Role of simulation in hemodynamic monitoring in cardiac surgery

The Editor,

Simulation-based health-care education has expanded tremendously over the past few years, as witnessed by the creation and growth of the Society for Simulation in Healthcare.[1] By definition, simulation is a technology to replace, or amplify real patient experiences with guided experiences, artificially contrived which evokes or replicates substantial aspects of the real world in a fully interactive manner.[2] Simulation-based learning can be helpful to develop health-care professional's knowledge, skills, and attitudes while protecting patients from unnecessary risks. Health-care simulators offer four main purposes – education, assessment, research, and health system integration in facilitating patient safety. Commonly used medical simulators are of virtual reality [Figure 1], screen-based [Figure 2], and mannequin-based/or realistic types, and they are quite varied in characteristics and fidelity (accuracy).[3]

Since cardiovascular disease is intimately linked to cardiovascular hemodynamics, accurate assessment of the patient's hemodynamic state is critical for the diagnosis and treatment of heart disease. Unfortunately, while a variety of invasive and noninvasive approaches for measuring cardiac hemodynamics is in widespread use, they still only provide an incomplete picture of the hemodynamic state of a patient. In this context, computational modeling of cardiac hemodynamics presents as a powerful noninvasive modality that can fill this information gap and significantly impact the diagnosis as well as the treatment of cardiac disease.

Simulations allow us to practice virtual hemodynamic stabilization of a patient in both a surgical and Intensive Care Unit environment. After undergoing a successful cardiac surgical repair, the patient may have complications of depressed myocardial contractility, bleeding, or hypotension in addition to many other complications. Simulators provide us with the option of choosing one of the three shock case scenarios: Cardiogenic shock, hypovolemic shock, and septic shock. One may use a combination of fluid/diuretics and inotropes/vasodilators to ensure that all vital signs (heart rate, blood pressure, and cardiac index) are maintained within acceptable limits.

Diagnostic information

The chest drain will provide a visual indication of blood loss. The fluid balance sheet indicates the fluid intake and output including the hematocrit. Poor urine output may be a sign of low cardiac index. Cold extremities indicate peripheral vasoconstriction, which may also be a sign of low cardiac index. This clinical sign is shown in the simulation by the limbs becoming progressively pale and blue. If the myocardial perfusion pressure (diastolic pressure – left atrial pressure) becomes <20 mmHg, the myocardium will become ischemic, causing further depression of contractility and the electrocardiogram will display elevated ST segments. The cardiac index can be measured, and a Starling curve plotted to illustrate the relationship between myocardial filling, contractility, and stroke volume index. A chest X-ray may be ordered if tamponade is suspected. Interventions include a variety of fluids and drugs, options of temperature control, cardiac pacing, or return to operating room if bleeding is excessive or tamponade is suspected.

Figure 1: Virtual reality simulator

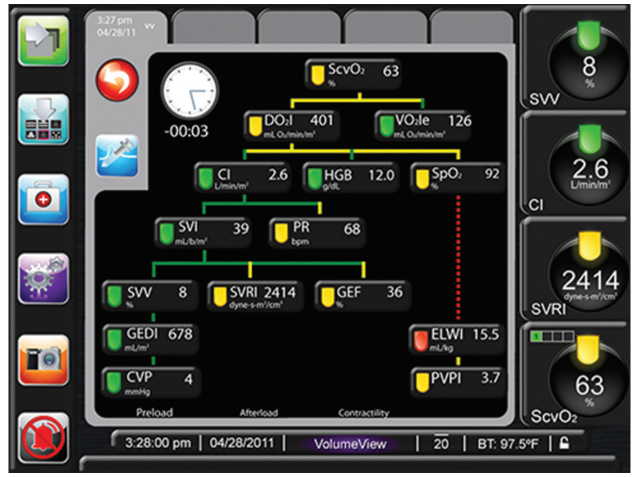

Figure 2: EV1000 screen-based simulator

Pulmonary artery catheter simulator is a screen-based program that allows users to insert the catheter, advance the catheter, and inflate the balloon to obtain a wedge pressure. Transesophageal/transthoracic echocardiography simulator allows the user to insert, advance, withdraw, flex, or rotate the probe to obtain multiple views transecting the heart in various planes.[6,7] The ultrasound image on the screen is adjusted on real time to match the probe's position. The mannequin simulator package is also available, and it can create stepwise learning process from basic information to advanced clinical application.

Simulation-based training has also been shown to enhance physician's performances during weaning from cardiopulmonary bypass.[4] Immersive training focusing on nontechnical skills are believed to be superior to passive discussion in traditional interactive teaching seminars. By providing a surrounding mimicking both the standardized process and dynamic crisis, high-fidelity simulation improves active memorization and enhances appropriate behaviors in real life while sparing patients from potential harm.[8]

In addition, the hemodynamic data obtained from the flow simulation can be directly used to investigate the flow patterns as well as clinically important variables such as pressure gradients, wall shear stresses, and vortex propagation.[5] To conclude, the proliferation of three/four-dimensional imaging technologies, increasing computational speeds, improved simulation algorithms, and the widespread availability of powerful computing platforms is enabling simulations of cardiac hemodynamics with unprecedented speed and fidelity.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Access this article online	
Quick Response Code:	Website: www.annals.in
	DOI: 10.4103/0971-9784.185559

Cite this article as: Singh A, Mehta Y. Role of simulation in hemodynamic monitoring in cardiac surgery. Ann Card Anaesth 2016;19:539-41.

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