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Invited Commentary
Venoarterial Air Embolism in a Fontan Patient by Matte et al.

Throughout history the practice of medicine has evolved as a result of numerous factors that incorporate technology into disease management in an effort to produce desirable patient outcomes. In cardiac surgery the evolution of this change has been both rapid—developing in less than 60 years-, and profound improving the lives of countless individuals with congenital or acquired heart disease. The application of cardiopulmonary bypass (CPB) as an integral component for facilitating cardiac surgery has been at the center of this development. However, the techniques used during cardiac surgery are extremely complex with patient outcome dependent upon the flawless performance of the surgical team with the impeccable application of mechanical devices. A variety of attendant functions have been incorporated into the system to enhance safety which include the utilization clinical guidelines, the use of checklists and timeouts, and the widening incorporation of simulators to provide practice and enhance competency.

There is little doubt that cardiac surgical patients operated on today benefit from these technological advances as evidenced by improved outcomes and lower morbidities when compared to historical controls. Much of this is predicated on global directives to maximize quality by focusing on system processes, while utilizing the best available evidence to create and direct care plans. Unfortunately, contrasting these efforts has been the realization that efforts to improve care have been hampered by the fact that, despite good intentions by health care providers and organizations, patient harm does occur. In the decade since the Institute of Medicine landmark publications (1,2) on patient safety in America, little evidence exists that demonstrates that systematic improvements in care have occurred, especially in the realm of cardiac surgery with CPB (3). Efforts are underway in many cardiac surgeon, cardiac anesthesia, and perfusion organizations to identify profession-specific opportunities to improve patient safety and reduce risk associated with cardiac surgery. Although risk reduction encompasses an understanding of how accidents occur and how they can be prevented, it still remains the clinicians responsibility to assure that unwanted, controllable variation is removed from complex procedures such as those seen in cardiac surgery.

In this issue of the Journal, the case report of Matte et al. reports on a bane of extracorporeal circulation—an air embolism. The authors are to be congratulated for reporting this unfortunate event since it is appreciated that clinical incidents are underreported in the medical literature, and that the data from cross sectional cohort studies on safety represent only a fraction of what is truly occurring. Air embolisms during CPB have occurred since the advent of cardiac surgery (4) and have been categorized by the volume (quantity) of air generated in the circuit as either micro or macro emboli. In the present case the latter is the classification since the volume of air originating from a pressurized venous reservoir was significant. Massive air embolism[1] (MAE) has been reported to occur approximately once in every 29,187 adult CPB procedures, but was not reported to have occurred in pediatric cardiac centers surveyed (5). There are a number of reasons that MAE is rarely encountered during cardiac surgery. The omission of bubble oxygenators from clinical practice in the 1990s greatly reduced arterial line air embolism. There are an array of safety devices incorporated in the heart-lung machine that include sophisticated level and bubble sensing systems that automatically, when activated, stop the movement of blood, and the use of electronic arterial line clamps during procedures where centrifugal pumps are used. When employing techniques of assisted drainage additional devices and techniques must be incorporated to improve safety. And finally an acute awareness and constant vigilance of the circuit and heart-lung machine by the perfusionist is mandatory during all extracorporeal procedures. The latter includes the correct operation of all devices associated with CPB and begins with a comprehension of the functional aspects of the extracorporeal equipment and an understanding of the instructions-for-use of all components of the CPB circuit.

In analysis of an incident arising from a complex system such as CPB, one would examine the root causes of the event so that changes to the system be developed that reduce the likelihood of a preventable occurrence. The authors state that they routinely kept the vent port of the venous reservoir closed with the "yellow" vented cap and that the inadvertent placement of a non-vented "blue" cap resulted in the sealing of the reservoir, and the retrograde MAE. The instructions-for-use of the Terumo FX 15 oxygenator states "Do not close the vent port, as this may cause positive pressure in the Hardshell Reservoir, resulting in back-flow into the solution or blood administration lines connected to the Hardshell Reservoir".[2] However, the issue of whether to remove the vented cap prior to use varies amongst manufacturers with some instructions stating to remove the cap altogether, while others leave this to the discretion of the user. In their discussion the authors state that they now open the reservoir to atmosphere by removing the vented cap during priming which is a prudent action. This is the standard in our practice as well and is a documentable line item on our institutions CPB checklist. Although it is

[1]Resulting in placing the patient in deep Trendelenburg position, cooling, and medications.

difficult to assess exactly how often an incident like this occurs, and that survey data is known to underreport true occurrence rates, one not need experience an event before being moved into action.

The development of techniques for minimally invasive cardiac surgery necessitates the use of peripheral access with smaller cannulae that routinely require the concomitant use of venous drainage with either vacuum or kinetic modes of assistance. Vacuum assisted venous drainage (VAVD) requires that the venous reservoir be sealed to facilitate drainage. These techniques have resulted in a reduction in cannula size for routine CPB and have been especially valuable during pediatric cardiac surgery due to anatomical challenges. Venous reservoirs approved for the use of VAVD either have an intrinsic positive pressure safety valve or require one, but the effectiveness of these devices is questionable (6). Although the source of venous reservoir pressurization in the present report did not occur with VAVD, this is arguably the most frequent cause of retrograde MAE. Most perfusionists either have seen this first hand or have known of someone to whom this has occurred. Anyone using VAVD must use a combination of safety systems to protect against this type of MAE, and these systems should be tested at the start of each case to assure that they are functioning properly (7). In addition, protocols for treating the patient who has undergone an MAE need to be readily available, reviewed regularly, and practiced by the entire cardiac team. The prompt and thorough actions by this surgical team in treating this patient for an MAE are commendable and more than likely resulted in the favorable outcome after this incident.

Alfred Stammers, MSA, CCP, PBMT
Director of Perfusion Services
Geisinger Health System
100 North Academy Ave.
Danville, PA 17822 USA
ahstammers@geisinger.edu

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[2]Terumo® Cardiovascular, Ann Arbor, MI. Instructions for Use, Capiox® FX 15, January 2009.