Haematic Antegrade Repriming procedure to initiate a safer cardiopulmonary bypass.

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Summary:

Background: Cardiopulmonary bypass is a safe technique frequently required in cardiac surgery. Despite that, it carries several undesired effects related to haemodilution, emboli and alterations on the coagulation and microcirculation. Different strategies like the minimized circuits (MiECC) or the retrograde autologous priming (RAP) have attemped to reduce its impact, but finally lead to inconsistent results as independent measures due to the heterogeneity on its practice. The haematic antegrade repriming (HAR) detailes a standardized materials and methodology that could offer a reproducible method inspired in evidence-based recommendations. **Description of the technique:** HAR is performed in a standardized Class IV MiECC that is reprimed antegradely with autologous blood obtained from the aorta of the patient, before the cardiopulmonary bypass (CPB) initiation. Then, CPB is started with the support of vacuum assisted venous drainage (VAVD). **Discussion**: The strict application of HAR results in a fix haemodilution of 300ml of crystalloid priming, avoiding the sudden haemodilution and the crystalloid embolism of the CPB initiation. The synergic effect that converges in HAR could exceed the evidence-based benefits of RAP, MiECC and VAVD promising to improve the outcomes in terms of transfusion, complications, stay and survival. **Conclusion**: HAR is proposed as a new approach to increase the safety of the CPB. Its overall benefits should be properly assessed and validated by current and further studies.

Background

Cardiopulmonary bypass (CPB) offers the extracorporeal support required during most of cardiac surgery procedures but is also related to undesirable effects. Despite the remarkable evolution regarding to its practice, CPB still contributes to an insult related to the haemodilution, the embolic release and alterations of the coagulation and the microcirculation that hinders the postoperative recovery (1–3).

During CPB initiation, in a conventional setup, the blood of the patient is replaced by the priming volume of the circuit instantly and then, being mixed with the autologous blood, causes a sudden haemodilution that is even increased later with the administration of a cardioplegic solution. Haemodilution has been identified as the mechanism that triggers postoperative coagulopathy, inflammatory response, tissular hypoxia and higher blood products requirement until discharge (4,5). The anaemic status and the subsequent transfusion augment the risk of glomerular dysfunction, rising levels of troponin, length of ventilation time and hospital stay as well as the mortality by individual exposure. This effect is even amplified when both appear in combination (6).

Additionally, some studies identified a certain amount of gaseous microemboli that remain in the oxygenation chamber after the conventional crystalloid priming that represent a matter of concern. These emboli are released to the bloodstream during different stages of the cardiac surgery procedure like the initiation of CPB and variations in flow and pressure on the oxygenation chamber (7–9).

We performed a systematic review using Pubmed, Cochrane and Embase under the following search descriptors: (cardiopulmonary bypass) AND ((minimally invasive) OR (minimize impact)). A total of 1835 results were obtained. Only clinical trials, randomized controlled trials, meta-analyses and systematic reviews were considered, resulting in 78 articles that were studied.

Considering that most strategies to tackle the aforementioned problems, offer only partial solutions (7,8), or involve heterogeneous practices that do not result in overall benefits (10–16), we propose Haematic Antegrade Repriming (HAR) as standardized strategy to implement a higher level of safety through reproducible results.

This new strategy, based on reducing the surface and repriming the circuit with autologous blood was developed by the perfusion team. Afterwards, the protocol was presented and validated by the surgical department to be applied in every patient.

Description of the technique

After applying HAR to the standardized MiECC (17), under the purposed methodology, the haemodilutional impact is reduced to 300ml of priming volume. To guarantee its replicability, the following procedure is defined by 6 positions and simple maneuvres to be successfully accomplished (Fig.1):

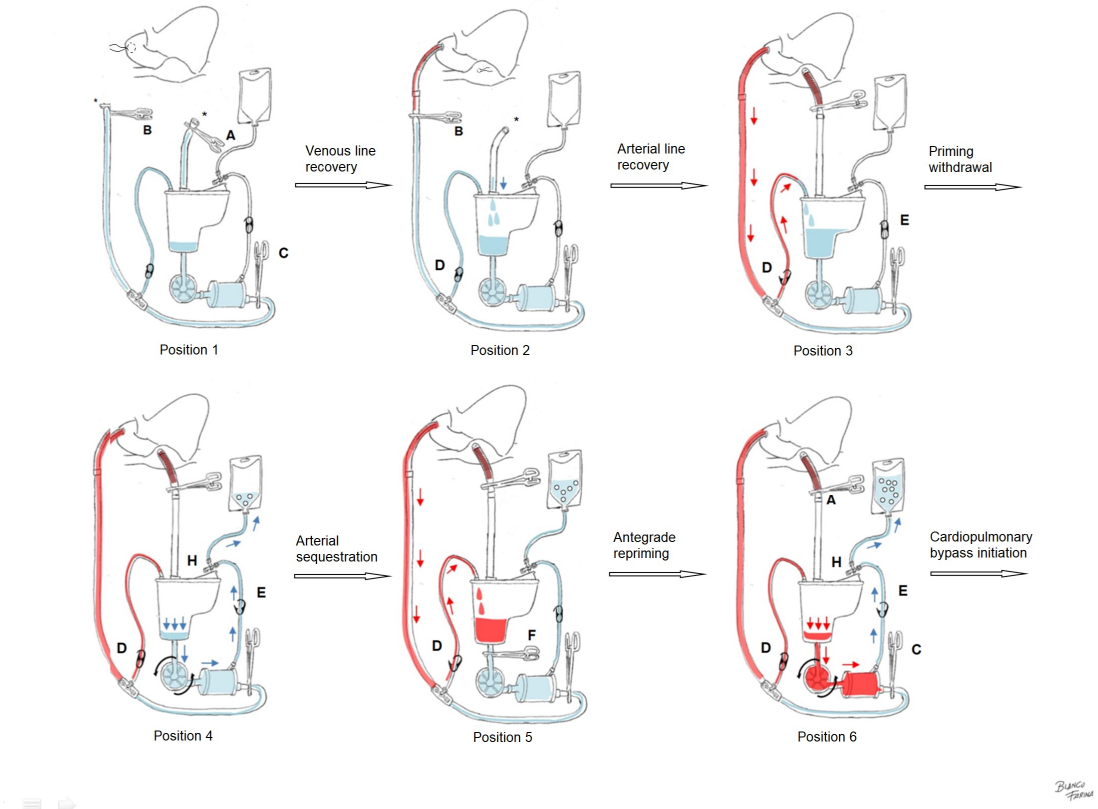

Fig. 1. HAR, the 6 steps procedure that results in 300ml of haemodilution

Step 1: Venous line recovery: Starting in Pos.1, set VAVD to -30mmHg. Remove clamp A, collecting 300±50ml of crystalloid volume in the reservoir. Replace clamp A afterwards.

Step 2: Arterial line recovery: Starting in Pos.2, remove clamp B after arterial line connection to the aortic cannula. Then remove clamp D, repriming the arterial line retrogradely until the recirculation line is primed with blood and clamp it back afterwards, avoiding the mixture of blood and crystalloid in the reservoir. The mean arterial pressure should be maintained above 60mmHg (MAP>60mmHg). In this manoeuvre, 50-80 ml of additional crystalloid are collected.

Step 3: Priming withdrawal:* When using a centrifugal pump (CP), increase the flow up to 2000rpm, then open clamp E. If using a roller pump (RP), first open clamp E, then set the flow rate to 250-500ml/min. This should displace the crystalloid volume contained in the reservoir towards the collector bag until there is no crystalloid volume in the reservoir (zero level).

Step 4: Arterial "sequestration":* Place Clamp F on the base of the reservoir to prevent blood from mixing with the crystalloid solution during "sequestration". Then, open clamp D gently (maintain a backflow between 100 and 300 ml/min, MAP>60mmHg) until 300-400ml of blood are obtained in the reservoir. Close clamp D afterwards.

Step 5: Antegrade repriming:* If using a CP, remove clamp F and increase the flow to 2000rpm, then open clamp E to reprime the circuit. If using a RP, first open Clamps F and E to avoid system over-pressurization, then initiate a 250-500ml/min flow. Antegrade repriming should be performed until the blood reaches the collector bag to maximize benefits. Once HAR is complete, ensure that clamp D and clamp E are closed. The 3-way stopcock H must also be closed, blocking flow to the collector bag.

Step 6: CPB initiation: set VAVD to -30mmHg and remove clamp A. If using a CP: raise the pump speed to 1500 rpm, remove clamp C and continue increasing CP speed to the target flow. If using a RP: remove clamp C and initiate perfusion progressively up to the target flow.

*Steps 3, 4 and 5 are performed during the venous cannulation and the suckers can be activated since the step 4.

When the procedure is applied, the coordination between the anaesthesiologist, the perfusionist and the surgeon should be maximized. During the "sequestration", the mean arterial pressure (MAP) has to be maintained ≥60mmHg. If brain near-infrared spectroscopy is available, saturation reductions over 15% of baseline should be avoided. If hypotension is observed, the Trendelenburg position and/or short-term α-agonist administration like phenylephrine (0.01-0.03mg I.V. bolus) could be applied as offset measures.

While HAR is being performed, venous cannulae placement should be verified by means of transesophageal echography to guarantee proper drainage.

Discussion

Strict application of the HAR protocol allows to obtain a fixed, reproducible and safe result, through the combined use of miniaturized extracorporeal circulation - MiECC, retrograde autologous priming - RAP and vacuum assisted venous drainage - VAVD. The benefits obtained from that combination potentially exceeds the benefits from the use of a standalone measure in terms of blood saving, complications, length of stay and survival (18,19).

Minimization of the circuit surface (MiECC Class IV) reduces the inflammatory response, blood product exposure, haemodilution, and coagulopathy after surgery (4,20,21).

RAP and its multiple variations have offered a significant reduction of haemodilution while other authors offer less homogenous results (14,18,22). With this regard, strict application of the HAR technique on the standardized circuit design (17), offers a fix and reproducible haemodilution of only 300ml; that is lower than referred by any other study in an adult circuit.

Furthermore, during the CPB initiation in a conventional setup ,the remaining microemboli that might persist in the oxygenation chamber are displaced by blood, with a subsequent release to the bloodstream (7,8). The application of HAR could potentially reduce the amount of bubbles because they are being displaced to the collector bag during the procedure. Observable benefits in organs and microcirculation are expected due to the decrease of the embolic aggression (3,5,23).

The inclusion of VAVD has been related to a reduction of postoperative blood transfusions without any major complication if the suction pressure is not lower than -40mmHg. More negative pressures should be avoided because they do not confer any benefit and could result in haemolysis and embolism (24,25).

HAR represents more than only a perfusion technique; it requires the full coordination of the surgical team during a short period of time. Once the learning curve is overcome, HAR may offer significant benefits that will be audited in further studies. As is the case during any other clinical procedure implementation, to decrease the associated risks of the learning curve, a

proctored and/or multimedia training of the team should be applied (26).

Limitations and Special Considerations of the Procedure

An absolute limitation to its application is that, if uncontrollable hemodynamic instability during cannulation occurs, CPB should be initiated even if it requires aborting HAR before it is completed.

After completion of HAR, if it turns out to be impossible to achieve target flow during the CPB, consider a vasoplegic syndrome linked to CPB (27). If vasoplegia is confirmed, prioritize the optimization of vascular resistance with vasoactive drugs and consider the infusion of crystalloid volume as a last resource if needed.

Conclusion

HAR represents a standardized method to decrease the impact of sudden haemodilution and emboli load related to CPB initiation by repriming of the circuit with autologous blood. Further studies will be carried out to validate the procedure and focus on the promising benefits of combining RAP, MiECC and VAD, thereby minimizing haemodilution to 300ml.

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