Miniaturized cardiopulmonary bypass: the importance of controlling the controllable

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Despite some demonstrable advantages, miniaturized cardiopulmonary bypass (mCPB) remains on the edge of clinical practice. Our team at the Hammersmith Hospital in London have deliberated at length on why its widespread adoption has not occurred.

The evolution from conventional to mCPB involved significant modifications that were all made simultaneously. This accelerated transition has been a key contributor in obstructing wider clinical acceptance. The risk is that these multiple changes can create an uncomfortable clinical environment for the cardiac team. For some users, this exposure has diminished the ability to embrace the advantages and the ambition to advance the technique.

Implementing change presents both advantages and disadvantages. It is our responsibility as a cardiac team, specifically the Perfusion profession, to balance the advantages against the disadvantages and deliver a technique that improves extracorporeal support.

On the surface, current mCPB research may be perceived as merely revisiting the same findings. This is not the case. We must consider publications in the context of guiding us to where mCPB needs to be, rather than presuming that it describes the finished article. The publication in this issue by Aboud et al. [1] is a prime example. The advantages of the technique are eloquently demonstrated, which are reduced haemodilution, reduced inflammatory markers, reduced haemolysis and reduced cardiac damage. Two significant disadvantages are also identified: excessive negative venous pressure and increased arterial air. Importantly, these disadvantages are described and quantified.

If we consider venous pressure, this is an important and underappreciated quality indicator for cCPB as well as mCPB. De Somer [2] makes the point that an increase in venous negative pressure will coincide with vein collapse when the negative pressure at the tip of the venous cannula exceeds ~4 mmHg. The relationship between the pressure at the tip of the cannula and the pressure in the venous line is patient specific. At the Hammersmith, we refer to this as the Patient Specific Venous Collapse Pressure (PSVCP). We have in vivo data to show that this threshold varies from ~5 mmHg to ~60 mmHg, depending on the IVC size, RA size, cannula size, cannula type, cannula position and patient circulating volume. By considering this information alongside the results published in Table 2 by Aboud et al., it is confirmed that for some patients, even gravity drainage is excessive. We have all experienced the visual consequence of this phenomenon in the form of venous line judder when using gravity venous drainage. Venous line pressure is not a routinely measured CPB parameter. Aboud’s research and our experience at the Hammersmith suggest it is a robust quality indicator and therefore should be monitored during all cases. Without a doubt, monitoring this parameter should be a minimum requirement for all mCPB.

The problem with excessive negative venous line pressure is 2-fold. First, it creates venous congestion. When the PSVCP is exceeded, it is equivalent to placing a clamp across the IVC. This will have an impact on end-organ perfusion and potentially, clinical outcome. The second consequence of excessive negative venous line pressure is the generation of gaseous micro-emboli. This problem is compounded when using a closed system as is the case with mCPB. This is confirmed by Aboud’s paper as significantly more air was detected in the arterial line of the mCPB group. As stakeholders in delivering better cardiopulmonary bypass, the question for all of us is ‘what do we do with the findings in Aboud’s research?’. The starting point should be to identify and control the controllable.

CONTROLLING EXCESSIVE NEGATIVE VENOUS LINE PRESSURE

Controlling excessive negative venous line pressure is done as follows: choose the appropriate cannula for the patient, cannulate properly, monitor venous line pressure, understand how to utilize this ‘new’ information, ensure the patient is adequately filled and regulate arterial and venous flow.

CONTROLLING ARTERIAL AIR

Controlling the venous line pressure will help. Then, we have to compromise the foreign surface area exposure and add a venous air removal device to the system. This may seem like a backward step, but it is a well-educated, informed compromise. For a 0.01 m² increase in foreign surface, the benefits of ‘active’ microscopic air removal can be reaped, rather than the ‘passive’ micro air removal offered using a cCPB hard-shell venous reservoir. To put this increase in foreign surface area in perspective, it is comparable with 25 cm of ½ tubing or 0.05% of the oxygenator as used in Aboud’s experiment. As described by Perthel et al. [3] in 2007, controlling this aspect of the mCPB circuit reduces the air in...
the arterial line below both the Perthel et al. and Adboud et al. cCPB group.

If we apply this philosophy to the mCPB system investigated by Aboud et al., we should evolve to a circuit that, in comparison with cCPB, offers reduced haemodilution, reduced inflammatory markers, reduced haemolysis, reduced cardiac damage, reduced arterial air and patient-appropriate venous line pressures.

The advantages of mCPB seem to be taking care of themselves. Identifying, accurately describing and understanding the disadvantages will put us in a position of strength, striving to control the controllable.

REFERENCES