JECT. 2013;45:218–219
The Journal of ExtraCorporeal Technology

Invited Editorial

Go With the Flow (probe)!

I am often amazed by how technology that allows safe cardiopulmonary bypass (CPB) continues to evolve and advance. Improvements in today's equipment and supplies have provided greater patient safety and fewer complications than in years past. Given the advancement of the technical aspect of cardiovascular perfusion, I believe that our profession has largely overlooked a major shortcoming in equipment used for CPB.

There are essentially four main objectives that perfusionists address during CPB: 1) adequate blood flow; 2) oxygenation/ventilation of blood; 3) temperature control of blood; and 4) anticoagulation of blood to allow such exposure to foreign surfaces. As clinicians, we expect that testing of parameters such as blood gas levels and anticoagulation of the blood during CPB is both accurate and precise. The Centers for Medicare & Medicaid Services regulates all laboratory testing (except research) performed on humans in the United States through the Clinical Laboratory Improvement Amendments of 1988 (1), and any site performing such testing must be licensed. Furthermore, the accuracy of laboratory testing equipment is routinely validated to ensure the accuracy of results. Even when inline monitors such as the CDI-500 (Terumo Cardiovascular Systems, Ann Arbor, MI) are used, results are typically validated against values generated by standard laboratory machines (2). Also, equipment such as gas blenders and heater/coolers undergo rigorous testing and clearance by the U.S. Food & Drug Administration. Perfusionists expect and insist that each piece of equipment functions properly to allow precise control and monitoring of parameters such as oxygenation, anticoagulation, and temperature during CPB.

Although each of the variables mentioned are closely controlled, regulated, and monitored, there is often a lack of precise monitoring of patient arterial blood flow. When using a centrifugal blood pump (CP), manufacturers incorporate a flow sensor that may be appropriately used on the arterial line for monitoring of patient arterial blood flow. However, when using a roller pump (RP), no such device is typically made available by the same manufacturers, and perfusionists often must rely on arterial pump speed as an indirect measure of flow to the patient. Hospitals may purchase standalone devices such as the HT110 Bypass Flowmeter (Transonic Systems Inc., Ithaca, NY), but these devices can be cumbersome and expensive and do not conveniently interact with heart–lung machines or electronic charting software. In an age when integration represents the future, addition of such equipment should be unnecessary.

Lee-Sensiba (3) reported in 1998 that an arterial purge line can "steal" as much as 40% of the intended pump flow away from patients at low flows. More recently, Wang et al. (4) showed that a significant amount of flow is diverted away from the patient when the arterial purge line is open and that shunting of blood flow could result in hypoperfusion. The authors concluded that a flow probe should be used distal to circuit shunts to monitor arterial flow. Additional larger shunts such as a hemoconcentrator or recirculation line are also incorporated into CPB circuits and theoretically steal even a higher percentage of patient flow. It is important to mention that even with no intracircuit tubing shunts open, pump speed does not necessarily reflect pump flow when the arterial pump is not 100% occlusive.

Although this editorial does not aim to debate the benefits of RPs versus CPs, there is plenty of evidence to suggest that RPs can be safely used for CPB. Saczkowski and colleagues (5) did a meta-analysis of 18 randomized controlled trials representing 1868 patients comparing RPs and CPs. Their study found no difference between RPs and CPs in postoperative blood loss, red blood cell transfusion, intensive care unit or hospital length of stay, or mortality. There were also no reported pump-related malfunctions or mishaps. It has also been shown that RPs may cause less hemolysis than CPs when the occlusion is set appropriately (6). Furthermore, multiple studies have shown that RPs are less hemolytic when set less occlusively than that which is recommended by manufacturers and typically used by perfusionists (7,8). However, use of a less occlusive RP may not be safe without the incorporation of a flow sensor on the arterial line as a result of the loss of forward flow. Although there are methods that may allow the perfusionist to estimate arterial blood flow (8,9), the patient's arterial flow is not a parameter that should be estimated but instead measured using a flow sensor. Also, any estimations done "on the fly" during CPB do not incorporate the impact of changes in blood temperature and viscosity. They are also generally not reflected in the perfusion record, particularly when using an autocapture electronic record.

Based on the outstanding work of researchers such as DeSomer (10) and Ranucci (11) and their colleagues, we have learned the importance of monitoring values such as

oxygen delivery index during CPB to avoid complications such as acute kidney injury and increased lactate formation. Some vendors are even beginning to incorporate real-time calculations of such values into their electronic charting software. Although these companies should be applauded for such efforts, the fact that these calculated values will often overestimate values such as oxygen delivery should not be overlooked. Clearly, manufacturers have the capability of providing such technology to RP users as evidenced by the fact that the technology is offered to users of their CPs. So why must perfusionists estimate one of the most important parameters related to CPB based on which circuit shunts are open, or based on the occlusiveness of the pump, or on the temperature and viscosity of the blood? How could such estimations be incorporated in real-time into perfusion charting software? Any perfusion record using pump speed as a measure of patient arterial flow is at risk of legal interrogation should that record ever be used to determine the impact of CPB on a negative patient outcome.

In conjunction with the International Consortium for Evidence-Based Perfusion, AmSECT introduced newly revised Standards and Guidelines in 2013 (12). Standard 7.3 states that "Arterial blood flow shall be monitored continually during CPB." This standard specifically states that arterial blood flow (and not arterial pump speed) shall be monitored. In the same document, Guideline 7.6 states that "Arterial blood flow should be monitored continually at a point in the CPB circuit where it accurately reflects the flow delivered to the patient during CPB (eg distal to intra-circuit shunts)." These standards and guidelines do not distinguish between a RP and CP nor does any of the guidelines state the benefit of one style of pump over the other. In other words, no matter what type of pump is used, these standards and guidelines should apply.

An arterial flow sensor should be considered a safety device. Imagine a scenario in which a RP user inadvertently sets the RP display for 1/2-inch tubing when 3/8-inch is actually being used, resulting in hypoperfusion of greater than 40%. Imagine a scenario in which a large intracircuit shunt is inadvertently left unclamped for a long period of time, resulting in potentially catastrophic hypoperfusion. Perfusionists, of course, have the ability to monitor many signals indicating hypoperfusion (blood pressure, arterial line pressure, venous saturations, etc.), but why take the chance? Although the accuracy of flow sensors is not perfect (according to Transonic's product brochure, ±4% when properly calibrated), this level of accuracy would largely protect patients from these types of incidents.

The choice of RPs versus CPs is still largely based on preference, and there is not an industry standard. There are clearly advantages and disadvantages to each type of pump. Although many perfusionists consider CPs safer than RPs, it is time that users of RPs improve the safety and precision of CPB by incorporating the use of an arterial flow sensor if they have not already done so. The arterial blood flow delivered to the patient is a crucial factor in determining the success of CPB. As perfusionists, we have a responsibility to measure and document patient arterial blood flow as accurately and precisely as possible.

Cory M. Alwardt, PhD, CCP
Mayo Clinic Hospital
Phoenix, Arizona

REFERENCES

1. Clinical Laboratory Improvement Amendments (CLIA). Available at: http://www.cms.gov/Regulations-and-Guidance/Legislation/CLIA/index.html?redirect=/clia/. Accessed January 4, 2014.
2. Bellaiche AL, Nielsen PF, Brantlov S, Moller MB, Winterdahl M. Clinical evaluation of the accuracy and precision of the CDI 500 in-line blood gas monitor with and without gas calibration. J Extra Corpor Technol. 2011;43:53–7.
3. Lee-Sensiba K, Azzaretto N, Carolina C, et al. Errors in flow and pressure related to the arterial filter purge line. J Extra Corpor Technol. 1998;30:77–82.
4. Wang S, Miller A, Myers JL, Undair A. 'Stolen' blood flow: Effect of an open arterial filter purge line in a simulated neonatal CPB model. ASAIO J. 2008;54:432–5.
5. Saczkowski R, Maklin M, Mesana T, Boodhwani M, Ruel M. Centrifugal pump and roller pump in adult cardiac surgery: A meta-analysis of randomized controlled trials. Artif Organs. 2012;36:668–76.
6. Lawson DS, Ing R, Cheifetz IM, et al. Hemolytic characteristics of three commercially available centrifugal blood pumps. Pediatr Crit Care Med. 2005;6:573–7.
7. Rawn DJ, Harris HK, Riley JB, Yoda DN, Blackwell MM. An under-occluded roller pump is less hemolytic than a centrifugal pump. J Extra Corpor Technol. 1997;29:15–8.
8. Tamari Y, Lee-Sensiba K, Leonard EF, Tortolani AJ. A dynamic method for setting roller pumps nonocclusively reduces hemolysis and predicts retrograde flow. ASAIO J. 1997;43:39–52.
9. Mongero LB, Beck JR, Orr TW, Kroslowitz RM, Lee-Sensiba K, Oz MC. Clinical evaluation of setting pump occlusion by the dynamic method: Effect on flow. Perfusion. 1998;13:360–8.
10. De Somer F, Mulholland JW, Bryan MR, Aloiso T, Van Nooten GJ, Ranucci M. O_2 delivery and CO_2 production during cardiopulmonary bypass as determinants of acute kidney injury: Time for a goal-directed perfusion management? Crit Care. 2011;15:R192–202.
11. Ranucci M, De Toffol B, Isgro G, Romitti F, Conti D, Vicentini M. Hyperlactatemia during cardiopulmonary bypass: Determinants and impact on postoperative outcome. Crit Care. 2006;10:R167.
12. Baker RA, Bronson SL, Dickinson TA, et al. Report from AmSECT's International Consortium for Evidence-Based Perfusion: American Society of ExtraCorporeal Technology standards and guidelines for perfusion practice: 2013. J Extra Corpor Technol. 2013;45:156–66.