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Method Article

Percutaneous cannulation for extracorporeal membrane oxygenation (ECMO): A method for pig experimental models

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A B S T R A C T

Pigs are often used for experimental models of cardiogenic shock, cardiac arrest or acute lung injury with veno-arterial (VA) or veno-venous (VV) extracorporeal membrane oxygenation (ECMO) implementation. Percutaneous (as opposed to surgical) cannulation in experimental models has potential advantages, including, less surgical trauma or stressful stimuli and less bleeding complications when compared to open chest cannulation. However, pig anatomy can also be a challenge because of the deep location and angled anatomy of the femoral artery. The Seldinger technique and the use of a percutaneous cannulation kit is feasible in pigs.

Summarized here we present (Graphical Abstract):

• Percutaneous ECMO cannulation method for non-cardiac surgeon.
• Establishment of this simple and rapid methods for pig experimental models.
• Predictable complications of this method.

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A R T I C L E  I N F O
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Specifications Table

| Subject Area | Veterinary Science and Veterinary Medicine  |
|--------------|--------------------------------------------|
| More specific subject area | Translational science, animal model for medical application |
| Method name | Ultrasound-guided percutaneous cannulation of ECMO for pig experimental models |
| Name and reference of original method | Percutaneous circulatory support system |
| Resource availability | / |

Methods details

Principles of ECMO

Extracorporeal membrane oxygenation is widely used in human intensive care to support lung injury (veno-venous (VV) ECMO) or circulatory failure (veno-arterial (VA) ECMO) [1]. The global concept is to remove blood from the venous compartment, pass it through an oxygenator membrane and then return the oxygenated blood into the circulatory system at a defined flow rate. In cases of lung failure without cardiac failure, the oxygenated blood is returned to the venous circulation. In case of heart failure, the oxygenated blood is returned to the arterial circulation. This technique was developed in the early 60's, but its use is now growing, opening new perspectives and new interrogation options for researchers.

Principles of percutaneous cannulation

Percutaneous access using the Seldinger technique is well known in clinical practice for catheter insertion (central venous or arterial) [2]. For establishing ECMO, due to the size of the cannula, the Seldinger technique is rarely used [3] and surgical access is still the preferred method [4]. The reported complications of this technique are mainly related to the insertion process, and include insertion failure due to a mismatch between vessel size and diameter of the cannula, as well as potential bleeding complications [5]. Long term complications include infection, limb ischemia and subsequent sensory-motor complications in humans [6,7].

Pig specificity

Pigs are often used for experimental models of cardiogenic shock, cardiac arrest or acute lung injury with VA or VV ECMO implementation [8,9]. Percutaneous cannulation in experimental models has potential advantages beyond the need for advanced surgical expertise: less stressful surgical stimuli are applied to the animal and less bleeding complications arise. But pig anatomy can also be a challenge because of the deep location and angled anatomy of the femoral artery.

In this protocol we will present the material and the procedure to perform percutaneous femoral cannulation for ECMO in Landras pigs. We will present only VA-ECMO cannulation, but VV-ECMO cannulation follows the same procedure with one jugular and one femoral venous access.

Material and methods

Ethics

All experiments pictured and described in this article were reviewed and approved by the Paris University Ethics Committee for Animal Experimentation (APAFIS #23056). The procedure for the care and sacrifice of study animals was in accordance with the European Community Standards on the Care and Use of Laboratory Animals.
Animal model and anesthesia

The procedure must be performed under general anesthesia to avoid pain and leg movement. Pigs must be in supine position.

Material

- Ultrasound (US) with a 8–12 MHz linear transducer probe for the vessel puncture guidance
- Local anesthetic (Lidocaine)
- Venous cannula (21 Fr, Biomedicus cannulae, Medtronic, USA) and percutaneous insertion kit (Maquet, Germany) including guide wire, vessel dilator, puncture needle, scalpel, syringe
- Arterial cannula (15 Fr or 16 Fr, Biomedicus cannulae, Medtronic, USA) percutaneous insertion kit (Maquet, Germany), including guide wire, vessel dilator, puncture needle, scalpel, syringe
- Centrifugal pump (Rotaflow Centrifugal Pump System, Maquet, Germany)
- Sutures
- Heparin

Procedure

Procedure for VA-ECMO femoral cannulation (Fig. 1)

- Assemble the ECMO
- Administer a bolus of intravenous unfractionated heparin (100 UI.kg$^{-1}$) to the animal
- Localize the vessels (artery and vein) using US
- Inject local anesthesia (Lidocaine) to limit pain in case of femoral nerve stimulation and to provide a vasodilatory effect
- Puncture the femoral vein with the needle, insert the guide wire (diameter and size adapted to the cannula, minimum length 150 cm)
Fig. 2. Procedure for cannulae connection to ECMO circuit and pump start. A: cannulae in place. B. Connection of the cannula to the ECMO circuit while dripping saline over the junction to avoid air bubbles in the circuit. C. Cannulae and circuit are connected. D. Starting the centrifugal pump prior to remove the venous clamp. E. Remove the arterial line clamp after the venous clamp. F. Ensure that the two cannulae have different color.

- Puncture the ipsi- or contralateral femoral artery with the needle, insert the guide wire (diameter and size adapted to the cannula, minimum length 100 cm)
- Make a 1 cm skin incision around each wire
- Start with the venous cannulation first
- Dilate the vessel progressively with increasing size dilators
- Confirm repeatedly that the wire is not bent by checking the smooth and free motion of the wire into the dilatator
- Insert the cannula after surface lubrication with saline
- Remove the wire and the introducer/dilator
- Clamp immediately to avoid blood loss
- Repeat the same procedure of progressive dilation and immediate clamping for the arterial cannula

Procedure for cannulae connection to ECMO circuit and for pump start (Fig. 2)
- Connect both cannulae to the ECMO circuit while dripping saline over tubing junction to avoid air bubbles in the circuit.
- Start the centrifugal pump while both cannulae are still clamped
- Remove the venous clamp first
- Then remove the arterial line clamp
Methods validation

Ultrasound

Vascular ultrasound should be used to: (1) guide the percutaneous needle puncture, and (2) control the guide wire position in the vessel.

Transthoracic ultrasound

Cardiac ultrasound can be used to localize the distal tip of the venous cannula in the right atrium or in the inferior vena cava.

Fluoroscopy

Fluoroscopy can also be used to localize the cannulas, mainly for VV ECMO to make sure the distance between cannula tips is great enough to avoid recirculation.

Additional information

Major complications

Bleeding is the main complication to be concerned about. Because of the angled anatomy of the femoral artery, the vessel dilatation can create an arterial lesion that cannot be fixed without open surgery. To avoid this complication, vessel dilatation and cannulation must also be smooth and careful. Another major and unpredictable complication can be the creation of an intra-abdominal false path. If the cannula (venous or arterial) perforates the vessel wall, it will rapidly induce hemorrhagic shock when the ECMO flow begins, with no chance to save the animal.

Cannula size

The cannula size depends on the animal weight (femoral artery diameter) and on the ECMO flow target. The larger the cannulae, the lower the resistance to flow.

ECMO anticoagulation

Even if the circuit and cannulae are coated with bioline, a bolus of unfractioned heparin (5000 UI) should be added in the pump priming solution, followed by repeated intravenous heparin injections of 100 UI.kg$^{-1}$ every hour.

ECMO weaning

The percutaneous cannulation approach is only feasible for non-weaning ECMO protocols. If the animals are to be maintained alive after ECMO removal, a surgical repair of the artery is required.

Training

Percutaneous ECMO implantation as described in this method article does not require specific surgical competencies and can be achieved by investigators trained in ultrasound and Seldinger’s technique.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
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