SPECIAL ARTICLE

Simulation of Cardiopulmonary Bypass Management: An Approach to Resident Training

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SIMULATION-BASED TRAINING is used in anesthesia in a variety of ways, such as task trainers for intubation and major vascular access, crisis resource management, transesophageal echocardiography (TEE), and screen-based simulation. The use of high-fidelity mannequin simulators in cardiac anesthesia training is somewhat limited by their inability to simulate the cardiopulmonary bypass (CPB) state. The programmed physiology of the Human Patient Simulator (HPS, Anesthesia Model CAE Healthcare, Sarasota, FL) does not allow the combination of an adequate perfusion pressure in the presence of asystole or serious arrhythmias such as ventricular fibrillation, which may exist during CPB. In a previously described HPS-based simulation scenario for cardiac anesthesia, which included patient management during CPB, the authors report keeping the actual scenario in "pause" mode for the period of CPB during the scenario. An external pressure input from a pressurized bag was fed in to demonstrate the perfusion pressure of CPB. During this period, common learning points related to management of the patient on CPB were discussed.[1]

The present article reports the design of a mannequin-based cardiac anesthesia simulation training (CAST) module to teach patient management during CPB and discontinuation of CPB and the authors' experience of using it in anesthesia resident training. The adaptations enabled the scenario to be mannequin-based throughout without any break in the progression of the case, maintaining a degree of realism and allowing for clinical interventions. The modifications applied, the construction of the scenario, and its successful implementation are described.

METHODS

Halfway into their 1 month rotation in cardiac anesthesia, first-year anesthesia residents underwent the CAST module. The training objectives were (1) to understand the impact of CPB on the underlying patho-physiology of coronary artery disease; (2) to recognize complications that may arise during the progression of CPB; (3) to be able to clarify individual roles of the operating team, specifically the anesthesiologist, surgeon, and perfusionist; and (4) to communicate clearly with the team to have a coordinated response in patient care.

Four residents at a time underwent the training, and three sessions were conducted for a total of 12 residents. They were given pre-reading material outlining the principles of managing patients on CPB. On the day of CAST, written consent was obtained for audiovisual recording during the scenario and confidentiality of peer performance and module content. They were then given a set of 10 multiple choice questions (MCQ) to answer as a pretest. A short teaching session on the principles of CPB followed. The residents then were orientated to the simulation environment. A cardiac surgical operating room layout was set (Figs 1 and 2). A HPS was intubated and draped, with standard cardiac anesthetic monitoring in progress according to institutional practice. Participants in the scenario included a surgeon, a perfusionist, and a scrub nurse, all playing their real-life roles. A separate screen displayed bispectral index (BIS), blood results, and TEE images or video clips at various stages, so that the resident anesthesiologist and the participants could interact to decide on management.

The scenario was conducted in 2 parts. During the first part, 2 of the residents managed the anesthesia together, while the other 2 were observers. These roles were reversed for the second part of the scenario.

The residents were instructed to take over the anesthetic management of a middle aged patient undergoing elective coronary artery revascularization, on cardiopulmonary bypass with the distal graft anastomoses in progress. The monitors at this time displayed asystole with MAP ~70 mmHg, CVP ~5 and nasal and rectal temperatures close to 34°C, with BIS around 44. As the case progressed, the following abnormalities were introduced in sequence: (1) respiratory alkalosis with severe hypokalemia, (2) BIS rising to 59 with rewarming, and (3) repeated ventricular fibrillation (VF) after aortic cross clamp release (Fig 3). They were expected to recognize and respond appropriately. With the VF, they were handed internal defibrillator paddle leads to connect and use in coordination with the surgeon. After rhythm stabilization and completion of the proximal anastomoses, the surgeon handed pacing leads to the residents to connect to and set up the pacemaker. At this point, the first part of the scenario ended and a short debriefing was done.

For the second part of the scenario, the managing anesthesia residents were swapped with the observing residents. The scenario continued with the aortic cross clamp removed and pacing established. In preparing to wean from CPB, inotropic support was prepared as considered necessary and a check list of parameters (Table 1) before weaning was verified. The patient then was weaned gradually off CPB with coordinated actions from the team. Hemodynamic stability was expected to be achieved, by titrating preload and inotropes as required. TEE images were available to show volume status and contractility. Heparin reversal followed and protamine was administered according to institution protocol. Halfway through protamine administration, the scenario was programmed to show a drop in blood pressure, with a TEE clip of an under-filled ventricle being displayed. The trainees were expected to manage a possible type I protamine reaction and thereafter complete protamine administration.

A short interval for hemostasis followed and the aorta was decannulated. Subsequently, the hemodynamics deteriorated, with a distending right heart on TEE image and the ECG remaining

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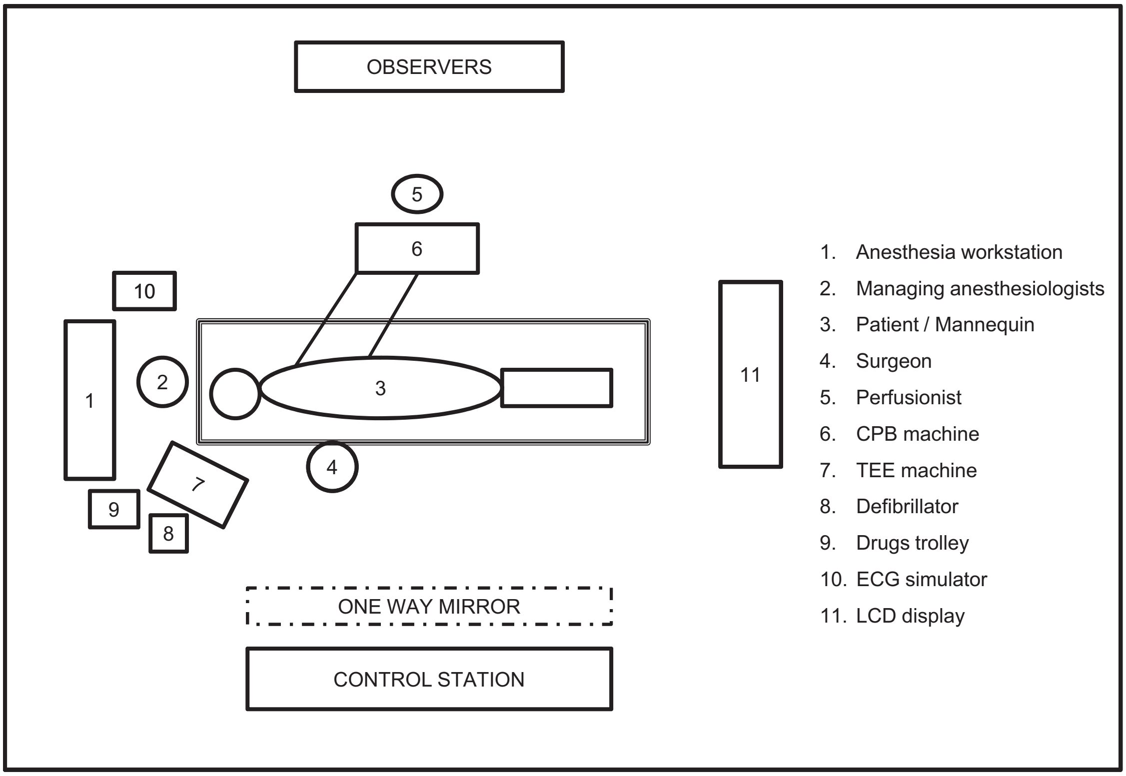

Fig 1. Diagram of layout of CAST operating room.

unchanged. A short discussion prompted by the surgeon followed and possible type III protamine reaction was considered among the differentials. Supportive CPB was reinstituted after heparinization. With hemodynamics reestablished, the scenario came to an end. Alternative response options such as introduction of an intra-aortic balloon pump for circulatory support also may be considered.

After each part of the case scenario, the participants were brought through a facilitated debriefing session. The debriefing session also included a short instructional interactive teaching component on the basics of TEE supported management. At the end, a post test consisting of another set of 10 MCQs was administered. Residents completed a module evaluation and feedback form at the end of the session.

RESULTS

All residents returned completed feedback forms, which sought opinion on the module organization and format, usefulness of the module to reinforce knowledge and understanding, stimulate learning, improve confidence in patient management, and to promote better communication with the rest of the cardiac surgical team. Feedback mostly was assessed as good or excellent (Fig 4). Course organization and format was evaluated as good or excellent by 88.1% and as average or fair by 11.9%. The average pretest score was 96% and the post-test score 99%.

DISCUSSION

In this pilot study, the authors tested the feasibility of adapting the HPS to simulate hemodynamics of CPB and, its application in teaching anesthesia residents the elements of patient management on CPB in a simulated cardiac operating room (OR) environment with improved realism.

Enabling CPB Simulation with Improved Realism

Simulating CPB requires the ability to maintain normal perfusion pressure and oxygenation in the presence of asystole or serious arrhythmias. To achieve this, the ECG electrodes were disconnected from the HPS mannequin while it was running at a baseline state with MAP 60 mmHg, and ECG input was added from an external simulator (HeartSim 200, Laerdal Medical AS, Stavanger, Norway). With this, the patient monitor was able to display any rhythm or even asystole, with normal perfusion impulses shown, simulating on-going extracorporeal circulation, without the need to pause the scenario. The anesthesia workstation was set up to show CPB mode on the ventilator with no bellows movements or end-tidal CO_2 tracings. The simulator was programmed not to deteriorate to a cardiac arrest in the absence of ventilation by enabling the ischemic index sensitivity option. Keeping the level of ischemia sensitivity of the mannequin to a very low level, such as <0.05, keeps the mannequin crash-proof. Enabling the intrinsic ventilation rate of the mannequin to 4 breaths per minute with a low tidal volume of 200 mL enabled the mannequin to hold saturation, with minimal chest rise to be noticed through the surgical drapes. Temperatures were displayed with the thermistor tips placed in water at suitable temperatures. During the aortic cross clamp release stage, the rhythm was still generated by the external ECG simulator.