

## Pressure and Flow Characteristics of a Novel Bidirectional Cannula for Cardiopulmonary Bypass

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### ORIGINAL ARTICLE

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## Pressure and Flow Characteristics of a Novel Bidirectional Cannula for Cardiopulmonary Bypass

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**Objective:** Femoral arterial cannulation is associated with a significant risk of lower limb ischemia. The aim of the study was to assess the pressure and flow in the femoral artery using a novel bidirectional femoral cannula in a sheep model of peripheral cardiopulmonary bypass.

**Methods:** Peripheral cardiopulmonary bypass was established using a multistage venous cannula inserted into the internal jugular vein and the bidirectional or a conventional arterial cannula into the femoral artery in seven adult ewes. Systemic and distal perfusion pressures and flow rates were measured during cardiopulmonary bypass with flow rates of 1, 2, 3, and 4 L/min. Lower limb venous oxygen saturation and lactate levels were also measured.

**Results:** A significantly higher blood flow in the lower limb using the bidirectional cannula was observed and compared with a conventional cannula at all flow rates (mean flow 115 mL/min vs 10 mL/min,  $P < 0.05$ ). The mean distal perfusion pressure was also significantly higher in the bidirectional cannula group (86 mm Hg vs 45 mm Hg at 4 L/min of flow,  $P < 0.05$ ). The bidirectional cannula was associated with higher venous oxygen saturations in the lower limb than in the conventional cannula group; however, lower limb lactate production was similar in the two groups.

**Conclusions:** This in vivo data demonstrates superior distal flow and pressure characteristics of a novel bidirectional cannula compared with a conventional femoral cannula during peripheral cardiopulmonary bypass.

**Key Words:** Bidirectional cannula, Cardiopulmonary bypass, Leg ischemia, Peripheral cannulation.

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Peripheral cannulation using the femoral artery for arterial inflow is often required for complex aortic surgery or cardiac surgical procedures using minimally invasive approaches. It is also used for prolonged cardiopulmonary support with extracorporeal membrane oxygenation. A significant risk of lower limb ischemic complications after prolonged femoral arterial cannulation has been reported in the literature. Hendrickson and Glower<sup>1</sup> reported an incidence of 11.5% after peripheral cardiopulmonary bypass (CPB). Extracorporeal membrane oxygenation support is associated with lower limb ischemic complication rates as high as 26%.<sup>2,3</sup> The size of the femoral cannula required to maintain a patient on adequate CPB support is often the same diameter as the patient's own femoral artery, and there is little room around the cannula for distal limb perfusion. Viability of the limb is dependent on collateral blood flow, which, if poor, can cause limb ischemia resulting in a requirement for fasciotomy or worse amputation. A number of techniques have been proposed to prevent this potentially devastating complication, including the use of an end-to-side femoral artery graft<sup>4,5</sup> or a downstream femoral perfusion catheter.<sup>1,6-8</sup> These techniques, however, are often cumbersome to perform and are not always reliable. They are also associated with bleeding complications and an increased risk of infection. They have, therefore, not been routinely adopted. Currently, there are no simple and effective methods for ensuring adequate lower limb perfusion

## CENTRAL MESSAGE

A novel bidirectional femoral cannula in a sheep model of cardiopulmonary bypass (CPB) showed significantly higher blood flow in the lower extremity when comparing animals that were cannulated with conventional cannula at all CPB flow rates.

## STUDY OUTLINE

- Animal study conducted between February and April 2011.
- Seven adult ewes (approximately 60 kg):
  - about the same circulating blood volume as adult humans;
  - femoral artery caliber is similar to adult human size.

## MATERIAL AND METHODS

- One side randomly chosen for the bidirectional cannula and the contralateral side for a standard femoral arterial cannula – both cannulae had same F size.
- Bidirectional cannula insertion technique similar to the standard cannula.
- Ultrasound flow probe applied to the femoral artery 2 to 3 cm distal to the insertion point of the cannula to measure cannula flow downstream.
- Femoral venous oxygen saturation and lactate levels measured on both sides.

## RESULTS

Bidirectional cannulae	Standard cannulae
No technical difficulties for insertion	No technical difficulties for insertion
Adequate systemic pressures achieved on bypass	Adequate systemic pressures achieved on bypass
Up to 130 mL/min distal flow (Fig 3 – P<0.05)	Very poor distal femoral perfusion
Higher distal perfusion pressure (Fig 4 – P<0.05)	Lower distal perfusion pressure
Venous saturation in the limb significantly higher (Fig 5 – P<0.05)	Venous saturation in the limb significantly lower

- No statistically significant difference in lactate production between the two groups was (short duration of each study and small number of animals), but was lower in the bidirectional group.
- No difficulties were encountered with removal of the bidirectional cannula.

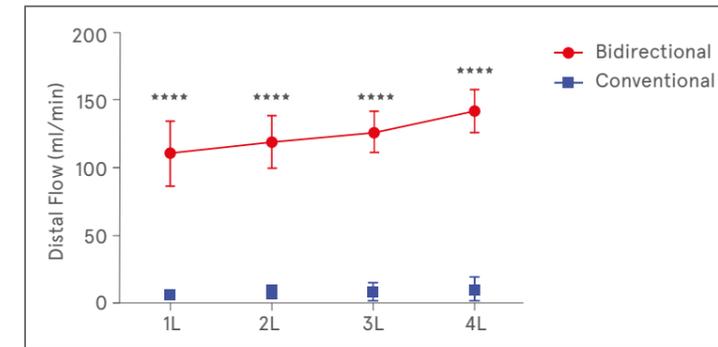
## KEY TAKE-AWAYS

- “In this study, we have demonstrated the feasibility of using a novel bidirectional femoral cannula in a sheep model of peripheral CPB to provide distal limb perfusion.”
- “The novel bidirectional cannula was simple to insert and position, and demonstrated good distal flow and pressure characteristics.”
- “The bidirectional cannula would be able to supply adequate blood flow to the lower limb at full CPB support.”
- “The bidirectional cannula design evaluated in this study does not rely on ultrasound for positioning.”
- “Flow through the second aperture is directed downstream rather than toward the back wall of the artery. The tapered shoulder allows for atraumatic insertion, provides tactile feedback during positioning, and prevents dislodgement of the side hole into the subcutaneous tissues.”
- “This is a well-designed and well-performed experimental study that clearly demonstrated the benefits of this bidirectional femoral cannula. **This study suggests that this cannula may have significant benefits in both minimally invasive valve and other cardiac surgical patients undergoing peripheral cannulation.**”

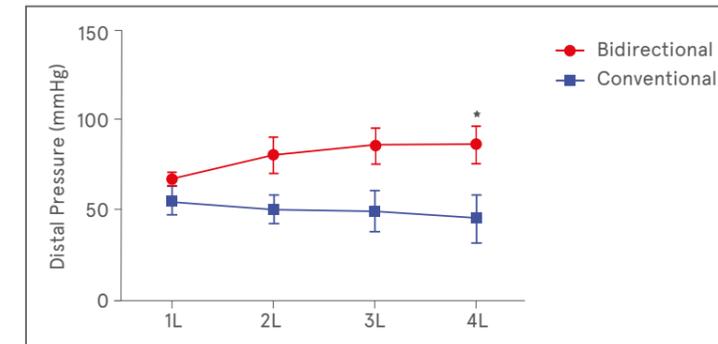
## CONCLUSION

*“In conclusion, we have demonstrated superior femoral artery flow and pressure characteristics of a novel bidirectional femoral cannula compared with a standard femoral cannula.”*

**Figure 3.** Flow in distal superficial femoral artery using bidirectional or conventional cannula (N=7 in each group). \*\*\*\*P<0.001.



**Figure 4.** Pressure in distal superficial femoral artery using bidirectional or conventional cannula (N=7 in each group). \*P<0.05.



**Figure 5.** Femoral vein oxygen saturation in bidirectional and conventional cannula groups (N=7 in each group). \*P<0.05.

