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From the Editor

Normalization of Deviance: Rocket Science 101

Robert Groom

In this issue, we are pleased to publish the original work of Dickinson and colleagues, *An in vitro study of the air handling properties of four cardiopulmonary bypass circuits,* along with an invited commentary from Tim Wilcox and Simon Mitchell, whose work on in vitro testing of bypass circuits is well known (*see page 206*). While the release of gaseous microemboli (GME) by cardiopulmonary bypass (CPB) circuits diminished with the replacement of the bubble oxygenator with hollow fiber membrane technology, this in vitro study along with the published work of others documents the shortcomings of CPB circuits when challenged by air entrainment in the venous inflow (1–10). Cardiopulmonary bypass circuits in use today do not completely eliminate GME, but is that important? While there is not sufficient evidence to say with certainty that a causal relationship exists between GME and neurological injury, there is a growing body of evidence from well designed clinical trials that shows an association between GME and injury. Pugsley and colleagues conducted a randomized trial to assess the efficacy of arterial line filters in the CPB circuit and found that GME had a dose-related effect on patients' neurocognitive outcomes (3). More recently, Borger and colleagues similarly showed that common perfusionist interventions, such as drug injections into or blood sampling from the circuit, resulted in higher GME counts and poorer neurocognitive scores (4). In December of last year, Ascione and colleagues, in a randomized trial of on and off bypass coronary artery bypass surgery, showed a dose-related relationship between emboli detected in the middle cerebral arteries with transcranial Doppler, new lesions in the retinal microcirculation, and biomarkers for brain injury (6).

On January 28th, 1986, at 11:28 AM, the space shuttle Challenger was launched, a mission that lasted only 73 seconds and was one of the greatest disasters in the history of space exploration. Prior to the launch that morning, The National Aeronautics and Space Administration (NASA) had collected eleven years of data documenting the erosion of the "O" rings on the solid rocket boosters. When ambient temperatures were low, the performance of the "O" rings was compromised. This information should have prevented the catastrophic launch. Diane Vaughn's best seller *Launch Decision* introduced a sociological explanation of the flawed decision making at NASA that she refered to as *"Normalization of Deviance,"* where evidence of a problem is minimized or ignored and there is a growing tolerance for things that are not quite right (11). This pattern of flawed thinking has recurred countless times throughout history. Ironically, in the last chapter of her book, Vaughn predicted there would be a similar future disaster at NASA. Her prophecy was fulfilled on January 16, 2003. Eighty-two seconds following the launch of the shuttle Columbia, a large piece of bipod ramp foam hit and damaged the External Tank Attachment ring on the Solid Rocket Booster skirt of Columbia. At that time, however, it was the opinion of engineers at NASA that these were of no consequence since foam debris strikes had occurred frequently on past missions. Like "O" ring erosion in the years before *Challenger*, foam anomalies became routine signals. On February 1, 2003, upon reentry, Columbia disintegrated in the sky over Texas, a consequence of the damaged foam shields. At the time of this writing the re-entry of the space shuttle Atlantis has been postponed until her heat shields may be thoroughly inspected due to concern over strikes from micrometeorites and orbital debris (MMOD) during orbit. NASA's engineers were knowledgeable, thorough, and appropriate in their response to this evidence of a problem. Atlantis landed safely on September 21 at 6:21 AM.

Should we be concerned about air entrained in the venous inflow? It is Rocket Science. Surgical teams should be knowledgeable about the likelihood of these pernicious events and respond appropriately by adopting a low tolerance for air entrained in the CPB circuit. Often, simple preemptive measures effectively eliminate venous line air. Jeff Riley's Classic in this issue (*see page 271*) is a review paper on GME by Butler from 1984 (12). We have had data documenting the GME issue since the inception of CPB in the 1950s, a classic example of normalization of deviance.

In closing, one of cardiac surgery's greatest pioneers died on March 7th following open-heart surgery. (See *In Memoriam: Sir Brian Gerald Barratt-Boyes, page 205.)*

Barratt-Boyes' pioneering work ushered in the era of total corrective surgical repair for newborns and infants, and homologous tissue valve replacement. He was an icon in our field who reminded us that we should have a low tolerance for deviation and that attention to detail is paramount.

"Good results in cardiac surgery are dependent primarily on events in the OR, but also accurate preoperative assessment and painstaking postoperative management. In each of these categories, particularly the first, there is no room at all for error (13)."

—Sir Brian Barratt-Boyes

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