Human Factors Analysis of a Near-Miss Event: Oxygen Supply Failure During Cardiopulmonary Bypass

Bruce D. Spiess, MD, FAHA,*¶ John Rotruck, MD,† Harry McCarthy, CCP,* Olga Suarez-Wincosci, MD,* Vigneshwar Kasirajan, MD,* Joyce Wahr, MD,‡¶ and Scott Shappell, PhD§

HUMAN ERROR (HE) CAUSES up to 100,000 deaths per year in medicine in the United States.[1–3] The Centers for Disease Control estimates that an equal number or more patients succumb to hospital acquired infections each year (preventable deaths, HE).[4] Reducing preventable medical injuries is a compelling urgent goal of the healthcare industry and government alike.

Cardiovascular operative care is a highly complex, teamwork-dependent endeavor requiring trust, training, and clear structured communication. The authors know from other high reliability/ high complexity industries (aviation/ nuclear power) that although individuals always will make errors, teams can be flawless. Crew resource management (CRM), an example of a method to reduce error because of human factors, has made its greatest improvements through empowerment of all team members to speak up, and reducing hierarchies in favor of valuing experience/wisdom. Near-miss events should be analyzed as early warnings to teams (the entire cardiac industry) so that they reduce the possibility that an individual error will go unchecked.

Human Factors Analysis and Classification System (HFACs, Fig 1) was developed for use by the U.S. Navy/ Marine Corps to investigate and reduce aircraft accidents.[5,6] HFACS identifies latent HE. It has been used in civil aviation, aviation maintenance, air traffic control, railroad and marine safety, and medicine.[5–13] HFACS has yet to be applied systematically to cardiac surgery but will be through the following program/s.

HE in cardiac surgery is being studied in the Flawless Operative Cardiovascular Unified Systems (FOCUS) initiative through a Learning of Errors through Networked Surveillance technique.[14,15] Prior studies of cardiac surgery have noted that 25-33% of adverse outcomes are preventable (HE).[6–8] These error rates in surgery were noted to be 2-4 times higher than those reported by the Institute of Medicine.[1,16–18] With at least 350,000 coronary artery bypass graft procedures annually, it is important that the cardiac care industry inspects itself, understands systemic latent weaknesses and establishes means to prevent morbidity and mortality.[19] The authors report a case in which the patient survived without injury, but the near miss was so close that had any reaction been different, the outcome would have been catastrophic. The authors' ensuing HFACS analysis pointed up a number of latent system errors, as well as a culture that left the cardiac operative team highly vulnerable to failure.

CASE PRESENTATION

A 61-year-old male, (85 kg, 173 cm), presented for mitral valve repair and 3-vessel coronary artery bypass graft. He had unstable angina, diabetes mellitus, 2 prior myocardial infarctions, and 40% ejection fraction. His heart was in atrial fibrillation, (85 beats/min rate controlled), and the surgical plan included a modified MAZE procedure.

The anesthetic was a balanced technique (fentanyl, midazolam, isoflurane). Surgery proceeded without difficulty (anesthetic induction, central catheter placement, midline sternotomy, cannulation of vessels, anticoagulation and progression to cardiopulmonary bypass [CPB]). Bitemporal cerebral oximetry (COx) (Somanetics/Covidien Inc, Invos, Cerebral Oximetry, Troy, MI) was utilized. Electrodes were placed before preoxygenation/induction and the display was positioned for the anesthesia team to see. The mediastinum was flooded with CO_2 and cardiotomy suction was utilized.

Arterial blood gas, hematologic, and biochemistry measurements were obtained before CPB and every 15-20 minutes (Table 1). The perfusionists and the anesthesiologist found worrisome elevated CO_2 readings but acceptable PaO_2 levels during CPB. Their discussion concluded that the cause of the high CO_2 was the entrained CO_2 from the field. The perfusionist turned up the "sweep flow" of incoming O_2 to the membrane oxygenator.

Between blood gases CPB #2 (CO_2-86 mmHg) and CPB #3 (CO_2-61.3 mmHg), a catastrophic failure of the O_2 supply to the CPB machine occurred. While the valve repair was being performed, with the left atrium open, on full-flow CPB, the surgeon exclaimed that the blood was black in the operative field. He held up the in-flow cannula of the CPB circuit as a dramatic demonstration to the team that the patient had low O_2

*From *Departments of Anesthesiology, Cardiac Surgery and Perfusion, Virginia Commonwealth University Medical Center, Richmond, Virginia; †Department of Anesthesiology, National Naval Medical Center, Bethesda, Maryland; ‡Department of Anesthesiology, The University of Minnesota, Minneapolis, Minnesota; §Department of Human Factors and Systems, Embrey-Riddle Aeronautical University, Daytona, Florida; and ¶Flawless Operative Cardiovascular Unified Systems (FOCUS) Initiative Team member.*

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Address reprint requests to Bruce D. Spiess, MD, FAHA, Virginia Commonwealth University Reanimation Engineering Shock Center (VCURES), 1101 East Marshall St Box 980695, Richmond, VA 23298-0695. E-mail: BDSpiess@HSC.VCU.EDU

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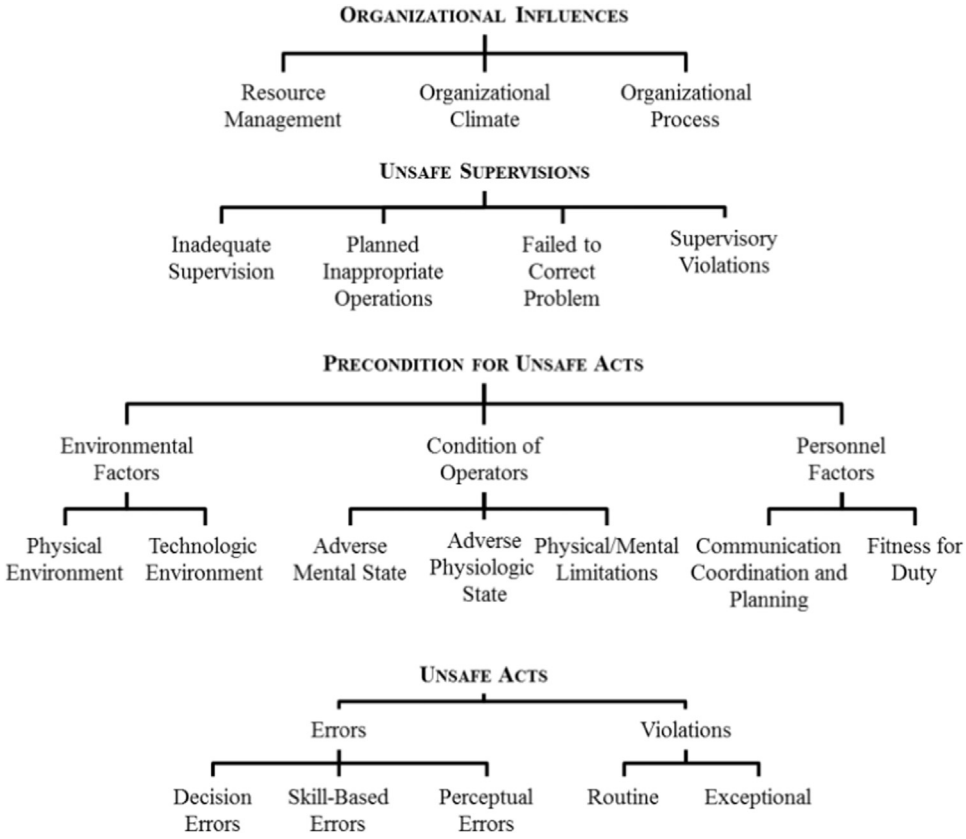

Fig 1. Organizational chart for HFACS.[5,6]

being supplied. Seconds before, the operating room door had been flung open when a second perfusionist entered. Coincident to this, the anesthesia team saw the Cox (Fig 2). No alarms were sounding. However, levels had dropped from 60-65% saturation to below 20%. The anesthesia team ventilated the lungs with 100% O_2, but the heart was not beating (no effect upon the cerebral hypoxia).

The perfusionist who had been summoned to the operating room said, "I know what the matter is, this happened to me several weeks ago." Within seconds, she had located the problem, which was a cracked plastic connector "T" piece used to house an O_2 sensor (Fig 3) that allowed the incoming flow of O_2 to escape. Therefore, the CPB oxygenator was without fresh O_2. During the time that the connector was being replaced and afterwards for some minutes, the operating room was overcome with confusion, anxiety, loud voices, and people speaking over each other. A concluding statement of, "I never want that to happen again" was perhaps obvious. During this time, when hypoxic blood was flowing through the CPB machine (flow was maintained), the inflow temperature was reset to 18°C to rapidly reduce tissue O_2 demand. Once the oxygenation problem had been solved the patient was rewarmed to 33°C to 34°C and then rewarmed further in the intensive care unit.

Table 1. Blood Gas and Pertinent Laboratory Investigative Values Noted During This Case. Note the $PaCO_2$, PaO_2 and Bicarbonate (HCO3) Values. The Near-Miss Event Happened Between Values CPB #2 and CPB #3. A Laboratory Sample Was Not Sent During the Activity of Recovering (Minutes) From This Event.

Blood Gas Data								
Time	pH	PaO2	PaCO2	Base Excess	HCO3	Hgb	% OxyHgb	Lactate
Baseline	7.42	460	38	0.6	25.0	13.7	96.9	1.2
CPB#1	7.25	262.8	65.2	1.2	28.7	9.7	97.4	
CPB#2	7.16	335	86	2.0	30.9	9.8	97.4	
CPB#3	7.28	310.2	61.3	1.7	28.8	9.2	97.2	
CPB#4	7.25	243	63	0.7	28.1	8.2	96.5	
Off bypass	7.40	357	40	0.3	25.3	8.8	96.9	1.6

Abbreviation: CPB, cardiopulmonary bypass.

Within 2 minutes, the Cox returned to baseline. The blood gases (CPB #3, 4) still had an elevated CO_2. The mitral valve repair was finished, atrium closed, and the patient weaned from CPB without further incident. The patient was transferred to the intensive care unit with minimal pharmaceutical support of his circulation and was extubated the next morning. He was awake without neurologic compromise that day and had an uneventful postoperative course.

DISCUSSION

Human Factors Analysis

This case presents a sobering near-miss O_2 supply failure. The event could well have led to death or permanent neurologic impairment. It was through considerable luck/skill, with the