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Simulation: The New "Triple Threat"

Commentary on the article by Sá Couto *et al.* on page 158

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Simulation is defined as the representation of the characteristics or behaviors of one type of system (or collection of systems) through the use of another type of system or model. In discussing healthcare simulation, these models may be physical models that can be touched and handled (mannequin), virtual models that are created by software and exist only in the memory of a computer, or hybrid models that require trainees to interface with not only their physical elements but also their virtual elements. The degree of fidelity of the models (the extent to which they approximate actual human beings) often has a direct influence on the extent to which trainees interacting with those models perform as they would in real life. The more the actions of the trainee during simulation mimic real-life performance the more likely the trainee will be able to identify and address any weaknesses that become manifest and improve on performance as a result of the simulated experience.

In this issue of *Pediatric Research*, Sa Couto *et al.* (1) describe a mathematical (virtual, not physical) model of the human heart undergoing the normal transition from *in utero* to *ex utero* life. The influence of unique anatomic structures such as the ductus arteriosus and foramen ovale, physiologic processes including elevated pulmonary artery pressure, and external factors such as clamping of the umbilical cord on blood flow and pressure at various locations within the cardiovascular system are discussed in detail. Through a careful review of the literature, the authors were able to obtain references for a number of parameters important in modeling the hemodynamic changes occurring in the first minutes and hours after birth; where this was not possible they were able to derive values based on clinical experience. Although the intent of this work is to create a working model of neonatal cardiovascular physiology to serve as the software platform for a human patient simulator to be used for training healthcare professionals, the implications of these efforts go well beyond this goal.

Creating highly realistic models of human physiology occurs through the collaborative efforts of clinicians, biomedical engineers, and others. While the engineers must develop an understanding of the complexity and underlying uncertainty of biologic processes, the clinicians must appreciate the need to reduce these complex processes to precise equations. Once the model is built, it not only must be compared with any standards derived from real patients that are available in the peer-reviewed literature but also must be tested against the experience of the seasoned clinician; then and only then can the model be considered to be a valid representation of an actual human being. The work presented by Sa Couto *et al.* is a wonderful example of this collaborative and iterative process.

The so-called "triple threat" was once held up as the ideal academician: someone who not only delivered competent and compassionate patient care but also was an independent, fully funded investigator performing state-of-the-art research who also somehow found a way to teach in a way that made complex topics easy to understand and inspired trainees to pursue careers in academic medicine. Arguably, the days of the human triple threat are numbered as the complexities and demands of modern healthcare, research, and training make it extremely difficult for one individual to have sufficient time to devote to all three of these pursuits let alone truly excel in each. However, simulation as a methodologic innovation is likely to become the new triple threat because it permeates first the domain of professional training followed by that of biomedical research and finally actual clinical care.

Relevance to Training and Assessment

Many readers are likely familiar with the use of simulation as a learning tool to facilitate the acquisition of cognitive, technical, and behavioral skills in healthcare professionals; this typically involves relatively inexperienced trainees and represents the most common application of the methodology in healthcare today. It should be mentioned, however, that simulation-based training has been used for decades in other industries where the risk to human life is high and in those industries, it is actually used more frequently by experienced professionals who need to maintain their skills. Simulation has the potential to be used to objectively assess and document whether a physician or other healthcare professional can competently deliver care to patients; once it is shown that performance while working with a patient simulator predicts performance when working with real human patients, it will be possible to use simulation for high-stakes assessment in much the same way as flight simulators are used today to determine whether a pilot is capable of safely flying a particular type of aircraft.

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Relevance to Research

Much of biomedical research involves determining the effects of a particular medical device or a pharmacologic agent on human physiology. If a model of human physiology is robust enough, experimental devices and pharmaceuticals can be tested on the model in lieu of testing on animals or living human beings. It is important to note that one need not await the development of a sophisticated patient simulator possessing a high degree of fidelity to a real human being before finding useful applications to biomedical research: Virtual models of single organs and organ systems can also be used to assess the potential effects of devices and pharmaceuticals and this is already occurring in research laboratories around the world today.

Relevance to Patient Care

A common contemporary application of simulation in healthcare is the use of radiologic data to plan and, to a less frequent extent, practice surgical interventions. Two- and three-dimensional images allow surgeons and interventional radiologists to "see" inside their patients and effectively visualize where and how they need to use their instruments to perform procedures such as tumor removal, pinpoint delivery of therapeutic agents, and other interventions. More realistic models, incorporating data that simulates not only anatomic features but also the patient's physiologic state, will allow the trial of a whole host of interventions in fairly rapid succession to determine which one will produce the optimal response in that patient. For example, it will one day be possible to use fetal imaging and biomarkers (obtained from maternal blood or amniotic fluid) to predict subsequent neonatal pathophysiology with a much higher degree of certainty than currently possible. No longer will the choice of pharmacologic agents, technologies such as mechanical ventilation, and other interventions delivered at the bedside be based primarily on limited evidence, personal bias, and/or guesswork. Imagine knowing before walking into the delivery room how the neonate about to be delivered will present and what will need to be done to provide that patient with optimal support. Although this may sound a bit farfetched, it nevertheless will be possible as patient models improve and the simulations in which they are used become more realistic.

To ensure that simulation fulfills its potential to enhance training, research and clinical care highly realistic models that accurately replicate actual human physiology will need to be developed; in addition, it will be necessary to precisely define optimal human performance and develop the assessment tools necessary to objectively measure it. Ultimately, as modeling of patient physiology and anatomy becomes more robust and our understanding of human performance in dynamic domains improves, it will become possible to prospectively predict both the type and timing of care and the composition and skill level of the team needed to deliver that care. The work by Sa Couto *et al.* is a great start in this direction.

REFERENCE

1. Sa Couto CD, Andriessen P, van Meurs WL, Ayres-de-Campos D, Sa Couto PM 2010 A model for educational simulation of hemodynamic transitions at birth. Pediatr Res 67:158–165