Technique Article

Hematic Antegrade Repriming: A Reproducible Method to Decrease the Cardiopulmonary Bypass Insult

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Abstract: The current practice of cardiopulmonary bypass (CPB) requires a preoperative priming of the circuit that is frequently performed with crystalloid solutions. Crystalloid priming avoids massive embolism but is unable to eliminate all microbubbles contained in the circuit. In addition, it causes a sudden hemodilution which is correlated with transfusion requirements and an increased risk of cognitive impairment. Several repriming techniques using autologous blood, collectively termed retrograde autologous priming (RAP), have been demonstrated to reduce the hemodilutional impact of CPB. However, the current heterogeneity in the practice of RAP limits its evidence and benefits. Here, we describe hematic antegrade repriming as an easy and reliable method that could be applied with any circuit in the market to decrease transfusion requirements, emboli, and inflammatory responses, reducing costs and the impact of CPB on postoperative recovery. Keywords: cardiopulmonary bypass, hematic priming, hemodilution, microemboli, MiECC.

Priming with a crystalloid solution is the conventional procedure used to prepare the extracorporeal circuit (ECC) for cardiopulmonary bypass (CPB). Although this process avoids a massive air embolism, a significant number of microbubbles still remain in the oxygenation chamber, representing an embolic risk during the CPB (1). There is strong evidence pointing to the fact that the conventional ECC causes an increased inflammatory response and transfusion requirements that could be reduced through the use of repriming techniques and by reducing the circuit surface area (2,3). The most recognized repriming technique is retrograde autologous priming (RAP). Despite its potential benefits, however, there is a lack of standardization in the practice of RAP (4–7).

It also leads to heterogeneous results that play a role in the current controversy and possible biases surrounding its level of recommendation and evidence strength (8,9).

With these concerns in mind, we describe a novel, simplified, and standardized method, “hematic antegrade repriming” (HAR), which offers beneficial features over RAP and reduces hemodilution to 300 mL for all patients, aiming to improve the outcomes of cardiovascular surgery procedures under CPB.

MATERIALS AND METHODS

HAR requires the use of a heart–lung machine, a class IV minimized circuit of 3/8 inch tubing diameter (Figure 1) (10), 1,000 mL of crystalloid solution for priming, three tubing
clamps, a vacuum-assisted venous drainage (VAVD) regulator, and a properly trained team. To shorten the circuit length, both the oxygenator and the lines are placed within the surgical field at the shoulder line of the patient. The HAR procedure is achievable using any brand of circuit on the market, by applying the standardized MiECC class IV design (10). In our protocol, the membrane size is prescribed according to the patient’s estimated body surface area (BSA) (DuBois) to guarantee a pump index of 2–2.4 L/min/m². Patients with estimated BSA less than 1.8 m² are perfused with an Inspire 6F tubing set from Livanova PLC, London, United Kingdom. Patients with BSA greater than 1.8 m² receive a Capiox FX25 circuit from Terumo Cardiovascular, Ann Arbor, MI. Both custom packs include VAVD tubing to complete the procedure and improve venous return.

HAR, “THE PROCEDURE”

The procedure is divided into three main stages: elimination of the exceeding crystalloid after conventional priming, blood sequestration to the reservoir, and antegrade repriming of the circuit. To guarantee the success of the practice, HAR should be carefully coordinated with the anesthesiologist and the surgeon. During the “blood sequestration,” mean arterial pressure (MAP) should be maintained more than 60 mmHg. If monitored, brain near-infrared spectroscopy reductions more than 15 % from the baseline should also be avoided. If hypotension occurs, the Trendelenburg position and/or short-term α–agonist administration (phenylephrine .01–.03 mg bolus) could be considered. During HAR, venous cannula placement should be verified using transesophageal echography.

To improve the replicability of the procedure, the sequence has been divided into six simple steps (Figure 2) (11). If, during ECC initiation, it is impossible to achieve the calculated flow, consider that a vasoplegic syndrome linked to CPB may be occurring (12). If vasoplegia is found, prioritize the optimization of vascular resistance with vasoactive drugs, and infuse crystalloid as a last resource if needed.

DISCUSSION

HAR has been developed as a unique multidisciplinary approach based on the application of detailed and standardized
extracorporeal materials and methodology that combines the theoretical benefits of classic repriming techniques, VAVD, and MiECC. These three concepts that converge in HAR have been independently recommended to reduce coagulopathy and the need for transfusions (2,13).

Since it was described by our center in 2014, HAR has been performed in every case to decrease the effects of sudden hemodilution, even if a further volume addition was predicted, without any deleterious side effects. The only exceptions when HAR was avoided were the cases of patient instability that required instant initiation of CPB. A preliminary retrospective study in 435 patients confirmed the expectation that HAR reduced transfusion risk and perioperative complications (14).

**Figure 2.** HAR, the six-step procedure. Step 1: Venous line recovery: starting in Pos.1, set VAVD to −30 mmHg. Remove clamp A, collecting 300 – 50 mL of crystalloid volume in the reservoir. Replace clamp A afterward. Step 2: Arterial line recovery: starting in Pos.2, remove clamp B after arterial line connection to the aortic cannula. Then, remove clamp D, re-priming the arterial line retrogradely until the recirculation line is primed with blood, and clamp it back afterward, avoiding the mixture of blood and crystalloid in the reservoir. The mean arterial pressure should be maintained above 60 mmHg (MAP > 60 mmHg). 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 2,000 rpm, then open clamp E. If using a roller pump (RP), first open clamp E, then set the flow rate to 250–500 mL/min. This should displace the crystalloid volume contained in the reservoir toward 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 > 60 mmHg) until 300–400 mL of blood are obtained in the reservoir. Close clamp D afterward. Step 5*: Antegrade re-priming: if using a CP, remove clamp F and increase the flow to 2,000 rpm, then open clamp E to re-prime the circuit. If using a RP, first open clamps F and E to avoid system over-pressurization, then initiate a 250–500 mL/min flow. Antegrade re-priming 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 three-way stopcock H must also be closed, blocking flow to the collector bag. Step 6: CPB initiation: set VAVD to −30 mmHg and remove clamp A. If using a CP, raise the pump speed to 1,500 rpm, then 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. Preprinted as: (11).
The hemodilutional impact reduction to 300 mL and the particular manner of the autologous priming may offer additional benefits. The antegrade repriming with blood under controlled conditions may reduce the presence of gaseous microemboli (GME), which play a primary role in postoperative neurocognitive alterations (15). A major contributor to the embolic load is CPB initiation, through the extrication of certain microemboli that may remain in the oxygenation chamber as a result of an inefficient priming with crystalloid solution (1,16). During HAR, these microemboli can be displaced by the increase in density caused by the influx of blood to the oxygenation chamber (17). Thus, GME can be directed to the collector bag rather than remaining in the circuit as a potential hazard. Therefore, it is likely that HAR achieves a reduction in GME delivery in comparison to crystalloid priming during CPB initiation. Exposure to lower hematocrit levels has also been correlated to neurocognitive injuries after CPB (18), indicating that HAR may offer neuroprotective benefits which should be explored in future studies.

HAR also offers some features that may reduce inflammatory response as compared with conventional CPB. The inclusion of a standardized class IV MiECC may lessen coagulopathic and inflammatory activation by reducing the contact surface area (3). Both sudden hemodilution induced by the “crystalloid emboli” and the release of the GME, that may persist in the circuit, trigger the inflammatory response by damaging the endothelial glycocalyx (EGL) during the CPB initiation. This EGL damage is evidenced by an increase of syndecan-1 and other degradation factor levels in plasma after CPB (19). EGL impairment induces to systemic postoperative alterations including edema, platelet and leukocyte adhesion, extravasation, and altered microvascular perfusion (19,20). Considering that HAR can reduce the impact of both, this may offer additional benefits also pointing at potential targets for further research to be conducted.

Despite the fact that VAVD application, in the range that is used, has been reported as safe in terms of postoperative complications (13), its overall impact in terms of evidence and the influence of the CPB initiation with and “empty venous line” still remains unclear (2). With these concerns in mind, a clinical trial to validate the embolic and neurocognitive impact reduction of HAR, in a short and mid-term postoperative period, is being conducted (21).

Current and further investigations could properly determine the benefits of HAR, explore the underlying mechanisms and the cost-effectiveness of the procedure, and validate the findings. In this regard, a proper training of the team as well as the standardization and detailing of the materials and methodology may offer a reduced risk of biases.

ACKNOWLEDGMENTS

Our maximum gratitude to the perfusionists Mr. Luc Puis for his uncountable support and to Mrs. Mikaela Allen for her training on RAP that settled the basis that has evolved to the current procedure.

REFERENCES