INVITED EDITORIAL

AIR HANDLING AND CARDIAC SURGERY *EDAC® Quantifier Introduces New Concepts in Solving an Old Problem*

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Although modern techniques of cardiopulmonary bypass (CPB) and better circuit designs have minimized the fatal cases of massive air embolism, recent investigations suggest that systemic air microembolization derived from extracorporeal sources still represents a common problem during conventional CPB. High numbers of air microemboli are one factor contributing to a reported 50-70% rate of cognitive deficits one week after CABG and 30% rate of long-term neuropsychologic impairment.

Four months ago, we integrated the EDAC® QUANTIFIER technology in our surgical practice and have found that this technology provides an amazing clinical picture of gaseous microemboli circulating within the extracorporeal circuitry. With the first five minutes of an uneventful conventional CPB, we documented a total of 2750 emboli (9.9 emboli.sec^{-1}) post arterial filter and 47 emboli in a few seconds (15.6 emboli.sec^{-1}) during blood sampling for blood gas analysis or drug administration.

While a number of factors, most notably transition from bubble oxygenators in the mid-1980s to today's membrane oxygenators, have reduced the rate of gross air embolism over the several decades, recent design improvements and current strategies of CPB in some instances have not been proven to reduce and may, in fact, increase the risk of gross air embolism during CPB. Drug injection, aortic cannula type and placement, internal properties of oxygenator and filters, levels of vacuum (<40 mmHg), high blood flow rates (6 L/min), temperature gradient, and long CPB duration are still sources of increased microemboli production and updated recommendations for precaution should be noted.

Risk recognition and risk stratification have received wide acceptance in cardiac surgery over the past decade. Researchers focus on factors associated with patient risk, develop and test strategies designed to improve the margin of safety and lead to risk neutralization. With respect to the age and physical condition of patients, many surgeons have found a shift toward older, frailer adults. The patient population referred for CABG has become more challenging. The results of this displacement could be altered to the benefit of the patients undergoing open heart surgery by continual improvement of the operative techniques as well as the technology of CPB systems.

An association has been demonstrated between intravascular microemboli and brain, myocardial or kidney injury during CPB. Surgical, anesthetic, and perfusion techniques should be directed toward reducing the number of microemboli delivered to the patient. To recommend interventions to reduce embolization, it is important to identify the source, quantity, and composition of microemboli detected during CPB.

Early detection of air embolism requires careful clinical observation. High-risk cases necessitate suitable detection devices and a high index of suspicion. Clinical indicators are unfortunately late signs of embolism. Moreover, they are non-specific. Transcranial Doppler (TCD) and transesophagial echocardiography are very sensitive but not widely available, expensive, and require additional training and continuous observation. End-tidal CO_2 or bispectral index (BIS) have poor specificity, are semiquantitative, and accuracy is affected by cardiac output.

The EDAC QUANTIFIER employs ultrasound technology to detect individual gaseous microemboli in blood flowing through an extracorporeal circuit. Disposable sterile connectors are inserted in the extracorporeal circuit tubing at up to three monitoring sites. The three-ultrasound channels standard with each unit allow for real time, simultaneous emboli detection at each connector. This allows locating the source of gaseous microemboli generated by the cardiopulmonary bypass machine or associated tubing. The unit has demonstrated count rates exceeding 1000 emboli per second, with diameters from 10 microns to the connector diameter, and with flow rates between 0.2 L/minute and 6.0 L/minute. The system performs reliably for a six-hour procedure in an operating room environment.

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We have designed studies for the evaluation of air handling characteristics of minicircuits vs. conventional, open vs. closed circuits, pulsatile vs. non-pulsatile flow, comparison of characteristics of extracorporeal circuits from different manufacturers and air generation in various procedures. We believe we have obtained revolutionary data of air embolism of significantly higher quantity than we expected, based on previous in vitro studies.

We have incorporated EDAC with cerebral oximetry, BIS, TCD, proinflammatory-hematologic parameters, indicators of myocardial preservation, psychological testing and clinical outcome. Initial results are promising for a perfect correlation with different monitoring devices, inflammation and psychological testing. EDAC alerts significantly before studied monitoring technologies.

We have benefited from EDAC-related data during aortic and venous cannulation, controlling venous return, reservoir level correction, drug administration, CO_2 manipulation and hematocrit for maintaining adequate cerebral saturation, management of temperature gradient, alerting the need of myocardial or ventilatory support in post-CPB period due to significant air embolism. Backup was vital in management of complex cardiac and high-risk cases.

We also had the opportunity to get scientific feedback about myths of cardiac surgery on closed circuits, minimized circuits, pulsatile flow and air handling capacity of various circuitry. It is a unique tool for the demonstration of quality assessment of different perfusionists or different centers in conducting CPB.

We believe data obtained via EDAC studies will change the future of cardiac surgery. The amount of air tolerated by humans and the definition of post-CPB neurologic dysfunction will be redescribed and, following large population studies, we can start discussing the underestimation of air embolism in patients suffering postoperative low cardiac output syndrome, renal failure or stroke.

References:

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