Simulation in Trauma/Advanced Cardiac Life Support

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Introduction

The goals of anesthesiology simulation training for trauma and advanced cardiac life support (ACLS) are to facilitate proficiency in the performance of specific required tasks through part-task training modalities, replicate real-life scenarios using high-fidelity simulation, and enhance both individual and team performance. Simulation of trauma/ACLS allows multidisciplinary teams to practice the coordination and communication skills required for management of low-frequency, high-acuity events. The focus of this chapter is on each of these components and their relevance to trauma and ACLS resuscitation training for the anesthesiologist.

Part-Task Trainers and Skill Acquisition

Part-task training focuses on dividing a complex task into components and intensive focus on those individual components. Part-task procedures such as placement of a chest tube in a mannequin or inserting an intravenous line in an artificial limb are relevant to trauma/ACLS. Benefits over higher-fidelity simulation include lower cost, portability of equipment, and emphasis on development of muscle and eye coordination for required procedural skills [1]. Restriction of resident work hours by the Accreditation Council for Graduate Medical Education (ACGME) raises legitimate concern about a decrease in procedural experience among young physicians. There is an increasingly perceived lack of procedural skills and patient management skills among newly trained physicians by departmental leaders [2]. Part-task simulation allows residents to practice procedural techniques in a safe setting with feedback about motor skill acquisition [3]. While part-task simulation training has proven effective for improving procedural skills among colorectal surgery residents, procedural skills are not yet measured or assessed for certification [4]. Part-task training may gain further emphasis in training programs, as procedural skill assessment is increasingly advocated.

Acquiring task proficiency requires a complex set of behavioral modifications. Motor skill acquisition occurs through the following three steps: cognition, integration, and automation [5]. Cognition involves the understanding of the task, integration involves coordinating mechanical skills, and automation involves performing the task with speed and efficiency [5]. The transfer of performance skills from part-task simulation, or low-fidelity models to higher-fidelity models, has been well documented. Therefore, it is helpful to create a foundation for trauma/ACLS training using part-task simulators to ameliorate the stress and variability of performing an unfamiliar procedure during an emergency situation. Simulation courses integrating part-task trauma/ACLS skills such as endotracheal intubation, cricothyroidotomy, and intravenous access with full simulations have been shown to increase medical student confidence when performing these tasks [3]. Part-task training for anesthesiology skills in trauma/ACLS includes endotracheal intubation, cricothyroidotomy, central and peripheral line placement, and chest compressions [6].

Endotracheal Intubation

Endotracheal intubation during ACLS or trauma situations is essential for airway protection and provision of adequate ventilation. Intubation during an emergency requires baseline proficiency. An airway-specific part-task trainer (Laerdal Airway Management Trainer; Fig. 23.1) has been utilized to evaluate force applied to the epiglottis, number of attempts required for intubation, time to intubation, and appropriate

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Fig. 23.1 Laerdal Airway Management Trainer. (Photo courtesy of Laerdal Medical. All rights reserved. www.laerdal.com)

hand position on the laryngoscope among healthcare providers [7]. Teaching laryngoscopy skills using a video laryngoscope may be more effective than traditional teaching with a standard laryngoscope. Those taught using a video laryngoscope for training and then subjected to simulated normal airway (Laerdal Airway Manager) and difficult airway (Sim Man) conditions required fewer attempts and repositioning maneuvers and had more confidence and improved knowledge of airway anatomy [8]. Furthermore, the use of video laryngoscopy for real-time airway establishment during ACLS chest compressions has been suggested to facilitate endotracheal intubation with shorter interruption of chest compressions. The goal is to fully secure the airway without interrupting chest compressions or with a brief pause of less than 5 seconds [9]. Mannequin studies comparing tools for airway establishment in trauma/ACLS situations may not translate to real-life situations. A randomized crossover mannequin study evaluating hands-off time for intubation showed no benefit of the video laryngoscope under easy intubating conditions, by experienced providers [10]. Further studies may demonstrate utility of the video laryngoscope during trauma/ACLS situations, particularly for difficult airways and providers with less airway experience. Furthermore, video laryngoscopy was superior to direct laryngoscopy for achieving intubation with no interruption in chest compressions in real patients in the emergency department [11]. These discrepancies likely reflect the various factors that influence emergency intubation in real circumstances; impaired visualization of the airway by blood, vomit, debris or secretions, anatomic challenges, patient positioning, and distractions such as noise level may make laryngoscopy in real trauma/ACLS situations more difficult [12].

Airway compromise is a leading cause of death in trauma patients, and immediate cricothyroidotomy in cases of failed ventilation or intubation can be lifesaving. Fewer than 1% of trauma patients require this maneuver, limiting exposure to, and practice of, this procedure. Part-task training for emergency airway access facilitates knowledge of anatomic landmarks and surgical dexterity. Detailed instructions for creation of affordable, low-fidelity cricothyroidotomy simulators are available [13].

Vascular Access

Obtaining vascular access in an unstable patient can be challenging. Simulation training for different approaches has been described. In situations such as upper thoracic trauma where superior vena cava flow may be disrupted, vascular access below the diaphragm is paramount to ensure flow via the inferior vena cava [14]. Obtaining access in the lower extremity is a challenging and unfamiliar task for untrained personnel. Advanced life trauma support (ATLS), a sub-segment of the American College of Surgeons, recommends placement of two large-bore intravenous lines (16 gauge or larger) in a patient with suspected of hemorrhagic shock or with serious injuries [14].

Intravenous access may be challenging in patients with hemodynamic collapse or certain injuries such as burns or fractures. A systematic review evaluated the impact of simulation training and outcomes for central venous catheter placement and found greater success and fewer attempts in groups exposed to simulation training for this procedure [15]. The established safety and efficacy of ultrasound-assisted central venous catheter insertion also highlights

Fig. 23.2 CVC Insertion Simulator2 for central venous access placement by Kyoto Kagaku LTD. (Photo courtesy of Kyoto Kagaku, Ltd. (www.kyotokagaku.com))

the importance of establishing competency among medical trainees with ultrasound-based techniques [16] (Fig. 23.2).

An alternative approach to obtaining access is by the intraosseous (intramedullary) approach, which can be lifesaving for vascular administration of resuscitation medications when peripheral access is delayed or impossible. A part-task simulator, the Stat Adult ALS Manikin with intraosseous Leg Trainer (Simulaids, Saugerties, NY), has been used to compare success rates of three devices that establish intraosseous access by paramedics [17]. Use of two different intraosseous access devices in real patients in the emergency room yielded equal success [18]. As this approach gains popularity, task training simulation teaching will be important, to ensure proper use and safety of intraosseous access during trauma and ACLS.

Chest Compressions

The first CPR mannequin defined the paradigm for part-task simulation in medicine. Resusci-Annie™ was developed in 1960, after Drs. Elam and Safar first demonstrated that mouth-to-mouth ventilation provided adequate oxygenation and elimination of carbon dioxide [19]. Dr. Safar commissioned a toymaker, Asmund Laerdal, to create the first lifelike CPR mannequin. While this mannequin lacks haptic feedback of higher fidelity simulators, it continues to be a powerful tool for assessment of part-task performance and skill acquisition. Today's Resusci-Annie, the Resusci Anne® QCPR (Laerdal Medical, Orpington, UK; Fig. 23.3) measures chest compression depth and rate using a displacement sensor, with a recording system.

Continuous evaluation and immediate improvement of chest compressions during CPR continue to be a major focus in ACLS simulation part-task training. Pozner and colleagues demonstrated that CPR feedback improved the quality of chest compressions [20]. Smartphone applications with a built-in accelerometer assist in CPR training with chest compression feedback [21]. The quality of chest compressions during CPR by medical students was similar when comparing human feedback by a second rescuer to a mechanized audiovisual device (HeartStart MRx with Q-CPR technology) [22]. The deterioration of chest compression quality with transport of a patient in a simulated maternal cardiac arrest study was demonstrated using the part-task CPR mannequin; interruptions in CPR were observed in 92% of cases in which transport was performed during CPR, compared to 7% in the stationary group, with demonstrated deficiencies in adequate depth of compressions, hand placement on the sternum, and allowance for elastic recoil [23]. CPR is a physically strenuous task, and rescuer performance declines quickly over time. A part-task simulator scenario of CPR administration compared three CPR feedback technologies (PocketCPR, CPRmeter, and iPhone app Pocket PCR) to CPR without feedback and found that effective compressions were not improved by any CPR feedback device and that the devices may cause substantial delay in CPR initiation [24]. With continued advances in technology using smartphone and other integrated technology, part-task training with CPR mannequins will continue to play a central role for validating this technology and for enhancing the performance of physicians integrating these new modalities.

Fig. 23.3 The Resusci Anne® QCPR adult CPR training mannequin with sensor to indicate correct hand placement, ventilation system with chest wall rise, and wired connectivity to SimPad SkillReporter or Resusci Ann Wireless SkillReporter software. (Photo courtesy of Laerdal Medical. All rights reserved. www.laerdal.com)

High-Fidelity Simulation for Exposure

Advanced Cardiac Life Support

High-fidelity simulation for advanced cardiac life support (ACLS) training has significantly improved in quality and technology in the past 20 years [25–27]. High-fidelity simulation, which is defined as an object or experience resembling a real-world object or scenario, has been extensively studied using ACLS and trauma scenarios. While part-task simulation focuses on acquiring the necessary skill to accomplish a specific task, high-fidelity training focuses on the overall experience of the trainee with an emphasis on teamwork, interpersonal skills, and clinical decision-making. Participants who underwent high-fidelity simulation training for ACLS achieved higher scores in skill, cognitive knowledge, and competency compared to a low-fidelity simulation group [28]. Third-year medical students exposed to a high-fidelity simulation curriculum on ACLS management tasks reported increased preparedness, comfort level, and ability to be in charge of a code as team leader compared to those exposed to a traditional curriculum [29]. It is unclear whether high-fidelity simulation during medical school increases clinical competency in residency. However, Wayne and colleagues demonstrated that medical residents exposed to high-fidelity ACLS scenarios had enhanced clinical performance after simulation training and achieved higher ACLS knowledge base scores compared to those who completed the American Heart Association ACLS provider course [30].

Trauma

The use of high-fidelity simulation to expose medical providers to trauma resuscitation training is worthwhile, as the rate of avoidable death after injury has been reported as high as 25% [31]. The implementation of trauma protocols has been shown to decrease the rate of preventable deaths based on large population-based models [32]. Team training through simulated trauma scenarios has also been shown to improve teamwork and interpersonal communication [30].

The use of simple mannequins compared to standardized patients for trauma team training has been compared [31]. Participants reported high educational quality with both modalities and equal credibility and sense of realism in scenarios that utilized a mannequin compared to a standardized patient. Although study participants favored scenarios in which standardized patients were used, both modalities were effective for fulfilling educational goals of leadership, cooperation, and communication. This study underscores the value of using mannequins to achieve high-impact team training through simulation.

Trauma and ACLS resuscitations are characterized by low-frequency, high-acuity events. The unpredictable nature of such events can evoke stress, and the importance of a unified, multidisciplinary team approach to management cannot be overstated. Simulation-based team training sessions improved mannequin survivability in high-fidelity trauma scenarios among healthcare team consisting of nurses, physicians, and respiratory therapists [33]. The authors of this study emphasized the benefit of simulation training toward the goal of

Table 23.1 Sample trauma/ACLS scenario

Title: Loss of consciousness after motor vehicle accident		
Audience: Anesthesia resident		
Objectives:	*Medical knowledge:* Identify signs and symptoms of an unstable trauma patient	
	Patient care: Diagnosis and management of cardiac arrest after trauma	
	Communication: Utilize crew resource management skills to manage a trauma emergency	
Case stem: Mr. Smith is a 41-year-old man who sustained a motor vehicle accident. Blunt liver trauma is suspected		
Room setup: Emergency room bay with patient supine on a stretcher. He was in a motor vehicle accident		
The patient will have a noninvasive blood pressure cuff, pulse oximetry, and EKG electrodes in place. An IV bag is hanging and primed but not yet placed. An emergency room nurse and physician serve as confederates. The patient is a Resusci Anne® QCPR adult CPR training mannequin with sensor to indicate correct hand placement, ventilation system with chest wall rise, and wired connectivity to SimPad SkillReporter software		
State	**Patient status**	**Learner actions**
Baseline	Otherwise healthy, acutely injured patient with slight somnolence HR, 112; RR, 20; BP, 89/40; SpO2, 94% (RA) A focused assessment with ultrasonography for trauma (FAST) exam reveals free fluid in the RUQ	The learner will introduce himself/herself to the patient and care team Assess patient orientation and level of consciousness Prioritize rapid IV placement and fluid administration Prioritize calling for a massive transfusion protocol (MTP)
Anxious and agitated	The IV is attempted twice without success Anxious appearing and agitated (over 1 minutes) HR, 131; RR, 30; BP, 65/45; SpO2, 90% (RA)	Generate a differential diagnosis Communicate concerns to the present team Call for help/backup care (surgical team) Prepare for possible intraosseous access Initiate supportive care for hypoxia/hypotension
Unresponsive	Unconscious ETCO2 10 mmHg	Recognize pulseless electrical activity (PEA) and initiate ACLS Adequate chest compression frequency and depth, ventilation, IV or IO access Epinephrine 1 mg IV or IO Initiation of MTP Communicate concerns with the team; review the 5Hs and 5Ts for etiology. ANTS system situational awareness
Recovery	Regains consciousness with ACLS and early resuscitation (after initiation of supportive care over 2 minutes) HR, 110; RR, 15; BP, 90/60; SpO2, 99%	Develop a plan for supportive/intensive care and transport while the operating room team is notified
Discussion points: Differential diagnosis of cardiac arrest after acute trauma; establishing rapid IV or IO access and activation of MTP; appropriate ACLS maneuvers; crew resource management in the ED for identifying surgical emergency patients		

overall efficiency of the crisis team, focusing on communication and functionality of the team rather than individual skills and contributions. See Table 23.1 for a sample scenario.

High-Fidelity Simulation for Assessment

Assessment of anesthesia performance during high-fidelity simulation of ACLS and trauma scenarios has become increasingly sophisticated. Gaba and colleagues demonstrated good inter-rater reliability and feasibility through the separate measurement of technical and behavioral performance of videotaped cardiac arrest and malignant hyperthermia scenarios using a specific, point-based checklist system [34]. The nontechnical performance in this study was scored in two separate time periods, before and after the critical event. Furthermore, timing for nontechnical scoring was specified to improve inter-rater reliability. This more refined scoring method was used by Mudumbai and colleagues [35]. A global rating system has been advocated over a checklist-based method for scoring the complex performance of trauma/ACLS in high-fidelity simulated scenarios. A global rating scale utilizing three categories of performance, knowledge, behavior, and overall performance, was found to have good inter-rater reliability for evaluation of anesthesiologist performance during cardiac arrest and other critical medical situations [36]. Interest in how simulation scores relate to other measures of ability has intensified with the American Board of Anesthesiology (ABA) initiation of simulation-based training as part of the Practice Performance Improvement and Assessment component for the Maintenance of Certification in Anesthesiology (MOCA). The validity of scores may be best when multiple scenarios are scored, using multiple observations, different patient encounters, and evaluation of both nontechnical and technical skills [37]. The performance of graduating anesthesiology residents was evaluated in multiple short scenarios and one long scenario, based on technical skills (using a set of key clinical actions) and nontechnical skills (using a validated scoring system, ANTS) [35]. This comprehensive study found moderate correlation between simulation scores and other markers of ability, including USMLE scores, ABA in-training examination scores, and faculty and nursing global ranking scores.

Multidisciplinary Team Training

Effective, multidisciplinary teamwork and communication are key for management of critical clinical events. In situ simulation may be the optimal approach for team training in the true clinical environment. In an observational study of a level 1 trauma center emergency department, team performance was measured at baseline and then after exposure to didactic sessions and in situ trauma simulation drills [38]. While the program improved teamwork and communication, the effect was not sustained after the drills were stopped. Thus re-exposure of multidisciplinary teams to in situ drills are required to prevent degradation of teamwork skills; the frequency with which retraining is needed has not yet been determined.

Defining the role of each team member during crisis management has the potential to improve team performance. The evaluation of a cognitive aid for role definition (CARD) used among 16 interprofessional operating room teams during in situ simulation of cardiac arrest found no significant differences in team performance with or without CARD use [39].

Communication among team members may hold greater relevance, in conjunction with each team member having a defined role during crisis management. Verbalizing situation assessments during a crisis in order to coordinate task management with the least time spent on task delegation and an emphasis on task performance may yield better team coordination [40]. Two-person anesthesiology teams managing a high-fidelity simulation of malignant hyperthermia had the lowest performance scores when a shared plan was not verbalized to the rest of the team [40]. A high-fidelity simulation study of communication between care providers (anesthesiologists and obstetricians) during maternal crisis management demonstrated a shortcoming in both the anesthesiologists' inquiry of the obstetricians' plan and in the formation of a jointly managed clinical plan [41]. Strategies to overcome deficient communication patterns that are identified between providers may be incorporated into both content development and debriefing of simulated crisis scenarios.

Curriculum Development and Resources

Assessment of Technical Skills

A scoring system for 12 simulated intraoperative scenarios can be utilized to distinguish skills of more experienced anesthesiologists from residents in early training [42].

Mudumbai and colleagues suggest multiple short scenarios using high-fidelity simulation to evaluate technical skills [35]. The appendix to this chapter provides key actions that can be used for short simulation scenarios such as acute hemorrhage, tension pneumothorax, and unstable ventricular tachycardia, all of which are pertinent to trauma/ACLS.

Assessment of Nontechnical Skills

The most widely accepted and validated scoring system for nontechnical performance in simulation for anesthesiologists is the Anaesthetists' Non-Technical Skills (ANTS) system developed by Fletcher and colleagues [43]. The ANTS system defines categories of teamwork, situational awareness, task management, and decision-making using a 4-point Likert scale and can be applied at specific time points within a simulation to avoid the issue of variable performance over time [34]. This application of the ANTS system with specific nontechnical elements measured at specific time points is described by Mudumbai and colleagues (Appendix C) [35].

Doumouras and colleagues described and evaluated a pilot of trauma team training curriculum focusing on nontechnical performance [44]. Deficiencies in trauma resuscitation often result from ineffective team leadership, nonstandardized communication among team members, lack of situational awareness, or inappropriate prioritization. The described curriculum emphasizes these components. A nontechnical skills scale for trauma (T-NOTECHS) enables teaching and assessment of teamwork skills during multidisciplinary trauma resuscitation and has been validated for clinical grading of nontechnical skills during simulated trauma scenarios [45].

Conclusion

The ability for anesthesiologists to perform critical tasks effectively, to recognize a crisis situation, and to coordinate a multidisciplinary response team with effective communication and technical performance requires a great deal of skill and practice. Anesthesiologists have limited exposure to low-frequency, high-acuity events such as unstable trauma or cardiac arrest. Low- and high-fidelity simulation will continue to serve as meaningful mechanisms of training and exposure of anesthesiologists to these situations, for optimization of personal and team-related performance.

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