

Human Factors and the Cardiac Surgical Team: A Role for Simulation

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Abstract: Human factors play an important role in determining the outcome of cardiac surgery. The interaction of humans with their equipment, and with each other in teams, is critical to success. Simulation provides a means of teaching and assessing the technical and non-technical skills of clinicians and can facilitate research into interventions to improve safety. Simulation in anesthesia has taken much from aviation and provides a model that could be extended to perfusion. The cost of setting up a simulation center (or even of adding a perfusion simulator to an exist-

ing center) is relatively high, but the potential return on this investment is also substantial, particularly at a time when access to patients for teaching and research is becoming harder. Different degrees of complexity and fidelity in simulation lend themselves to different objectives, whether in teaching, assessment, or research. In the longer term, comprehensive simulations of cardiac surgical procedures involving all participants in meaningful simulated roles may be possible. **Keywords:** human factors, simulation, cardiac surgery, performance. *JECT. 2007;39:264-266*

INTRODUCTION

The contribution of human factors to outcome in cardiac surgery has become increasingly obvious over the last few decades (1-5). Human factors is a domain shared by professionals from almost any health care background who become interested, not as much in advancing the science of their subject, as in the safe and effective application of that science to patient care. A large part of this involves improving aspects of teamwork. Cardiac surgery is a field of surgery in which teamwork is particularly important. Close communication and coordinated activity between the perfusionist, the anesthetist, the nursing staff, and the surgeons (primary and assistant) is essential.

In one traditional view, human factors involves observation in the field, identification of ergonomic deficiencies in equipment or the wider system, addressing these through innovations intended to facilitate the interaction between humans and their environment (with an emphasis on technology), and evaluating these innovations using various clinical research methodologies. It is primarily about improving the design of the things humans use in their work or in their everyday life (6,7). In health care, there has been a strong move to shift the emphasis when

things go wrong to addressing the system rather than the people who work within it (8). However, the easy gains in safe system design have mostly been made, and the greatest opportunity for future improvements in the performance of the cardiac surgical team lies in recognizing that the human is a key element of the complex system of health care (9,10). The human may be the hardest part of any system to change (11), but it is a part that cannot be ignored. It is a matter of improving all elements of the system together. The aim should be to make it easier for clinicians to do their job, but at the same time also to include training and the promotion of attitudinal change to improve human performance and ensure that advantage is taken of innovations in equipment, drugs, or the environment. In health care at least, most initiatives to improve safety depend on some degree of engagement by the people who will interact with them. This implies education. It implies evaluation of clinicians (12) and of equipment and of the interaction between the two (13,14). It also implies research into the performance of clinicians, particularly in teams (15), and particularly in relation to non-technical skills (16), notably when stressed or fatigued (17). In each of these activities, simulation provides a novel and potentially very powerful tool with many potential advantages over the clinical environment (18-20).

Simulation for all of these purposes is used in a number of industries, is very well established in aviation, and is gaining traction in health care generally and in anesthesia

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in particular. Simulation has been used in perfusion (21) (R. Morris, personal communication, 2007), and simulators of varying sophistication are now available for a range of surgical procedures (22).

Anesthesia provides a good case study for the application of simulation to perfusion. Simulation centers of anesthesia are proliferating, but there are few standards, and there is considerable variation in infrastructure and expertise. Commercially available anesthesia simulators have many powerful attributes, but also limitations, notably in physiologic and pharmacologic modeling and in reliability. Skeptics criticize high costs, limitations in realism, and lack of validation and remind us that findings or experiences in the simulator may not apply to the clinical situation (23–25). It has been estimated that setting up a simulation center in the United States cost approximately US\$876,000 and running it costs approximately US\$361,000 per year (26). In health care, the competition for limited resources for training and research is intense. Many simulation centers have found financial sustainability elusive. An optimistic rush to adopt simulation from aviation has given way to increased recognition of the hard realities of actually using it effectively to improve outcomes for our patients.

It is possible to categorize simulators in several different ways (20). The fidelity of the simulation experience is as much about the simulated environment and the contribution of role-playing participants as the simulator. Nevertheless, a key aspect of simulation for clinical fields such as anesthesia and perfusion is the modeling of physiology. The degree to which this is realistic and autonomous is critical for high-end simulation training, evaluation, and research. At present, there is much still to be done before the modeling of physiology and pharmacology in anesthesia simulators permits the type of training and evaluation currently accepted as the norm in aviation.

Simulation has several attributes of value to adult education, relevant to the cardiac surgical situation (19). It allows learners to be actively engaged in the educational process, in solving real life problems, and in gaining relevant (albeit simulated) clinical experience, and it provides opportunities for practice, for feedback, and for reflection (27). Simulation has been used to impart knowledge and teach skills in many medical disciplines. However, evidence that simulation enhances education is limited: outcome measures have varied, and controls have been few and not always the most effective alternative educational methods available. The assumption that simulation provides the answer to modern day barriers to learning on patients is far from proven. Effective learning is dependent on educational principles that apply whether simulation is used or not, and these are sometimes neglected by enthusiasts for simulation. Clarity about the objectives of any educational exercise is essential. The

choice of educational method should be informed by the nature of the task in question, not by the fact that one happens to own a simulator. The use of shortcuts to facilitate simulation-based education may actually serve as a poor role model for clinical practice and have the unexpected and undesirable effect of teaching bad habits. The notion that simulation is worthwhile in itself is as much a trap for the tyro educationalist as opposition to simulation may be an impediment to progress for some traditionalists.

The gold standard for research into clinical questions is to study them in real patients, but barriers to doing this may include risk to patients, the fear of medico-legal repercussions for participants, and the cost when the events of interest are rare and large studies are needed. With simulation, clinical scenarios can be standardized, participants can be observed and videotaped, rare events can be produced on demand, and the environment is relatively safe for all concerned (15,28). Our New Zealand group is developing and refining a model for research into human factors in the operating room. We are using a multi-layered approach, which involves studying the same question at different levels of simulation, beginning with simple and efficient micro-simulations and validating findings in more comprehensive and realistic scenarios. We are collaborating with the Institute of Biomedical Engineering at the University of Auckland to improve the autonomous physiologic and pharmacologic models of our simulator to enhance our capacity to use powerful, objective, task relevant outcome measures in our research, such as severity and duration of hypoxia or hypotension. The next step will be to integrate simulators relevant to surgery and perfusion and increase the proportion of participants in our scenarios who are subjects of the research, functioning as a team, rather than faculty playing roles.

Simulation-based assessment is accepted in aviation, and pilots who fail are immediately stopped from flying until remedial training can be provided and competence shown at a repeat assessment. Because it is thought that evidence for the validity of simulation for the assessment of anesthetists is still needed, there has been reluctance to use simulation in the assessment of anesthetists, at least in New Zealand and some Australian units. It is time to re-evaluate this position, even if conclusions about competence are restricted to the context of the simulated environment. Our experience in research suggests that many participants appreciate explicit feedback and would gain from knowing whether they have achieved acceptable levels of performance or not. There is no greater reason to doubt the relevance to clinical practice of performance in a simulator than there is to doubt that of performance in a multiple-choice examination, and the use of simulation for this purpose is probably overdue.

A project to provide simulations genuinely relevant to

perfusionists and cardiac anesthetists in the Auckland center is probably the next step, with the addition of meaningful simulated surgical tasks to integrate surgeons into the simulations as a longer-term goal. This will require funding for the purchase of a perfusion simulator, or alternatively (given very limited availability), the development of such a simulator locally.

Having obtained or developed the perfusion simulator, our experience suggests that considerable work will be needed to achieve convincing simulations of relevant scenarios. It is logical to begin with training. The ideal would be to develop modules to teach psychomotor or cognitive skills (such as advanced ECG recognition, technical tasks for perfusionists, and advanced interpretation of blood gas and coagulation test results for all participants), which can be integrated into complex scenarios focused on the use of these skills within the team, under pressure, while caring for the simulated patient. From experience in anesthesia, it is likely that such a course would be relevant to both trainees and advanced practitioners. Once a credible course has been established, consideration can be given to extending the objectives to evaluation of the performance of participants. More excitingly, it will be possible to adapt the scenarios for use in human factors research directly related to perfusion, cardiac anesthesia, and, in time, the whole cardiac surgical team.

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