-stented area. It is important to fix the cannula to the skin to avoid accidental decantation. A purge with saline serum (or back flushing) and an appropriate ACT is necessary to elude the formation of thrombi inside the cannula. (Color version of figure is available online at www.optechtcs.com.)

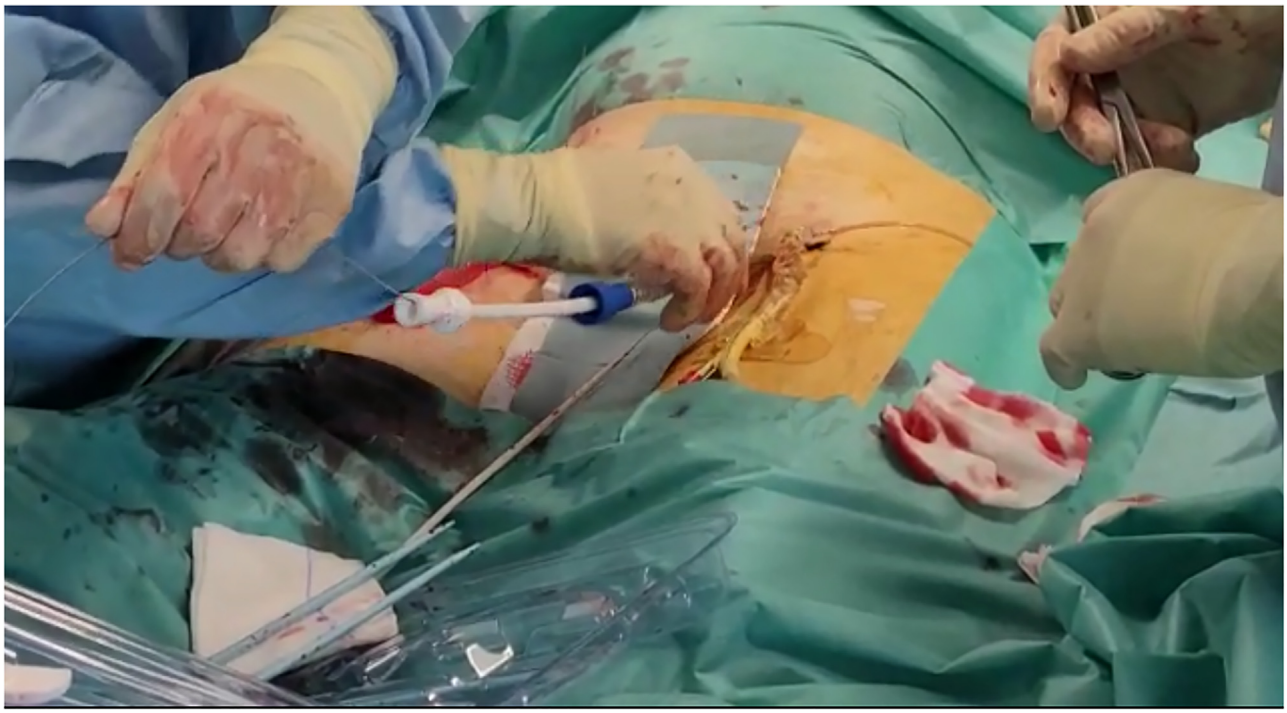

Figure 10 On-guide cannulation of the common femoral vein with a cannula that will reach the right atrium through the inferior vena cava. In this case it is a 25 Fr and 55 cms Maquet cannula. For venous drainage, it is preferable to use a multi-perforated cannula which will promote aspiration on several levels; once the orifices of the cannula are in the vein, the internal stylet must be slightly withdrawn and continue to advance on the guide (in the image) until reaching the right atrium. This technique will prevent perforation and kinking. (Color version of figure is available online at www.optechtcs.com.)

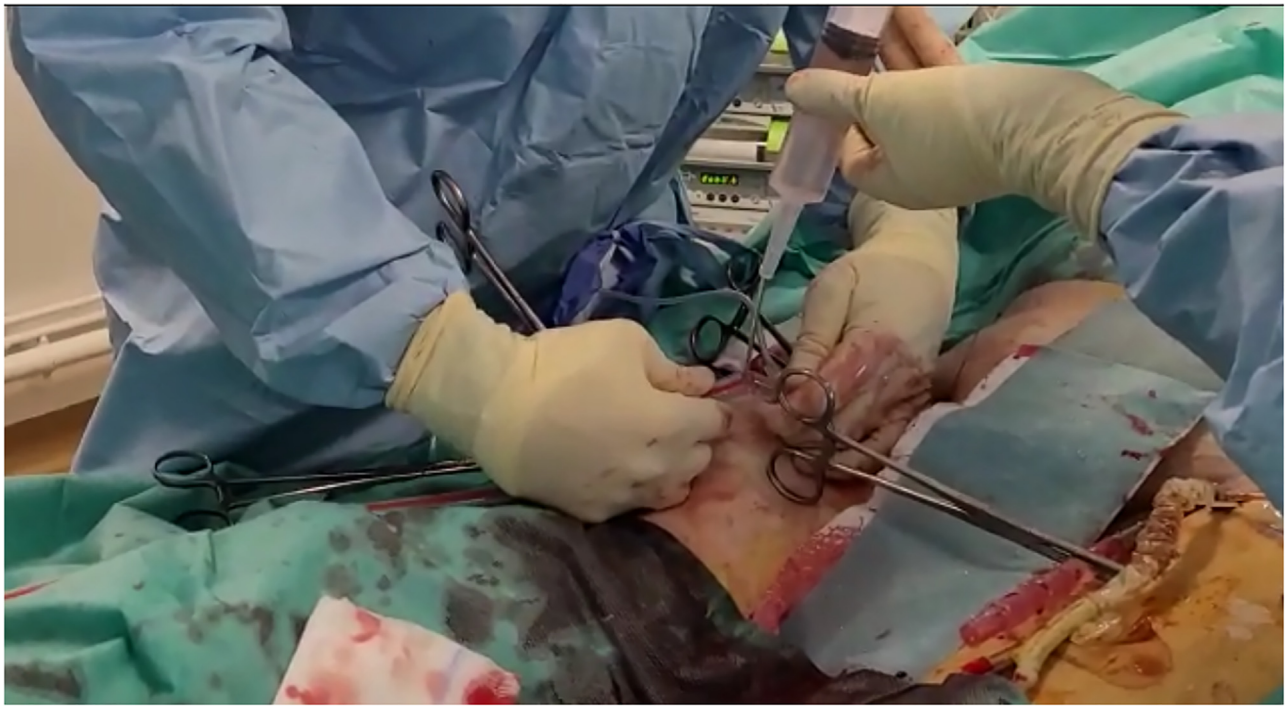

Figure 11 ECMO lines are taken on the operating field, clamped and cut. They will be connected to the arterial and venous cannulas in place by purging the air inside thanks to a continuous injection of saline serum at the time of connection. (Color version of figure is available online at www.optechtcs.com.)

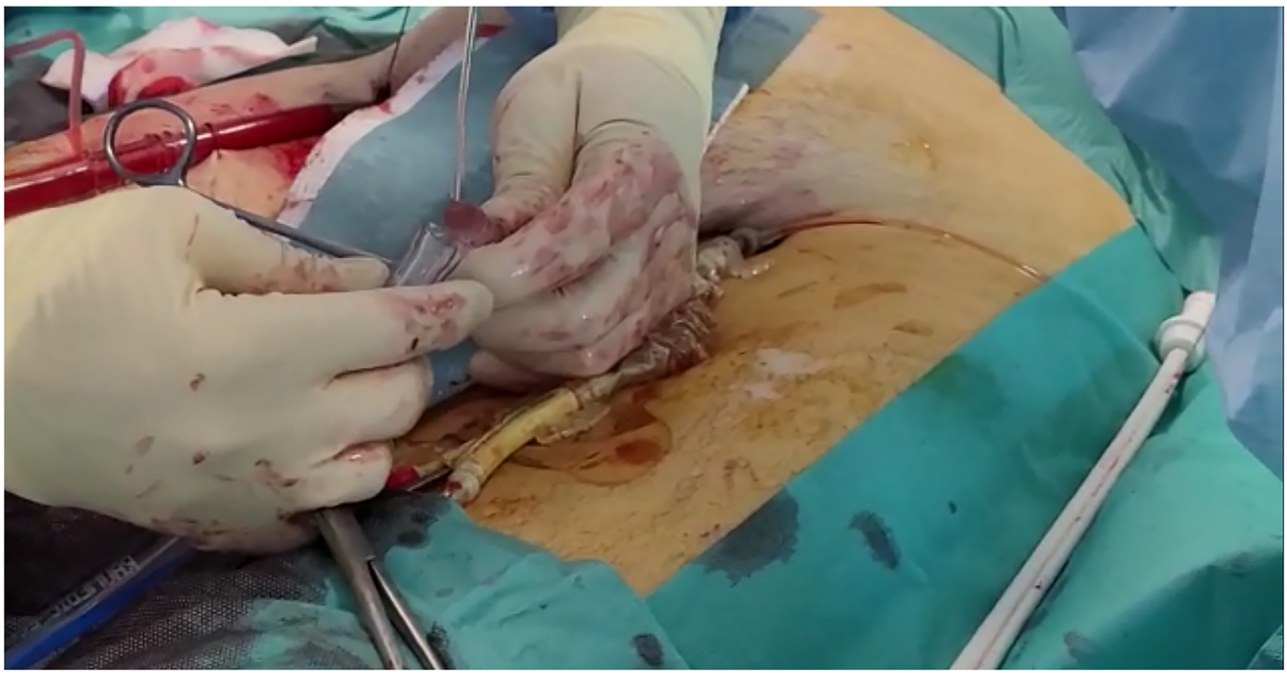

Figure 12 Purging and connection of the venous line to the venous cannula with saline solution. (Color version of figure is available online at www.optechtcs.com.)

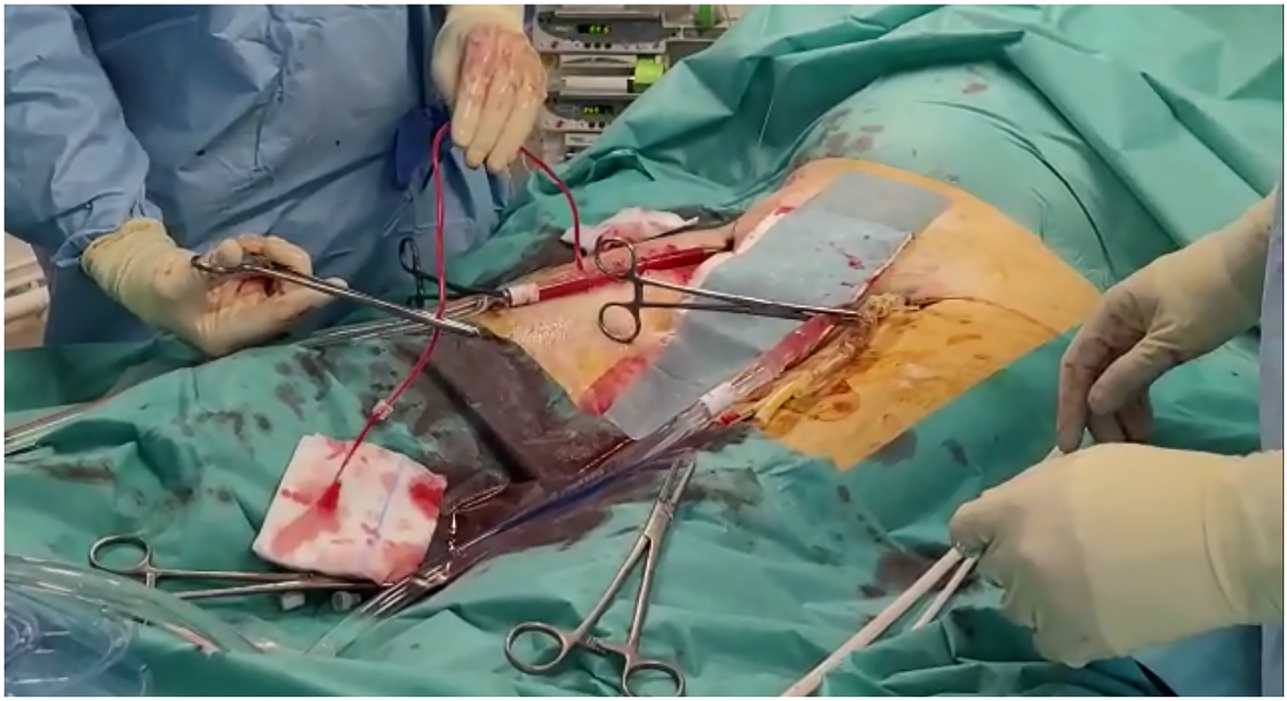

Figure 13 The reperfusion line is connected to the stopcock of the arterial cannula. This tap should be placed on the side, without creating pressure on the skin. The line must be purged of air in two possible ways: 1. at the start of ECMO by unclamping the arterial line and the reperfusion line without initially unclamping the arterial cannula. 2. Before starting ECMO, by removing the arterial cannula clamp and the reperfusion line clamp (in the picture) without removing the arterial line clamp; the patient's blood which will then pass through the reperfusion line will purge it. Once purged, connect it to the reperfusion cannula and start support by unclamping all the lines. (Color version of figure is available online at www.optechtcs.com.)

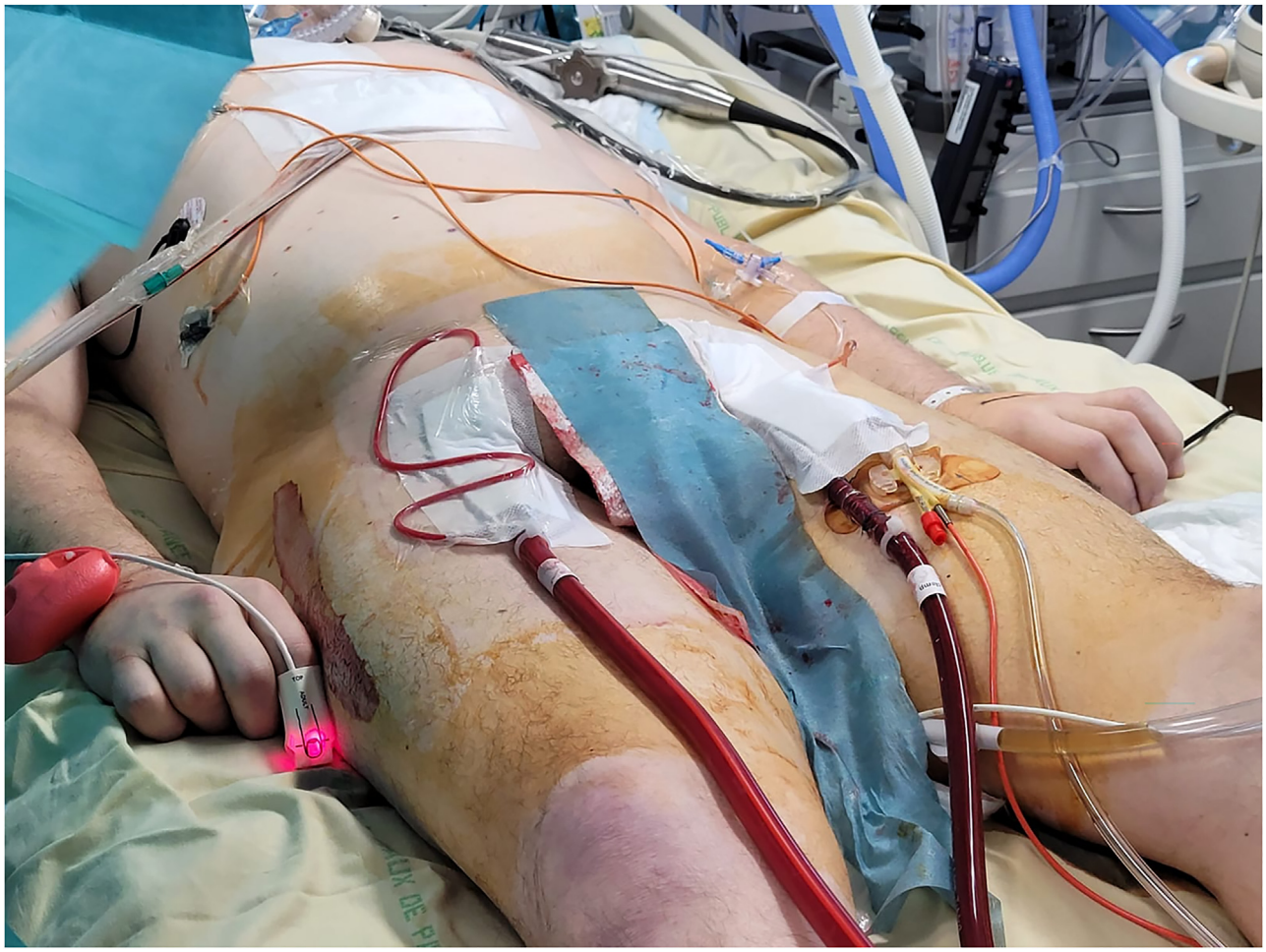

Figure 14 ECMO is in place. The cannulas are attached to the skin at least three different points (including an X point at the connector). The junction between the ECMO line and the connector is secured by a plastic tie. Dressings are made to maintain sterility as best as possible. The reperfusion line is secured and pressed against the skin using a Tegaderm type dressing to avoid accidental decannulation. If necessary, a Doppler echography can be perform on distal arteries to check the correct flow provided by the distal reperfusion cannula; even more, if the ECMO is settled up in hybrid OR, an angiography through the sheath could be useful to check this point. On the image, note the patient's sternotomy dressing: the ECMO was, in this case, put in intensive care in the early postoperative period. (Color version of figure is available online at www.optechtcs.com.)

Conclusions

The survival of patients who have undergone postcardiotomy ECMO is mainly conditioned by the initial critical phase.[1] Mortality is then very high, being able to wean from ECMO only about 60% of patients. Survival in the hospital drops to 36.1%.[20] However, patients who resist this acute phase have an early good prognosis and apparently have an optimal 1- and 3-year survival.[2]

All these results can be improved by using a systematized protocol for the implantation and management of ECMO, favoring percutaneous peripheral placement, secured by ultrasound control of vascular access, and while respecting the Seldinger technique. Reperfusion should be systematic and cannulation bilateral to avoid limb ischemia. A left ventricular offloading system like intra-aortic balloon pump is strongly recommended, going as far as the Impella if pulmonary edema is established and the offloading is ineffective.

Finally, the fixation of the ECMO lines must be ensured by stitches and special dressings such as the Horizontal Tube Attachment Device (HTAD) (Hollister Inc., Libertyville, IL). The possible complications that can arise during implantation, during assistance and when weaning from ECMO must be known by the whole team in order to plan and ensure prevention.

References

1. Meani P, Matteucci M, Jiritano F, et al: Long-term survival and major outcomes in post-cardiotomy extracorporeal membrane oxygenation for adult patients in cardiogenic shock. Ann Cardiothorac Surg 8 (1):116–122, 2019. https://doi.org/10.21037/acs.2018.12.04
2. Lorusso R, Raffa GM, Alenizy K, et al: Structured review of post-cardiotomy extracorporeal membrane oxygenation: Part 1—Adult patients. J Heart Lung Transplant 38(11):1125–1143, 2019. https://doi.org/10.1016/j.healun.2019.08.014
3. Bellumkonda L, Gul B, Masri SC: Evolving concepts in diagnosis and management of cardiogenic shock. Am J Cardiol 122(6):1104–1110, 2018. https://doi.org/10.1016/j.amjcard.2018.05.040
4. Sauer CM, Yuh DD, Bonde P: Extracorporeal membrane oxygenation use has increased by 433% in adults in the United States from 2006 to 2011. ASAIO J 61(1):31–36, 2015. https://doi.org/10.1097/MAT.0000000000000160
5. Smedira NG, Blackstone EH: Postcardiotomy mechanical support: risk factors and outcomes. Ann Thorac Surg 71(3):S60–S66, 2001. https://doi.org/10.1016/S0003-4975(00)02626-6
6. Lorusso R, Whitman G, Milojevic M, et al: 2020 EACTS/ELSO/STS/AATS expert consensus on post-cardiotomy extracorporeal life support in adult patients. Eur J Cardiothorac Surg 59(1):12–53, 2021. https://doi.org/10.1093/ejcts/ezaa283
7. Biancari F, Dalén M, Fiore A, et al: Multicenter study on postcardiotomy venoarterial extracorporeal membrane oxygenation. J Thorac Cardiovasc Surg 159, 2020(5). https://doi.org/10.1016/j.jtcvs.2019.06.039. 1844-1854.e6
8. Seldinger SI: Catheter replacement of the needle in percutaneous arteriography: A new technique. Acta Radiol 39(5):368–376, 1953. https://doi.org/10.3109/00016925309136722
9. Danial P, Hajage D, Nguyen LS, et al: Percutaneous versus surgical femoro-femoral veno-arterial ECMO: A propensity score matched study. Intensive Care Med 44(12):2153–2161, 2018. https://doi.org/10.1007/s00134-018-5442-z
10. Lamb KM, DiMuzio PJ, Johnson A, et al: Arterial protocol including prophylactic distal perfusion catheter decreases limb ischemia complications in patients undergoing extracorporeal membrane oxygenation. J Vasc Surg 65(4):1074–1079, 2017. https://doi.org/10.1016/j.jvs.2016.10.059
11. Ahn HJ, Lee JW, Joo KH, et al: Point-of-care ultrasound−guided percutaneous cannulation of extracorporeal membrane oxygenation: Make it simple. J Emerg Med 54(4):507–513, 2018. https://doi.org/10.1016/j.jemermed.2017.12.013
12. Benassi F, Vezzani A, Vignali L, et al: ultrasound guided femoral cannulation and percutaneous perfusion of the distal limb for VA ECMO: Distal limb perfusion for VA ECMO. J Card Surg 29(3):427–429, 2014. https://doi.org/10.1111/jocs.12319
13. Nanjayya VB, Murphy D: Ultrasound Guidance for Extra-Corporeal Membrane Oxygenation General Guidelines. ELSO General Guidelines for All ECLS Cases 1–5, 2015
14. Bréchot N, Demondion P, Santi F, et al: Intra-aortic balloon pump protects against hydrostatic pulmonary oedema during peripheral venoarterial-extracorporeal membrane oxygenation. Eur Heart J Acute Cardiovasc Care 7(1):62–69, 2018. https://doi.org/10.1177/2048872617711169
15. Bakhtiary F, Keller H, Dogan S, et al: Venoarterial extracorporeal membrane oxygenation for treatment of cardiogenic shock: Clinical experiences in 45 adult patients. J Thorac Cardiovasc Surg 135(2):382–388, 2008. https://doi.org/10.1016/j.jtcvs.2007.08.007
16. Hsu PS, Chen JL, Hong GJ, et al: Extracorporeal membrane oxygenation for refractory cardiogenic shock after cardiac surgery: Predictors of early mortality and outcome from 51 adult patients. Eur J Cardiothorac Surg 2009. https://doi.org/10.1016/j.ejcts.2009.07.033. S1010794009007672
17. Cheng R, Hachamovitch R, Makkar R, et al: Lack of survival benefit found with use of intraaortic balloon pump in extracorporeal membrane oxygenation: A pooled experience of 1517 patients. J Invasive Cardiol 27(10):453–458, 2015
18. Meani P, Gelsomino S, Natour E, et al: Modalities and effects of left ventricle unloading on extracorporeal life support: A review of the current literature: Modalities and effects of left ventricle unloading on extracorporeal life support. Eur J Heart Fail 19:84–91, 2017. https://doi.org/10.1002/ejhf.850
19. Nuding S, Werdan K: IABP plus ECMO—Is one and one more than two? J Thorac Dis 9(4):961–964, 2017. https://doi.org/10.21037/jtd.2017.03.73
20. Biancari F, Perrotti A, Dalén M, et al: Meta-analysis of the outcome after postcardiotomy venoarterial extracorporeal membrane oxygenation in adult patients. J Cardiothorac Vasc Anesth 32(3):1175–1182, 2018. https://doi.org/10.1053/j.jvca.2017.08.048