How Does Ultrasound Simulation during High Fidelity Simulation Contribute to the Development of Emergency Ultrasound Skills Amongst Emergency Medicine Trainees?

A Thesis

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By

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ABSTRACT

The growing worldwide use of clinician-performed ultrasound (CPU) marks a dramatic change in bedside medicine and patient care. With steadily improving portability, accessibility and technology, ultrasound use continues to grow amongst many medical specialties. Likewise, the application of CPU in emergency medicine is increasing. Emergency Medicine (EM) is a medical specialty "based on the knowledge and skills required for the prevention, diagnosis and management of acute and urgent aspects of illness and injury…" (International Federation for Emergency Medicine, 1991). Increasingly, emergency physicians are using emergency department ultrasound (ED U/S) to enhance their assessment of critically-ill patients (American College of Emergency Physicians, 2008).

The purpose of this study was to evaluate and describe those aspects of ultrasound simulation (during HFS) that contribute to the development of critical care ED U/S skills. Secondly, it was of interest to assess how a novel ultrasound simulator (**edus^2**) compared to video playback on a laptop in terms of the above-mentioned aspects. The population of interest included both EM trainees and faculty.

This investigation was a randomized, prospective, crossover study with two intervention treatments for all participants. In Phase I, EM trainees and faculty from London, UK, were invited to participate in one of four day-long critical-care HFS sessions during which they participated in four critical-care scenarios. Faculty were involved in assisting with session debriefing and feedback. All participants completed two cases with each intervention. In Phase II, faculty in Saskatoon, SK, Canada, were invited to review video recordings of the sessions from Phase I and evaluate the educational merits of the two ED U/S simulation interventions.

This study produced both quantitative and qualitative data. As this study looked at two interventions and how they could contribute to the development of ED U/S skills, pre- and post-intervention changes were analysed for statistically significant differences between them. *T*-test analyses were used for comparisons. Effect sizes (Cohen's d) were calculated where statistically significant findings were observed. Qualitative data was assessed through emergent thematic analysis and triangulation.

The findings of the study support the integration of ED U/S simulation into HFS. Integration was found to be of value to both trainees and faculty by allowing trainees to demonstrate knowledge of indications as well as correct image interpretation and general integration of ED U/S into critical care ($p<0.05$). Trainees described an increased motivation to develop their ED U/S skills as well as greater desire to use ED U/S in everyday practice.

Furthermore, the **edus^2** was identified as being the preferred training intervention. The **edus^2** met functional fidelity through its real time and hands-on applicability. Faculty preferred the **edus^2** as it allowed for better assessment of trainee skills that then influenced session debriefing and formative feedback. Faculty in Phase II found the **edus^2** intervention sufficient in offering basic insights into trainee ED U/S skills and mastery ($p<0.05$).

Implications of the study include support for the use of ultrasound simulation during HFS for the development of critical care ED U/S skills amongst EM trainees. Further study on the effects of such hybrid simulation on clinical performance is warranted.

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"If the essence of our calling is being at the bedside when needed, should we not collectively embrace anything that may improve the bedside care of the critically ill?"

- Dr. Andrew Kirkpatrick

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CHAPTER I

INTRODUCTION

The growing worldwide use of clinician-performed ultrasound (CPU) marks a dramatic change in bedside medicine and patient care. With steadily improving portability, accessibility and technology, ultrasound use continues to grow amongst many medical specialties. Likewise, the application of CPU in emergency medicine is increasing. Emergency Medicine (EM) is a medical specialty "based on the knowledge and skills required for the prevention, diagnosis and management of acute and urgent aspects of illness and injury…" (International Federation for Emergency Medicine, 1991). Most critically-ill patients presenting to emergency departments are urgently assessed by a variety of means. Cardiorespiratory monitoring, bedside history taking, physical examination, and point-of-care testing all play a part in today's initial evaluation of the critically-ill emergency department (ED) patient.

Increasingly, emergency physicians are using emergency department ultrasound (ED U/S) to enhance their assessment of critically-ill patients (American College of Emergency Physicians, 2008). In Canada, the dramatically positive impact of ED U/S on patient care has resulted in the adoption of ED U/S as a clinical skill to be possessed by all EM graduates (The Royal College of Physicians and Surgeons of Canada, 2011).

Many of the critical illnesses encountered in the emergency department merit assessment with ED U/S. The American College of Emergency Physicians (2008) stated that the evidence supporting the use of ED U/S is substantive and growing rapidly. In Canada, the indications for its use now include the assessment of many common ED presentations including critical illness states such as shortness of breath, chest pain, shock and trauma (Canadian Emergency Ultrasound Society, 2009).

Performing ED U/S as a psychomotor task involves mastery of image generation through appropriate probe manipulation. However, performing ED U/S in the critical-care setting is complicated by the patient's precarious clinical state and resulting surroundings (intravenous lines and pumps, blood pressure cuffs and monitors with respective leads, and other members of the resuscitation team), which may create obstacles and challenges in terms of timing and access to the patient. Effective ED U/S performance relies on situational awareness, understanding of the rationale for employing a specific scan or technique at a given time, and ability to accurately and rapidly interpret the findings.

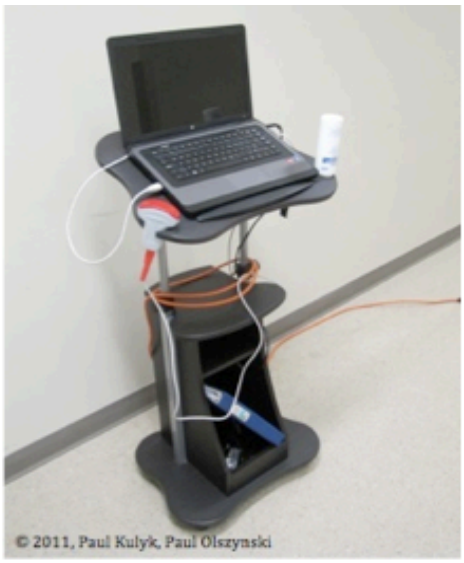
This relationship of a specific task to its broader clinical context echoes the view taken with respect to already established resuscitation algorithms. As emphasized in the American Heart Association Guidelines for Cardiopulmonary Resuscitation (Berg et al., 2010), individual aspects of critical care (including chest compressions, airway management, rescue breathing, rhythm detection and defibrillation) should be employed in a "simultaneous, *choreographed* (emphasis added) approach." Such choreography strives to minimize interruptions in critical actions (namely chest compressions) while ensuring the patient receives all appropriate assessments and therapies. This choreography requires team members to practice timing, provider positioning and communication.

In much the same way, emergency physicians must not only master the skill of generating ultrasound images, but they must also become efficient at incorporating such scanning into their resuscitation *choreography*. Competence in critical care ED U/S can be divided into three broad components: awareness of indications with associated rationale, the technical skill of image generation with simultaneous interpretation of findings, and, lastly, the

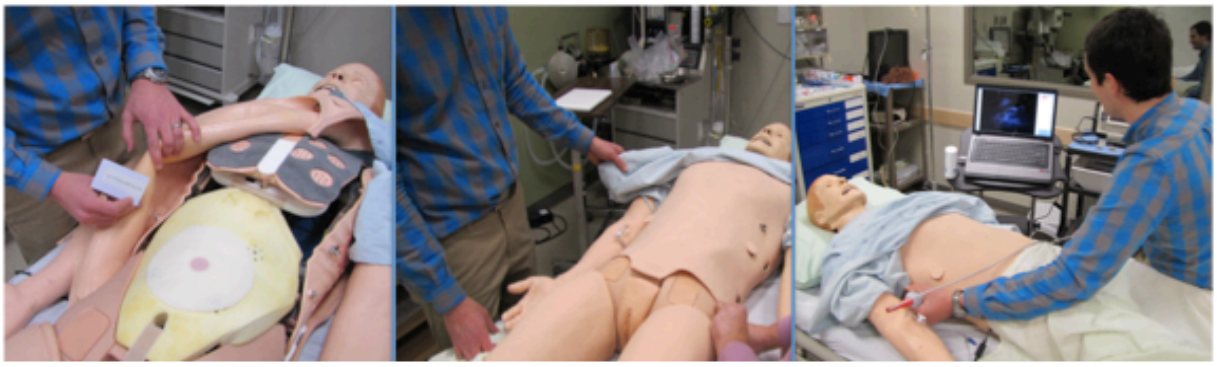
appropriate, safe integration of ED U/S during critical care resuscitation (as a part of or an extension of resuscitation choreography).

At present there is no unified national curriculum for ED U/S training in EM (Kim et al., 2012; Woo, Nussbaum, & Lee, 2009). As such, there remain a number of questions regarding the optimal method to nurture this relatively novel skill amongst both trained physicians and trainees. Of significant interest is how to best integrate the ED U/S skills of trainees into the care of critically-ill patients. It is possible that simulation-based interventions will play a significant role in bridging these ED U/S skills into the arena of critical-care management (Sidhu et al., 2012; Atkinson et al., 2013).

It is with this possibility in mind that the author and colleague (Dr. Paul Kulyk) developed a novel ED U/S simulator, the **edus^2**. The **edus^2** is an ED U/S simulator made up of a laptop, a laptop stand, and a modified ultrasound probe. When used during high-fidelity simulation (HFS), the **edus^2** can play pre-recorded video clips of areas of interest through the coupling of those videos to specific Radio Frequency Identification Device (RFID) cards placed under the skin of any commercially available HFS mannequin. A small USB-based RFID scanner has been embedded inside a hollowed low-frequency ultrasound probe to serve as a simulated probe. Passing the **edus^2** probe over a RFID card located beneath a mannequin's skin initiates a video clip of the corresponding anatomic area (on the HFS mannequin) to be viewed by the trainee on the **edus^2** screen. Multiple scans are possible during any given scenario (by placing several cards under the skin of the mannequin) including thoracic, cardiac, abdominal, and pelvic scans (see Figure 1).



Step 1. Placement of RFID cards under the rubber skin of the HFS mannequin (multiple cards can be placed throughout the mannequins body representing different scanning areas).
Step 2. Re-attachment of mannequin skin (in some mannequin models the rubber skin is either partially lifted or entirely removed and then re-attached for placement or cards).
Step 3. Trainee participating in the HFS scenario simply brings the **edus²** to the patient's bedside and places the probe over the proper landmark for the scan they desire to perform. The **edus²** then plays the video that has been coupled to the RFID card placed under the skin once the probe (with RFID reader within) is placed in near proximity.



Step 1 **Step 2** **Step 3**

Figure 1. The **edus²** (ED U/S Simulator).

The **edus²** represents one way of integrating ED U/S into HFS. Other approaches include placing a laptop on a video cart and playing videos of scans as requested by trainees (Kobayashi, Shapiro, Nagdev, & Gibbs, 2010), or introducing a task-trainer beside the HFS mannequin to be turned to and used when indicated during the scenario (Girzadas, Jr. et al., 2009). The strengths and weaknesses of these approaches remain to be fully evaluated and described.

Purpose

The incorporation of ED U/S simulation into HFS, through what can be described as hybrid simulation, may enhance the development of ED U/S competence (defined as the ability to appropriately employ ED U/S during the assessment and management of patients). Hybrid simulation offers an intermediary step whereby the skills learned outside the critical-care context (i.e.: at courses, through scanning healthy volunteers and patients who are otherwise well) can be re-integrated into a clinical environment in a way that is developmentally appropriate (Kneebone, 2009) and poses no risk to real patients. In such a setting, competence with critical care ED U/S can be safely assessed and further developed.

The figure below (Figure 2) illustrates some of the ways that ED U/S simulation during HFS may contribute to the development of ED U/S skills. This list includes (but is not limited to): greater fidelity and integration, opportunity for trainees to show what they know, assessment of skills, opportunities for feedback, impact on the supervision cycle, and lastly, opportunities for transfer of learning. These aspects of ultrasound simulation in HFS (as well as others identified by participants during the study) were evaluated and described by both EM trainees and faculty.

Figure 2. Examples of aspects of ED U/S simulation that may contribute to ED U/S skills.

The purpose of this study was to evaluate and describe those aspects of ultrasound simulation (during HFS) that contribute to the development of critical care ED U/S skills. Secondly, it was of interest to compare the two ultrasound simulation interventions (a novel ultrasound simulator (**edus**^{2}) vs. video playback on a laptop) in terms of the above-mentioned formative aspects.

Research Design

This study was designed to evaluate and describe how ultrasound simulation in HFS contributed to the development and assessment of critical care ED U/S skills (defined as knowledge of indications, image acquisition with interpretation, and overall integration) amongst EM trainees. Furthermore, the study integrated two different forms of ultrasound simulation (a

simple laptop vs. the **edus^2**) for comparison. This was a randomized, prospective, crossover study with two intervention treatments for all participants. The study was divided into two phases: Phase I (course phase) and Phase II (video review phase).

In Phase I (course phase), EM trainees and faculty from the London Specialty School of Emergency Medicine (London, UK), were invited to participate in one of four day-long critical care HFS session during which they participated in four critical care scenarios. Each simulated case was designed to highlight the importance of ED U/S in critical care. EM faculty were involved in observing the scenarios and then assisting with session debriefing and feedback. EM trainees and faculty were randomly assigned to one of two groups according to their arrival to the simulation suite. The first participant was assigned to Group A, the second to arrive was assigned to Group B, the third to Group A, and so on. Both groups completed two cases with one of the ultrasound simulation interventions and then crossed over to the other intervention for the remaining two cases. In Phase II (review phase), EM faculty from the University of Saskatchewan (Saskatoon, SK, Canada) who possessed ED U/S expertise were invited to review video recordings of the sessions from Phase I. Through the use of standardized forms (Appendix D), these faculty participants were asked to assess the interventions' on their capability to assist in the assessment of trainee ED U/S skills (see figures 3 and 4). An intervention capable of assisting in the assessment of trainees' skills is useful for the formative process as it allows for tailored and specific feedback.

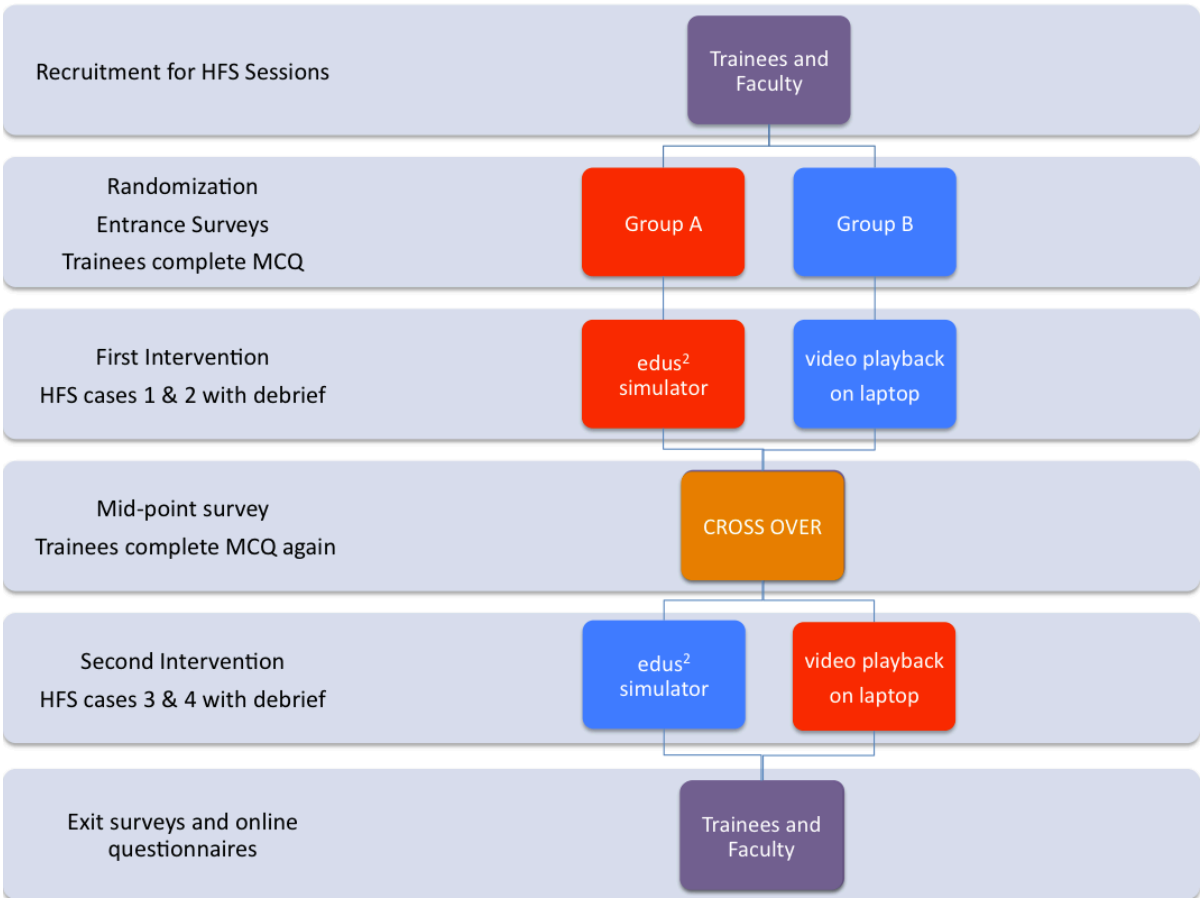


Figure 3: Phase I Study Design (course phase)

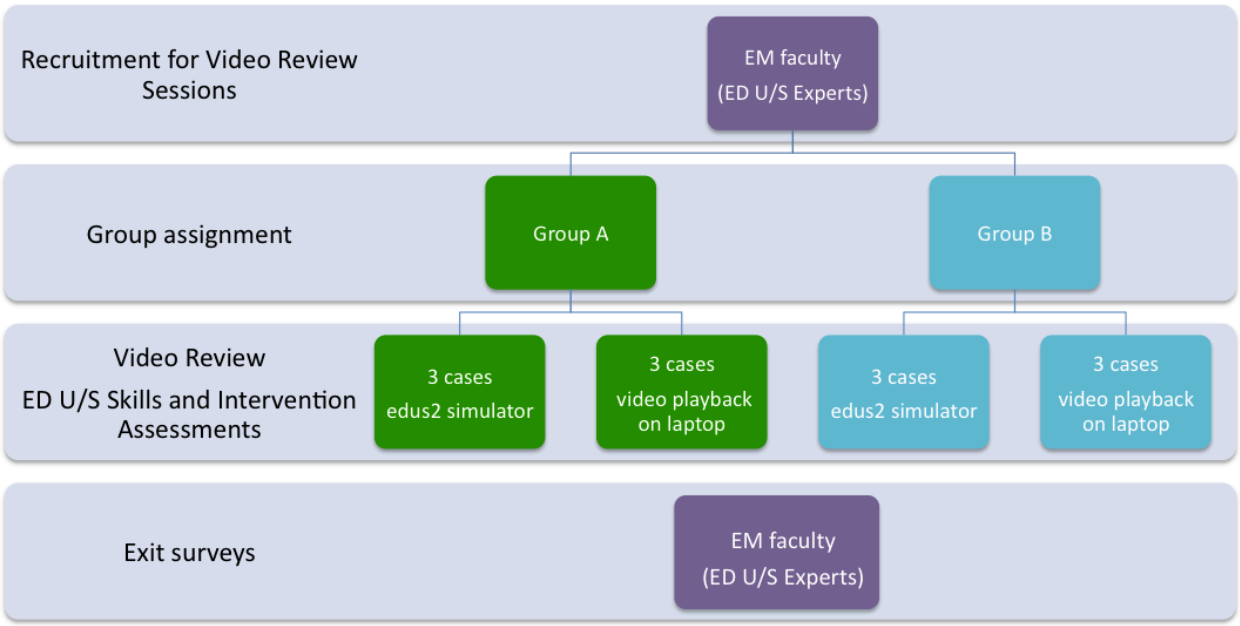


Figure 4. Phase II Study Design (review phase)

ED U/S Training Today

Currently, practicing physicians interested in developing competence in ED U/S generally do so through course attendance and reading, by performing practice scans on patients and volunteers, and through video review. The limitations of these learning experiences relate in part to the rarity with which physician can apply their *developing* ED U/S skill-set to the management and care of critically-ill patients. Given how vital a role ED U/S can play in the assessment and management of such patients (American College of Emergency Physicians, 2008; Labovitz et al., 2010), opportunities for improved patient outcomes may be missed.

When considering postgraduate trainees, the above limitations are further compounded by two key issues: firstly, EM trainees are still in the process of mastering their broader resuscitation skill-set, and secondly, there are geographic regions where there is a scarcity of adequately-trained instructors and appropriate equipment resources (Atkinson et al., 2013).

EM trainees are still in the process of developing their core resuscitative skill-set and further learning may be hampered by the excessive cognitive load created by combining both still-maturing resuscitation skills and budding ED U/S skills. Due to the relative infrequency with which critically-ill patients present to the ED, and the challenges of managing time-sensitive conditions such as shock while simultaneously developing as complex a skill as ED U/S, post-graduate trainees may be less likely to use ED U/S in their initial assessments of such patients. This represents a missed opportunity for genuine learning, skill development, and better patient care. It is possible that simulated clinical environment interventions such as simulation-based training may improve trainee integration of ED U/S into the management of critically-ill patients.

Furthermore, given that ED U/S is still an emerging clinical skill in Canadian EM, there is currently no central or core ED U/S curriculum (Kim et al., 2012). The Canadian Emergency Ultrasound Society (CEUS) has established training standards and credentialing for practicing physicians who wish to achieve mastery in ED U/S (Canadian Emergency Ultrasound Society, 2009). This credential serves as a nationally recognizable benchmark for basic ED U/S skill mastery and confers onto successful candidates the designation of 'Independent Practitioner', represents recognition of mastery of basic ED U/S skills, and the ability to perform and interpret specified scans without supervision.

Residency-based ED U/S training is increasing throughout Canadian EM residency programs. It remains uncertain how to best deliver U/S training for EM trainees so the curriculum varies from one institution to another (Kim et al., 2012; Woo et al., 2009). Those EM trainees who are interested in making ED U/S their special interest are choosing to pursue specialized training in ED U/S, beyond that of training during residency, through year-long

fellowships completed near or at the end of their EM training program (Emergency Ultrasound Fellowships, 2014).

In EM residency programs where there is a lack of a robust U/S training program (due to scarcity of instructors and/or resources for such training) residents are encouraged or expected to attend ED U/S courses and undertake apprenticeship through credentialing bodies such as CEUS, much like already-practicing physicians (Kim et al., 2012; Woo et al., 2009). Such is the current case with the University of Saskatchewan EM residency program. The same can be said for EM trainees of the London Specialist School for Emergency Medicine, where the demand for ED U/S training is great but the scarcity of courses and costs of training make it difficult to pursue.

Simulation for Skill Acquisition

Simulation-based skill acquisition is becoming increasingly common (McGaghie, Issenberg, Petrusa, & Scalese, 2010). The current evidence supports its use in the development of clinical skills, albeit largely in the realm of procedural skills. And while medical schools are increasingly interested in making use of simulation technology, it is not without controversy (Ten Eyck, Tews, & Ballester, 2009; Schwartz, Fernandez, Kouyoumjian, Jones, & Compton, 2007). Some critics have pointed out that assessments of gains in skills have, to date, largely been confined to assessment in simulated environments rather than during real patient care (Sidhu et al., 2012). The majority of ultrasound simulation studies' outcomes are framed within the simulation context and as such, much of the evidence offers only indirect evidence on skill development (Sidhu et al., 2012). The use of task trainers, defined as simulation devices designed to train a learner on a particular task that is associated with or is part of a broader more complex task, has been shown to reduce training times for procedural skills in many specialties including surgery, medicine and anesthesia (McGaghie et al., 2010; Bradley & Ker, 2010).

Specific ED U/S task trainers are available commercially. These trainers usually include a limited torso or body part for scanning and incorporate the use of ED U/S machines for scanning practice (i.e.: CAE Vimedix). The educational value of some ED U/S task trainers is questionable (Sidhu et al., 2012). Given the benign nature of ultrasound waves and the generally non-invasive nature of ED U/S (except for invasive scans such as pelvic and esophageal or where ultrasound guidance includes central venous catheters and drains) it seems reasonable that learners develop the technical/manual aspects on ED U/S on real volunteers and patients rather than on expensive, less-than-real, task trainers.

The limitations of the non-simulation-based approach (the traditional approach), is the limited frequency with which trainees would be able to safely employ and integrate their skills when it matters most, namely during the care of critically-ill patients. Here, a relative lack of familiarity with positive ED U/S findings (patients with actual symptomatic pericardial effusions, traumatic free fluid in the abdomen or a leaking aortic aneurysm) as well as the added stress and cognitive load associated with the management of a critically-ill patient, may result in less than satisfactory performance of both the resuscitation and sonographic assessment of the patient.

This challenge can be addressed through the incorporation of task trainers within HFS. The result is a hybrid simulation where two or more simulation modalities are combined to enhance learning opportunities. HFS provides trainees an opportunity to practice managing critically-ill patients in real-time without any risk to real patients (Kim, 2005). The timing and sequence of assessment maneuvers, the giving of appropriate orders and the recognition of a need for greater assistance are all clinical skills that can be developed and practiced in HFS. Furthermore, improving clinical adherence to complex resuscitative algorithms can also be

accomplished through HFS training (Sawyer et al., 2011; McGaghie et al., 2010). As ED U/S is increasingly recognized as a core component of resuscitation (Labovitz et al., 2010; Weingart, Duque, & Nelson, 2009; Lanctot, Valois, & Bealieu, 2011), its integration into critical-care HFS seems inevitable and perfectly logical.

Bringing ED U/S into Simulation

Critical care ED U/S requires a clinical skill-set that may be suited for practicing in HFS through hybrid simulation interventions. The use of hybrid simulation interventions is documented in cardiology, anesthesia and more recently in EM (Girzadas, Jr. et al., 2009; McGaghie et al., 2010). Thus far, limitations with regard to ED U/S hybrid simulations have included the need for dedicated life-size mannequins that are not capable of HFS animation, high cost, and generally limited case repertoire. Some training programs have introduced ED U/S findings into HFS through the use of video playback of prerecorded scans on laptops placed at the bedside within the HFS suite (Kobayashi et al., 2010).

Kobayashi et al. (2010) published five such core cases for use by emergency medicine training programs during HFS sessions. The limitation in this approach is the lack of any technical, hands-on (psychomotor task) component. In the above model, learners simply ask for ED U/S images that are then played for them by a facilitator. This represents a step forward as it incorporates the important cognitive aspects of ED U/S into patient assessment and management, but fails to address the choreographic challenges often encountered with its use in critical care. Questions such as timing during cardiopulmonary resuscitation or its use in the initial assessment of trauma patients may remain unaddressed during the simulation as the images can be obtained at any time without engaging the simulated patient.

The recent introduction of an HFS-incorporable ED U/S task trainer (**edus^2**) by the author and colleague (Dr. Paul Kulyk) in 2012 was motivated by the above limitations (both those of commercial ED U/S task-trainers as well as the video playback model). The **edus^2** can be used on any make of HFS mannequin, thus allowing trainees to use ED U/S during the management of critically-ill patients in HFS (see Figure 1).

Much like the repeated rehearsal of Advanced Cardiac Life Support algorithms has been shown to improve care, in part through a process described by Ericcson, Krampe, and Tesch-Romer (1993) as deliberate practice, it was anticipated that use of an ED U/S simulator during HFS could result in improved performance in the clinical setting. Thus far, only a few recent promising studies have investigated integrating ED U/S into HFS as a means of enhancing ED U/S skills and use (Kobayashi et al., 2010; Girzadas, Jr. et al., 2009).

Definition of Terms and Concepts

Over the past few decades, medical education has benefitted from broader education research. A major challenge for medical education researchers is making their own areas of study accessible to those outside the medical field so as to gain from others' educational expertise and feedback. To this end, three major aspects of this study will be defined below: the concept of resuscitation in Emergency Medicine, the role of ED U/S, and simulation- based medical education (SBME) with specific reference to the **edus^2**.

Resuscitation in Emergency Medicine

Although suffering from various symptoms ranging from chest pain to headaches to ankle injuries, the majority of patients presenting to the ED do not exhibit significantly altered vital signs (heart rate, blood pressure, respiratory rate, oxygen saturation and temperature) (Canadian Institute for Health Information, 2014). The identification of those patients with significant

disease/ailment rests upon the careful assessment of the patient, which includes thorough history taking, appropriate physical examination, and the ordering and interpretation of key investigations.

This diagnostic process, or 'work up', usually takes hours, which is reasonable given the normal physiologic state of most patients (normal vital signs). On the other hand, the assessment of physiologically abnormal patients, with altered vital signs, can be significantly different: Depending on the severity of the abnormalities in vital signs, these patients may require rapid temporizing management in addition to a thorough diagnostic assessment.

The concept of resuscitation was born of the above reality, where multiple actions must occur in both the short- and medium-term in order to simultaneously normalize the patient's physiologic parameters while also identifying and treating the source(s) of the problem. At the extreme, this is seen in cardiopulmonary resuscitation where patients have suffered cardiac arrest and an effort is undertaken to re-animate them through a *choreographed* series of rapid assessments, treatments and decisions. The space between normal physiology and cardiac arrest is the realm within which resides the broader concept and process known as resuscitation.

Resuscitation experts from Ottawa's Acute Critical Events Simulation program point to three key strategies for performing resuscitation well. They advocate the ABC approach (prioritizing problems according to Airway, Breathing, Circulation and so forth), the use of concurrent management (assessment and treatment being done concurrently as appropriate) and lastly the R&R strategy (re-assessment and re-evaluation) (Neilipovitz, 2008). These experts also recommend that resuscitationists develop strong Crisis Resource Management skills (CRM) that relate to leadership, communication and situational awareness. These skills and strategies must

be integrated into, and thus modify, the more classical approach to physiologically normal patients (Neilipovitz, 2008).

Furthermore, resuscitation demands an additional procedural skill-set that includes airway management with intubation, placement of central venous catheters, chest drains and increasingly, the skillful use of ED U/S (Atkinson et al., 2013; Canadian Emergency Ultrasound Society, 2009). These skills are also often referred to as critical care and management skills. For the purpose of this study, resuscitation skills and critical care skills are essentially interchangeable.

It is no surprise that to become an expert resuscitationist, trainees must master both the individual components of resuscitation as well as their integration into the clinical setting. This integration starts under direct clinical supervision and proceeds until the trainee becomes sufficiently competent and skilled to work under limited or no supervision. Simulation based medical training has been proven to assist in this formative process (McGaghie et al., 2010).

The frequency with which EM physicians encounter patients requiring emergent care or resuscitation varies with hospital setting. In the Saskatoon Health Region, statistics from the Strategic Health Information and Performance Support program showed that between April of 2012 and March of 2013 approximately 11 500, or 12%, of all emergency department patients met criteria for emergent or resuscitative assessment (this is based on local triage data as per Canadian Triage and Acuity Scale with CTAS 1 and 2 being considered resuscitative and emergent respectively, see Figure 5) (Canadian Institute for Health Information, 2014). Most Saskatoon Health Region ED physicians see approximately 20 patients per eight-hour shift and thus will see an average of two patients requiring emergent or resuscitative assessment per shift (SHIPS data). These patients suffer from a variety of diseases that include several medical,

surgical and traumatic conditions. The scenarios chosen for this study are representative of such patients and include: blunt abdominal trauma with intra-abdominal bleeding, a ruptured abdominal aortic aneurysm, a large pericardial effusion resulting in shock, and cardiac arrest secondary to a massive pulmonary embolism (Kobayashi et al., 2010).

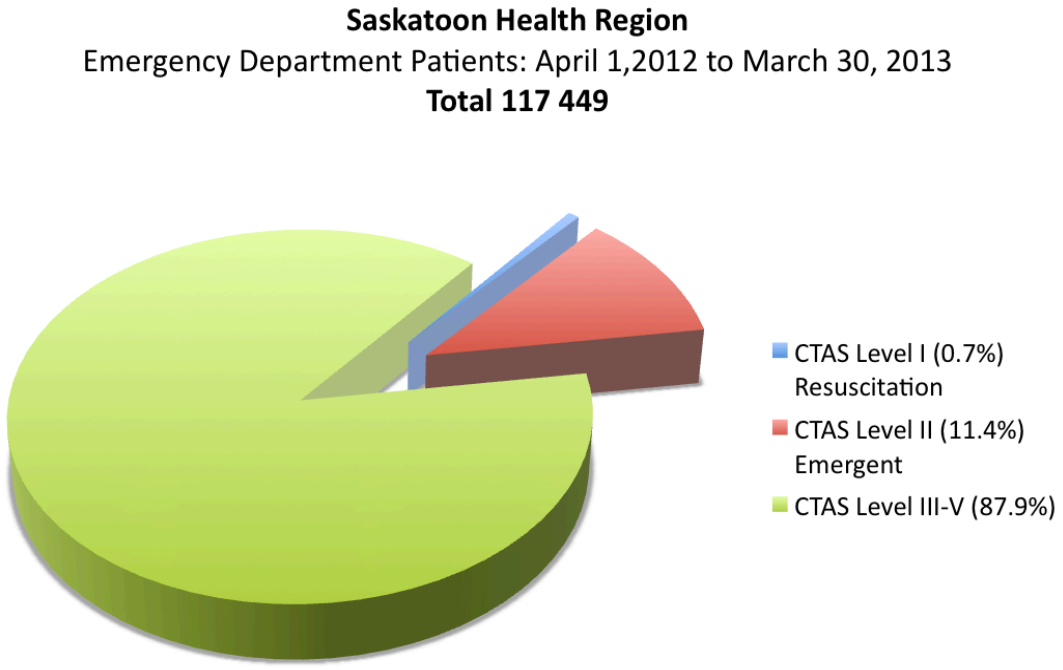


Figure 5. Proportion of patients presenting to Saskatoon Health Region Emergency Departments that require Emergent and/or Resuscitative Care (CTAS Level I or II).

It is also worth noting that while Figure 2 clearly illustrates that emergent care is a relatively small portion of ED volume in terms of patients, this is not the case when one looks at time spent with each patient and resources expended. Critically-ill patients require disproportionately large amounts of both time and resources on the part of the physician as well as department in general. Such patients often require one-to-one nursing and physicians frequently dedicate in excess of an hour providing care to each of these patients.

Emergency Department Ultrasound

Many of the critical illnesses encountered in the ED merit assessment with ED U/S. The utility of ED U/S is well illustrated by the following examples of patients presenting with unexplained hypotension: a pregnant woman, an older patient with back pain or a patient with severe shortness of breath and pleurisy. In the above, assessments for ectopic pregnancy, ruptured abdominal aortic aneurysm, and massive pulmonary embolism, respectively, are enhanced (faster, with greater sensitivity and specificity) by the use of ED U/S and represent official indications for its use (Henneberry et al., 2012).

The evidence supporting the use of ED U/S is growing rapidly and indications for its use now include the assessment of many common ED presentations. The Canadian Emergency Ultrasound Society (2009) described the following list as official indication for ED U/S: shock, trauma, focused cardiac ultrasound, abdominal aorta, pregnancy (first trimester), procedural guidance, thoracic pathology including pneumothorax and pleural effusions, deep venous thrombosis, biliary disease, renal/bladder, soft tissue, musculoskeletal, ocular, and nerve identification for anesthetic blocks.

The indications for ED U/S that can be relevant to resuscitation and critical care include thoraco-abdominal scanning (lung, heart, aorta, inferior vena cava, and abdominal cavity), as well as ultrasound-guided central venous catheter placement (Canadian Emergency Ultrasound Society, 2009; Atkinson et al., 2013).

Simulation at the College of Medicine, University of Saskatchewan

The College of Medicine at the University of Saskatchewan houses a modern simulation suite within the Clinical Learning Resource Centre of the Health Sciences Building. The suite consists of resuscitation rooms/operating theatres, a control room, and debriefing rooms. The

suite employs the use of three mannequins for simulation exercises (Sim Man, Sim Man 3G, & Sim Baby; Laerdal Medical Canada, Ltd., Toronto, Canada). Mannequins can be assessed for heart and lung sounds, demonstrate chest rise and pulses, speak and answer questions, blink and vomit, have intravenous lines inserted, have respirations assisted with bag mask ventilation and be intubated and defibrillated. The resuscitation rooms house a crash cart with defibrillator, electrocardiogram machine, full cardiorespiratory monitoring, a video-laryngoscope for difficult intubations, and (more recently) an ED U/S simulator (**edus^2**).

Mannequins are controlled from the control room by a facilitator, while audiovisual equipment allows for tracking of all events to allow for maximal interaction and fidelity. Such "on the fly" mannequin programming is at times referred to as "medium fidelity" (Sidhu et al., 2012). The suite also holds task-trainers, including central venous line trainers, intubation mannequins, intravenous canulation trainers, and pelvic models.

Development and Use of the edus^2

The ED U/S simulator (**edus^2**) is a portable bedside ultrasound device that allows for the integration of ED U/S into HFS. Trainees using the **edus^2** gain the opportunity to determine when to use bedside ultrasound (indications), how to properly hold and place the probe (image generation), how to assess scans as displayed on the **edus^2** screen (image interpretation) and how to efficiently integrate all of the above within the context of a critical care HFS scenario.

The **edus^2** (a laptop computer combined with a modified probe) plays video clips that are appropriate to the areas of interest by coupling those videos to specific radio-frequency-identification device (RFID) cards placed under the skin of an HFS mannequin. The probe is simulated through use of a small USB-based RFID scanner encapsulated in a hollowed ultrasound probe. Trainees must place the probe in the correct anatomical landmark (within 2

cm) in order for the scanner to read the RFID. Multiple scans are possible during any given scenario and can include thoracic, cardiac, abdominal and pelvic scans. Once the appropriate scan has been initiated, no further manipulation of the probe can be done to improve or alter the video clip (i.e.: rotating or sweeping maneuvers will not alter the image). To the author's knowledge, this was the first such ED U/S simulator that allowed for actual use of a simulated ultrasound probe on any available manufactured HFS mannequin, resulting in seamless incorporation of ED U/S into HFS scenarios.

Assumptions

This study was designed to capitalize on the standardized nature of simulation-based learning. It can be reasonably assumed that use of the proposed hybrid simulation intervention (combining two forms of simulation, here a HFS mannequin and suite with an ultrasound simulator) will be reproducible in other simulation suites. This speaks to the reproducibility of the intervention and may encourage other Canadian and UK EM training programs to consider the findings of this study as meaningful in terms of training and resource considerations.

However, questions remain about the nature of participant trainees and their baseline ED U/S skill set and how these may compare to trainees at other centers. This study was designed for EM trainees who have already had baseline ED U/S training as well as previous experience with simulation based medical education. The degree of this familiarity was determined through an entrance survey and multiple-choice question (MCQ) test as a means of further describing the trainees. Any application of the findings from this investigation should only be entertained on a group of similar baseline training.

The validity of the data collection tools was determined through a variety of indirect measures. The knowledge-testing MCQ assessment has expert-based validity as its contributing

authors are renowned leaders in ED U/S of the American College of Emergency Physicians. The ED U/S skills observation form was created in consultation with local leaders in ED U/S and was also tested during a trial of the study performed at the University of Saskatchewan. The self-reporting survey was adapted with permission from that used by Girzadas and colleagues (2009) in their assessment of a hybrid simulation intervention with a pelvic task trainer for the assessment of shock and ectopic pregnancy.

As with any study that involves self-reporting, this study relied heavily on the sincerity and integrity of participants. It was expected that all participants (both EM trainees and EM faculty) would answer truthfully and engage in the study scenarios. By making the study voluntary and by ensuring that participants understood the formative nature of the experience, it was hoped that motivated trainees and faculty would self-select for participation.

Limitations

As an experimental study designed to assess development of ED U/S skills, application of the results from this study should be limited to EM trainees and ED U/S training. Generalization of findings to medical students or practicing physicians would not be appropriate. It may be possible that other levels of trainees may stand to benefit from this hybrid simulation intervention and future studies could be directed at assessing this. Furthermore, such a study could be powered to determine which group, if any, stands to benefit the most from this type of educational intervention.

Another limitation of the study is that it was dependent on the availability of simulation-based medical education technology. Training programs that do not have access to such training environments might encounter a challenge in using this educational technology. This is a surmountable challenge because the **edus^2** or video playback hybrid intervention could be done

with patient actor volunteers who are playing the role of a critically-ill patient (these patients could then have the RFID tags used with the **edus^2** taped to a shirt for scanning opportunities) in a real ED setting during an educational session (Olszynski & Kulyk, 2013).

As co-creator of the **edus^2** and an EM sonologist, the author's personal biases in favor of the simulator intervention risked compromising both the study design and analysis. Several steps were taken during the design and implementation of the study to mitigate bias in this investigation. Firstly, the decision to carry out the study at another institution served to minimize personal biases and conflicts of interest that may exist between the author and students known to him as well as other faculty at his institution. Secondly, the use of previously designed cases by Kobayashi and colleagues (2010) ensured that the HFS scenarios were not biased toward one type of intervention or the other (these cases were designed for use with video playback prior to the development of the **edus^2**). Thirdly, consultation with experts in the fields of EM and ED U/S allowed for objective determination of performance in the two study arms through the selective use of the American College of Emergency Physician's online MCQ ED U/S exam (American College of Emergency Physicians, 2014).

In addition, the use of recently and externally-designed data tools (see Appendix C) added validity to the study design as these had been created by authors of a previous, similar ED U/S hybrid simulation study (Girzadas, Jr. et al., 2009). These data tools were modified and expanded upon; the Visual Analogue Scale (VAS) was replaced with the more commonly encountered Likert Scale, in order to minimize the risk of misinterpretation by participants.

Lastly, it should be known that the author does not hold any commercial patents with relation to the **edus^2**, nor has he received any financial compensation in relation to it or ultrasound simulation in general. The **edus^2** project is under creative commons license, meaning

that others may share, modify and distribute aspects of the project freely so long as they attribute the work accordingly and agree to share in kind.

Delimitations

Trainee participants were medical graduates enrolled in an EM specialty-training program in the UK. In Canada, we refer to such trainees as EM residents and assign them postgraduate year designations ranging from one to five years. In the UK, these trainees are commonly referred to as Specialist Trainees (ST) in EM. By this stage in their training, most have been exposed to a basic ED U/S curriculum that includes basic cardiac, aortic and trauma scanning, as well as vascular access. Exposure to obstetrical ED U/S in uncommon in the UK, therefore the Pulmonary Embolism/Pulseless Electrical Activity arrest scenario that includes peri-arrest echocardiography (which is part of the Level I ED U/S training in the UK) was selected as the forth case. In addition, it was expected that all trainees would have had some degree of simulation-based training throughout their medical education (simulation-based training being defined as any training that employs simulation aides to replicate clinical tasks or scenarios).

Faculty participants were UK-based EM physicians or senior trainees (Specialist Trainees in year five or greater) deemed sufficiently experienced to act as faculty during the course sessions (as agreed to by London study supervisor, Dr. Tim Harris). Here, too, the requirement was that these faculty participants were clinicians who used ED U/S extensively in practice *and* had familiarity with simulation-based education.

Phase I of the study took place in London, UK in the spring of 2013. This first Phase included four full day sessions between April 30th and June 11th. Trainees and faculty came together at Whipps Cross University Hospital and completed a full day of critical care scenarios

(four cases with debriefing after each case). Phase II of the study took place in Saskatoon, SK, Canada where EM faculty were enrolled in pairs to observe and assess recordings of the Phase I scenarios with the use of standardized intervention assessment forms (Appendix D).

The results of this study are applicable to EM ST trainees in the UK. Given the number of similarities between UK and Canadian residency training, it is likely the results also apply to Canadian EM residents.

Significance of the Study

The current move towards patient-oriented healthcare, where safety and patient autonomy are rightfully of utmost importance, is posing significant challenges for medical education (Aggarwal & Darzi, 2011). Whereas previous apprenticeship models risked exposing patients to complications due to inexperience of trainees, today's medical training programs are striving to develop innovative ways of nurturing clinical skill development in safe and effective ways (Kim, 2008; Aggarwal & Darzi, 2011; McGaghie et al., 2010).

There is evidence that simulation in medical education can partially address the above concerns by introducing trainees to complex cognitive and psychomotor tasks in a safe environment (Aggarwal & Darzi, 2011; Neilipovitz, 2008). Furthermore, studies included in a recent critical review of simulation research supported improved clinical performance following simulation-based educational interventions in several realms, including more effective resuscitation skills, decreased complications in central venous catheter placement, improved surgical performance, and improved neonatal outcomes in deliveries complicated by shoulder dystocia (McGaghie et al., 2010). This study adds to the existing research regarding both psychomotor skill development as well as the more complex task of safe and effective integration of ED U/S into critical care.

This study drew from best practices in simulation in medical education. With a heavy reliance on assessment and feedback, reflection on action and the principles of skill development, this study reinforces emerging practices at medical schools throughout the country (Weller, Nestel, Marshall, Brooks, & Conn, 2012; Bradley & Ker, 2010).

Medical educators are increasingly trying to make evidence-based decisions regarding educational programming and resources. This study will help inform the medical education community as to the value of this and similar simulation interventions in the training of EM graduates. Simulation tools will be of increasing importance as data and evidence on safety, cognitive error and procedural skill development (and decay) become increasingly known. Of future interest is whether such an intervention may be of value to undergraduate students who are far less familiar with the medical concepts involved in this study (specifically critical care medicine and ED U/S). It seems reasonable to consider that a simplified experience combined with specifically tailored cases may prove worthwhile but this would need to be carefully explored.

In addition, this study may serve to further demonstrate the relevance of cognitive load theory to medical education. If trainees find use of the **edus^2** (with its simplified image-generation feature) or the video playback intervention helps with developing their interest, knowledge and comfort with ED U/S, then it would be worthwhile seeing how this type of learning compares to a more challenging task-training model (i.e.: CAE Vimidex). Here the question would be in whom and at what level of training would the cognitive load of the more challenging hybrid scenario be found more appropriate and how would this impact the psychological fidelity of the simulation. Thus, the study results may contribute to the literature regarding scaffolding student learning (through their Zone of Proximal Development), as well as

further inform current work on the importance of psychological fidelity and its effect on learning within HFS.

The findings of this study may contribute to understanding the role of simulation of ED U/S training within EM training programs. Specifically, the comparison of the **edus^2** to video playback during HFS offers insights into the role of *hybrid ultrasound simulation* in the development of ED U/S skills amongst EM trainees. Further study, to assess the impacts of such an intervention on clinical practice, is warranted. This may ultimately help educators decide on resource allocation and prioritization.

CHAPTER II

LITERATURE REVIEW

The use of simulation in medical education is growing rapidly. The body of evidence supporting its use for the improved acquisition of a range of clinical competencies is increasingly robust (Issenberg, McGaghie, Petrusa, Lee, & Scalese, 2005; McGaghie et al., 2010). It is possible that EM trainees developing their ED U/S skills may benefit from simulation-based training opportunities (Sidhu et al., 2012). Specifically, the use of hybrid simulation may help trainees incorporate specific bedside skills such as ED U/S into their broader critical care skill repertoire. This review presents current knowledge regarding psychomotor skill development, the role of simulation in medical education (with special consideration to skill development) and relevant learning theories and concepts.

ED U/S as more than a Psychomotor Skill

Given that ED U/S is a relatively new modality in Canadian EM, there is currently no central or core ED U/S curriculum. Currently, both EM trainees as well as many practicing emergency physicians are undertaking ED U/S training. From an instructional perspective, the adoption of ED U/S by already-practicing physicians as compared to EM trainees is clearly quite different. According to Joyce and Showers (1980), mastery of new skills requires a much greater effort than the fine-tuning of existing ones. While a practicing EM physician readily grasps the applicability of ED U/S in resuscitation, these truths may be less than obvious to an EM trainee. Development of such clinical skills requires the learner to fully understand the rationale in addition to developing the actual psychomotor skill. Many ED U/S instructors have suggested that EM trainees stand to benefit from a tailored approach to ED U/S training that recognizes their limited clinical expertise.

In the mastery of complex psychomotor skills there exists an interdependence of cognition and manipulative skill that has been studied extensively. Bloom and colleagues (1956) were the first to identify the three domains of learning in what is now known as Bloom's Taxonomy. The three domains include the cognitive, the affective and the psychomotor domains. This model has been revised and adapted several times, including in the medical education literature, to best suit the given area of study (Anderson et al., 2000).

As described by the Advanced Trauma Life Support Instructor Program (an example of the Bloom's taxonomy applied to medical education) psychomotor skills are primarily taught through hands-on practice. The steps of psychomotor skill development include: conceptualization, visualization, practice, correction and re-enforcement, skill mastery and skill autonomy (American College of Surgeons, 2008). Trainees draw on the first four above-mentioned principles of psychomotor skill development, with an emphasis on practice, in order to move toward mastery.

This sequence reasonably describes the development of image generation skills amongst trainees. For the most part, lectures and self-directed study of the scan(s) in question offers the trainee a sense of context and direction (conceptualization and visualization). Supervised practice on patient volunteers and real patients (when appropriate) moves trainees towards mastery in image generation, but does not ensure skill autonomy in the clinical context. Unlike central venous catheter insertion, successfully generating ED U/S images is only part of the challenge. Timely and efficient use of the machine, properly interpreting the findings, and integrating all of this into the care of a critically ill patient is much more complex. This is why ED U/S training is about more than just learning a specific psychomotor skill.

As a trainee's probe manipulation and image generation skills reach proficiency and efficiency, it may be expected that clinical integration will naturally follow. Ideally, this would happen in the clinical setting whereby the trainee is advanced from being *asked* to perform the scan (under direction from their clinical preceptor) to autonomously retrieving the ED U/S machine and employing it as indicated during real patient care (as witnessed by their clinical preceptor who can then validate competence and autonomy have been achieved). While such a progression would be ideal, the current lack of advanced ED U/S expertise amongst the majority of EM physicians, combined with a scarcity of teaching time, leaves doubts as to whether this last step toward autonomy in critical care is taking place.

And while the process of conceptualization and visualization include understanding the rationale for the procedure, it does not fully address, nor teach, how a clinical skill as complex as bedside ultrasonography should be integrated in the context of critical care.

Questions persist as to how best teach the integration of new psychomotor skills into clinical practice (Kneebone, Scott, Darzi, & Horrocks, 2004). In an era of patient-centric medicine where practice by novice trainees on real patients is no longer acceptable (Aggarwal & Darzi, 2011), many psychomotor tasks need to be learned outside the clinical context. The question then becomes how can these complex skills be best re-introduced into trainees' clinical practice?

Kneebone and colleagues (2004) made the case for the use of HFS in surgical training to address this challenge of novel skill integration. They proposed an interactive relationship where the clinical and simulated environments complement each other in a regular and consistent fashion. In EM training, simulating encounters of critically-ill patients may allow trainees to focus on the complex mix of problem solving and psychomotor skills associated with ED U/S in

a way that maximizes their learning. A complex learning intervention such as HFS calls on and draws from all three learning domains. Through engaging cases, the application of knowledge, and the opportunity to complete complex tasks, ED U/S simulation in HFS offers a robust learning experience. In essence, trainees may get an opportunity to learn the complete choreography of resuscitative ED U/S within the broader and more challenging context of resuscitation.

Learning Theory

The field of androgogy includes several theories or constructs related to learning. As Kaufman and Mann (2010) describe in Swanwick's Understanding Medical Education, rather than treating these as alternate or competing views, it is more likely that they all contribute valuable insights into the complex process that is learning. Much like the many windows of house offer varying insights to the nature of the home, these theories give insight to the opportunities and challenges encountered when working with learners.

Adult Learning Theory and Social Cognitive Theory both emphasize the importance of new learning being linked or attached to previous knowledge and experiences. This has important implications for the introduction of ED U/S to the assessment of critically ill patients by EM trainees. If the trainees do not have a solid understanding of the critical illnesses in question, it is possible that adding ED U/S to their list of tasks may be overwhelming (van Merrienboer & Sweller, 2010). This may explain why some trainees seem reluctant to use ED U/S during real patient encounters.

The use of ED U/S in HFS may address this challenge in three ways. Firstly, EM trainees will have the opportunity to see how the information gained by performing ED U/S may enhance their understanding of the pathophysiology in question during a given HFS scenario. Secondly,

through repeated practice of integrating ED U/S findings into clinical decision making, trainees will presumably be more comfortable doing so in real patient encounters. Thirdly, given that the **edus^2** offers only a simplified simulation of image generation (proper probe handling and land-marking is all that is required), trainees can focus on interpreting scans without as much attention to probe movement and thus enjoy a slightly decreased cognitive load.

Another key element of learning is the role of reflection and feedback (Kaufman & Mann, 2010). The integration of ED U/S into HFS allows trainees to become aware of their own abilities. It also gives faculty a better insight into these abilities. From here, feedback can be offered for either re-enforcement or correction. One of the strengths of simulation-based learning (with associated feedback and reflection) is that trainees can then go back and adjust their skills accordingly (Kneebone et al., 2004).

Cognitive Load Theory

Consider the use of ED U/S in the management of a patient in cardiogenic shock. For the seasoned emergency physician, adding focused cardiac ultrasound to an already familiar shock algorithm is unlikely to be overwhelming. The new task (ED U/S) does not, in this instance, result in an overwhelming cognitive load (van Merrienboer & Sweller, 2010). On the other hand, for an EM trainee who is just beginning to successfully integrate crisis management skills into their biomedical knowledge whilst still a novice sonologist, the added challenge of generating and interpreting a focused cardiac scan may result in what is described as an excessively high cognitive load.

Cognitive Load Theory (CLT) proposes a cognitive architecture where working memory is limited and expertise only develops once new knowledge is assimilated, stored into long-term memory, and is accessed almost automatically. The implication, then, is that the sum of all

information to be consciously recalled and applied during resuscitation is potentially too large for the novice or even middle-level trainee. The consequences of this overload may include poorer learning and performance while managing the case (both core resuscitation skills as well as ED U/S-related), rushed and substandard image generation and interpretation, and frustration with both the case and ED U/S.

As described earlier, competence of ED U/S skills can be described as the understanding and mastery of indications, image acquisition with image interpretation and clinical integration. These three aspects combine to make up the clinical skill or competency employed by expert emergency sonologists in clinical settings. For physician trainees, these aspects are generally learned in a progressive manner, starting with the familiarization of basic U/S physics, the functions of ultrasound machines, and the simplest of its applications (Socransky & Wiss, 2012). By CEUS standards, integration of ED U/S skills into clinical practice requires a lengthy apprenticeship during which time trainees have the opportunity to practice and slowly master all aspects of ED U/S. According to the principles of CLT, this long apprenticeship is quite valuable, if not absolutely essential.

CLT posits that learners can only work with and incorporate a fixed amount of novel information at any given time. This is because the process of learning requires the use of working memory, which has limitations when processing novel information. For example, for the novice sonologist, the ability to use a U/S machine begins with the recollection of newly acquired information about its many functions and modes. Early in training, it is not uncommon to use improper scan modes or hold the probe incorrectly.

It is through repetition and re-reading that trainees slowly develop automaticity in the use of the bedside U/S. Automaticity, as defined by Ericcson, Krampe, and Tesche-Romer (1993), is

the acquisition of skill mastery that then requires little to no conscious cognitive effort. Interestingly, CLT also suggests that once something has been learned and firmly organized in one's mind through the creation of schemas (mental patterns), it becomes a nearly effortless cognitive task, ready to be called upon when needed. In short, tasks or topics that are well known can be accessed and applied without significant cognitive effort. These key principles of CLT are very relevant to ED U/S training for two reasons. Firstly, CLT offers support for the creation of differentiated ED U/S instruction for EM trainees. By acknowledging the already significant cognitive load associated with the attempted management of critically-ill patients we can begin to structure more effective learning and practice experiences. The second aspect of CLT's relevance pertains specifically to how it can guide the creation of simulated experiences that maximize ED U/S learning.

Learning and Transfer

When training a physician in the use of ED U/S, it is expected that despite variations in future patient conditions, the trainee will be able to apply (or transfer) his/her newly assimilated knowledge to somewhat novel situations, cases, and problems. Such abilities help define expertise in a given field (Bransford et al., 2000). As postgraduate medical trainees and residency programs face new challenges related to work-hour restrictions and competency-based education (Nasca, Philibert, Brigham, & Flynn, 2012), understanding the process for transfer of learning and the development of expertise becomes much more important (Bransford et al., 2000).

The HFS setting is rich with many of the key aspects that Bransford and colleagues (2000) identified with effective transfer of learning: opportunities to apply new knowledge, a contextualized and flexible learning environment, and reliance on close supervision and

feedback.

Deliberate Practice

An area of particular interest relates to 'time on task' and its influence on transfer of learning. The work of Ericsson, Krampe, and Tesch-Romer (1993) on the development of expertise and the role of deliberate practice (DP) has brought significant attention to the hours required by any person, regardless of talent, to develop expertise. In their work, Ericsson et al. (1993) posit that it is through a combination of long hours and deliberate attention to specific aspects of the skill or competence in question that one can achieve expertise. In other words, it is not "practice make perfect", but "perfect practice makes perfect."

DP infers "a highly structured activity explicitly directed at improvement of performance in a particular domain" (Duvivier et al., 2011). Based on work done by Issenberg et al. (2002), Duvivier and colleagues (2011) proposed that DP is implemented through specific design principles. These include: (a) repetitive performance of intended cognitive or psychomotor skills (b) rigorous skills assessment (c) specific informative feedback and (d) better skills performance.

As such, many educators see potential in the ability of well-designed learning interventions, such various simulations, to shorten the required 'time on task' associated with clinical competencies (McGaghie et al., 2010).

Zone of Proximal Development

The concept of layering or "scaffolding" learning is not new to healthcare professional training (Sanders & Welk, 2005). It stands at the root of most applied professions where apprenticeship plays a vital role in training. Its origins are found in Vygotsky's Sociocultural Development Theory (Vygotsky, 1978). Here, expertise (defined as the ability to complete a task independently) is gained through careful guidance of trainees through their Zone of Proximal

Development (ZPD). The ZPD is therefore defined as "the distance between the actual developmental level (as determined by independent problem solving) and the level of potential development (as determined through problem solving in collaboration with more capable peers)."

Such guidance is important because it allows for tailored trainee development and addresses factors that may be detrimental to learning (including excessive cognitive loads, performance anxiety and safety concerns). This can be achieved through careful HFS scenarios/case design.

For novice learners, ED U/S simulation cases could be designed to highlight core ED U/S indications and skills. With mastery of such cases and increased competence on the part of the trainee (movement within their respective ZPD), a gradual increase in complexity in cases would be appropriate. Increased confidence on the part of the trainees would then hopefully translate into more frequent use and greater competence with ED U/S in clinical practice. It should be highlighted that the move to clinical practice does not assume a loss of supervision and feedback. As Kneebone and colleagues suggested (2004), clinical and simulated practice should be at interplay where feedback and development flow between and within both environments.

Simulation in Medical Education

The role of simulation in medical education has grown steadily over the past several years (McGaghie et al., 2010). However, there continue to be questions about the most appropriate use of simulation. As medical education literature suggests, it is the curriculum that should drive the use of technology, not the other way around (Bradley & Ker, 2010). While more recent studies demonstrated that simulation can offer a superior learning experience for specific objectives (Sawyer et al., 2011), it is no panacea. Perhaps of greatest concern are

simulation's substantive costs (Norman, Dore, & Grierson, 2012; Brydges, Carnahan, Rose, Rose, & Dubrowski, 2010).

Increasing demands from a growing number of indications and a desire for higher fidelity all contribute to a healthy debate about the appropriate use and funding of this technology. For example, the degree to which fidelity should be pursued (meaning how closely the simulation approximates the real task or encounter) is a key concern as recent research into fidelity and transfer of learning has shown surprisingly minimal correlation (Norman et al., 2012).

There also continues to be controversy with regard to the use of simulation to teach basic content or procedural tasks that could also be taught or practiced using more traditional methods (Ten Eyck et al., 2009; Schwartz et al., 2007). Sidhu and colleagues (2012) raised this point in their review of the role of simulation in ultrasound training. They questioned the utility of thoracoabdominal ultrasound trainers when training in image generation can be safely and efficiently practiced on volunteers and real patients with no real risks.

This being the case, one might wonder when exactly use of simulation for ED U/S training is most appropriate. The literature would suggest that ultrasound-guided procedural tasks (peripheral and central venous canulation, thorocentesis, paracentesis, foreign body extraction and joint aspiration) as well as invasive scans (pelvic ultrasound in symptomatic first trimester pregnancy and transesophageal echocardioography) show promise in terms of improving trainee performance and thus also patient care and safety (Sidhu et al., 2012; McGaghie et al., 2010).

Development of Clinical Competence

HFS experiences move EM trainees along Miller's (1990) framework of clinical competence from *knowing how* to *showing how*. This transition into performance is critical in exposing students to gaps in knowledge and process. As can be attested to by many a physician,

it is commonplace for students early in their clinical clerkship to describe a feeling of ineptitude. What has often been dismissed by students as a failure of pre-clerkship training may actually be (at least in part) an inevitable consequence of the transition from *knowing how* to *showing how*. ED U/S skills are likely no different.

The opportunity to employ what one thinks he/she is capable of is in many ways a perfect learning experience. Whether it is at the bedside or in simulation, trainees gain a great deal by actually using the skills they have been studying and preparing. Moreover, in simulation environments they stand to benefit from direct feedback and an opportunity for corrective action. This process is consistent with what many refer to as the supervision cycle (Launer, 2010). In it, learners "move continually from 'unconscious incompetence' through 'conscious incompetence' to 'conscious competence' and finally 'unconscious competence'." These movements are facilitated by supervisors/preceptors and enhanced by various learning opportunities.

It is during these experiences that a trainee may become aware that they have been holding the U/S probe incorrectly or that their understanding of a specific image was incorrect. This disjuncture, as experienced in simulation scenarios, creates a desire to learn more about the specific skill (Jarvis, 1993). Had the learner missed the opportunity to try it in the scenario and instead had only read about it for an exam, he/she may have not become aware of the error.

Unique and trainee-specific learning opportunities include missed opportunities to perform a scan, difficulty land-marking for probe placement and incorrect image interpretation. This brings us to a key strength of simulation, namely safety.

Safety for both Patients and Trainees

During HFS, students gain an opportunity to practice life-saving skills on a physiologically and anatomically simplified model of a real patient. The mannequin's illness can

be made less or more complex to manage depending on the scenario and trainee level. Here one can identify safety in two dimensions: the safety of the learner and the safety of the patient. Learner safety relates to the psychological and personal safety felt by a trainee. By being able to practice in an artificial environment, the learner has the ability to practice a new skill, make adjustments as per feedback from facilitators and reflect on improvement without fear of harming a patient. This psychological safe space likely also contributes to the significant approval that simulation has received from trainees (Bradley & Ker, 2010).

Patient safety advocates have been major drivers of simulation use in medical training and healthcare performance (Aggarwal & Darzi, 2011). The old adage "see one, do one, teach one" has been modified by some educators to "see one, *sim one*, do one, teach one." Whether considering task trainers or again HFS scenarios, evidence suggests improved performance in real life after simulated practice (McGaghie et al., 2010). Performance is directly related to patient care and safety, especially when considering one's performance in placing a central venous line, an endotracheal tube or coordinating resuscitation (Aggarwal & Darzi, 2011).

A recent study of the Neonatal Resuscitation Program by Sawyer et al. (2011) revealed that the most significant gains in performance come with deliberate practice through the completion of a series of simulated scenarios spaced out over time (months). Interestingly, the researchers demonstrated that it was deliberate practice, and not progression in one's residency program, that was most associated with improved performance of NRP skills such as airway management and successful management of intravenous fluid resuscitation.

The consideration of DP has implications for ED U/S simulation use in that it suggests that singular exposures may add little as compared to repeated opportunities of focused specific practice for skill development.

The Role of High Fidelity

Fidelity in HFS scenarios has been traditionally defined as the degree of authenticity that a given simulation exhibits in relation to the real task or situation (Norman et al., 2012). In the same way that role-play scenarios replicate real situations and provide guided practice for transfer to actual work related settings, HFS scenarios are a gateway to proficient practice out on the ward, clinic, or ER. Through a combination of modestly animated mannequins, properly simulated clinical environments and purposefully designed patient scenarios, educators can create learning experiences that are greater than the sum of their parts.

> The addition of the dimension of 'stress' of a complex skill in a dynamic and uncertain situation and the combination of technical and non-technical skills required to deal with the situation effectively typifies the experience presented by the 'high fidelity' simulators. (Maran & Glavin, 2003, p.26)

Some authors further divide simulation fidelity into engineering fidelity and psychological fidelity. The former relates to the physical characteristics of the simulation, whereas the latter focuses on the critical elements of a simulation and its ability to accurately simulate the specific behaviors that are being sought (Maran & Glavin, 2003).

Fidelity (in its broadest sense) is generally highly desired (McGaghie et al., 2010), but this is countered by a frequently encountered and undesirable correlation between fidelity and cost, particularly for engineered fidelity. The more an attempt is made to replicate a real life scenario, the more the replication will cost. Thus, it seems appropriate that if a tool is used regularly in the clinical setting, then it should be presented in the simulation of that clinical setting.

As described earlier, the re-integration of psychomotor skills into clinical practice is a relatively new concern born out of a progressive and justified re-orientation of medical training

that is safety and patient-centric. Simulation has been identified as a possible part of the solution. The concern about re-integration of ED U/S skills into clinical practice has led to the creation of a portable ultrasound simulator (**edus^2**) for use in HFS that, while not offering a high degree of task training, does allow for the integration (psychological fidelity) of ED U/S into a critically-ill patient's assessment and management. The simplification of ED U/S as a psychomotor task may in fact prove to be a strength, rather than weakness, of this educational innovation.

By simplifying a rather complex motor task, learners may be better able to grasp other key aspects of ED U/S while not worrying about the finer motor skills that require further development. This could be supported by a concept known as "progressive fidelity" proposed by Brydges et al. (2010) whereby a gradual increase in task complexity resulted in learning gains. It is also supported by the concept of a ZPD and CLT (discussed earlier in this chapter).

Existing use of ED U/S Simulation in HFS

Kobayashi and colleagues (2010) created a series of five HFS scenarios that highlighted the value of ED U/S. The Emergency Medicine Ultrasound Simulation (U/SS) Case Scenario Package (Med Ed Portal) offers EM trainees the integration of ED U/S findings through video playback of scans on a lap top computer placed within the HFS suite (Kobayashi et al., 2010). The educational objectives of the package include "to be able to integrate simulated ultrasonographic findings with manikin-based simulation scenarios to help trainees apply bedside sonography in real-time to critical patient care decisions" (Kobayashi et al., 2010).

Girzadas and colleagues (2009) pursued a higher degree of fidelity in their study of a hybrid simulation scenario combining HFS with pelvic task trainer as a means of assessing both trainee learning as well as faculty assessment of skills. The study involved a female patient presenting to the ED in shock secondary to a ruptured ectopic pregnancy. EM trainees were

randomized to the HFS scenario with integration of ED U/S as either video playback or use of the pelvic ultrasound task trainer/mannequin hybrid. In the hybrid arm, image generation and interpretation were entirely dependent on trainee skills in these domains. The authors concluded that their hybrid simulation did improve the educational experience of trainees and also enhanced faculty's ability to evaluate trainee endovaginal ultrasound skills.

In 2012, the author and a colleague (Dr. Paul Kulyk) developed a novel ED U/S simulator (**edus^2**) to enhance the integration of ED U/S into HFS scenarios. The **edus^2** is made up of a laptop computer, a simulated probe (RFID scanner) and several RFID cards that can be placed under the skin of any HFS mannequin. It allows for the seamless integration of ED U/S into any critical care HFS (Kulyk & Olszynski, 2012).

Parks and colleagues (2013) recently studied another method of hybrid ultrasound simulation whereby an ultrasound task trainer (CAE Vimedix, CAE Healthcare Canada, Saint-Laurent, QC) served as both the simulated patient and ultrasound simulator (Parks, Atkinson, Verheul, LeBlanc-Duchin, 2013). Here the focus was on image generation and diagnosis, not overall critical care skills and management. SonoMan is another example of this type of trainer (Simulab corporation, 2014).

Sidhu and colleagues (2012) published a systematic review addressing the role of simulation-based education in ultrasound training. This review was not discipline specific and focused on the development of actual ultrasound skills (the psychomotor aspects of ultrasound image generation). Not surprisingly, the researchers found that the majority of the literature detailed "higher-stakes" ultrasound procedures including ultrasound guided central venous line placement and thorocentesis, as well as invasive diagnostic uses including pelvic ultrasound and esophageal echocardiography. The majority of the studies offered evidence of skill acquisition,

but these were largely restricted to the simulated environment (i.e.: transfer demonstrated on mannequins rather than real patients) with only one study showing evidence of transfer into clinical practice (Mendiratta-Lala, Williams, de, Bonnett, & Mendiratta, 2010).

The authors also questioned the utility of basic diagnostic ultrasound trainers (transabdominal and transthoracic) given the benign nature of ultrasound waves and the ease with which real patients and volunteers can be recruited for such training.

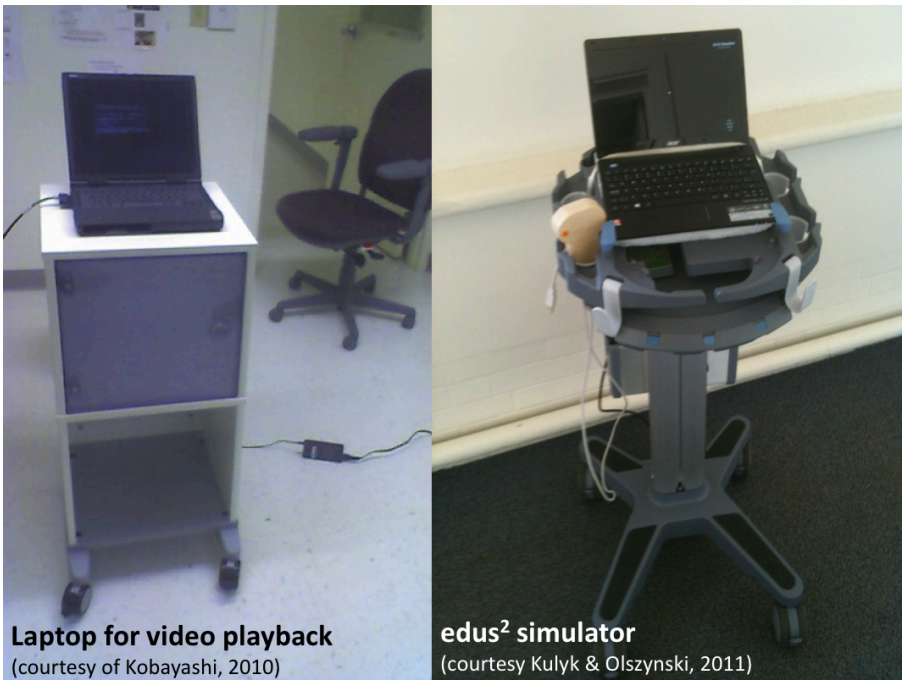


Figure 6. The two ED U/S simulation interventions investigated in this study.

Conceptual Framework

The caring for and management of critically-ill patients is complex. It requires both a range of cognitive and affective skills as well as specific psychomotor skills. Learning theories inform us that skills need be learned and developed in a progressive fashion with plenty of opportunity for practice (Joyce & Showers, 1980). Giving trainees the opportunity to manage critically-ill patients in HFS scenarios offers a safe and effective environment where such skills can be

developed. The addition of ED U/S into HFS (through video playback or **edus^2**) incorporates an important element of emergency medicine resuscitation.

It was hypothesized that through hybrid simulation interventions (use of the **edus^2** simulator or simple laptop), trainee skill development would be enhanced. Trainees would gain insights into their own skills and use of ED U/S in critical care while instructors/faculty would be better capable of assessing trainee skills, thus offering better opportunities for feedback and correction. Additionally, it was of interest to the authors to compare the two ultrasound simulation interventions as a means of determining if one was a better educational intervention than the other.

Data collection tools (both qualitative and quantitative) were developed to evaluate for several aspects of training including learning achieved, ability for the assessment of skills, and overall impressions of the experience from both trainees and faculty.

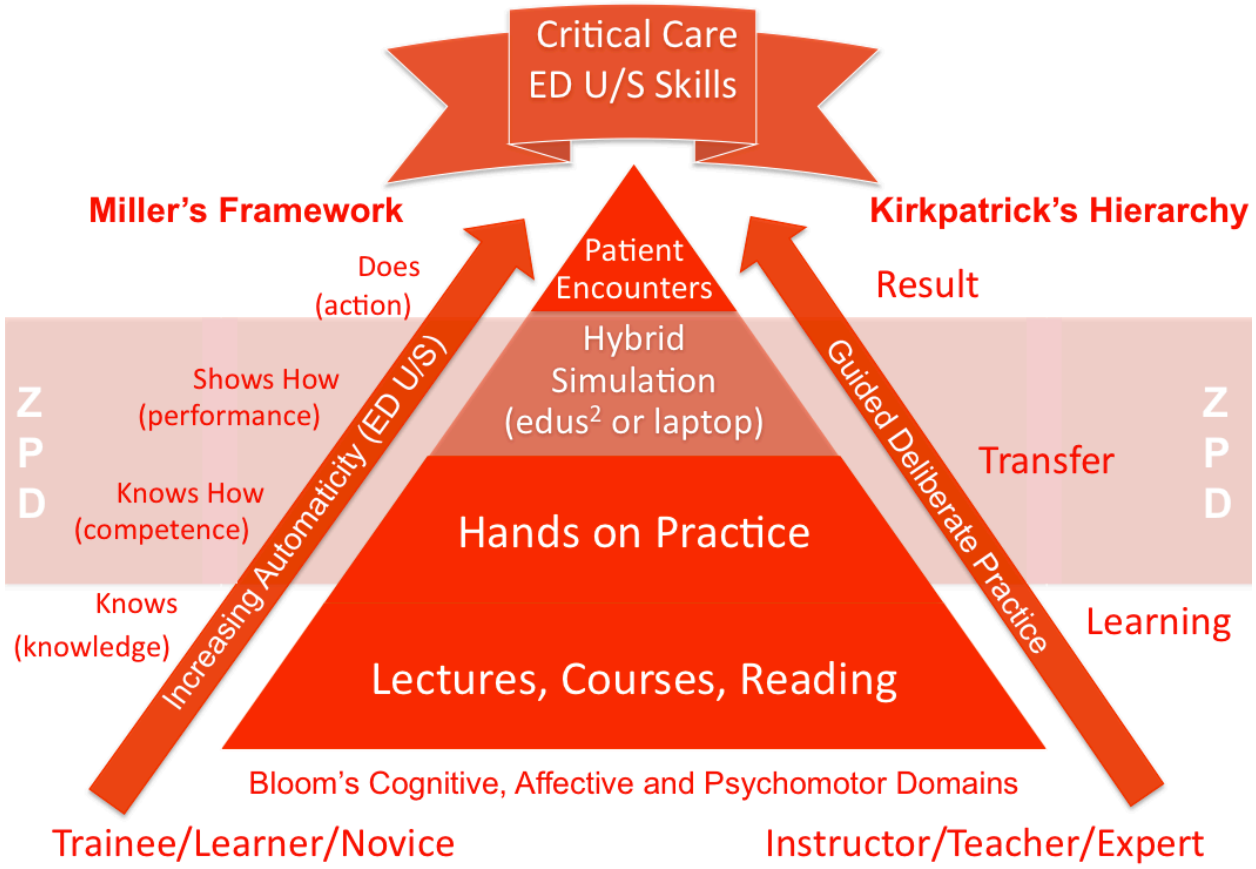


Figure 7. Conceptual Framework

The conceptual framework illustrates key concepts supporting the use of ED U/S simulation in HFS. Learning takes place according to Bloom's three domains (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Development is paired through interplay between the trainee and the instructor/preceptor. As per CLT, as trainees become more proficient with ED U/S (relying less on short term memory and more so on both long-term and motor memory) they become increasingly capable to focus on the clinical picture before them. Faculty can identify aspects of trainee ED U/S use that require further development and subsequently may create opportunities for deliberate practice. Simultaneously, clinical competence can be assessed using Miller's framework (Miller, 1990), while recognizing the challenges inherent to the assessment

of critical care skills (namely the infrequency and non-standardizability of such cases). Lastly, Kirkpatrck's Hierarchy of evidence (Kirkpatrick, 1996) allows one to evaluate whether transfer of learning has taken place and may help with determining if the intervention will have any impact on actual patient care.

Medical educators are increasingly trying to make evidence-based decisions regarding educational programming and resources. This study will help to inform the medical education community as to the value of such simulation interventions in the training of EM graduates. It is probable that these tools will be of increasing importance as data and evidence on safety, cognitive error and procedural skill development (and decay) become increasingly known. Of future interest is whether such an intervention may be of value to undergraduate students who are far less familiar with the medical concepts involved in this study (specifically critical care medicine and ED U/S). It seems reasonable to consider that a simplified experience combined with specifically tailored cases may prove worthwhile.

Furthermore, this study may serve to further inform the relevance of cognitive load theory to medical education. If trainees find use of the **edus^2** (with its simplified image generation feature) or the video playback intervention helps with developing their interest, knowledge and comfort with ED U/S then it would be worthwhile seeing how this type of learning compares to a more challenging task-training model (i.e.: CAE Vimedix). Here the question would be in whom and at what level of training would we find the cognitive load of the more challenging hybrid scenario more appropriate and how would it impact the psychological fidelity of the simulation and to what extent does that matter in transfer to real work situations?

CHAPTER III

METHODS

To assess the impact of the two simulation interventions on critical care ED U/S skill development it was necessary to design the study within the context of existing and planned HFS sessions. These sessions were delivered by several simulation staff facilitators to both EM trainees and faculty in a large simulation suite (Medical Education Training Suite, Whipps Cross Hospital, London, UK). Each day-long session included four critical care cases.

A pilot study was carried out at the University of Saskatchewan several weeks prior to the study proper, which helped identify and address some of the major logistical challenges. For example, during the pilot study HFS scenarios it was observed that the simple laptop intervention was often inadvertently left far from the patient's bedside. Since it did not *need* to be by the patient to function (no probe to be placed on the patient) it was often placed against the outer wall of the room. When in use, this resulted in trainees turning their attention away from the case. This significant flaw, and possible confounder, was easily corrected by ensuring that both interventions be placed at the same location near the bedside during each case. The pilot session also allowed for testing of the ultrasound simulation equipment as well as preliminary statistical analysis to assist with estimating the required sample size.

Study Purpose

The purpose of this study was to evaluate and describe the aspects of ultrasound simulation (during HFS) that contribute to the development of critical care ED U/S skills Secondly, it was of interest to assess how a novel ultrasound simulator (**edus^2**) compared to video playback on a laptop (a comparable intervention) in terms of the above-mentioned developmental aspects.

Study Design

This was a prospective, randomized, cross-over trial involving post-graduate trainees (Specialist Trainees in EM) and EM faculty from multiple medical institutions in the greater area of London, UK and Saskatoon, SK, Canada. The study was divided into two phases. Phase 1 (the course) took place in London, UK and involved both EM trainees and EM faculty. Phase II took place in Saskatoon, Canada and involved EM faculty watching video recordings of the EM trainees participating in HFS scenarios during phase 1 (see Appendix A, Figure 5).

Study Setting and Population

Phase I was conducted at the Whipps Cross Hospital of the Barts Health Trust in London, UK. Phase II was conducted in the Saskatoon Health Region, Saskatoon, SK, Canada. There were two populations of interest in this study: EM trainees and EM faculty. The intended trainee population included EM trainees enrolled in post-graduate training (residency or equivalent) in London, UK. It was expected that these participants had previous experience with simulation based medical training as well as possessed basic knowledge in ED U/S. The second population of interest was EM faculty (physicians who regularly teach trainees) who were also experts in ED U/S. UK EM faculty from London as well as Canadian EM faculty with ED U/S expertise were the target faculty populations for the study.

EM Faculty for Phase I of the study were selected by the local study coordinator (Dr. Tim Harris) based on perceived expertise in ED U/S and overall teaching skill-set. Of the eight faculty physicians in the study, five were full-time consultants in EM. The remaining three were senior trainees deemed sufficiently experienced in EM and ED U/S (by study supervisor, emergency physician, and ED U/S instructor, Dr. Tim Harris) to serve as faculty facilitators for the course.

Study Protocol

Phase I can be summarized as the 'course' phase during which several trainees (25) and faculty (eight) participated in a day-long HFS session (at one of four separate course dates over a six-week span). Phase II can be described as the "review" phase during which time EM physicians in Canada watched the video recorded scenarios from Phase I (the course phase) and assessed the developmental aspects and differences of the interventions. These differences, though frequently encountered during primary outcome analysis, were then further explored in the analysis of the secondary question, namely the comparison of the two interventions in relation to their impact on ED U/S skill development.

Phase I

EM trainees from various training institutions belonging to the London Specialty School of Emergency Medicine (throughout London, UK) were recruited to participate in the study through poster advertising and email. These trainees were then randomized based on order of arrival to the simulation centre into two groups (A & B) with two to four trainees per group (depending on the number of participants recruited for the session that day). Each trainee group was assigned to one of two study arms that involved both the use of the **edus^2** as well as video playback of ED U/S images on a simple laptop for a total of four HFS scenarios. Group A trainees completed their first two cases with the ED U/S simulator (**edus^2**) followed by two cases with the use of video playback on a simple laptop displaying ED U/S findings. Group B was assigned the same cases with the exception that the first two cases were completed with video playback on a laptop with the following two cases then completed with the use of the **edus^2** (this cross-over design served to inform the researchers of the value of each intervention, whether certain cases favored one educational intervention over the other or whether one was superior to

the other in all scenarios). All trainees completed an entrance MCQ exam (based on the American College of Emergency Physician's EMSONO online exam) as a means of establishing level of knowledge as well as the success of group randomization. Questions were projected using audiovisual equipment. Trainee responses were recorded onto MCQ answer sheets.

Trainees were oriented to either intervention by the principle investigator just prior to their commencement of the respective arm of the study. Only once they had completed two cases and completed post-intervention assessments were trainees then oriented to the other intervention (assessments found in Appendix C).

During cases with the **edus^2**, trainees had to employ the simulator by bringing it to the patient's (mannequin) bedside and manipulating the simulated ultrasound probe (this included holding the probe correctly, identifying and then land-marking the appropriate scanning area and then interpreting the images displayed). When using the video playback on simple laptop, trainees would search the laptop menu screen for a clip of a specific scan of interest and then play the respective video clip. All cases were video recorded for review by Canadian EM faculty at a later date (second phase).

Prior to starting the HFS scenarios, as well as after completing two scenarios with a given intervention, trainees rated their learning experience. They were asked how well the two different interventions aided in their ability to apply, generate, interpret and integrate ED U/S findings during the HFS scenario (see Appendix C, Trainee Intervention Assessment Forms). In addition, during the mid-way evaluation (before cross-over), the trainees once again completed the same MCQ assessment of their ED U/S knowledge and skills. Questions were projected using audiovisual equipment. Trainee responses were recorded onto MCQ answer sheets that were designated "post-intervention".

Each HFS scenario was followed by a standardized debriefing session led by two study facilitators. This included the nurse confederate from the case in question who possessed extensive simulation debriefing knowledge and whose debriefing focus was crisis resource management. If and when during the debriefing questions regarding ED U/S arose, the second facilitator (EM physician and expert in ED U/S) provided direction and answers to the trainees. No formal script or specific direction was provided to the faculty participants.

It was anticipated that the two interventions might have generated different questions from the trainee participants (i.e.: trainees having just completed the video playback intervention arm of the study may not ask questions about probe placement and landmarks while those in the **edus^2** intervention may do so as they may have struggled with that item during the scenario).

In order to capture differences in the debriefing experiences that followed each intervention, the EM faculty simulation facilitators were also surveyed (see Appendix C, EM Faculty Intervention Assessment Forms). These surveys were focused on the debriefing experiences that followed each case as well as the simulated cases themselves. All EM faculty involved in scenario debriefings were paired with a nurse facilitator who was an expert in crisis resource management debriefing. By combining the two facilitators, it was felt that all groups enjoyed the benefit of both expert simulation debriefing as well as ED U/S expertise.

During both intervention arms the U/S video clips (either on **edus^2** or the laptop used for the video playback arm) were played near or at the bedside, as would be the case during a typical resuscitation scenario in a real emergency room.

Phase II

In Phase II of the study, EM community faculty members from the University of Saskatchewan in Saskatoon, SK, Canada, reviewed the video recordings of randomly paired

scenarios with a clear focus on the assessment of ED U/S skills and the interventions themselves. An evaluation tool was designed to capture the attention of the faculty raters on the three basic aspects of ED U/S competence: knowledge of indications with rationale, image acquisition and interpretation skills, and ED U/S integration. This tool was designed in consultation with Saskatoon EM physicians with expertise in ED U/S (see Appendix D, Phase II Faculty Intervention Assessment Forms).

In addition, with each case evaluators were simultaneously rating the extent to which the given intervention (**edus^2** or video playback on the laptop) allowed for the assessment of the trainee's ED U/S skills. It was this assessment of the interventions by faculty that was of the most interest. Faculty observers assessed a random sample of both the **edus^2** and the video playback simulation scenarios (matched by case type so that they could be assessed in a standardized fashion). There were two faculty members per Group And due to recruitment challenges, only two groups (total of four Canadian faculty raters). Each pair reviewed three pairs of randomly selected completed scenarios (three of each intervention). The intervention scores of the two reviewers in each pair were assessed for inter-rater reliability using intraclass correlation coefficients, with scores greater than 0.70 indicating high agreement between raters.

Similar to a previous study by Girzadas et al. (2009), self-reporting was utilized. In this study, we modified the Girzadas survey from a Visual Analogue Scale to a 10-point Likert Scale (permission to modify obtained from author). Pre- and post-intervention results were compared and analyzed in order to determine the strengths of either intervention as well as whether one was perceived as superior to the other. This was done using paired samples t-tests.

Scenario Development

Each trainee group completed a total of four scenarios. In order to minimize bias, cases designed prior to the development of the **edus^2** by Kobayashi and colleagues (Kobayashi et al., 2010) were used for each scenario. Participants were divided into two groups (A and B). Participants in Group A completed the first two scenarios with the use of the **edus^2** while Group B completed the same first two scenarios with the use of video playback of ED U/S findings on a simple laptop. The two groups then crossed over with A then doing two new cases with the video playback intervention and Group B now using the **edus^2** for the same cases.

The four cases chosen represent the shock or peri-arrest states associated with the following conditions: ruptured aortic aneurysm; blunt abdominal trauma with hemoperitoneum; cardiac tamponade (symptomatic pericardial effusion); and, cardiac arrest secondary to massive pulmonary embolism. These case packages included patient scripts (where appropriate), all vital signs as the case progressed, as well as debriefing material. All study faculty and simulation staff were involved in ensuring standardization of each scenario. Each EM faculty participant was provided an online resource to prepare for the debriefing sessions. Dr. Danielle Hart's "High Fidelity Case-based Simulation Debriefing: Everything You Need to Know" (2012) offers evidence informed advice on debriefing in HFS.

Scenario Players

Each scenario included two EM trainee participants (one leader, one helper), a nurse confederate (also an expert in CRM), a paramedic confederate, and when appropriate, an additional actor confederate. Confederates are members of the simulation team that play predetermined roles in order to facilitate the flow of the scenarios as well as aid in recreating the limitations related to resources and personnel. The simulation equipment included the

mannequins SimMan and SimMan 3G (Laerdal Medical Canada, Ltd., Toronto, Canada). To replicate female patients the mannequins had wigs placed on their scalps and mannequins were provided additional moulage treatments in order to make them appear stated age. All major roles (that of patient as well as nurse and paramedic confederates) were practiced prior to study launch to ensure reproducibility and fairness. This role training was carried out at the Whipps Cross Hospital simulation suite and included all study faculty and the primary investigator. The primary investigator performed the patient voice for all scenarios in order to ensure consistency across sessions. Whenever groups had more than two trainees, each member of the group was given the opportunity to lead one case and assist with another.

Trainees not directly involved in a given case were seated in the control room for the duration of the scenario. They were encouraged to actively observe the scenarios while at times also being asked to play roles such as phone consultant or additional physician to help when called upon by the team leading the case. Regardless of their role in a given case, all EM trainee participants completed post-intervention surveys after each intervention.

For both interventions, trainees were briefed that an ultrasound simulator was available if they felt it was appropriate to use and that the facilitating nurse confederate could assist them with its use. As mentioned previously, a short orientation to each of the interventions was given to the trainees just prior to entry into each intervention arm.

Scenario Debriefing

As per best practices in simulation-based medical education, each scenario was followed by a standardized debriefing session. Each scenario was run for approximately 15 minutes followed by approximately 30 minutes of debriefing led by EM faculty with expertise in ED U/S and assisted by the associated nurse facilitator (also well versed in simulation facilitation and

debriefing). Debriefing EM faculty did not have prior knowledge of the nature of the self-reporting tools nor the MCQ test that has been designed and administered for the assessment of learning. Debriefing was intentionally focused on aspects of CRM. When questions regarding ED U/S arose, they were answered to the best of the abilities of the EM faculty.

The impressions of the EM faculty who co-facilitated the debriefing sessions with the trainees were of interest. Their impressions on the impact of the two ultrasound simulation interventions on the debriefing sessions were captured through surveys (see Appendix C, EM faculty Intervention Assessment Forms) at the end of each intervention arm. Specifically, it was of interest whether either intervention promoted more discussion and ultimately more learning than the prior simulation experiences. Furthermore, it was of interest to see if the faculty perceived a difference between the two. If so, this difference could be explained by a number of factors. For example, trainees may gain greater awareness of knowledge deficits (disjuncture) by completing the scenarios with the **edus^2**. Additionally, EM faculty may have been better able to hone their feedback on specific ED U/S skills as a result of increased awareness of the trainee's skill set (as gained through observing the case play out within each intervention arm).

Use of MCQ

While capturing the impressions of faculty facilitators offers an indirect measure for learning gains, the use of a standardized MCQ test was intended to assist with quantifying these gains. However, the use of MCQ is not without drawbacks. This is especially true when the teaching intervention in question (ultrasound simulation in HFS) is as much, if not more, about transfer of learning as it is about knowledge gains. As noted by Bransford et al. (2000), "different kinds of learning experiences can look equivalent when tests of learning focus solely on remembering." The question stems were contextualized to the critical care setting but fall

short of being able to capture some of the more subtle aspects of ED U/S competence such as timing, let alone being completely unable to assess items such as probe driving skills.

Trainees completed the mid-point MCQ test (same questions as pre-intervention test) after their second case and debriefing session. Firstly, it was of interest whether or not trainees had improved scores in the topics covered during the first two cases after having completed and debriefed the two scenarios (blunt abdominal trauma with hemoperitoneum and leaking abdominal aneurysm). Furthermore, if there was a change in scores, it was of interest whether one intervention was associated with this change more than the other.

Given the limited size of the pilot study (two trainees), the MCQ test was not piloted prior to the study proper. Its external and face validity (as described above) seemed sufficient for its incorporation into the study. The determination of sample size by the statistician (Krista Trinder) was based on a sample of the survey questions.

Use of self-reporting and written tests

This study relied on self-reporting as well as MCQ-type tests to assist in the assessment of the two interventions and the respective impacts they had on trainee development. Self-reporting was used to allow trainees to rate their experiences as well as report on the impact of the interventions on their ultrasound skill development. In addition, self-reporting was also used to assess for changes in confidence as well as trainee perceptions of ED U/S competence. It is important to emphasize that these reports of competence were not gathered to serve as surrogate measures of individual trainee skills. Norman and Eva (2010) suggested that there is a poor correlation between perceived competence and actual observed performance. Instead, the objective here was to assess what impact either intervention may have had on trainee self-awareness and skill development afterwards.

Given the above, *changes* in trainee perceptions of skill and competence may be related to the validity (external) and fidelity (psychological) of the interventions. These findings were then compared with MCQ performance as well as faculty perceptions of the adequacy of either intervention in terms of realistic integration of ED U/S into HFS.

Insights from the Pilot Study

A pilot of the study was completed at the University of Saskatchewan on October 2, 2012. Participants included two EM residents (both of whom have both simulation experience as well as basic ED U/S knowledge), an EM community faculty member with Independent Practitioner status (as designated by the Canadian Emergency Ultrasound Society), a senior EM resident, a former ER nurse (now physician), two simulation facilitators; and the author in the role of simulation facilitator. The pilot provided many insights into the strengths and weaknesses of the study design. Sample size was determined with the assistance of a statistician.

Firstly, in regards to placement of the media cart during the video playback arm (laptop and audiovisual cart), it was discovered that the protocol could be biased against the video playback intervention if the laptop was placed on an adjacent table or in the corner of the room. Such placement during the pilot study resulted in the trainees looking away from the patient and/or momentarily disengaging from the case. This was contrasted with the natural bedside placement of the **edus^2** where the trainee continues to engage directly with the patient mannequin while generating the desired ED U/S image. While this natural bedside position may be one of the strengths of the **edus^2**, there was no reason why the media cart used in the video playback arm could not have the benefit of the same placement at the bedside. This resulted in the addition of explicit instructions for media cart placement during scenario set up and completion.

Secondly, the EM community faculty observer (who was in charge of ED U/S skill assessment) suggested that the trainees be instructed to verbalize any ED U/S tasks that they cannot perform during the scenario as a means of allowing some greater degree of assessment during the video playback arm of the study. This could be considered as much a communication skill as it is a modest surrogate for demonstrating a psychomotor task. The trainee could then receive at least a partial assessment on their image acquisition evaluation.

As one of the foundational objectives of HFS in EM, the development of communication skills (an essential part of crisis management) is indeed vitally important (Weller et al., 2012). One could argue that such instructions to the participants (to verbalize skills they are unable to demonstrate) are simply further encouraging this "think aloud" technique that is often encouraged. It could also be suggested that this verbalization is a natural step upward along Miller's (1990) framework for clinical competence (going from being able to *show* how upward to being able to *explain* how). However, such instruction to trainees may have unnecessarily confounded the study and may have resulted in a loss of valuable insights with regard to the strengths and weaknesses of the two interventions. As a result, no such instructions were given to the EM trainees in Phase I of the study proper.

Data Collection

Data from both trainees and faculty players contributed to the analysis for both the primary and secondary study objectives. Data collected over the spatial and temporal separation associated with Phases I and II was also combined to assist in answering the primary and secondary study questions.

In order to inform whether our population sample indeed represented our target population, all participants completed an entrance survey and an ED U/S MCQ test. This

assisted with the assessment of learning that took place during the study. After completion of the first two scenarios, participants in both groups once again completed the same ED U/S MCQ test as before, in addition to the self-reporting survey. This provided a comparison of learning achieved between the two treatment arms. Upon completion of the fourth scenario, there was a final administration of the survey but not the MCQ test (see Appendix A, Figure 3, for overview of study design).

Throughout each scenario and in both arms, audiovisual equipment was used to record all encounters. Afterward, trained EM faculty reviewed the recordings while being instructed to assess ED U/S performance in the realms of indication awareness, image acquisition, interpretation and integration. After completion of Phase I, all trainees were invited to complete an online survey at which time their reflections and opinions about the experience were collected (originally, participants were to be invited for a focus group session but this was deemed logistically impossible and so an online survey was distributed following ethics board approval) . This survey was made available to the trainee participants on June 25, 2013 (with a range of 2-10 weeks from the time they would have attended their session).

All faculty members involved, including simulation faculty participating in Phase I as well as faculty raters in Phase II, were given an opportunity to provide feedback regarding their experiences. Faculty raters in Phase II completed assessment forms using a five point marking scale. Differences in scoring between raters within each scenario were assessed using *t*-test analysis. All qualitative feedback was assessed through emergent theme analysis.

Design of Data Collection Instruments

This study required the development of several data collection instruments. Impressions of both trainees and faculty on the utility of hybrid simulation were obtained through a 10-point

Likert Scale; the questionnaire has been previously used and was adapted with permission from the original developers of the tool (Girzadas, Jr. et al., 2009). The questionnaires were further developed in consultation with evaluation specialist at the College of Medicine at the Uiversity of Saskatchewan. The extent of learning achieved was in part assessed through a standardized series of multiple choice questions (modified with permission for contextual validity) originally designed by the American College of Emergency Physician's Emergency Ultrasound Division (American College of Emergency Physicians, 2014). International leaders in ED U/S originally developed this exam.

The assessment of observable behaviors and skills took place through recordings of the scenarios. The specific skills assessed were identified through consultation with experts in the field of ED U/S. The skills can be divided into the three broad categories of: knowledge of indications, image acquisition and interpretation skills, and finally clinical integration. All data instruments were piloted at the University of Saskatchewan (Saskatoon, SK, Canada) and then further modified after consultation with UK simulation faculty in order to ensure correct use of terminology and proper role-play by simulation confederates.

Outcome Measures

This study was designed to evaluate and describe the aspects of ultrasound simulation that contribute to the development and assessment of ED U/S skills. Primary study outcomes included both objective measurements of learning and assessment as well as subjective impressions of learning and assessment through self-reporting by both EM trainees and EM faculty. Secondary outcomes pertained to the comparison of the two ultrasound simulation interventions in relation to the above aspects.

Objective measurements of learning were assessed through the MCQ. The first was through the analysis of all MCQ results. It was postulated that both interventions could have facilitated increases in MCQ scores. It was also deemed possible that one intervention could generate a greater degree of engagement and more tailored feedback. This might have then translated into greater learning gains and therefore better scores on the MCQ test after each intervention.

Additional evaluations and descriptions of learning included feedback from trainees on self-reports as well as descriptions of the debrief processes as per the faculty. It could be assumed that if faculty described a significant discussion regarding ED U/S during debrief that in fact learning was taking place.

Surveys of both EM trainees and faculty were combined to provide data on perceptions of learning during either intervention, impressions on strengths and weaknesses, as well as reports on how either intervention may have influenced debriefings.

Data Analysis

This study produced both quantitative and qualitative data. Quantitative data included test scores, survey scores assessed with a Likert Scale, and observational data on the value of each intervention from skill assessment in Phase II. As this study assessed two interventions and how they could contribute to the development and assessment of ED U/S skills, pre- and post-intervention changes were assessed for statistically significant differences between them. The significance (alpha) level for all analysis was set at $p<.05$, which is consistent with most education and psychology literature. All standard deviations are to be interpreted as denoting that value in either axis direction (positive and negative).

T-test analyses were used for comparisons of pre-post intervention scores within interventions as well as comparisons between the two interventions at different time-points. Effect sizes (Cohen's d) were calculated where statistically significant findings were observed.

Qualitative data analysis included thematic and emergent analysis from written responses in self-reports and online feedback. All quantitative results were gathered and entered into an excel spreadsheet. The author and a second evaluator (Krista Trinder) independently completed thematic analysis of the qualitative data. The thematic analysis then underwent triangulation where only themes agreed to by both assessors were included in the final analysis.

The secondary study outcomes involved the comparison of the two interventions. Here again evaluation scores of the interventions were compared and, where statistically significant differences were identified or scores appeared substantially different, effect sizes were also calculated. Likewise, qualitative/descriptive data relating to the two interventions were compared analyzed using emergent thematic analysis and triangulation.

Ethical Considerations

Participation in this study, both in the creation of data instruments as well as involvement in the study proper, was voluntary. Faculty participants received an honorarium for their participation (gift voucher from Amazon.com). Participants were advised, both in writing and verbally, that they were free to withdraw from the study at any time (see Appendix B, Consent Forms). All written materials and videos were de-identified and stored according to Research Ethics Board standards. Trainee participants were assured that their performance in the HFS would in no way affect their standing as post-graduate trainees. It was with this mind that EM faculty from the University of Saskatchewan, rather than the UK, were chosen to act as the faculty who carried out the video evaluation of trainees and interventions.

There was potential for perceived risk on the part of trainees when partaking in observed simulation-based learning. It was possible that they would experience significant anxiety out of a desire to perform well in front of both EM faculty instructors/facilitators as well as their peers. Significant trainee anxiety has been studied and identified in the context of the ATLS observed simulated clinical exam where it was found the test anxiety exceeded that of real clinical encounter anxiety (Quilici et al., 2005).

In anticipation of this, efforts were made to address this potential for anxiety. All consent forms clearly highlighted the formative nature of this experience. Trainees were assured that those faculty members involved would not be communicating trainee performance to program coordinators or other faculty. Additionally, each group of trainees and faculty shared in an icebreaker session prior to starting the sessions. Such techniques have been shown to foster a sense of collegiality and cooperation while also reducing anxiety (Hart, 2012). It was on these grounds that ethics approval was granted.

Addressing Personal Bias

Several steps were undertaken during the design and implementation of the study to mitigate the risk of bias. Firstly, the decision to carry out the study at another institution served to minimize personal biases and conflicts of interest that may exist between the author and students as well as other faculty at the author's institution. Secondly, the use of previously designed cases by Kobayashi and colleagues (2010) ensured that the HFS scenarios were not biased toward favoring one type of intervention over the other (these cases were designed for use with video playback prior to the development of the **edus^2**). Thirdly, consultation with experts in the fields of EM and ED U/S allowed for a more objective determination of performance in the two study arms through the selective use of the American College of Emergency Physician's ED

online MCQ ED U/S exam. In addition, the use of recently and externally designed data tools (Girzadas, Jr. et al., 2009) added validity to the study design as these were put together by other researchers interested in ED U/S training.

Furthermore, the author and associate (Dr. Paul Kulyk) have registered the **edus^2** project under a creative commons license. It stipulates that other users may share (to copy, distribute and transmit the work) and remix (to adapt the work) the **edus^2** plans and project under the following conditions: Attribution — others must attribute the work in the manner specified by the author or licensor (but not in any way that suggests that we endorse them or make use of their work), Noncommercial — others may not use this work for commercial purposes. Share alike — If others alter, transform, or build upon this work, they may distribute the resulting work only under the same or similar license to this one. These conditions remove all commercial interests from the project and reduce possible biases and conflicts of interest.

CHAPTER IV

RESULTS

This was a randomized, prospective, cross-over study. In total, there were 25 trainees and eight faculty that participated in Phase I (UK) and four faculty participated in Phase II (Canada).Trainees and faculty members were randomly assigned to either Group A or B at arrival to the Medical Education Training Suite at Whipps Cross Hospital (London, UK). Average pre-intervention MCQ score for all trainees was 71.5%, which suggests familiarity with ED U/S as would be expected for middle- and upper-level trainees. Most of the trainees (21/25) had had previous HFS experience with the majority of trainees having had 3-5 previous HFS experiences. Nearly all had attended a level I ED U/S course or equivalent course (21/25). And while all had had some experience in ED U/S, most (15/25) had not completed the requisite number of scans needed for certification as Independent Practitioners.

Primary and secondary outcomes are displayed below with quantitative data being presented first, followed by qualitative data wherever appropriate.

Previous ultrasound simulation experiences

Participants (both trainees and faculty) in phase 1 were asked to rate previous experiences involving the integration of ED U/S into HFS training. The vast majority of both trainees and faculty responded that to date previous HFS experiences had only poorly, if at all, integrated ED U/S into HFS with a rating of 3.26 out of ten (all scores out of a possible ten, ranging from poor at zero to excellent at ten).

In terms of how well previous such integration had tested their knowledge of indications, trainees recorded an average score was 3.0 (SD 2.15). The ability of previous experiences' ability to test trainee ED U/S interpretation skills was rated at 2.65 (SD 2.48). Finally, integration

of ED U/S in general was also rated low at 2.61 (SD 2.15). Respondents likewise rated the ability of previous experiences in terms of simulating use of ED U/S in critical care low at 3.26 (SD 2.73). Faculty were similarly unsatisfied with previous attempts at integration of ultrasound into simulation, rating them at 4.75.

Primary Study Question

In what ways and to what extent can the two ultrasound simulation interventions contribute to ED U/S skill development? Nearly all trainees felt that each of the two interventions (**edus^2** and video playback on laptop) offered a superior learning experience compared to previous experiences vis-a-vis integrating ultrasound into HFS scenarios (Table 1).

Table 1. Trainees Pre- and Post-Evaluations of the Investigated Interventions.

Question	**edus²**			**Simple laptop**		
	Pre Mean (SD)	Post Mean (SD)	Pre-Post **edus²** Statistics	Pre Mean (SD)	Post Mean (SD)	Pre-Post **laptop** Statistics
1. Please rate how well previous/this high fidelity simulation scenarios tested your knowledge of **INDICATIONS** for ED U/S.	3.00 (2.15)	8.09 (1.20)	Mean Δ=6.09 *t*(22)=-9.05 *p*<0.001 *d*=-2.92, r=-0.825	3.00 (2.15)	7.57 (1.56)	Mean Δ=4.57 t(22)=-7.42 p<0.001 d=-2.43, r=-0.77
2. Please rate how well previous/this high fidelity simulation scenarios tested your ability to use a U/S machine to ***GENERATE*** a U/S image.	2.74 (2.36)	5.61 (2.78)	Mean Δ=2.87 *t*(22)=-4.86 p<0.001 d= -1.53, r=-0.61	2.74 (2.36)	4.61 (3.07)	Mean Δ=1.87 t(22)=-2.84 p=0.009 d=-0.67, r=-0.32
3. Please rate how well previous/this high fidelity simulation scenarios tested your ability to ***INTERPRET*** video-playback U/S images.	2.65 (2.48)	7.30 (2.51)	Mean Δ=4.65 *t*(22)=-6.91 p<0.001 d=-1.86, r=-0.68	2.65 (2.48)	6.91 (1.90)	Mean Δ=4.26 t(22)=-6.18 p=0.001 d=-1.93, r= -0.69
4. Please rate how you felt previous/this high fidelity simulation scenarios tested your ability to ***INTEGRATE*** (diagnosis and management) ED U/S findings as related to the patient's condition.	2.61 (2.15)	8.09 (1.28)	Mean Δ=5.48 *t*(22) =-10.21 p<0.001 d=-3.10, r=-0.84	2.61 (2.15)	7.65 (1.82)	Mean Δ=5.04 t(22)=-9.23 p<0.001 d=-2.53, r=-0.78
5. Please rate the overall ability of previous/this high fidelity simulation scenarios to simulate the use of ED U/S in the management and assessment of critically ill patients.	3.26 (2.73)	8.09 (1.24)	Mean Δ=4.83 *t*(22)=-8.20 p<0.001 d=-2.28, r=-0.75	3.26 (2.73)	7.83 (1.47)	Mean Δ=4.57 t(22)=-6.66 p<0.001 d=-2.08, r=-0.72

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

The trainee evaluations of previous experiences and interventions consisted of five questions as they relate to the ability of the learning experience to address key aspects of ED U/S competence. As described earlier, competence would include mastery in such areas as: knowledge of indication, image generation and interpretation, the integration of findings into the clinical assessment as well as the overall choreography of ED U/S integration into critical care. Both interventions were rated as superior to previous experiences in all the above domains.

Trainees were also asked about their levels of confidence with respect to the five above mentioned domains at pre-intervention, after two cases and after four cases. Increased confidence was more associated with the increased number of cases (four), rather than in relation to either intervention (see Tables 2 and 3). When mean intervention scores after two cases were assessed (using a Cronback Alpha >0.7), it was found that confidence increased more after use of the simple video playback intervention than with the **edus^2**, but after cross-over and the completion of all four cases, both groups demonstrated significant increases in confidence.

Table 2. Pre- and Post-intervention Self-rating of Confidence in Indications and Image Generation after Two Cases with Investigated Interventions.

	edus²			**Simple laptop**		
Please rate your overall level of **confidence** with ED U/S in terms of:	Pre Mean (SD)	Post Mean (SD)	Pre-Post **edus²** Statistics	Pre Mean (SD)	Post Mean (SD)	Pre-Post **laptop** Statistics
a) Knowledge of indications.	6.29 (1.68)	7.29 (1.20)	Mean Δ=1.00 T(13)=-2.03 p=0.063 d= -0.69, r=-0.32	6.82 (1.25)	8.00 (1.26)	Mean Δ=1.18 t(10)=-3.14 p=0.011 d=-0.94, r=-0.43
b) Image generation.	4.79 (1.89)	5.36 (2.31)	Mean Δ=0.57 T(13)=-1.85 p=0.088 d= -0.27,r=-0.134	5.82 (2.14)	6.18 (2.36)	Mean Δ=0.36 t(10)=-0.71 p=0.492 d=-0.16, r=-0.08
c) Image interpretation.	5.36 (1.69)	6.43 (1.91)	Mean Δ=1.07 T(13)=-2.69 p=0.019 d=-0.59, r=-0.28	5.91 (1.64)	6.73 (1.90)	Mean Δ=0.82 t(10)=-2.17 p=0.055 d=-0.46, r=-0.23
d) Image integration.	4.79 (1.88)	6.64 (1.69)	Mean Δ=1.85 T(13)=-5.64 p<0.001 d=-1.03, r=-0.45	6.00 (1.67)	6.91 (1.81)	Mean Δ=0.91 t(10)=-3.32 p=0.043 d=-0.52, r=-0.25
e) Management & assessment of critically-ill patients.	5.93 (1.98)	7.00 (1.18)	Mean Δ=1.07 T(13)=-.3.72 p=0.010 d=-0.66, r=-0.31	6.18 (2.18)	7.91 (1.14)	Mean Δ=1.73 t(10)=-2.51 p=0.031 d=-0.58, r=-0.28
Mean Confidence (of the above five)	5.43 (1.63)	6.54 (1.47)	Mean Δ=1.11 T(13)=-4.55 p=0.001 d=-0.72, r=-0.34	6.15 (1.54)	7.15 (1.33)	Mean Δ=1.00 t(10)=-2.58 p=0.028 d=-0.69,r=-0.33

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

Table 3. Pre- and Post- Self-rated Confidence in Indications, Image Generation etc. after Four Cases (Interventions Combined).

Please rate your overall level of **confidence** with ED U/S in terms of:	Pre-intervention Mean (SD)	After Four Cases Mean (SD)	Pre-Post Four Cases Statistics
a) Knowledge of indications	6.52 (1.50)	7.68 (1.77)	Mean Δ= 1.16 t(24)=-2.44, p=0.022
b) Image generation	5.24 (2.03)	6.28 (2.35)	Mean Δ= 1.04 t(24)=-3.98, p=0.001
c) Image interpretation	5.60 (1.66)	7.16 (1.99)	Mean Δ= 1.56 t(24)=-5.19, p<0.001
d) Image integration	5.32 (1.87)	7.24 (1.92)	Mean Δ= 1.92 t(24)=-6.29, p<0.001
e) Management & assessment of critically ill patients.	6.04 (2.03)	7.60 (1.19)	Mean Δ= 1.56 t(24)= -3.98, p=0.001
Mean Confidence	5.74 (1.60)	7.19 (1.66)	Mean Δ= 1.45 t(24)=-5.49. p<0.001 d=-0.89 r=-0.41

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation

Grouping all five domains together (Cronbach alpha being >0.7), there was a small, though statistically significant, increase in overall confidence with the **edus^2** (mean pre-intervention 5.43, SD 1.63 to post **edus^2** 6.54, SD 1.47). Subsequent to completing all four cases (and having used both interventions), both groups of trainees reported an increase in their overall confidence in terms of ED U/S use (from pre-intervention score of 5.74, SD 1.6 to post four cases 7.19, SD 1.66).

In terms of knowledge testing, no statistically significant differences in MCQ scores were generated after completion of the first two cases (Table 4). It should be noted that only 17/25 trainee MCQ scores were included in the analyses due to the fact that administration of the MCQ test at the first course was significantly compromised as a result of technical factors (AV equipment issues) as well as mislabeling of answer sheets (no pre/post labeling). These problems were addressed following the first session and corrected for the subsequent session dates.

Table 4. Pre- and Post-Intervention MCQ Scores after Two Cases.

Groups	Pre-intervention mean (SD)	Post-intervention mean (SD)		Pre-Post Statistics
		edus[2]	Simple laptop	
Group A	76.5% (10.44)	79.70%(13.97)	NA	Mean Δ= 3.2% t(9) =-1.06, p=0.318
Group B	75.50% (16.73)	NA	73.88%(15.91)	Mean Δ= -1.62 t(7)=0.84, p=0.427

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation

The above results offer evidence of adequate randomization of participants as there was no difference between the two study arms (groups A and B). There was no significant change in MCQ scores after either intervention. The lack of any significant change in MCQ results speaks to the difficulty of assessing for knowledge gain through the use of externally-developed assessment tools. It is also possible that the concepts being learned during the HFS sessions had less to do with fact and recall and more to do with process and integration, something that is difficult to assess through MCQ testing.

Trainees completed an online follow-up exit survey 8-10 weeks after participating in the study. The survey included both quantitative and qualitative components. Eighty percent (20/25) of the trainees responded to the survey, though two did not complete the survey in its entirety.

In terms of impact of the session on their clinical work, the majority of trainees expressed an increased awareness of indications for use of ED U/S. As one trainee commented, the course increased "the number of situations in which I would consider using ultrasound." This common theme was coupled with what another trainee described as an increased "enthusiasm for practicing U/S scanning (and) an appreciation of the value of U/S scanning in management of

critically ill patients." More advanced trainees described a lesser impact as they "already use U/S scanning as a part of (their) examination in many patient encounters."

In keeping with the above comments, the session impacted trainee training and education by encouraging most trainees "to seek more training in U/S scanning and to reach Level I sign off and beyond." Some of the more advanced trainees noted that the session inspired them to "get involved in U/S teaching having done this course."

Phase I faculty impressions. Faculty participants were also asked to rate the interventions and not the performance of the trainees. This was done by asking them about the ability of either intervention, or previous experiences, to inform them on trainee ED U/S skills. Both interventions were scored favorably in terms of integrating ED U/S into HFS when compared to previous experiences (Table 5). Assessments of both interventions demonstrated a significant increase in scores for all domains/measures. There was a significant difference in scores in ability to assess trainee skill set (specifically, image generation) as well as impact on feedback during debriefing. In these areas, the **edus^2** scored significantly higher. Faculty members described an increased awareness of trainee skill-set, thus allowing more informed feedback to trainees.

Table 5. Phase I Faculty Ratings of Investigated Ultrasound Interventions within HFS.

Question	**edus^2**			**Simple laptop**		
	Pre Mean (SD)	Post Mean (SD)	Pre-Post **edus^2** Statistics	Pre Mean (SD)	Post Mean (SD)	Pre-Post **laptop** Statistics
1. Please rate how well the previous high fidelity simulation scenarios allowed you to assess a trainee's knowledge of INDICATIONS for ED ultrasound.	5.63 (2.07)	8.88 (1.64)	Mean Δ=3.25 t(7)=-3.39, p=0.012 d=-1.74, r=-0.66	5.63 (2.07)	7.88 (1.73)	Mean Δ=2.25 t(7)=-2.15 p=0.069 d= -1.18, r= -0.51
2. Please rate how well previous high fidelity simulation scenarios allowed you to assess a trainee's use of an ultrasound machine to GENERATE an ultrasound image.	4.13 (2.75)	7.50 (2.45)	Mean Δ=3.37 t(7)=-3.73 p=0.007 d=-1.29, r=-0.54	4.13 (2.75)	2.63 (2.77)	Mean Δ=-1.5 t(7)=1.63 p=0.15 d=0.54, r=0.26
3. Please rate how well previous high fidelity simulation scenarios allowed you to assess a trainee's ability to INTERPRET video-playback ultrasound images.	5.13 (3.18)	9.00 (1.07)	Mean Δ=3.87 t(7)=-4.15 p=.004 d=-1.63, r=-0.63	5.13 (3.18)	7.88 (1.25)	Mean Δ=2.75 t(7)=-2.31 p=0.054 d= -1.13, r= -0.5
4. Please rate how you felt previous high fidelity simulation scenarios allowed you to assess a trainee's ability to INTEGRATE (diagnosis and management) ED U/S findings as related to the patient's condition.	5.00 (2.88)	9.13 (0.64)	Mean Δ=4.13 t(7)=-4.33 p=0.003 d=-1.98, r=-0.7	5.00 (2.88)	7.50 (1.41)	Mean Δ=2.50 t(7)=-2.24 p=0.06 d=-1.10, r=-0.48
5. Please rate the degree to which the intervention (edus^2) assisted you in offering feedback to the trainee regarding his/her ED U/S skills and development.	4.75 (3.06)	8.63 (1.30)	Mean Δ=3.88 t(7)=-3.92 p=0.006 d=-1.65, r=-0.63	4.75 (3.06)	4.88 (2.03)	Mean Δ=0.13 t(7)= -0.11 p=0.916 d= -0.05, r= -0.02

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

While faculty participants did rate the laptop intervention as being superior to previous experiences for assessing some aspects of ED U/S competence (knowledge of indications and image interpretation), the table above illustrates that despite this faculty did not see any advantages to the laptop intervention in improving the debrief and feedback of trainees.

The **edus^2** was rated as a far greater improvement over previous interventions in all aspects/domains of listed ED U/S competence. Likewise, thematic analysis of the written responses of faculty reinforced the quantitative data with generally favorable comments for both interventions. Many faculty members commented that both interventions allowed for "a reasonable assessment of (knowledge) of indications" while others added that the interventions clearly "added ED U/S into the decision making process."

Additional developmental features indentified with the **edus^2** included the ability to assess trainee use of ED U/S in real time as well as basic probe handling: "I was able to assess their use of u/s in cardiac arrest and the timing of echo with CPR. Hence it can be easier to debrief them." This theme relates to the previously described concept of resuscitation choreography and further emphasizes a significant difference between the two interventions. It is with insights into probe handling, timing and overall integration that faculty then felt able to provide feedback to trainees.

The next series of questions posed to Phase I faculty related to the actual impact the interventions had on the debriefing sessions that followed the simulation scenarios (Table 6).

Table 6. Pre-and Post-Intervention Phase I Faculty Ratings of Intervention's Impact on Debrief & Feedback.

Question	**edus²**			**Simple laptop**		
	Pre Mean (SD)	Post Mean (SD)	Pre-Post **edus²** Statistics	Pre Mean (SD)	Post Mean (SD)	Pre-Post **laptop** Statistics
5. Please describe the degree to which previous/this high fidelity simulation sessions that had integrated ED U/S impacted the direction of the debrief session held after each HFS cases.	5.50 (2.93)	8.63 (1.69)	Mean Δ=3.13 t(7)=-2.60 p=0.035 d=-1.31, r=-0.55	5.50 (2.93)	7.25 (1.04)	Mean Δ=1.75 t(7)=-1.67 p=0.139 d=-0.80, r=-0.37
7. Please rate the overall ability of previous/this high fidelity simulation experiences to allow for the assessment of trainee ED U/S skills.	4.38 (2.88)	8.00 (1.85)	Mean Δ=3.62 t(7)=-4.01. p=0.005 d=-1.50, r=-0.60	4.38 (2.88)	6.00 (1.77)	Mean Δ=1.62 t(7)=-1.93 p=0.096 d=-0.68, r=-0.32

Mean Δ = mean change (post-pre) *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

The video playback on a simple laptop intervention was rated as not being significantly better than previous experiences for debriefing and feedback. The **edus^2** intervention was perceived to have a substantially higher impact on debrief as compared to previous experiences.

One faculty participant explained that the **edus^2** allowed for "feedback on everything from positioning of equipment, to communication with patient, to documentation and medico-legal issues." On the other hand, faculty felt the laptop intervention offered them very little insight into trainee skills and as such made it hard to bring up ED U/S skills during debrief. This "lack of ownership of the skill made the feedback less applicable to the trainees."

Table 7 offers a more global assessment of the two interventions. Here EM faculty participants clearly distinguish between the two interventions, demonstrating that the **edus^2** intervention was the only one that demonstrated a significant advantage in integrating and simulating ED U/S in critical care scenarios.

Table 7. Phase I Faculty Impressions of Intervention's Ability to Simulate ED U/S in Critical Care.

		Simple laptop		**edus^2**	
Question	Pre-Mean* (SD)	Post Mean (SD)	Pre-Post Statistics	Post Mean (SD)	Pre-Post Statistics
8. Please rate the overall ability of previous/this high fidelity simulation scenarios to simulate the use of ED U/S in the management and assessment of critically ill patients.	4.88 (2.80)	6.63 (1.60)	Mean Δ= 1.75 t(7)=-1.57, p=0.160 d=-0.77 r=-0.35	8.75 (1.04)	Mean Δ= 3.87 t(7)=-4.65, p=.002 d=-1.83 r=-0.68

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation, *This pre-mean score applies to entire trainee group

Phase II faculty impressions. Phase II faculty rated both interventions highly in terms of the interventions' capacity in helping demonstrate the trainees' skills in terms of knowledge of indications and integration (see Table 8, questions 1-5). The **edus^2** simulator was rated superior

in the realm of image generation and fidelity as compared to the laptop. Scores comparing the ability of the interventions to allow for the assessment of image generation skills amongst trainees met statistical significance. In terms of helping faculty identify a trainee's proper use of the ultrasound probe as well as proper identification of landmarks, the effect sizes in favor of the **edus^2** were large, 4.41 and 6.52, respectively.

Table 8: Phase II Faculty Ratings of the Interventions in Terms of How Well They Assist in Assessing Trainee ED U/S Skills and Knowledge.

Please rate the **INTERVENTION**'s performance in allowing the trainee to show their ED U/S skill set during this scenario.	Post edus^2 Mean (SD)	Post- laptop Mean (SD)	Comparative Statistics
1. Knowledge of indications.	4.58 (1.02)	4.08 (1.56)	t(10)=-0.66, p=0.526
2. Image generation a) Proper use of probe and machine.	3.58 (0 .49)	1.42 (0.49)	Mean Δ= t (10)=7.63, p<.001 d= -4.41, r= -0.91
2. Image generation b) Correct anatomical landmarks.	4.33 (0.52)	1.25 (0.42)	Mean Δ= t (10)= 11.36, p<.001 d= -6.52, r= -0.96
3. Image interpretation.	4.67 (0.82)	4.92 (0.20)	t (10)=-.63, p=0.484
4. Image integration.	5.00 (0.00)	4.75 (0.61)	t (10)=1.00, p=0.341

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

Comparing opportunity for assessment (showing how), faculty in Phase II scored each intervention based on five parameters. The data demonstrated that the **edus^2** was superior in offering insight into basic "hands on" use ED U/S. Inter-rater reliability was good for judges 1 and 2 (0.70), and excellent for judges 3 and 4 (0.84).

Secondary Study Outcomes

How do the two interventions compare? The secondary study outcomes describe differences in performance/effectiveness between the **edus^2** and the simple laptop simulators. As illustrated by some of the primary outcome data, while trainees generally rated both interventions favorably, faculty in both Phases I and II demonstrated a strong preference for the **edus^2** (see Table 5).

During the follow-up exit survey, when asked about preference for either of the interventions or previous experiences with ED U/S simulation, all 18 participants that completed the survey recorded that they preferred the **edus^2** to the video playback on the simple laptop. Previous ultrasound simulation experiences were preferred by 17% (3/18) of the trainees.

Trainees were then asked to provide rationale for their rankings. These responses were were analyzed thematically and then triangulated. The following concepts/themes offer insight into the rankings.

Trainees felt that the **edus^2** was superior in terms of fidelity. As one trainee put it, "holding the probe makes the simulation closer to reality and real time." The themes of "real-time" and "hands-on use" dominated the survey responses. This was contrasted with the artificial nature of the videos found on the laptop. "The laptop meant you were trying to find the correct (clip), which detracted from the simulation."

Faculty rated the **edus^2** as being superior to the simple laptop intervention with a mean intervention assessment score of 8.63 (SD 1.32) for the **edus^2** and 6.15 (SD 1.29) for the video playback on simple laptop ($p<.001$) (Table 9).

Table 9. Comparison of Interventions by Phase I Faculty.

	Post-edus[2] Mean (SD)	Post-Laptop Mean (SD)	Statistical Information
1. Please rate how well the high fidelity simulation scenarios allowed you to assess a trainee's knowledge of **INDICATIONS** for ED ultrasound.	8.88 (1.64)	7.88 (1.73)	t(7)=-2.65 p=0.033 d=-0.59, r=-0.28
2. Please rate how well the high fidelity simulation scenarios allowed you to assess a trainee's use of an ultrasound machine to ***GENERATE*** an ultrasound image.	7.50 (2.45)	2.63 (2.77)	t(7)=-4.93 p=0.002 d=-1.86, r=-0.68
3. Please rate how well the high fidelity simulation scenarios allowed you to assess a trainee's ability to ***INTERPRET*** video-playback ultrasound images.	9.00 (1.07)	7.88 (1.25)	t(7)=-3.21 p=0.015 d=-0.96, r=-0.43
4. Please rate how you felt the high fidelity simulation scenarios allowed you to assess a trainee's ability to ***INTEGRATE*** (diagnosis and management) ED U/S findings as related to the patient's condition.	9.13 (0.64)	7.50 (1.41)	t(7)=-3.87 p=0.006 d=-1.49, r=-0.60
5. Please rate the degree to which the intervention assisted you in offering feedback to the trainee regarding his/her ED U/S skills and development.	8.63 (1.30)	4.88 (2.03)	t(7)=-6.71 p<0.001 d=-2.20, r=-0.74
Mean Assessments of the interventions.	8.63 (1.32)	6.15 (1.29)	t(7)=-8.92 p<0.001 d=-1.9, r=-0.69

Mean Δ = mean change (post-pre); *t*(n: *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

Cronbach alpha was 0.94 pre-intervention, 0.70 post-laptop and 0.91 post-**edus**^{2} (a Cronbach alpha of >0.70 is required to assert that the response grouping is consistent).

Comparing self-rated competence as related to the interventions.

In terms of self-rated competence (retrospective, response shift bias) there was a statistically significant difference between the two groups after the first two cases (Table 10).

Group A, which did its first two cases using the **edus^2**, recorded a pre-intervention competence of 4.21 out of ten (SD 2.42). After having completed two cases with the **edus^2**, the students were asked once again to reflect on what they now thought their competence had been prior to arriving for the session. The group's mean score for previous competence was essentially unchanged at 4.79 (SD 2.22). Group B, on the other hand, recorded a significant increase in competence rating after having completed their first two cases with the simple laptop intervention. That group's pre-intervention score was 5.50, (SD 2.12) whereas after two cases with laptop intervention recorded an increased self-rated competence of 6.91 (SD 1.45), indicating that they now perceived that they had under-estimated their competence prior to the session (pre-intervention).

Table 10. Phase I Trainee Self-rated Competence after Two and Four cases.

Question	**Group A (edus^2 first)**			**Group B (laptop first)**		
	Pre Mean (SD)	Post Mean (SD)	Pre-Post **edus^2** Statistics	Pre Mean (SD)	Post Mean (SD)	Pre-Post **laptop** Statistics
AFTER 2 CASES: Please indicate your current level of competence (just prior to this session) with ED U/S	4.21 (2.42)	4.79 (2.22)	Mean Δ=0.58 T(13)=-1.42 p=0.179	5.55 (2.12)	6.91 (1.45)	Mean Δ=1.36 t(10)=-2.89 p=0.016 d= -0.75, r=-0.35
AFTER 4 CASES: Please indicate your current level of competence (just prior to this session) with ED U/S	4.79 (2.22)	6.00 (2.32)	Mean Δ=1.21 t(13)=-3.32 p=0.006 d= -0.91, r= -0.41	6.91 (1.45)	7.45 (2.07)	Mean Δ= .54 t(10)=-0.79, p=0.449 d=-0.76, r=-0.35

Mean Δ = mean change (post-pre); *t*(n): *t*-test with n degrees of freedom; p: statistical significance level; d: Cohen's d; r: correlation.

After four cases, Group A (initially **edus^2** then simple laptop) had demonstrated an increase to 6.00 (2.32; t(13)=-3.32, p=0.006), whereas Group B (now having used **edus^2** after initially using the simple laptop intervention) recorded no additional increase in self-rated competence with a score of 7.45 (SD 2.07; t(10)=-0.79, p=0.449).

When assessing self-rated confidence in skills (combination of five items: knowledge of indications, generation, interpretation, integration and overall competence), Group A showed improvement after going from **edus^2** (M=6.54, SD= 1.48) to completion of the video arm (M= 6.98, SD 1.69; t(13)=-.3.04; p= .009). Group B, on the other hand, having moved on from video (M= 7.14, SD 1.33) and completed **edus^2**, showed no statistically significant improvement (M= 7.45, SD 1.65; t(10)=-1.22; p= 0.251.

The graphs below (Figures 7 and 8) illustrate two findings. The first is that trainees develop an increased sense of competence (retrospective) when completing the simple laptop ultrasound simulation intervention. The second is that confidence increases are associated primarily with repeated exposure to ED U/S cases more so than to any one intervention in particular.

Figure 8. Self-rated *Competence* after Two and Four cases.

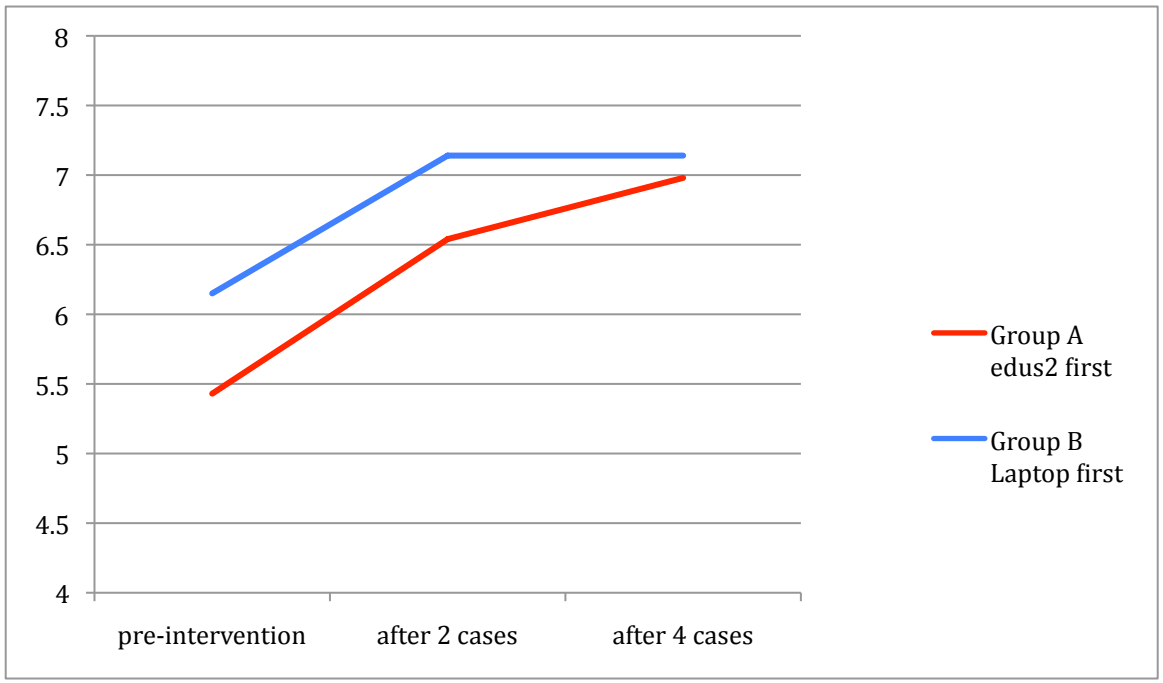


Figure 9: Self-rated *Confidence* after Two and Four cases.

Matching the interventions to trainee skill level. This was determined by using trainee pre-intervention knowledge assessments (MCQ scores) and dividing them into two groups

(below and above median MCQ score). These two groups were then matched with the intervention scores to see if there was relationship between knowledge level and preference of intervention. There was no statistically significant difference in **edus^2** ratings between upper and lower performing trainees (7.18 and 6.93, p= 0.744). While not statistically significant, there was a larger difference between the upper and lower groups when rating the simple laptop intervention with mean scores of 6.10 and 6.92 (p=0.187 respectively). Effect size (Cohen's d) was calculated to be 0.64 (medium). Based on these data, it would require a substantially larger study of a total of 80 participants (40 in each group) to determine if this effect would have statistical significance.

Summary of Findings

The findings of the study support the integration of ED U/S into HFS through both interventions assessed here. The aspects of ED U/S skill development associated with ultrasound simulation in HFS were assessed and described by both trainees and faculty. The two interventions were found to be of value by both trainees and faculty in terms of allowing trainees to demonstrate knowledge of indications as well as correct image interpretation and general integration of ED U/S into critical care ($p<0.05$). Qualitative data analysis revealed that trainees attributed the simulation experience to an increased motivation to further develop their ED U/S skills as well as increase use of ED U/S in everyday practice.

Furthermore, the **edus^2** was identified as being the preferred teaching intervention. Trainees preferred it to the simpler simulation, as it appears to have better met psychological fidelity through its real time and hands-on application. Faculty preferred the **edus^2** as it allowed for significantly better assessment of trainee skills and subsequently had a greater impact on session debriefing and formative feedback. This was especially true when assessing the trainee's

ability to efficiently maneuver and integrate the use of ED U/S at the bedside. Despite only offering a limited challenge in terms of image generation, faculty found the **edus^2** intervention sufficient in offering basic insights into trainee ED U/S skills and mastery ($p<0.05$).

Chapter V

DISCUSSION

As supported by previous research, critical-care skills require careful attention to multiple events and processes including the proper use of bedside tools and the sequence of actions to be undertaken by the resuscitationist. It appears that ultrasound simulation, both basic use of a laptop and even more so through the use of the **edus^2**, may aid in the development of this important choreography as well as offer faculty a glimpse into a trainees ED U/S competence thereby allowing for formative feedback and further skill development.

ED U/S Simulation: Some is Better than None

In terms of ultrasound integration into HFS, nearly all trainees favored both interventions over previous experiences. Trainees rated both interventions favorably (mean scores of 6.15 for the simple laptop and 8.63 for **edus^2**) and described each as offering a reasonable integration of ED U/S into critical-care scenarios. This may be related to the fact that both interventions, though not identical, offered trainees a *simplified* form of the more complex task of critical-care ultrasound. As Kneebone et al. (2004) stated, one of the strengths of simulation is that it "offers controllable levels of challenge that can be adjusted according to individual need." This tailored delivery based on complexity is consistent with developmental learning theories explained earlier (ZPD, CLT, scaffolding and Miller's Framework).

While the quantitative survey results show little difference between the two interventions, the qualitative data offers a different picture where the **edus^2** is clearly preferred. There are several possible reasons for this difference. Firstly, by offering two interventions with somewhat different levels of realism and complexity, it is possible that trainees of varying skill levels found one or the other intervention more applicable to their specific level of skills and knowledge. It is

possible that less experienced trainees (defined as those with pre-intervention MCQ scores below the median) scored the video laptop intervention more favorably than did experienced trainees (effect size = 0.64; p=0.187) because the simple laptop intervention was still well within their ZPD, whereas more experienced trainees found it too easy. Further study with a greater number of participants would assist in assessing this hypothesis. Such trainees would find the opportunity to introduce ED U/S into the clinical scenario and interpret the findings as played for them on the laptop enough of a cognitive challenge (van Merrienboer & Sweller, 2010).

Thematic analysis of the qualitative data revealed that all trainees preferred the **edus^2** as it offered "a more hands on experience in real time." With the **edus^2**, some of the generation task (fine probe driving) has been taken care of and as such trainees can focus on other aspects of integration including the choreography of critical care U/S during resuscitation. From a broader curriculum perspective, critical-care ultrasound may be best taught through a combination of training environments. Basic land-marking and probe driving skills could be taught outside the clinical context on patient volunteers or even basic task trainers; SonoMan is an example of this type of trainer (Simulab corporation, 2014). These skills can then be re-integrated and further built upon through integration of ED U/S into critical care HFS. This type of "progressive fidelity" (Brydges et al., 2010) may prove to be a more efficient way to teach a complex skill-set like critical-care ultrasound and should be subjected to rigorous research and development.

As evidenced in the surveys, most trainees reported that the area in which they struggled most, and therefore had the least confidence in, was image generation (mean image generation score for all trainees was 5.24, the lowest mean value of all confidence parameters). Trainees rated both interventions as mediocre in terms of their ability to teach image generation: simple laptop received a rating of 4.61 and **edus^2** was rated as 5.61, with no statistically significant

difference between the two. While the **edus^2** did offer the opportunity for trainees to show proper probe handling as well as scan land-marking, trainees expressed a frustration by not being able to "drive the probe." In contrast, EM faculty involved in both phases clearly preferred the **edus^2** and even described being able to assess (to a limited extent) basic probe handling as exhibited by the trainees.

Learning the Moves: The Choreography of Critical Care Ultrasound

The term "resuscitation choreography" has, to date, largely been used to refer to the coordination of multiple critical actions in the context of advanced cardiac life support (Berg et al., 2010). The introduction of ultrasound into resuscitation room has generated new questions about the sequence of these important events. Trainees must learn not only how to scan, but also when to scan, how long to scan for and when to re-scan. For example, the above authors emphasize minimal interruption to cardiopulmonary resuscitation, with rhythm and pulse checks lasting no longer than 10 seconds, as longer pauses are associated with poorer outcomes. Some EM sonologist experts, such as Dr. James Ripley of the SonoCave blog (2014), have done a great job of highlighting this reality and have attempted to teach, through podcast, the proper sequence of events, with specific focus on ED U/S, during cardiac arrest. Based on this study and related simulation literature, it could be argued that the next step should be to attempt this new choreography in HFS.

Furthermore, this introduction of critical-care ultrasound and re-sequencing of events is dependent on the nature of the resuscitation in question. The established resuscitation sequences of trauma, cardiac arrest and undifferentiated shock are not identical; neither is the integration of ultrasound into these scenarios. Protocols developed with this in mind include Echo Guided Life Support (EGLS) by Lanctot, Valois, and Bealieu (2011) and Rapid Ultrasonography in Shock

and Hypotension (RUSH) by Weingart, Duque, and Nelson (2009). This leads to the possibility that either there exists a critical-care-ultrasound choreography, or more appropriately, that critical-care ultrasound belongs within a broader concept of resuscitation choreography that encompasses the various resuscitation sub-classes (trauma, cardiac arrest and undifferentiated shock).

While individual scans or components can be easily taught on healthy volunteers, it is the integration of multiple scans in a safe, sound and reproducible sequence that remains a training challenge. As this study showed, ED U/S simulation offers trainees an opportunity to rehearse those steps in a simulated high-stakes setting.

Thematic analysis of qualitative data in this study revealed that both trainees and faculty described both interventions as offering an opportunity to perform complex resuscitation sequences while integrating ED U/S. Faculty members in Phase I strongly preferred the **edus^2** intervention as it offered more insight into the trainees' ability to integrate ED U/S into the resuscitation of the simulated patient. For trainees identified as not yet competent in the choreography of resuscitation with ultrasound, further time on such tasks/ repeated sessions with scenarios using ED U/S simulation may prove beneficial. Such longitudinal interventions could be the focus of future research in this area. Certainly, evidence exists to support such interventions in similar areas including Advanced Cardiac Life Support.

> …students who train on simulators show better performance in real situations in a variety of domains, including laparoscopy, catheter insertion, advanced cardiac life support (ACLS) and auscultation. Some of these gains have been shown in highly authentic transfer tasks, such as actual response to ACLS events. (Norman et al., 2012, p. 2)

One of the educational phenomena at the core of the above findings is DP (Ericsson et al., 1993). As described earlier, DP involves "a highly structured activity explicitly directed at improvement of performance in a particular domain (Duvivier et al., 2011). Both interventions gave trainees a chance to practice integrating ED U/S into their management of critically-ill patients. The limits of this *practice* related to the degree to which either intervention re-created the actual task. Faculty in both phases rated the **edus^2** as superior on this criterion and noted that they were far better to discuss issues related to "real time" integration when trainees were using the **edus^2**.

In contrast, the video playback on the laptop was criticized for allowing trainees (especially assistant members of the team) to access all video clips without having to engage the patient or the rest of the resuscitation team. Faculty preceptors felt that this disconnected use of the video playback laptop intervention significantly reduced the potential for feedback, especially in the realm of choreography. Such challenges could be countered, and in fact were overcome, by a small number of trainees when they disciplined themselves and their group to only employ the simulator when it would be actually possible to do so at the bedside during the HFS scenario. This type of corrective behavior was witnessed three times by members of Group A and not at all by Group B (only trainees who had first used **edus^2** acted to limit access to the video playback laptop intervention to real time during their 3rd and 4th scenarios).

Though such corrective measures can be introduced, and in fact have been by others (Kobayashi et al., 2010), they represent a major limitation associated with the video playback on laptop intervention. Such attempts were reported by the trainees as breaking the realism of the scenario. It also added an unwelcome distraction for the team leader as he/she had to consciously suspend disbelief in order to immerse him/herself into managing the critically-ill patient.

Making the Most of the Spotlight

There is increasing interest, and in fact a developing mandate, to adopt competency based training in medical education (Nasca et al., 2012). Here the educational system becomes outcome-driven and focused on knowledge application rather than knowledge acquisition (The Royal College of Physicians and Surgeons of Canada, 2009). Such training models are based on the premise that individual trainees require varying degrees of instruction, exposure and practice in order to master a specific skill or set of skills. As a result, it should be the demonstration of mastery, rather than simply time spent on task (as has often been used as a surrogate in some skill areas such as communication, organization and collaboration), that should result in trainee assessment and when appropriate, advancement.

The competency-based approach relies heavily on direct observation. The results of this study highlighted how the appropriate integration of ultrasound into HFS created opportunities for assessment and formative feedback. In essence, the integration of ED U/S into HFS fits well within a competency-oriented training paradigm.

Furthermore, the HFS setting offers a level of faculty focus seldom achievable in everyday clinical practice. Faculty involved in the HFS sessions can devote a great deal of attention on the trainees in question, not needing to worry about losing situational awareness as they might while supervising a trainee during real critical care encounters. This "moment in the spotlight" is sought out in medical education, and one that should be maximized by both the trainees and faculty involved, creating opportunities for tailored feedback to the trainee.

While both interventions offered integration of ED U/S into the HFS scenario, the **edus^2** was rated as superior in terms of opportunity for assessment and feedback. In phase 2 of the study, when asked to assess the intervention's ability to expose the trainees' basic handling of an

ED U/S machine (probe holding, land-marking) faculty ranked the **edus**^{2} as being superior to video playback on the laptop.

The limits of these assessments are found in the fact that they exist only within a simulated environment, rather than actual clinical care. The frameworks proposed by Miller (1990) and Kirkpatrick (1996) emphasize that such simulated environments are not the same, nor can they be equated to, real patient encounters. In both frameworks, assessments of clinical competence should ultimately be made at the patient's bedside. While this is quite achievable for the majority of clinical skills, it becomes problematic when assessing critical care skills. The very nature of critical care makes real time assessments of trainees challenging for even the most experienced of resuscitationists.

Not surprisingly then, critical care specialties including anesthesia and EM, are interested in developing robust processes for the assessment of competence in simulated settings (McGaghie et al., 2010). In short, HFS may prove to be the setting where critical care competence meets Miller's framework.

As with the pilot study, some trainees managed to make the best of the spotlight regardless of which intervention arm they were participating in. Such trainees managed to verbalize (show how) they would perform scans even in the absence of a probe (as was the case with the simple laptop intervention). It seemed possible that one of the interventions may prove more likely to induce verbalization of skills (with trainees explaining where they would place the probe, how they would perform the scan, etc.) than the other. This was observed in the performance of three of the Group A participants as they completed scenarios three and four with the simple laptop intervention. Such verbalization of the ED U/S task served as a type of compensation mechanism that allowed for at least an indirect assessment of ED U/S image

acquisition skills. It is difficult to ascertain whether such verbalization has any significant impact on feedback during debrief of these specific scenarios.

Clarifying the Role of Fidelity

The authenticity of the experience unquestionably shapes the way in which a simulation intervention will be received and perceived by both trainees and educators. While engineered fidelity may offer an initial 'wow' factor, it is the psychological fidelity (as experienced through the actual use of the intervention) that is of greatest relevance to all involved (Norman et al., 2012; Kneebone et al., 2004). With regard to simulating ED U/S use, the question of fidelity lies in the assessment of whether or not the trainees felt as though they were actually scanning the patients under their care. As suggested by Norman et al. (2012), such psychological fidelity can be achieved with varying levels of engineered fidelity depending on the nature of the task that is being simulated or the stage of training.

For this study, the objective was overall integration of ED U/S into critical care by introducing interventions that address several key aspects associated with its use including knowledge of indications, timing, basic probe handling and placement and image interpretation. It was not the objective of the simulation interventions to teach or demonstrate the details of probe driving, which for the most part can be practiced on patient volunteers as well as real patients.

Hamstra and colleagues (2014) recently published an important article addressing the challenges associated with the language of fidelity. They make the case for the need to move beyond such terminology. They recommend the term functional fidelity and moreover, the concept of "functional task alignment" (Hamstra et al, 2014, p. 389) where the simulation intervention is defined by the objectives and tasks associated with the intervention, rather than its

physical resemblance or structural features. This novel framework might replace terms like HFS with a more accurate descriptive term like Acute Critical Care Simulations or Crisis Resource Management Simulations.

With the above in mind, the study data illustrate that both interventions proved capable of simulating the integration of ED U/S into critical care. The majority of trainees and all faculty participants described the two interventions as being superior to previous attempts at integrating ED U/S into critical-care simulation that they had experienced.

In terms of quantitative assessment, trainees rated the two interventions as essentially equal in all domains of the task. This included rating both poorly in the realm of simulating image generation. Analysis of the qualitative data told a somewhat different story, with overwhelming clear preference for the **edus^2** intervention. This may be explained by the fact that it was only during the qualitative survey that trainees had the opportunity to directly compare the two interventions (i.e.: which of the two did you prefer?)

Faculty in Phase I consistently rated the **edus^2** as superior to the laptop-video-playback intervention (both quantitative and qualitative). Faculty in Phase II noted its superiority in the realms of probe handling and land-marking (quantitative).

The findings of this study confirmed that "different genres of simulators can be combined to increase both engineering and psychological fidelity." (Maran & Glavin, 2003). This study, like others preceding and similar to it, refers to this combination as hybrid simulation. Given the current evidence regarding the inadequacy of fidelity as a descriptor for such interventions (Hamstra et al., 2014), it may be that future studies will instead focus on the tasks being simulated. This shifts focus away from the types of simulators and shifts it onto the goal of the learning experience (in this case, integration of ED U/S into critical care)

Perceptions and Deceptions of Competence

In this study, there appeared to be a relationship between the fidelity of the intervention and trainee *perceptions* of competence (where fidelity was considered low, perceptions of competence increased, see Figure 7). Such perceptions are important because they play a role in trainee learning and adoption of feedback. The supervision cycle (Launer, 2010) proposes that trainees can only develop competence in a skill only once they have become aware that they do not possess it (going from unconscious incompetence to conscious incompetence).

In this study, trainees were asked to rate their perceived competence in critical care ED U/S. The trainees' average pre-intervention self-rated competence scores were: 4.21 for Group A and 5.55 for Group B. Upon completion of two cases in their respective intervention arms, trainees were asked to once again reflect on their pre-intervention skills and perceived competence (essentially their competence prior to participation in the study). These results were then compared to their original pre-intervention scores.

Such comparisons of "pre and then" were initially designed to address a confounding study phenomenon known as response shift bias (Howard & Dailey, 1979). Response shift bias can be encountered in self-reporting when the respondents' measurements (or metric) change during an intervention. This change in metric is most often acquiring a higher standard than one had prior to the educational intervention. This would usually result in retrospective pre-test means being lower than pre-intervention test means. If researchers were to compare pre-tests to post-tests self-assessments they might find very little change or even that learning and skills have declined.

With self-report measures (which including assessments of one's own abilities) the metric resides within the study participants. As such, the metric can be directly

> affected by the intervention. If participants' levels of self-knowledge change as a result of the intervention, then this metric may also shift, making comparisons before and after more challenging. (Howard & Dailey, 1979, p. 23)

In this study, the presence and identification of a response shift was of interest. The identification of such a shift, its direction and magnitude, offers insight into the different effects that the two interventions may have on trainee skill development. Such assessments begin with participant perceptions of their current competence. Trainees were asked to reflect on their overall ED U/S competence just prior to arriving at the course and record a score on a Likert scale. This reflection may have included perceptions on the different aspects of ED U/S competence including knowledge of indications, image generation and interpretation as well as logistical challenges like timely integration at the bedside during critical-care encounters. In an indirect way, trainees were asked what exactly were the demands of the task and how well have they been able to (up until that moment) meet those demands.

After each group completed two cases (each group in a specific intervention arm), the trainees were asked to once again reflect on their (then) competence. The data revealed that trainees who had completed two cases with the **edus^2** did not record a change in the perception of their competence. That is to say that how they perceived the demands of the task (ED U/S) had not been changed by the experience of simulating use of ED U/S with the **edus^2**. It could be said that their perceptions of the difficulty and complexity of the tasks had in fact been validated by participation in the cases associated with the **edus^2**.

Trainees who completed their first two cases with the laptop intervention adjusted their perception of their prior competence with regard to the task (ED U/S). These Group B trainees

recorded statistically significant increases in self-reported (then) competence. In essence, the data suggested that the trainees, having completed two cases with the simple laptop intervention, now thought that they had been more competent than they had previously reported. This could be explained by the fact that the demands of the task (ED U/S) seemed lessened during use of the simple laptop intervention, or their individual skill-sets perceived as greater, following participation in two cases with a simplified ultrasound simulation intervention. This evidence of a response shift, as associated with the laptop intervention, raises intriguing questions about the possible consequences of simplified, perhaps over-simplified, simulation.

If the change, or shift, in self-reported competence represents a response as to what was newly perceived after the simplified ultrasound intervention to be the actual demands of the task, then it is possible that trainees internalized an inaccurate understanding of the real demands of ED U/S. Inaccurate is used to describe this scenario because the laptop intervention proved to be poor at recreating many of the cognitive and psychomotor challenges associated with ED U/S in critical care. This explanation relates to the authenticity, and psychological fidelity, of the simulation intervention and has implications for further training and motivation.

If, on the other hand, the response shift reflects a change in their perceptions of their *own skills and competence* (i.e.: I'm better at this than I had thought), then there are equally significant concerns about the impact of such an intervention on the trainee's skill development. Specifically, it may adversely influence their responses to feedback due to where they now position themselves within the previously mentioned supervision cycle (Launer, 2010). If they now consider themselves as consciously competent, when in fact they have reverted to being unconsciously incompetent, then antagonism may surface when a preceptor challenges that self-perception. Such a false sense of competence may also adversely affect dedication to training

and mastery.

Limitations Revisited

This study has several limitations. The first relates to the one-time nature of the intervention. The most successful simulation interventions are designed to be longitudinal (over several months or years) and as such harness the fullest potential of key constructs like DP. In this study trainees were asked about the perceived impact of the single session on their future clinical work and education but the study did not actually follow/verify those reports, nor does the study inform us on the impact of repeated exposure to the intervention.

Another limitation of this study is its reliance on MCQ and questionnaires to assess for learning and trainee skill development. The lack of any significant change in MCQ results may be related to the difficulty of assessing for knowledge gain through the use of externally-developed assessment tools. While the test broadly addressed indications and application of critical care ED U/S, none of the questions related directly to the scenarios completed during the session. Supervision and observation in real clinical contexts would be preferable, but this would involve significant logistical problems. Furthermore, given the limited exposure associated with the one-day intervention, it is unlikely that a significant impact could be measured through gains associated with DP. The limited number of trainee participants also made meeting statistical significance challenging.

Despite significant efforts to reduce bias, it is possible that the author's involvement in the sessions (as the voice of the simulated patients and orienter of the two interventions) may have biased some of the trainee and faculty responses in favor of the interventions. While trainee participants were largely unaware of my relationship to the **edus^2**, some of the faculty members did familiarize themselves with the **edus^2** intervention (through the online website) prior to

arrival for their designated session. The impact of such bias is difficult to measure, but would likely favor the **edus**^{2} over the simple laptop intervention.

The involvement of local EM experts in ED U/S carried with it similar risks of personal bias. As highlighted throughout the study, there is still a paucity of expertise in ED U/S amongst practicing EM physicians. As such, it became clear that any success in recruitment would require involving colleagues who share a similar passion for ED U/S. It should be noted that two of the Phase 2 EM physicians have significant training in medical education and as such one would hope this would assist them in forming objective opinions and scores for the two interventions.

Future research

Cognitive Errors in Emergency Medicine

Of increasing interest in medicine, and especially EM, is the role of cognitive processes and more specifically cognitive error. Croskerry (2003) has written extensively on the nature of cognitive processing in EM as well as cognitive errors. He suggested that one way of possibly guarding trainees and physicians from certain errors is to recreate (simulate) conditions in which such errors occur as a means of making trainees aware of potential pitfalls.

As he suggested in his work, this kind of "metacognition" could be fostered through several methods including simulation where scenarios are carefully designed to expose error. For example, a scenario in which the trainee is expecting, with high pre-test probability, to generate a positive finding on ED U/S only to find it to be normal or inconclusive should force the trainee to reconsider their primary working diagnosis. This type of dramatic shift in diagnosis is not easy and sometimes leads to cognitive errors whereby instead the findings and results are ignored or rationalized to suit one's initial assessment. Anecdotally, such events occurred during the study where a small number of trainees convinced themselves of a finding that was not there. Such an

error could lead to misdiagnosis and inappropriate care.

By developing their "cognitive forcing strategies" in HFS, trainees and physicians may be better able protect themselves and their patients from cognitive error.

Mastering Resuscitation Choreography

A significant advantage attributed to the **edus^2** related to its ability to realistically reproduce many of the essential steps associated with critical care ED U/S. Developing a repertoire of steps for use of ED U/S during resuscitation and emergent care will require deliberate practice.

While this study was limited to a one-day long intervention, future studies could be directed at determining whether repeated exposures to this training intervention (and subsequent DP) results in more efficient use of ED U/S during real care, including the use of resuscitative ultrasound protocols such as EGLS and RUSH. We would expect a learning curve with greater returns early and diminishing improvements with repeated practice. Such a study would best employ blinded raters to observe EM trainees during real resuscitation events and score them according set performance parameters.

Conclusion

The integration of critical care U/S into HFS represents a natural step in the evolution of ED U/S training in residency. This progression is driven by a desire by both EM trainees and faculty to safely integrate ED U/S into the real care of critically ill patients. EM trainees desire opportunities to apply and demonstrate their developing skills, while simultaneously faculty are increasingly seeking out opportunities to assess and offer formative feedback to trainees.

Key conceptual frameworks such as Vygostksy's ZPD, Cognitive Load Theory, Bloom's Taxonomy of Learning and Deliberate Practice all support the integration of ED U/S simulation

into HFS for trainee skill development. Furthermore, the use of such training interventions for assessment of trainees and transfer of learning is supported by Miller's Pyramid of Clinical Competence, and Kirkpatrick's Hierarchy of Evidence in medical education. The findings in this study of two ED U/S simulation interventions are largely consistent with and support the above concepts and frameworks.

This study was designed to evaluate how ultrasound simulation during HFS might contribute to the development and assessment of critical care ED U/S skills (defined as knowledge of indications, image acquisition with interpretation, and overall integration) amongst EM trainees. The findings of the study support the integration of ED U/S into HFS (through either intervention). Such integration was found to be of value by both trainees and faculty in terms of allowing trainees to demonstrate knowledge of indications as well as correct image interpretation and general integration of ED U/S into critical care.

Furthermore, the **edus^2** was identified as being a superior teaching intervention as it allowed for significantly better assessment of trainee skills and subsequently greater impact on session debrief and formative feedback. Despite only offering a limited degree of image generation, faculty found the **edus^2** intervention sufficient in offering basic insights into trainee ED U/S skills and mastery.

Implications of the study include continued support for the integration of ultrasound simulation during HFS training. Further study on the effects of such ultrasound simulation interventions on clinical performance is warranted.

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APPENDIX A

Recruitment Material

Phase I Recruitment poster for EM trainees.

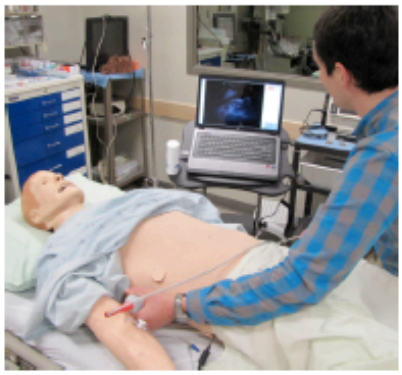
Barts Health NHS
NHS Trust

Emergency & Intensive Care Ultrasound
High Fidelity Simulation Course

Introducing a **NOVEL** Simulator That Integrates Ultrasound During Real-time Resuscitation

Topics include management of the following condition:
Cardiac Tamponade, Trauma, Ruptured AAA and Massive PE

GET A CHANCE TO INTEGRATE YOUR U/S SKILLS DURING RESUSCITATION CASES!!!



Who do we want? EM Specialist Trainees
What? Half or Full day course of hands-on resuscitation and u/s training with experts in EM and U/S
Where? Whipps Cross Hospital @ the MET Suite
When? April 30, May 14, June 4 and 11 (both am & pm)
Why? 1:1 Faculty to Learner ratio! You are certain to run cases!
Contact: EDUScourse@hotmail.com to sign up or inquire.

This course is FREE! Space is Limited!

This course is part of a simulation study organized through the University of Saskatchewan. Your participation is entirely voluntary.

Phase I Recruitment Poster for EM Faculty

Barts Health NHS
NHS Trust

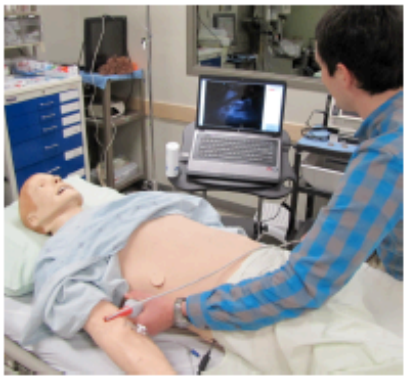
Emergency & Intensive Care Ultrasound

High Fidelity Simulation Course

Introducing a **NOVEL** Simulator That Integrates Ultrasound During Real-time Resuscitation

Topics include management of the following condition:
Cardiac Tamponade, Trauma, Ruptured AAA and Massive PE

BOOK THIS PD DAY & GET A CHANCE TO USE A NOVEL U/S SIMULATOR FOR USE IN HFS SETTINGS!!!



Who do we need? EM Physicians with expertise in U/S
What? Full day course of hands-on resuscitation and u/s training for EM trainees followed by tailored debrief sessions
Where? Whipps Cross Hospital @ the MET Suite
When? April 30, May 14, June 4 and 11 (both am & pm)
Why? Play a leadership role in resuscitation and ultrasound training. Assist in developing a new EM course!

Contact: EDUScourse@hotmail.com to sign up/inquire.
Honorarium will be included.
This course is part of a simulation study organized through the University of Saskatchewan. Your participation is entirely voluntary.

APPENDIX B

APPLICATION FOR APPROVAL OF RESEARCH PROTOCAL

Application for Approval of Research Protocol (U of S)

1. Supervisor(s): Dr. Kalyani Premkumar, Department of Medical Education
Dr. M. D'Eon, Department of Medical Education
Dr. Pat Renihan, Educational Administration

1a. Student: Paul Olszynski, Masters of Educational Adminstration

1b. Dates of study Start Date: March 2013
Completion date: June 2013

2. Title of Study

How Does an Ultrasound Simulator Contribute to the Development and Assessment of Emergency Department Ultrasound (ED U/S) Skills in EM trainees?

3. Abstract

Last year, Paul Kulyk and I successfully created an Emergency Department ultrasound simulator that allows for the seamless integration of bedside ultrasound into the assessment and care of critically ill patients as encountered during high fidelity simulation scenarios (www.edus2.com). The impetus for this invention stemmed from a desire to help trainees safely incorporate Emergency Department ultrasound, an increasingly important bedside tool, into the management of critically ill patients (see Appendix A).

By giving trainees an opportunity to practice using Emergency Department ultrasound in a simulated environment, it is our belief that trainees' skills and confidence will increase resulting in an increased likelihood for the incorporation of Emergency department ultrasound into clinical care. It is yet to be determined in what ways and to which extent the use of such an ultrasound simulator improves skills and confidence amongst trainees. The study I propose will be a randomized, prospective, crossover, study with both an intervention and control treatment for all participants.

My study will assess how our novel ultrasound simulator (**edus^2**) compares to video playback in the development and assessment of critical care ED U/S skills (defined as knowledge of indications, image acquisition and image interpretation) amongst EM trainees? Outcome measures include both objective and subjective data. Objective measures will include performance on MCQ test and observed skills assessment. Subjective data will include rating of both the intervention and learning achieved through survey and group discussion.

This study will hopefully assist EM faculty and training programs interested in evidence based teaching of ED U/S as well as further explore the merits of simulation in medical education for learning, skill development and transfer to practice. My intention is to carry out the research in London, England as well as Saskatoon, Canada. Local ethics approval will be obtained in both the UK and Canada.

4. Funding

Financial support (partial) has been preliminarily approved by The College of Medicine at the University of Saskatchewan. Costs specific to study implementation (including the creation of a faculty observation/assessment training video as well as costs associated with simulation facility use) will be re-reimbursed pending approval from the Dean's office.

5. Conflict of Interest

Paul Olszynski is the co-creator of a novel ED U/S simulator (**edus**^{2}) as well the lead investigator for this study. He is also an assistant clinical professor with the College of Medicine at the University of Saskatchewan where his teaching responsibilities regularly include lecture, small Group And simulation-based teaching. He is also an ED U/S instructor with the EDE courses 1 and 2 (basic and advanced applications).

6. Participants

The participants that will be enrolled in phase 1 of this study are UK-based Specialist Trainees in Emergency Medicine as well as UK-based EM faculty. The simulation facility is based in the Barts Health Authority. There are several reasons for carrying out this first phase of the research outside of our own University (of Saskatchewan). Given the relatively small size of our institution, biases related to my relationships with EM trainees may confound study results. Additionally, smaller trainee numbers limit participant sample size making it difficult to power the study for statistical significance. Our intention is to recruit approximately 20 EM trainees and 6 EM faculty members for a total number of 26 participants in phase 1.

For the second phase of the study, videos of the UK trainees will be reviewed by EM faculty members at the U of S who have competence in ED U/S (Independent Practitioner Status as per the Canadian Emergency Ultrasound Society). These faculty members will be rating the trainee skills and intervention performance with regard to skill assessment for a given intervention (**edus**^{2} vs video playback). Our intention is to recruit 4-6 EM faculty members for this second phase of the study.

7. Consent

Participants will be recruited by their local training programs. This study and its training scenarios fall under the realm of simulation-based education with which participants are already familiar with and understand. Given that participation in the study includes high quality training interventions it is anticipated that trainees will be interested in being involved. Recruitment will take the form of announcements at educational rounds and poster advertising. As chief investigator, I will make announcements at educational sessions and will hand out consent forms for trainees to read prior to signing up for the study.

As such, trainees will have an opportunity to sign up anonymously (thus less likely to feel coerced into participation). Simulation faculty at the study location at Whipps Cross Hospital will coordinate participants to arrive for their respective sessions.

Consent will be obtained through a written invitation to participate in the study (see Appendix B). It is expected that participants will have read and understood the consent document. They will be invited to ask any additional questions upon arrival at the simulation facility at Whipps Cross Hospital.

8. Methods

The proposed study is a prospective, randomized, cross-over, trial involving post graduate trainees (Specialist Trainees in Emergency Medicine) and EM faculty from multiple medical institutions in the greater area of London, UK and Saskatoon, Canada. The study will be divided into two phases. Phase 1 will take place in London, UK and will involve both EM trainees and EM faculty (see Appendix C, Figures 1, 2, 3). Phase 2 will take place in Saskatoon,

Canada and will involve EM faculty watching video recordings of the EM trainees participating in HFS during phase 1 (see Appendix C, Figure 4).

Phase 1

EM trainees from the various training institutions within the UK will be randomized into two groups (A & B). Each group will be assigned to one of two study arms involving both the use of the edus2 as well as video playback of ED U/S images. Group A will be assigned to completing their first two cases with the ED U/S simulator (edus2) followed by 2 cases with the use of video playback for ED U/S findings. Group B will be assigned the same cases with the exception that the first two cases will now be completed with video playback for ED U/S with the following two cases now completed with the availability of the edus2 (this cross over design will inform the researchers if certain cases favor one educational intervention over the other or whether one is superior to the other in all scenarios). During cases with the edus2, trainees will have to manipulate the simulated US probe by correctly holding the probe, land marking the appropriate scanning area and then interpreting the images shown.

Participating EM trainees will complete entrance, mid point and exit surveys (see Appendix D). They will also challenge a web based MCQ exam (modified American College of Emergency Physicians Emergency ultrasound exam) following each survey. Answer to questions form the MCQ tests will only be provided at the completion of phase 1.

Participating EM faculty will observe the scenarios and facilitate debrief after each case (see Appendix G). They will be asked to complete entrance, mid point and exit surveys with regard to each completed scenario while rating the respective intervention's performance in informing the observer to trainee competence in the realms of knowledge of indications, image acquisition, and image interpretation. As in a previous study by Girzadas et al (2009), visual analog scales (VAS) from that study (adapted with permission) will be used for the self-ratings.

During the video playback intervention cases, trainees will ask for a clip of a specific scan of interest. All cases will be recorded for review by faculty in Phase 2.

Prior to starting the HFS scenarios, as well as after completing two scenarios with a given intervention, trainees will rate their learning experience. They will be asked how well the two different interventions aid in their ability to apply, generate and interpret ED U/S findings (see Appendix D).

Each HFS scenario will be followed by a standardized debrief session where the focus will be crisis resource management (Appendix G). If and when questions regarding ED U/S arise, scripted answers will be provided in order to ensure appropriate and consistent responses. It is anticipated that the two interventions may generate different questions by the trainee participants (i.e.: trainees having just completed the video playback component of the study may not ask questions about probe placement and landmarks while those in the edus2 intervention may do so as they may have struggled with that item during the scenario)

Phase 2

In the second phase of the study, EM faculty at the University of Saskatchewan in Saskatoon will be divided into two specific intervention arms (see Appendix C, Figure 4). A minimum of 2 faculty per intervention (edus2 or video playback) will review all trainee scenario recordings while completing assessment forms (see Appendix F). In addition, entrance and exit surveys (see Appendix E) will be completed by participating faculty.

9. Storage of Data

Upon completion of the study, all data (pre-intervention, mid-intervention and post-intervention surveys, MCQ test results, video recordings of trainees and skill observation data forms) will be securely stored by the researcher's primary advisor, Dr. K. Premkumar at the University of Saskatchewan. All documents, including videos, will be kept for a period of 5 years and then destroyed. Video data may be reviewed at a later date for further sub-analysis for a period of up to 5 years.

10. Dissemination of Results

The results of this study will be presented as part of my thesis work in partial fulfillment for a degree of Master of Education in Educational Administration. It is my intent to also submit this work for publication in a journal of medical education. In addition, results may be presented at a conference. The identity of all participants will be protected.

11. Risks and Benefits

There is potential for perceived risk on the part of trainees when partaking in observed simulation-based learning. It is possible that they risk experiencing significant anxiety out of a desire to perform well in front of both EM faculty instructors/facilitators well as peers. Significant trainee anxiety has been studied and identified in the context of the ATLS observed simulated clinical exam where it was found the test anxiety exceeded that of real clinical encounter anxiety (Quilici AP et al, 2005)

In anticipation, efforts will be made to address this potential for anxiety. All consent forms will clearly highlight the formative nature of this experience. Trainees will be assured that those faculty members involved will not be communicating trainee performance to program coordinators or other faculty.

12. Confidentiality

All self-report data (both of EM trainees and EM faculty) will be kept anonymous. MCQ test scores will be tracked amongst participants for change in score but will also be kept anonymous. Video recordings will be altered to ensure anonymity of the study participants. Group discussions post-intervention will be analyzed through emergent thematic analysis and no person-identifying quotes or comments will be used in the presentation of the results.

As lead investigator, I will be coordinating the study and will be present during each session. A participant log will be kept whereby initials will be used to keep track of participation. A letter/numerical code will be assigned to each participant and that will be used during study analysis (i.e.: John Smith in Group A, J.S on participant log, A100 on data collection material) For EM faculty, coding will include the intervention, and the corresponding participant (edusA100 and videoA100). No one outside the study team will have access to the participant log.

13. Debriefing and Feedback

As with best-practices recommendations, all simulation scenarios will be followed by a debrief session (see Appendix J). The focus of these sessions will be critical care/ crisis management skills and not only ED U/S. That said, scripts are be prepared should trainees ask specific questions related to ED U/S. Furthermore, all participants (trainees and faculty) will be invited to participate in focus group discussions (albeit in 2 groups with trainees and faculty are separated).

Participants will also be given the option of following up with the study's results as they become available.

14. Required Signatures

Researcher _____

Supervisor _____

Supervisor _____

Department Head _____

15. Contact Information

Paul A Olszynski
143 Skeena Crescent
Saskatoon, Sk
S7K-4G6
p.olszynski@usask.ca

Consent Form for EM Trainees

How Does an Ultrasound Simulator compare to video playback during simulation in the Development and Assessment of Emergency Department Ultrasound Skills in EM trainees

Thank you for your consideration to participate in this education study.

Purpose: The purpose of this study is to compare two simulation interventions designed to facilitate Emergency Department Ultrasound (ED U/S) skill development. By comparing these two different approaches it is hoped that we will identify the respective strengths and weaknesses of each intervention.

Procedures: Participation in this study will involve the completion of 4 high fidelity simulation scenarios. The scenarios include critically ill patients similar to cases you have completed in the past. You will be randomly assigned to one of two groups for the study. As per best practices in simulation education, each 15-minute case will be followed by a 30-minute debrief session. In order to gain a better understanding of the impact of ultrasound simulation you will also be asked to complete surveys and answer questions before, during and after your 4 cases. You can expect this session to take approximately 7 hours. You will also be invited to a focus group session a few days after your session (1 hour long). This too is entirely voluntary. It is during this focus group that you will have further opportunity to provide feedback and insights on your learning experience.

Videos of each scenario will be used to determine the suitability of the two teaching interventions in the assessment of ED U/S skills by EM faculty. The faculty involved in reviewing the videos will be EM staff physicians in Canada who have no prior knowledge of trainee identity or training level.

The high fidelity simulation scenarios, surveys and tests in which you will participate are strictly for the purpose of this study. Your performance during this study (simulation scenarios and tests) will be kept anonymous and stored safely as per ethics requirements.

Potential Risks: Participating in high fidelity simulation scenarios can cause significant stress and/or anxiety. This study is being undertaken with the primary objective of improving training for EM trainees, not for summative assessment. As such, we invite you to engage in the scenarios to your fullest capacity while remembering that this is purely educational by nature. There is no pass/fail or marking component assigned to you in this study. Furthermore, your participation will be tracked anonymously. No member of the study team, nor EM faculty participant, will communicate your performance to your respective supervisors. You will be asked to submit only your initials for a study participant log and nothing else. Thereafter you will be assigned a participant code and it will be this code that will be used during data analysis.

Throughout your participation the study team will do its best to ensure a positive learning environment. We are there to answers questions and respond to your feedback. Please take the debriefing sessions as opportunities to delve into questions and also take a moment to relax. The study team will also lighten the mood with an icebreaker during introductions.

Potential Benefits: Immediate benefits to EM trainees include a high quality learning experience focused on critical care skill development. Indirect and potential benefits to trainees include future implementation of similar interventions (such as the one in which you will participate) into standard or core curriculum.

Confidentiality: Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals. Moreover, the Consent Forms will be stored separately from the (materials used), so that it will not be possible to associate a name with any given set of responses.

Withdrawal: Please be assured that your participation in this study is voluntary and should you choose not to participate, it will not affect your standing with your respective training program. You may withdraw from the study at any time. Your right to withdraw data from the study will apply until results have been disseminated; data has been pooled, etc. After this it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

If you have any questions or concerns, please feel free to contact me via email p.olszynski@usask.ca. You may also contact my thesis supervisor, Dr. Premkumar at the University of Saskatchewan (kalyani.premkumar@usask.ca) and/or my UK supervisor, Dr. Tim Harris (Tim.Harris@bartshealth.nhs.uk).

This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call collect.

I, _____, have read and understand the description provided above. I am aware of the nature of the study and understand that I am free to withdraw at anytime during the course of the study. A consent form has been given to me for my records.

_____ _____

(Signature of Participant) (Date)

_____ _____

(Signature of Researcher) (Date)

Consent Form for EM Faculty

How Does an Ultrasound Simulator compare to video playback during simulation in the Development and Assessment of Emergency Department Ultrasound Skills in EM trainees

Thank you for your consideration to participate in this study.

Purpose: The purpose of this study is to compare two simulation interventions designed to facilitate Emergency Department Ultrasound (ED U/S) skill development. By comparing these two different approaches it is hoped that we will identify the respective strengths and weaknesses of each intervention.

Procedures: Your participation in this study will involve the assessment of EM trainees' ED U/S skills in critical care during high fidelity simulation as well as the assessment of the educational intervention being studies.

Phase 1 Faculty Participants
EM trainees in this study will complete 4 high fidelity simulation scenarios. The scenarios include critically ill patients similar to cases you facilitated in the past. You will be randomly assigned to one of two groups for the study. As per best practices in simulation education, each 15-minute case you observe will be followed by a 30-minute debrief session. You will be expected to facilitate a debrief session with a focus on critical care management as well as answer specific questions on ED U/S as relevant to the cases.

In order to gain a better understanding of the impact of ultrasound simulation you will also be asked to complete surveys and answer questions before, during and after the 4 cases. You can expect each session to take approximately 7 hours. We ask that you consider facilitating 1 – 2 sessions (7-14 hours of your time). You will also be invited to a focus group session a few days after your session (1 hour long). This too is entirely voluntary. It is during this focus group that you will have further opportunity to provide feedback and insights on the educational interventions involved with other participant colleagues.

Phase 2 Faculty Participants
In the second phase of the study, videos of each scenario will be used to determine the suitability of the two teaching interventions in the assessment of ED U/S skills by EM faculty. EM staff physicians in Canada who have no prior knowledge of trainee identity or training level will be video raters for this study.

The high fidelity simulation scenarios and surveys in which you will participate are strictly for the purpose of this study. All reports will be kept anonymous and stored safely as per ethics requirements.

Potential Risks: Participating in high fidelity simulation scenarios can cause significant stress and/or anxiety for trainees.. This study is being undertaken with the primary objective of improving training for EM trainees, not for summative assessment. As such, we invite you to engage in the scenarios to your fullest capacity while remembering that this is purely educational

by nature. There is no pass/fail or marking component assigned to trainees in this study. Furthermore, trainee participation will be tracked anonymously. No member of the study team, nor EM faculty participant, will communicate trainee performance to his/her respective supervisors. You will be asked to submit only your initials for a study participant log and nothing else. Thereafter you will be assigned a participant code and it will be this code that will be used during data analysis.

Throughout your participation the study team will do its best to ensure a positive learning environment. We are there to answers questions and respond to both trainee and faculty feedback. Please take the debriefing sessions as opportunities to delve into questions and also take a moment to relax. The study team will also lighten the mood with an icebreaker during introductions.

Potential Benefits: There are no direct benefits to EM faculty. It is possible that faculty participants will find the study and the interventions enlightening and therefore may offer an opportunity to improve their training programs.

Compensation: Given the significant time commitment being requested, EM faculty will be compensated at a rate of approximately 50$/hour. Funding for this aspect of the study is from the College of Medicine at the University of Saskatchewan.

Confidentiality: Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals. Moreover, the Consent Forms will be stored separately from the (materials used), so that it will not be possible to associate a name with any given set of responses.

Withdrawal: Please be assured that your participation in this study is voluntary and should you choose not to participate, it will not affect your standing with your respective training program. You may withdraw from the study at any time. Your right to withdraw data from the study will apply until results have been disseminated; data has been pooled, etc. After this it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

If you have any questions or concerns, please feel free to contact me via email p.olszynski@usask.ca. You may also contact my thesis supervisor, Dr. K. Premkumar at the University of Saskatchewan (kalyani.premkumar@usask.ca) and/or my UK supervisor, Dr. Tim Harris (Tim.Harris@bartshealth.nhs.uk).

This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call collect.

I, _____, have read and understand the description provided above. I am aware of the nature of the study and understand that I am free to withdraw at anytime during the course of the study. A consent form has been given to me for my records.

_____ _____

(Signature of Participant) (Date)

_____ _____

(Signature of Researcher) (Date)

APPENDIX C

Data Collection Tools for Phase I

EM Trainee
Pre-Intervention
Data Collection Form

1. Please indicate your current level of competence (just prior to this session) with ED U/S

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat competent					Fully competent

2. Please indicate your current level of comfort with High Fidelity Simulation

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat comfortable					Fully comfortable

3. Please indicate the number of times you have participated in High Fidelity simulation activites/learning throughout your medical training

0 1-3 3-5 5-10 >10

4. Please rate how well previous high fidelity simulation scenarios tested your knowledge of **INDICATIONS** for ED ultrasound.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

5. Please rate how well previous high fidelity simulation scenarios tested your ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

6. Please rate how well previous high fidelity simulation scenarios tested your ability to ***INTERPRET*** video-playback ultrasound images.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

7. Please rate how you felt previous high fidelity simulation scenarios tested your ability to ***INTEGRATE*** (diagnosis and management) ED U/S findings as related to the patient's condition.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very Well

8. Please rate the overall ability of previous high fidelity simulation experiences to assist with developing and improving your ED U/S skills.

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat Very well

9. Please rate the overall ability of previous high fidelity simulation scenarios to simulate the use of ED U/S in the management and assessment of critically ill patients.

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat very well

10. Please rate the overall utility of ED U/S in assisting you in the management and assessment of critically ill patients.

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat Very useful

11. Please rate your overall level of **confidence** with ED U/S in terms of:

a) Knowledge of indications

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

b) Image generation

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

c) Image interpretation

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

d) Image integration

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

e) Management and assessment of critically ill patients.

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

11. Please rate how often you are currently using ED U/S in the management of critical care patients.

1 2 3 4 5 6 7 8 9 10

not at all sometimes regularly

Additional
Comments:_____
_____
_____
_____
_____
_____

EM Trainee
Post edus2 Intervention
Data Collection Form

1. Please rate how well the scenarios tested your knowledge of **INDICATIONS** for ED ultrasound.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

2. Please rate how well the scenarios tested your ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

3. Please rate how well the scenarios tested your ability to ***INTERPRET*** the video-playback ultrasound images.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

4. Please rate how you felt the scenarios tested your to ***INTEGRATE*** (diagnosis and management) the ED U/S findings as related to the patient's condition.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

5. Please rate the overall ability of these cases to assist with improving your ED U/S skills.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

6. Please rate the overall ability of these cases to simulate the use of ED U/S in the management and assessment of critically ill patients.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

7. Please rate the overall ability of these cases in improving your ability to manage patients who are critically ill.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very useful

8. Having completed 2 cases, please indicate your current level of competence (just prior to this session) with ED U/S

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat competent					Fully competent

9. Having completed 2 cases, please rate your overall level of **confidence** with ED U/S in terms of:

a) Knowledge of indications

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat confident					Very confident

b) Image generation

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat confident					Very confident

c) Image interpretation

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat confident					Very confident

d) Image integration

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat confident					Very confident

e) Management and assessment of critically ill patients.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat confident					Very confident

10. Please rate how likely you are to use ED U/S in the management of critically ill patients.

1	2	3	4	5	6	7	8	9	10
not at all				sometimes					regularly

EM Trainee
Post video-playback Intervention
Data Collection Form

1. Please rate how well the scenarios tested your knowledge of **INDICATIONS** for ED ultrasound.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

2. Please rate how well the scenarios tested your ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

3. Please rate how well the scenarios tested your ability to ***INTERPRET*** the video-playback ultrasound images.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

4. Please rate how you felt the scenarios tested your to ***INTEGRATE*** (diagnosis and management) the ED U/S findings a related to the patient's condition.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

5. Please rate the overall ability of these cases to assist with improving your ED U/S skills.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

6. Please rate the overall ability of these cases to simulate the use of ED U/S in the management and assessment of critically ill patients.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

7. Please rate the overall ability of these cases in improving your ability to manage patients who are critically ill.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

8. Having completed 2 cases, please indicate your current level of competence (just prior to this session) with ED U/S

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat competent Fully competent

9. Having completed 2 cases, please rate your overall level of **confidence** with ED U/S in terms of:

a) Knowledge of indications

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

b) Image generation

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

c) Image interpretation

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

d) Image integration

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

e) Management and assessment of critically ill patients.

1 2 3 4 5 6 7 8 9 10
Not at all Somewhat confident Very confident

10. Please rate how likely you are to use ED U/S in the management of critically ill patients.

1 2 3 4 5 6 7 8 9 10
not at all sometimes regularly

Instructor
Pre-Intervention
Data Collection Form

1. Please rate how well the previous high fidelity simulation scenarios allowed you to assess a trainee's knowledge of **INDICATIONS** for ED ultrasound.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

2. Please rate how well previous high fidelity simulation scenarios allowed you to assess a trainee's use of an ultrasound machine to ***GENERATE*** an ultrasound image.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

3. Please rate how well previous high fidelity simulation scenarios allowed you to assess a trainee's ability to ***INTERPRET*** video-playback ultrasound images.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

4. Please rate how you felt previous high fidelity simulation scenarios allowed you to assess a trainee's ability to ***INTEGRATE*** (diagnosis and management) ED U/S findings as related to the patient's condition.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

5. Please describe the degree to which previous high fidelity simulation sessions (that had integrated ED U/S) impacted the direction of the debrief session held after each HFS cases.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Please explain:

_____

_____

_____

6. Please rate the degree to which previous high fidelity simulation scenarios assisted you in offering feedback to the trainee regarding his/her ED U/S skills and development

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Please explain:

_____
_____
_____

7. Please rate the overall ability of previous high fidelity simulation experiences to allow for the assessment of trainee ED U/S skills.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

8. Please rate the overall ability of previous high fidelity simulation scenarios to simulate the use of ED U/S in the management and assessment of critically ill patients.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Instructor/Faculty
Post edus2 Intervention
Data Collection Form

1. Please rate how well the scenarios allowed you to assess the trainee's knowledge of **INDICATIONS** for ED ultrasound.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

2. Please rate how well the scenarios allowed you to assess the trainee's ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

3. Please rate how well the scenarios tested allowed you to assess the trainee's ability to ***INTERPRET*** the video-playback ultrasound images.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

4. Please rate how you felt the scenarios allowed you to assess the trainee's ability to ***INTEGRATE*** (diagnosis and management) the ED U/S findings a related to the patient's condition.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

5. Please describe the degree to which the intervention (edus2) impacted the direction of the debrief session held after each case.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Please explain:

_____

_____

_____

6. Please rate the degree to which the intervention (edus2) assisted you in offering feedback to the trainee regarding his/her ED U/S skills and development

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Please explain:

_____

_____

_____

7. Please rate the overall ability of these cases to assess the ED U/S skills of the trainee.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

8. Please rate the overall ability of these cases to simulate the use of ED U/S in the management and assessment of critically ill patients.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Instructor/Faculty
Post video playback Intervention
Data Collection Form

. Please rate how well the scenarios allowed you to assess the trainee's knowledge of **INDICATIONS** for ED ultrasound.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

2. Please rate how well the scenarios allowed you to assess the trainee's ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

3. Please rate how well the scenarios tested allowed you to assess the trainee's ability to ***INTERPRET*** the video-playback ultrasound images.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

4. Please rate how you felt the scenarios allowed you to assess the trainee's ability to ***INTEGRATE*** (diagnosis and management) the ED U/S findings a related to the patient's condition.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

5. Please describe the degree to which the intervention (video playback) impacted the direction of the debrief session held after each case.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Please explain:

_____

_____

_____

6. Please rate the degree to which the intervention (video playback) assisted you in offering feedback to the trainee regarding his/her ED U/S skills and development

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

Please explain:

_____

_____

_____

7. Please rate the overall ability of these cases to assess the ED U/S skills of the trainee.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

8. Please rate the overall ability of these cases to simulate the use of ED U/S in the management and assessment of critically ill patients.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat					Very well

HFS EDUS Study follow-up online survey for EM trainee participants

As a follow up evaluation of your participation in the study entitled: How Does an Ultrasound SimulatorContribute to the Development and Assessment of Emergency Department Ultrasound (ED U/S) Skills inEM Trainees? we are requesting you answer this brief, anonymous questionnaire. Responses will be combined with those of others in hopes of better understanding the educational merits / limits of the interventions in question.

Participation is voluntary, if you have any question about the study you can ontactp.olszynski@usask.ca. This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975. By completing and submitting the questionnaire, YOUR FREE AND INFORMED CONSENT IS IMPLIED and indicates that you understand the above conditions of participation in this study.

Page #1
1. To which trainee group did you belong?
Group A
Group B

2. In terms of the interventions, please choose all that apply:
- I operated the ultrasound probe based simulator during a case
- I observed others operate the ultrasound probe based simulator during a case
- I was in mission control room while others operated the ultrasound probe based simulator during a case
- I operated the laptop video-playback ultrasound simulator during a case
- I observed others operate the laptop video-playback ultrasound simulator during a case
- I was in mission control while others operated the laptop video-playback ultrasound simulator during a case

3. Having completed the HFS EDUS course/study, please rank the ED ultrasound simulation interventions in order of your preference (do so by dragging the rank item on the left over to the corresponding intervention).
- The simulator with the handheld ultrasound probe
- the laptop on the steel cart that played ultrasound clips
- Previous ultrasound simulation from a previous course

4. Please elaborate on your reasons for choosing your rank order in question 3.

_____

5. With regard to question 3, please briefly describe your previous experience with ED U/S simulation during High Fidelity
Simulation Scenarios

_____

6. In terms of the course interventions (simulator with probe the laptop with video clips), what are the advantages/disadvantages
of each of the intervention?
Advantages _____
Disadvantages _____

Page #2

7. In what ways and to what extent has the ED U/S simulation experience influenced your clinical work? Please explain.
_____

8. In what ways and to what extent has the ED U/S simulation experience influenced your education/training? Please explain.
_____

9. After having attended the course, how would you describe your level of confidence in terms of your ED U/S skills?
Increased overall confidence in my ED U/S skills
Decreased overall confidence in my ED U/S skills
No change in overall confidence in my ED U/S skills

10. Please explain your answer to question 9
_____

11. Please share with the study team any additional thoughts regarding your experience at the course and/or the use of ultrasound simulation in the development of your ED U/S skills.
_____

APPENDIX D

Data Collection Tools Phase II

Instructor/Faculty
During Intervention
Tamponade Data Collection Form

Please use the following scale for scoring

1	2	3	4	5
Not at all	Minimally	Somewhat/Describes	Mostly	Completely

1. Please describe the trainee's knowledge of **INDICATIONS** for ED ultrasound.

a) Employs ED U/S to assist with the assessment of the patient (either asks for video playback or employs the edus2) 1 2 3 4 5

b) Uses appropriate scans

- Subxiphoid for PCE 1 2 3 4 5

2. Please rate the trainee's ability to use an ultrasound machine to ***GENERATE*** an ultrasound image during this scenario.

a) Appropriate technique (verbalization in video playback arm)

- appropriate (simulated) use of gel, towels, exposure 1 2 3 4 5
- probe marker in proper position (either to patient right or cephalad) 1 2 3 4 5
- correct anatomical landmarks for PCE 1 2 3 4 5
-

3. Please answer if the trainee was able to ***INTERPRET*** the video-playback ultrasound images

a) Correctly identifies

- pericardial effusion 1 2 3 4 5
- evidence of tamponade 1 2 3 4 5

5. Please describe the trainee's ability to ***INTEGRATE*** (diagnosis and management) the ED U/S findings as related to the patient's condition.

a) Emergent pericardiocentesis 1 2 3 4 5

b) TIME to ED U/S: _____

6. Please rate the **INTERVENTION**'s performance in allowing the trainee to show their ED U/S skill set during this scenario.

a) Knowledge of indications 1 2 3 4 5

b) Image generation

- Proper use of probe and machine 1 2 3 4 5
- Correct anatomical landmarks 1 2 3 4 5

c) Image interpretation 1 2 3 4 5

d) Image integration into clinical management 1 2 3 4 5

e) TIME to ED U/S:_____

6. Please rate the overall ability of **this case** to assess the ED U/S skills of the trainee.

1 2 3 4 5 6 7 8 9 10

Not at all Somewhat competent Fully competent

Instructor/Faculty
During Intervention
AAA Data Collection Form

Please use the following scale for scoring

1	2	3	4	5
Not at all	Minimally	Somewhat/Describes	Mostly	Completely

1. Please describe the trainee's knowledge of **INDICATIONS** for ED ultrasound.

a) Employs ED U/S to assist with the assessment of the patient (either asks for video playback or employs the edus2) 1 2 3 4 5

b) Uses appropriate scans

- Addominal scan from sub-xiphoid to peri-umbolical 1 2 3 4 5

2. Please rate the trainee's ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

a) Appropriate technique (verbalization for video playback arm)

- appropriate (simulated) use of gel, towels, exposure 1 2 3 4 5
- probe marker in proper position (either to patient right or cephalad) 1 2 3 4 5
- correct anatomical landmarks for AAA 1 2 3 4 5
-

3. Please answer if the trainee was able to ***INTERPRET*** the video-playback ultrasound images

a) Correctly identifies

- Abdominal Aortic Aneurysm 1 2 3 4 5

4. Please describe the trainee's ability to ***INTEGRATE*** (diagnosis and management) the ED U/S findings as related to the patient's condition.

a) Emergent consult to Vascular surgery 1 2 3 4 5

5. Please rate the **INTERVENTION**'s performance in allowing the trainee to show their ED U/S skill set during this scenario.

a) Knowledge of indications 1 2 3 4 5

b) Image generation

- Proper use of probe and machine 1 2 3 4 5
- Correct anatomical landmarks 1 2 3 4 5

c) Image interpretation 1 2 3 4 5

d) Image integration into clinical management 1 2 3 4 5

e) TIME to ED U/S: _____

6. Please rate the overall ability of **this case** to assess the ED U/S skills of the trainee.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat competent				Fully competen	

Instructor/Faculty
During Intervention
FAST Data Collection Form

Please use the following scale for scoring

1	2	3	4	5
Not at all	Minimally	Somewhat/Describes	Mostly	Completely

1. Please describe the trainee's knowledge of **INDICATIONS** for ED ultrasound.

a) Employs ED U/S to assist with the assessment of the patient (either asks for video playback or employs the edus2)	1	2	3	4	5
b) Uses appropriate scans					
- Subxiphoid for PCE	1	2	3	4	5
- Rt and Lt. Flank for upper quadrant scans for abd free fluid	1	2	3	4	5
- Suprapubic for pelvic free fluid	1	2	3	4	5
- repeat FAST with change in patient status	1	2	3	4	5

2. Please rate the trainee's ability to use an ultrasound machine to ***GENERATE*** an ultrasound image.

a) Appropriate technique (N/A for video playback arm)					
- appropriate (simulated) use of gel, towels, exposure	1	2	3	4	5
- probe marker in proper position (either to patient right or cephalad)	1	2	3	4	5
- correct anatomical landmarks for FAST	1	2	3	4	5

-

3. Please answer if the trainee was able to ***INTERPRET*** the video-playback ultrasound images

a) Correctly identifies					
- no pericardial effusion	1	2	3	4	5
- Free Fluid in the RUQ	1	2	3	4	5
- No Free Fluid in LUQ	1	2	3	4	5
- No Pelvic fluid seen	1	2	3	4	5
- Free Fluid seen on repeat scan in RUQ	1	2	3	4	5

4. Please describe the trainee's ability to ***INTEGRATE*** (diagnosis and management) the ED U/S findings a related to the patient's condition.

a) Emergent surgical consult in setting hemoperitoneum	1	2	3	4	5

5. Please rate the **INTERVENTION**'s performance in allowing the trainee to show their ED U/S skill set during this scenario.

a) Knowledge of indications	1	2	3	4	5
b) Image generation					
- Proper use of probe and machine	1	2	3	4	5
- Correct anatomical landmarks	1	2	3	4	5
c) Image interpretation	1	2	3	4	5
d) Image integration into clinical management	1	2	3	4	5

e) TIME to ED U/S: _____

6. Please rate the overall ability of **this case** to assess the ED U/S skills of the trainee.

1	2	3	4	5	6	7	8	9	10
Not at all				Somewhat competent				Fully competent	

APPENDIX E

SIMULATION SCENARIO

I. **Title:** U/SS case 3 Multi-trauma patient with Liver Laceration / Intra-abdominal Hemorrhage

II. **Date Created:** January 31, 2006
Date Revised: December 22, 2007

III. **Category:** Ultrasound Simulation; Teamwork / Resident Core Curriculum; ACLS

IV. **Target Audience**: undergraduate and graduate medical trainees and staff, nurses, paramedics

V. **Learning Objectives or Assessment Objectives**

A. Primary -
- a.) recognition and management of semi-stable trauma patient
- b.) recognition and management of natural progression / deterioration of hemorrhaging intra-abdominal lesion
- c.) recognition and management of hemorrhaging liver laceration
- d.) integration of serial or repeated bedside ultrasonography into an organized trauma resuscitation
- e.) deployment of teamwork behaviors

B. Secondary -
- a.) appropriate airway management
- b.) appropriate circulatory support
- c.) appropriate consultation and disposition

C. Critical actions checklist (see Appendix A, figure)-

1. Simple checklist of critical actions
   - a.) call for help (Level I trauma- blunt trauma with hypotension)
   - b.) establishment of team structure with role assignment
   - c.) deployment of appropriate communications and teamwork behaviors
   - d.) primary trauma survey
   - e.) basic airway / breathing management (100% oxygen administration)
   - f.) recognition of circulatory dysfunction
   - g.) basic circulatory support (cardiac monitor, intravenous access, fluid administration)
   - h.) advanced circulatory support (blood product administration, Foley)
   - i.) secondary trauma survey
   - j.) traumatic hypotension evaluation and management (reviews injury mechanism and patterns, implementation of specific testing and treatment- CXR, pelvis XR, FAST #1 [negative])
   - k.) recognition of initial response to circulatory support
   - l.) recognition of recurrent hemodynamic deterioration (partial-responder state)
   - m.) institution of early packed red blood cell (PRBC) transfusion
   - n.) traumatic hypotension re-evaluation and management (incl. FAST #2)

o.) recognition of abnormal FAST #2 [positive right upper quadrant (RUQ) fluid stripe]
p.) disposition to operating room (OR)

2. Optimal sequence of critical actions- expected sequence as above
3. Duration to critical actions- resuscitation to be completed within 20-25 minutes of starting scenario
4. Behavioral ratings- see Appendix A, figure

VI. ACGME Competencies Assessed

A. Patient Care
B. Medical Knowledge
C. Interpersonal/Communication Skills

VII. Environment and Props

A. Lab Set Up – Emergency Department in simulation center / lab
B. Manikin Set Up –
   a.) advanced medical simulation manikin
   b.) male patient moulage with street clothing, c-collar / backboard, O2 mask
   c.) lines needed: right antecubital 18g IV
   d.) drugs needed: PRBC, fluid (normal saline [NS])
C. Props – see "USS CASE 3 IMAGES" folder
   (basic airway and code blue cart is assumed)
   a.) ECGs: sinus tachycardia 90-100s
   b.) bedside ultrasound: normal FAST
   abnormal FAST (fluid in Morrison's Pouch)
D. Distractors – none

VIII. Simulation Personnel and Assigned Roles (Faculty, Actors, etc)

A. Roles – paramedic x 1-2, nurse x 1, trauma surgeon
B. Who may play them – other residents, other students, actors
C. Action Role – supportive (see narrative)

IX. Case Narrative (describes what the learner will experience)

A. Paragraph narrative overview of case and how case starts-

At 1pm, EMS brings in a 35 year old man who was a restrained passenger from an motor vehicle crash (MVC) who was struck on his side ("T-boned") by a pickup truck, some intrusion of door into passenger compartment, prolonged extrication because door was stuck. Patient is alert and talking, complaining of mild right chest pain, says it hurts a little to breathe. No obvious extremity deformities. VS in the field: HR 96, BP 95/60, Sa02 99% on 100% NRB. NS 1L running; 750 cc remaining.

B. Patient information-

1. Name/Age/Sex: Brian R. 35 year old male
2. Mode of arrival: EMS
3. Accompanied by: none (driver refused treatment)
4. Triage Note: n/a
5. Chief Complaint: **"My chest hurts a little when I breathe. Can you get this plastic neck thing off?"**
6. Past Medical History: **tuberculosis exposure remotely (+PPD)**
7. Medications and Allergies: none, **allergic to niacin (flushing)**
8. Family and Social History: occasional smoker; welder
9. Patient's Initial Exam:

Vital signs:
- heart rate: **98 bpm**
- blood pressure: **97/58**
- respiratory rate: 12
- oxygen saturation: 99% on 100% NRB; 98% RA
- temperature: 98.4

Airway: intact

Breathing: **slight splinting on right**

Circulation: good pulses, warm extremities

Secondary Exam: well-developed male

HEENT: normal

Neck: no JVP noted; **midline neck tenderness**

Lungs: clear bilateral with full inspiration
right chest + costal tenderness

Cardiac: normal

Abdomen: **right costal margin tenderness**

Extremities: warm

Neurologic: GCS 15 (E4/V5/M6). pupils 4mm

Additional information:

Fingerstick blood sugar: normal

EKG: normal sinus rhythm 96

C-spine XR: normal

CXR: no pneumothorax or hemothorax

pelvis XR: normal

FAST #1: negative FAST #2: +fluid in right upper quadrant (Morrison's Pouch)

C. Flow diagram with branch points, times of expected interventions and reactions from Sim Man with notes (see Appendix A, figure + B)

Case progression:

1. After 2 liter fluid bolus for "soft" hypotension, blood pressure improves for 15 minutes.
   Vital signs: heart rate: 94 / minute
   blood pressure: 108 / 70 mmHg
   respirations: 11 / minute
   Trauma resuscitation + evaluation continue during this time.

2. After 15 minutes of hemodynamic stability (approximately 20 minutes into scenario), blood pressure starts to drop into systolic 80s. [Note: simulation scenario time may be "accelerated" if needed to accommodate this temporal progression by programming event button for advancement to recurrent hypotensive manikin frame/state.] Patient will still remain semi-stable at SBP 90s with blood products, but SBP does not go above 100. FAST #2 at this point will be positive.

3. Given persistent hypotension despite fluid resuscitation in a semi-stable state with a positive FAST, the patient should be dispositioned urgently to the operating room. (Diagnostic peritoneal lavage [DPL] is an option and will be positive.)

4. The patient will remain alert with minimal complaints in the persistently "semi-stable" state for the remainder of the case. (This may make the decisions regarding imaging (FAST, CT) and disposition issues (O.R., Interventional Radiology) more subtle.)

D. Distracters in case: none

E. Trends needed: none

X. Instructors Notes (what the instructor must do to create the experience)

A. Tips to keep scenario flowing in lab and via computer
   - presentation of patient in extremis hypotension.
   - lulls in activity may be broken with re-entry of EMS

B. Tips to direct actors- as above

C. Scenario programming- see Appendix B
   1. Optimal management path
   2. Potential complications path(s)
   3. Potential errors path(s)
   4. Program debugging

XI. Debriefing Plan

A. Method of debriefing

1. This is a case of a blunt thoracoabdominal trauma patient who is hiding a significant liver laceration and intra-abdominal hemorrhage. With minimal complaints and partially-responsive vitals signs that start to deteriorate, he needs to remain in the Resuscitation area and be dispositioned based on his instability and changing bedside sonographic findings.

2. Debriefing Topics

a.) didactic content

- emergency ultrasound in trauma patients (FAST / E-FAST)
  - 4+ views
  - limits of detection
  - serial or repeat FAST exams for re-examination of patients with persistent or recurrent instability

- liver laceration with free intra-abdominal hemorrhage
  - presentation
    - -intra-abdominal injuries associated with chest injury and hematuria as surrogate markers
    - -10% of abdominal injuries diagnosed by CT have no abdominal tenderness or abdominal wall bruising
    - -*may* have profound hemodynamic instability
  - evaluation
    - -labs (serial bloods, lactate)
    - -role of bedside FAST to assess presence of intra-abdominal bleeding
    - -? DPL
    - -operative evaluation / laparoscopy
    - -CT scan if patient is hemodynamically stable
  - treatment
    - -aggressive hemodynamic resuscitation
    - -interventional radiology
    - -operative exploration / management
  - -disposition
    - -OBS admit
    - -ICU admit
    - -Interventional Radiology
    - -O.R.

b.) teamwork behaviors

- -leadership
  - -resuscitation leadership establishment
  - -role and responsibility assignment
- -collaboration
  - -recognition and integration of team input

-error recognition and correction
-communication
-callouts of critical information
-callbacks for confirmation of information
-situational awareness
-continued patient reassessment
-plan development and execution
-task prioritization
-workload assessment
-team member cross-monitoring
-requests for assistance
-professionalism

XII. Pilot Testing and Revisions

A. Numbers of participants- 3-5 learners (1-2 leaders)
B. Performance expectations, anticipated management mistakes
-not obtaining FAST #1
-not reassessing patient with change in status
-not repeating FAST

XIII. Authors and their affiliations

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Additional authors: Arun Nagdev, MD; RIHMSC, Rhode Island Hospital
Frantz Gibbs, MD; RIHMSC, Rhode Island Hospital

XIV. Additional Debriefing Materials:

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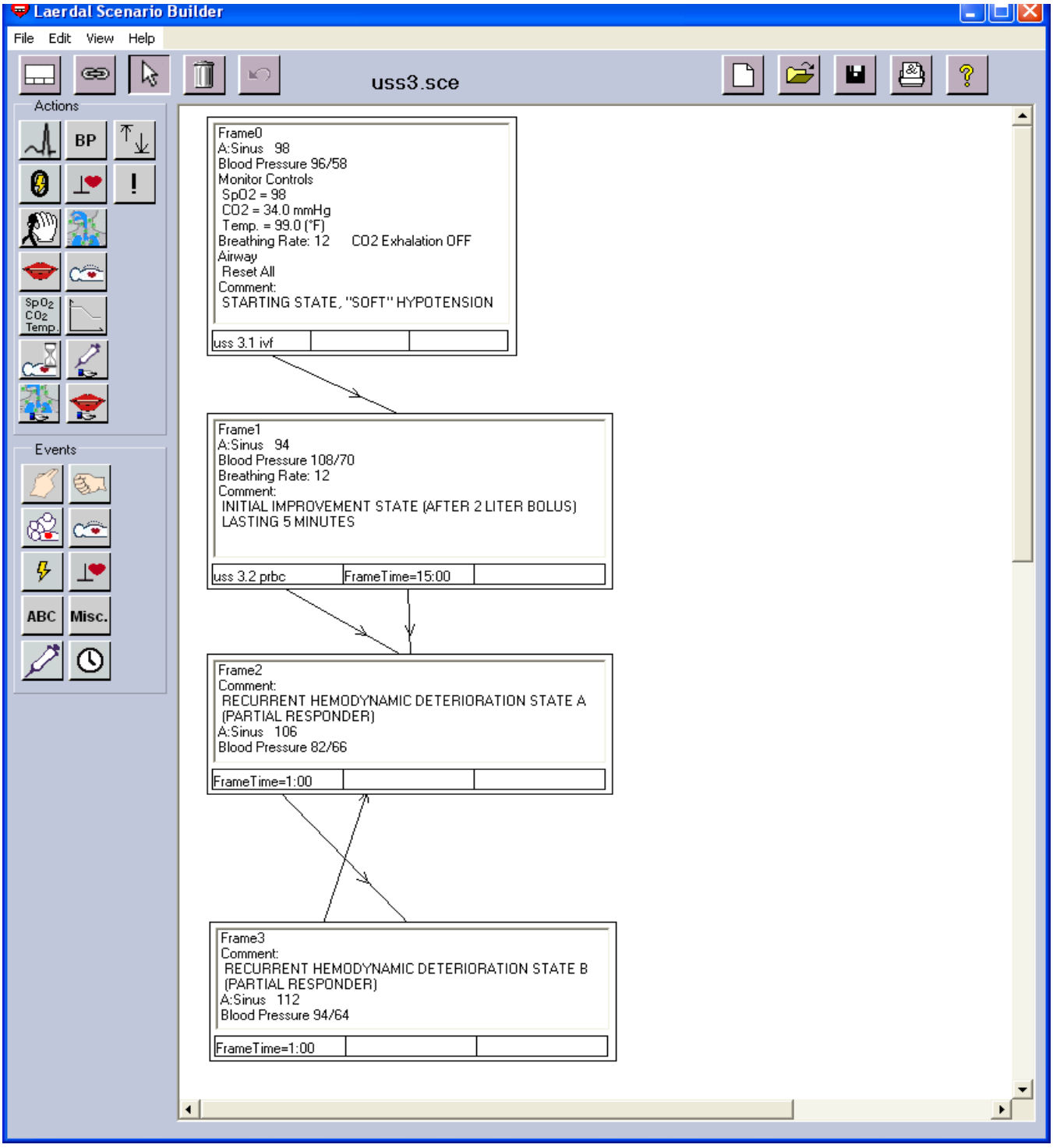
Laerdal SimMan v2.2 scenario content



Note: The events to force transitions to a new frame will need to be edited via the "Edit Event Menus" feature within Scenario Builder

I. Title: U/SS Case 5
Elderly Patient with Syncope / Leaking Abdominal Aortic Aneurysm

II. Date Created: February 8, 2006
Date Revised: December 22, 2007

III. Category: Ultrasound Simulation; Teamwork / Resident Core Curriculum; ACLS

IV. Target Audience: undergraduate and graduate medical trainees and staff, nurses, paramedics

V. Learning Objectives or Assessment Objectives

D. Primary -
- f.) recognition and management of semi-stable non-traumatic patient
- g.) recognition and management of hypotensive patient progressing into extremis
- h.) recognition and management of unstable patient with suspected leaking aortic aneurysm
- i.) integration of bedside ultrasonography into an organized medical resuscitation
- j.) deployment of teamwork behaviors

E. Secondary -
- d.) appropriate airway management
- e.) appropriate circulatory support
- f.) appropriate consultation and disposition

F. Critical actions checklist (see Appendix A, figure)-
1. Simple checklist of critical actions
- q.) call for help (Level I trauma- fall with hypotension)
- r.) establishment of team structure with role assignment
- s.) deployment of appropriate communications and teamwork behaviors
- t.) primary trauma survey
- u.) basic airway / breathing management (100% oxygen administration)
- v.) recognition of circulatory dysfunction
- w.) basic circulatory support (cardiac monitor, intravenous access, fluid administration)
- x.) advanced circulatory support (blood product administration, Foley)
- y.) secondary trauma survey
- z.) evaluation and management of potential traumatic causes of hypotension (reviews injury mechanism and patterns, implementation of specific testing and treatment- CXR, pelvis XR, FAST [negative])
- aa.) exclusion of traumatic causes of hypotension
- bb.) evaluation and management of non-traumatic causes of hypotension (lab testing (hematocrit, electrolytes , toxicologic screens, ultrasonographic aortic evaluation, etc))
- cc.) recognition of abdominal aortic aneurysm with thrombus on abdominal ultrasonography

dd.) emergent vascular surgery consultation

2. Optimal sequence of critical actions- expected sequence as above
3. Duration to critical actions- resuscitation to be completed within 20-25 minutes of starting scenario
4. Behavioral ratings- see Appendix A, figure

VI, ACGME Competencies Assessed

D. Patient Care
E. Medical Knowledge
F. Interpersonal/Communication Skills

VII. Environment and Props

E. Lab Set Up – Emergency Department in simulation center / lab
F. Manikin Set Up –
   a.) advanced medical simulation manikin
   b.) male patient moulage with street clothing, c-collar / backboard, O2 mask
   c.) lines needed: right antecubital 18g IV
   d.) drugs needed: PRBC, fluid (normal saline)
G. Props – see "USS CASE 5 IMAGES" folder
   (basic airway and code blue cart is assumed)
   a.) ECGs: sinus tachycardia 150
   b.) bedside ultrasound: no fluid in Morrison's Pouch
   abd. aortic aneurysm with thrombus
H. Distractors – patient brought in as a questionable trauma secondary to syncopal episode; heart rate not elevated secondary to hypertension medications

VIII. Simulation Personnel and Assigned Roles (Faculty, Actors, etc)

D. Roles – paramedic x 1-2, nurse x 1, trauma surgeon
E. Who may play them – other residents, other students, actors
F. Action Role – supportive (see narrative)

IX. Case Narrative (describes what the learner will experience)

F. Paragraph narrative overview of case and how case starts-

At 2pm, EMS brings in a 65 year old man who was found down at home. His wife states he walked over to the restroom after eating a meal. She then heard a loud noise in the bathroom and found the patient on the floor. She did not note any seizure activity and immediately called EMS. Found in a supine position on the floor as per EMS, he was awake, alert, responsive to verbal stimuli. VS in the field: HR 84, BP 90/50, SaO2 99% on 100% NRB. In the Emergency Department, the patient is moaning and complaining of generalized aches and pains, including headache and lower back pain. The patient has been immobilized

with a cervical collar and backbboard, has an 18g IV in his right antecubital fossa with 1liter normal saline running wide open.

G. Patient information-

1. Name/Age/Sex: Jim C. 65 year old male
2. Mode of arrival: EMS
3. Accompanied by: wife
4. Triage Note: n/a
10. Chief Complaint: **"Everything hurts !"**
11. Past Medical History: **hypertension, diabetes,"high cholesterol"**
12. Medications and Allergies: **atenolol, captopril, hctz, glucophage, lipitor, aspirin; NKDA**
13. Family and Social History: occasional smoker; retired dentist
14. Patient's Initial Exam:

Vital signs: heart rate: 88 bpm
blood pressure: **92/54**
respiratory rate: 18
oxygen saturation: 99% (100% NRB); 98% RA
temperature: 98.4F
Airway: intact
Breathing: clear bilaterally
Circulation: **weak pulses,** warm extremities

Secondary Exam: male patient on backboard
HEENT: **small contusion right forehead**
Neck: no JVP noted; **[+] midline tenderness**; c-collar
Lungs: clear bilateral with full inspiration
Cardiac: normal
Abdomen: **diffuse tenderness**
Back: **diffuse bony tenderness**
Extremities: warm, no signs of trauma
Neurologic: **GCS 12 (E4/V4/M5)**. pupils 4mm

Additional information:
Fingerstick blood sugar: 135
EKG: normal sinus rhythm 88
C-spine XR: normal CXR: no acute findings pelvis XR: normal
FAST: negative
Aortic Ultrasound : 5x4 cm abd. aortic aneurysm + thrombus

H. Flow diagram with branch points, times of expected interventions and reactions from Sim Man with notes (see Appendix A, figure + B)

Case progression:

1. Initial presentation of syncopal patient with unknown etiology. Trauma evaluation should be started secondary to assumed fall (patient is brought in full immobilization).

Vital signs: heart rate: 84 / minute
blood pressure: 80 / 40 mmHg
respirations: 16 / minute

2. Patient may be initially treated as an unstable trauma patient with appropriate evaluation and imaging (c-spine, chest and pelvis radiographs). FAST can be performed to detect intra-abdominal bleeding (negative). With an initial negative trauma evaluation and continued hypotension after 2 liters of saline infusion, other etiologies should be proposed (autonomic / adrenal insufficiency, cardiac contusion, septic shock). The patient remains unstable and cannot go to computed tomography.

3. A bedside abdominal / aortic ultrasound reveals an infrarenal abdominal aortic aneurysm with thrombus. The resident will need to emergently consult vascular surgery to arrange disposition. The patient will not improve with colloid infusion.

I. Distracters in case: suspected traumatic etiology of hypotension; blunted tachycardia secondary to hypertension medication

J. Trends needed: (see Appendix B)

X. Instructors Notes (what the instructor must do to create the experience)

D. Tips to keep scenario flowing in lab and via computer
- presentation of patient with persistent hypotension
- lulls in activity may be broken with entry of wife

E. Tips to direct actors- as above

F. Scenario programming- see Appendix B
5. Optimal management path
6. Potential complications path(s)
7. Potential errors path(s)
8. Program debugging

XI. Debriefing Plan

B. Method of debriefing

1. This is a case of a syncope patient with persistent hemodynamic instability of unclear etiology. Initial evaluation must include a rapid trauma evaluation for potential sources of hypotension. After determining the absence of thoracic, abdominal, pelvic, long bone or external blood loss, other etiologies must be suspected. As a leaking abdominal aortic aneurysm (AAA) can bleed into the retroperitoneal space in an occult manner yet cause significant instability, ultrasound evaluation of the aorta to determine AAA presence / absence can aid in timely management / disposition (and can also evaluate for AAA rupture). Early colloid administration can be also beneficial.

2. Debriefing Topics

a.) didactic content

- emergency ultrasound in trauma patients (FAST)
  - 4+ views
  - limits of detection (retroperitoneal space)
  - additional utility in evaluating AAA rupture into peritoneum

- abdominal aortic aneurysm with retroperitoneal bleeding
  - presentation
    - -hypotension of unknown etiology (patients commonly unaware of pathology)
    - -hemodynamic instability (may be absent or profound)
  - evaluation
    - -labs (serial bloods, lactate)
    - -role of bedside FAST to assess presence of intra-abdominal bleeding
    - -role of bedside ultrasound for aortic aneurysm
    - -CT scan / angiography if patient is stable
  - treatment
    - -aggressive hemodynamic resuscitation
    - -vascular surgery consultation
  - -disposition
    - -Interventional Radiology (? stenting) or Operating Room [OR]

b.) teamwork behaviors

- -leadership
  - -resuscitation leadership establishment
  - -role and responsibility assignment
- -collaboration
  - -recognition and integration of team input
  - -error recognition and correction
- -communication
  - -callouts of critical information
  - -callbacks for confirmation of information

-situational awareness
-continued patient reassessment
-plan development and execution
-task prioritization
-workload assessment
-team member cross-monitoring
-requests for assistance
-professionalism

XII. Pilot Testing and Revisions

C. Numbers of participants- 3-5 learners (1-2 leaders)
D. Performance expectations, anticipated management mistakes
-not obtaining FAST
-not obtaining ultrasound of aorta

XIII. Authors and their affiliations

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Additional authors: Leo Kobayashi, MD; RIHMSC, Rhode Island Hospital
Frantz Gibbs, MD; RIHMSC, Rhode Island Hospital

XIV. Additional Debriefing Materials:

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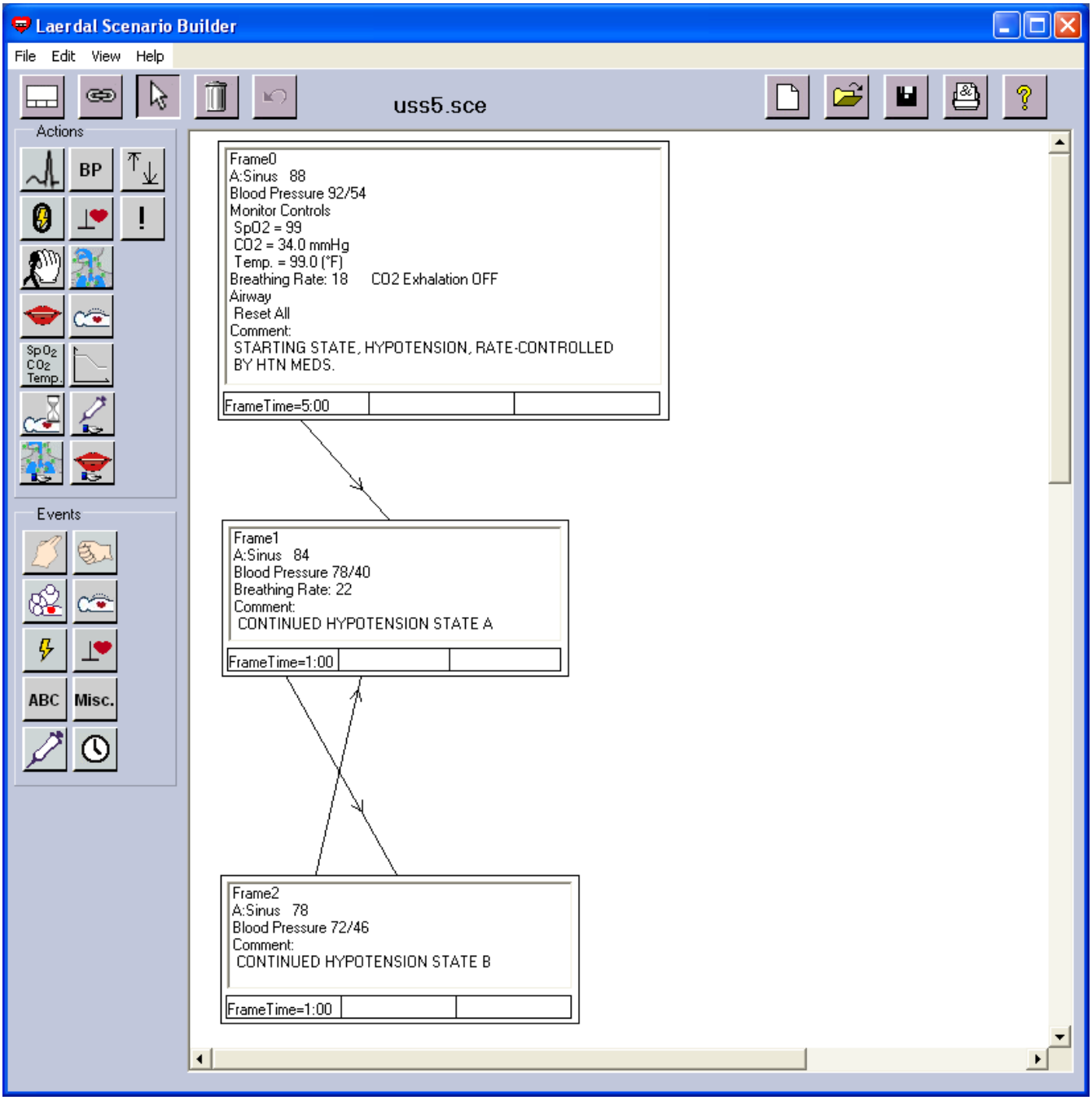
Constantino TG, Bruno EC, Handly N et al. Accuracy of emergency medicine ultrasound in the evaluation of abdominal aortic aneurysm. *J Emerg Med* 2006: 29(4): 455-60.

Knaut AL, Kendall JL, Patten R et al. Ultrasonographic measurement of aortic diameter by emergency physicians approximates results obtained by computed tomography. *J Emerg Med* 2005; 28(2): 119-26.

O'Connor R. Aneurysm, abdominal. In eMedicine Specialties > Emergency Medicine > Cardiovascular. Bessman E, Talavera F, Setnik G et al. (eds), eMedicine Web site. Updated October 26, 2005. Available at: http://www.emedicine.com/emerg/topic27.htm Accessed December 11, 2006.

Tang A, Euerle B. Emergency department ultrasound and echocardiography. *Emerg Med Clin North Am* 2005; 23(4): 1179-94

Laerdal SimMan v2.2 scenario content



Note: The events to force transitions to a new frame will need to be edited via the "Edit Event Menus" feature within Scenario Builder

Title: USS case 2
Cardiogenic Shock Secondary to Malignant Pericardial Effusion

XV. Date Created: February 12, 2006
Date Revised: December 22, 2007

XVI. Category: Ultrasound Simulation; Teamwork / Resident Core Curriculum; ACLS

XVII. Target Audience: undergraduate and graduate medical trainees and staff, nurses, paramedics

XVIII. Learning Objectives or Assessment Objectives

G. Primary -
- k.) recognition and management of non-traumatic hypotensive patient
- l.) recognition and management of cardiac tamponade causing hemodynamic instability or collapse
- m.) integration of bedside ultrasonography into an organized medical resuscitation
- n.) deployment of teamwork behaviors

H. Secondary -
- g.) appropriate airway management
- h.) appropriate circulatory support
- i.) appropriate consultation and disposition

I. Critical actions checklist (see Appendix A, figure)-

1. Simple checklist of critical actions
- ee.)recognition of respiratory failure (dyspnea, hypoxia)
- ff.) recognition of impending circulatory failure
- gg.) call for help
- hh.) establishment of team structure with role assignment
- ii.) deployment of appropriate communications / teamwork behaviors
- jj.) basic airway management (100% oxygen administration with bag-valve-mask or Bilevel Positive Airway Pressure (BiPAP) ventilation)
- kk.) advanced airway management (endotracheal intubation or BiPAP deployment, placement confirmation and securement, ventilator management)
- ll.) advanced circulatory support (cardiac monitor, fluid hydration)
- mm.) non-traumatic hypotension evaluation + management (reviews differential diagnosis, implements specific testing + treatment)
- nn.) recognition of pericardial effusion and cardiac tamponade as possible source of hypotension in non-traumatic elderly patient; use of bedside echocardiography to assess cardiac tamponade
- oo.) institution of aggressive fluid administration
- pp.) pericardiocentesis
- qq.) supportive therapies upon improvement of circulatory function

rr.) emergent Cardiac Surgery / Interventional Radiology consultation 2. Optimal sequence of critical actions- expected sequence as above

3. Duration to critical actions- resuscitation to be completed within 20-25 minutes of starting scenario
4. Behavioral ratings- see Appendix A, figure

XIX. ACGME Competencies Assessed

G. Patient Care
H. Medical Knowledge
I. Interpersonal/Communication Skills

XX. Environment and Props

I. Lab Set Up – Emergency Department in simulation center / lab
J. Manikin Set Up –
   a.) advanced medical simulation manikin
   b.) male patient moulage with bedtime clothing
   c.) lines needed: none
   j.) drugs needed: pt prescription bottles, IV fluid (normal saline [NS])
K. Props – see "USS CASE 2 IMAGES" folder
   (basic airway and code blue cart is assumed)
   a.) ECGs: narrow complex rhythm 100s, low voltage, strain pattern
   b.) bedside ultrasound: pericardial fluid with tamponade
   c.) special resuscitative equipment (BiPAP, pericardial drainage kit)
L. Distractors – none

XXI. Simulation Personnel and Assigned Roles (Faculty, Actors, etc)

G. Roles – paramedic x 1, nurse x 1
H. Who may play them – other residents, other students, actors
I. Action Role – supportive (see narrative)

Case Narrative (describes what the learner will experience)

K. Paragraph narrative overview of case and how case starts-

At 1am, EMS brings in a 67 year old man who developed severe shortness of breath and weakness in bed at home while trying to get to sleep. He has been ill for the past week or so with loss of energy and appetite, taking aspirins for generalized malaise, aches, and swelling Further history is limited due to severe dyspnea. Medics were able to bring his medications bottles. No family / contact is available at this time.

L. Patient information-

1. Name/Age/Sex: Demetrios S. 67 year old male
2. Mode of arrival: EMS
3. Accompanied by: n/a
4. Triage Note: n/a
15. Chief Complaint: **"i...can't...breathe...suffocating"**
16. Past Medical History: **"blood clots", (EMS ? emphysema, gout, hypertension, prostate cancer (prostatectomy, radiation treatment in past), perforated colonic diverticulum (colostomy + reversal)**
17. Medications and Allergies: **"can't...remember"**
    (EMS brought bottles of Cardizem, Bumex, Proscar, lisinopril, aspirin)
    - allergic to sulfa
18. Family and Social History: smoker
19. Patient's Initial Exam:

Vital signs: heart rate: **112 bpm**
blood pressure: **62/48**
respiratory rate: **32**
oxygen saturation: **91%**
temperature: 98.8
Airway: intact
Breathing: **dyspneic / tachypneic**
Circulation: **weak femoral pulses, cool extremities**

Secondary Exam: elderly male
HEENT: NCAT
Neck: **JVP noted at 7cm**
Lungs: **coarse rhonchi + rales throughout**
Cardiac: **tachycardic, sl. muffled heart sounds**
Abdomen: sl. distended, non-tender, **diminished BS**
Extremities: **cool, 2+ edema**
Neurologic: GCS 15 (E4/V5/M6).

Additional information:
Fingerstick blood sugar: **168**
EKG: **narrow complex 100s, low voltage, strain pattern**
CXR: **cardiomegaly, pulm edema**

Bedside ultrasound: +large amount pericardial fluid, RV collapse

M. Flow diagram with branch points, times of expected interventions and reactions from Sim Man with notes (see Appendix A, figure + B)

Case progression:

1. Airway and breathing management with O2, endotracheal intubation or BiPAP mask ventilation. Some improvement in oxygenation, but persistent hypotension. After positive-pressure ventilation (intubation / BiPAP), auto-PEEP with reduced systemic venous return compounded by effects of congestive heart failure (CHF) treatments result in worsening tamponade physiology:
   Vital signs: heart rate: 122 / minute
   blood pressure: 54 / 40 mmHg
   respirations: ventilated
   oxygen saturation: poor waveform, 90s?

2. If performed, bedside emergency echocardiography will reveal a large amount of pericardial fluid and RV collapse. FAST and abdominal ultrasonography will be unremarkable (slight abdominal ascites). This should lead to both aggressive isotonic fluid infusion and pericardiocentesis (non-guided, "ultrasound battery just died") within 5 minutes, or the patient will go into PEA and arrest. If not performed previously, the arrest should prompt bedside echocardiography and reveal the diagnosis. Disposition for further definitive treatment (pigtail pericardial catheter, pericardiotomy, pericardial window, etc) will need to be arranged for case completion.

N. Distracters in case: broad differential, including the following etiologies
   -cardiogenic (+cardiac risk factors, prior clots)
   -endocrine
   -hemorrhagic
   -hypovolemic
   -iatrogenic / medication
   -neoplastic / paraneoplastic
      - occult lung CA with metastases
      - unclear history of prostate CA extent
   -sepsis

O. Trends needed: none

XXII. Instructors Notes (what the instructor must do to create the experience)

G. Tips to keep scenario flowing in lab and via computer
   - presentation of patient in extremis / hypotension.

H. Tips to direct actors- as above

I. Scenario programming- see Appendix B

9. Optimal management path
10. Potential complications path(s)
11. Potential errors path(s)

12. Program debugging

Debriefing Plan

C. Method of debriefing

1. This scenario involves a non-traumatic hypotensive presentation in an elderly patient. Non-detected lung cancer with metastatic pericardial lesions is causing pericardial effusion and cardiac tamponade. Necessary resuscitative ventilatory management (endotracheal intubation or BiPAP) results in further clinical deterioration due to intra-thoracic mechanical consequences of positive-pressure ventilation. Bedside ultrasonographic examinations can rapidly narrow the differential and establish the cause of cardiopulmonary instability for definitive intervention. Early resuscitation with crystalloid and pericardial fluid evacuation can prevent arrest.

2. Debriefing Topics

a.) didactic content

- bedside emergency echocardiography
  - indications
  - windows (subxiphoid, parasternal)
  - findings (structural, functional)

- airway management
  - indications and technique of endotracheal intubation
  - complications of positive pressure ventilation

- pericardial effusion with tamponade physiology
  - presentation
    - -size and rapidity of volume accumulation critical
    - -21% of cancer patients have pericardial metastases (primary: lung, breast, leukemia / lymphoma)
    - -inconsistent nature of Beck's triad
    - -pulsus paradoxus
    - -can be overlooked as "just CHF"
  - evaluation
    - -EKG, chest xray may be misleading
    - -role of bedside echocardiography to assess presence of pericardial fluid (>1cm = large)
    - - formal echocardiography (transthoracic, transesophageal), CT / MRI if patient is hemodynamically stable
  - treatment
    - -hypotension
      - -aggressive hemodynamic resuscitation
      - -bedside pericardiocentesis (ultrasound-guided)
  - -disposition
    - -Inteventional Radiology vs. Operating Room [OR] (pigtail pericardial catheter, pericardiotomy, pericardial window, etc)

- PEA
  - assessment of "electrical" cardiac activity
  - assessment of "mechanical" cardiac activity
  - differential diagnosis (reversible causes)
    - -hypovolemia
    - -hypoxia
    - -hydrogen ion
    - -hyper- or hypo-kalemia
    - -hypothermia
    - -tablets
    - -tamponade
    - -tension PTX
    - -thrombosis (coronary)
    - -thrombosis (PE)
  - use of epinephrine (not vasopressin)
  - specific interventions
    - -sodium bicarbonate
    - -fluid bolus
    - -needle decompression: bilateral
    - -pericardiocentesis: use kit
    - -thrombolytics
    - -rewarming: target 92deg F
  - continuing (prolonged) resuscitative efforts
    - -hypothermia
    - -PE

b.) teamwork behaviors
- -leadership
  - -resuscitation leadership establishment
  - -role and responsibility assignment
- -collaboration
  - -recognition and integration of team input
  - -error recognition and correction
- -communication
  - -callouts of critical information
  - -callbacks for confirmation of information
- -situational awareness
  - -continued patient reassessment
  - -plan development and execution
  - -task prioritization
  - -workload assessment
  - -team member cross-monitoring
  - -requests for assistance
- -professionalism

IX. Pilot Testing and Revisions

E. Numbers of participants- 3-5 learners (1-2 leaders)

F. Performance expectations, anticipated management mistakes
   -not considering pericardial effusion and tamponade

-not exploiting ultrasonography to include or exclude life-threatening diseases on the differential
-premature termination of resuscitative efforts

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XI. Additional Debriefing Materials:

Meltser H, Kalaria VG. Cardiac tamponade. *Catheter Cardiovasc Interv* 2005; 64(2): 245-55.

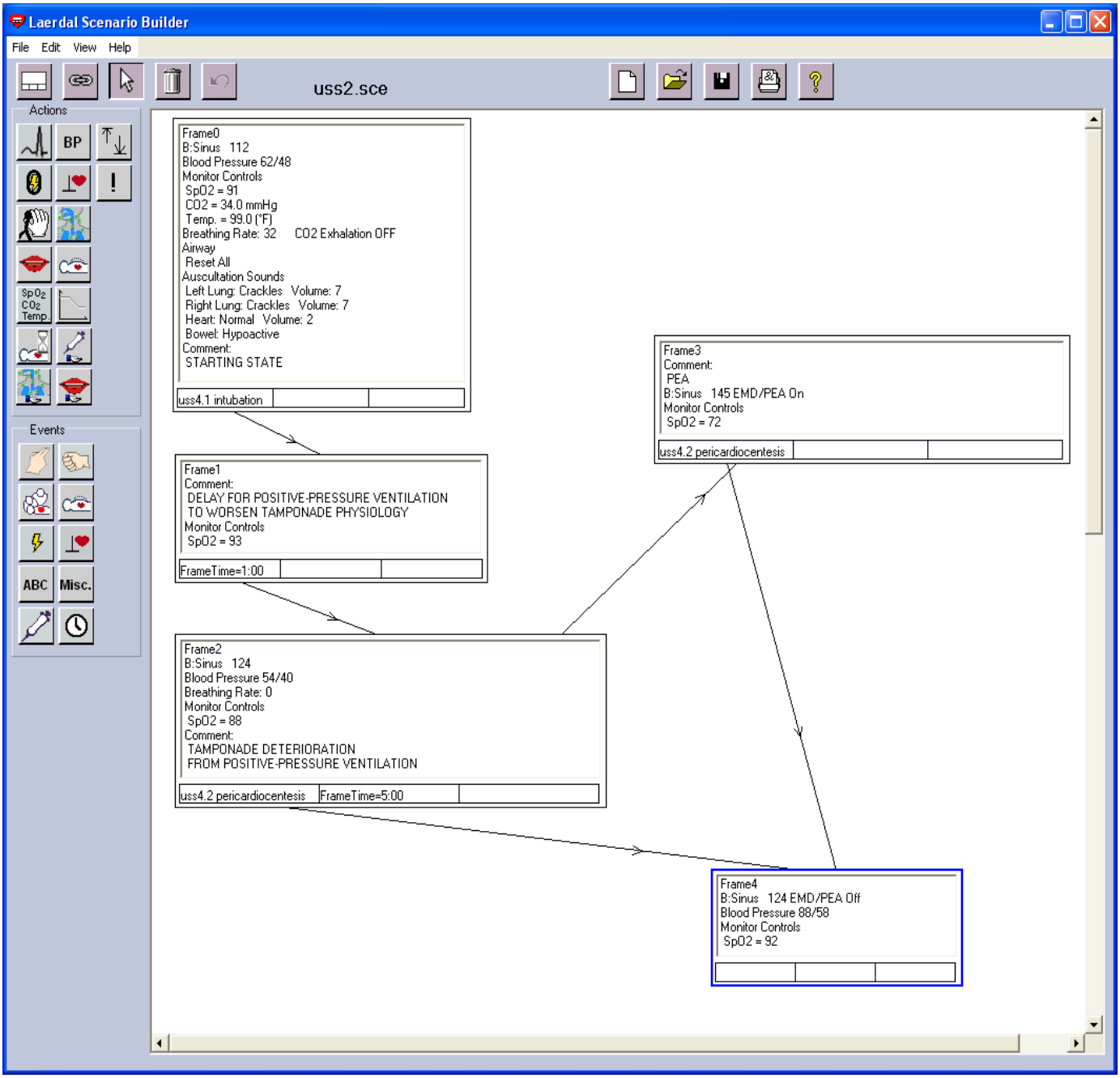
Shabetai R. Pericardial effusion: haemodynamic spectrum. *Heart* 2004; 90(3): 255-6.

Strimel WJ, Noe S. Pericardial effusion. In eMedicine Specialties > Medicine, Ob/Gyn, Psychiatry, and Surgery > Cardiology. Pearlman JD, Talavera F, Oudiz RJ et al. (eds), eMedicine Web site. Updated September 7, 2006. Available at: http://www.emedicine.com/med/topic1786.htm Accessed December 11, 2006.

Tang A, Eueule B. Emergency department ultrasound and echocardiography. *Emerg Med Clin North Am* 2005; 23(4): 1179-94.

Yarlagadda C, Hout WM. Cardiac tamponade. In eMedicine Specialties > Medicine, Ob/Gyn, Psychiatry, and Surgery > Cardiology. Kelly RF, Talavera F, Oudiz RJ et al. (eds), eMedicine Web site. Updated September 1, 2005. Available at: http://www.emedicine.com/med/topic283.htm Accessed December 11, 2006

Laerdal SimMan v2.2 scenario content



Note: The events to force transitions to a new frame will need to be edited via the "Edit Event Menus" feature within Scenario Builder

I. Title: Massive Pulmonary Embolus with Pulseless Electrical Activity (ACLS Cardiac Arrest)

II. Date Created: July 12, 2005
Date Revised: December 22, 2007

III. Category: Ultrasound Simulation; Teamwork / Resident Core Curriculum; ACLS

IV. Target Audience: undergraduate and graduate medical trainees and staff, nurses, paramedics

V. Learning Objectives or Assessment Objectives

J. Primary -
- o.) recognition and management of pulseless electrical activity (PEA)
- p.) recognition and management of massive pulmonary embolism (PE) causing hemodynamic instability or collapse
- q.) integration of Advanced Cardiac Life Support (ACLS) protocols into an organized medical resuscitation
- r.) integration of bedside ultrasonography into an organized medical resuscitation
- s.) deployment of teamwork behaviors

K. Secondary -
- k.) appropriate airway management
- l.) appropriate circulatory support
- m.) appropriate use of thrombolytics and anticoagulant therapies
- n.) appropriate consultation and disposition

L. Critical actions checklist (see Appendix A)-

1. Simple checklist of critical actions
- ss.) recognition of unresponsiveness
- tt.) recognition of respiratory failure (apnea)
- uu.) recognition of circulatory failure (pulselessness)
- vv.) call for help and defibrillator
- ww.) establishment of team structure with role assignment
- xx.) deployment of appropriate communications and teamwork behaviors
- yy.) basic airway management (100% oxygen administration with bag-valve-mask ventilation)
- zz.)"quick-look" rhythm analysis (non-shockable rhythm recognition)
- aaa.) basic circulatory management (CPR)
- bbb.) advanced airway management (endotracheal intubation or laryngeal mask airway deployment, placement confirmation and securement, ventilator management)
- ccc.) advanced circulatory support (cardiac monitor, vasoactive agents [epinephrine, vasopressors], peripheral + central venous access)
- ddd.) PEA recognition (i.e. continues CPR, does not defibrillate or cardiovert)

eee.) PEA evaluation and management (reviews differential diagnosis, implementation of specific testing and treatment)
fff.) recognition of massive PE as probable source of PEA
ggg.) recognition of progressive deterioration of PEA into recurrent pulseless ventricular tachycardia (VT)
hhh.) institution of thrombolytic therapy
iii.) continued respiratory and circulatory support after thrombolytic administration
jjj.) supportive therapies upon improvement of circulatory function
kkk.) critical care medicine consultation
lll.) disposition to critical care setting

2. Optimal sequence of critical actions- expected sequence as above
3. Duration to critical actions- resuscitation to be completed within 30-35 minutes of starting scenario
4. Behavioral ratings- see Appendix A

VI. ACGME Competencies Assessed

J. Patient Care
K. Medical Knowledge
L. Interpersonal/Communication Skills

VII. Environment and Props

M. Lab Set Up – Emergency Department in simulation center / lab
N. Manikin Set Up –
a.) advanced medical simulation manikin
b.) female patient moulage with street clothing
c.) right short leg cast or splint
d.) lines needed: right arm 20g IV
o.) drugs needed: adrenergic agonists (epinephrine, norepinephrine infusion)
antiarrhythmic (lidocaine, amiodarone)
fibrinolytics (tPA, rPA, TNKase as per institutional guidelines/protocols)
anticoagulants (heparin infusion)

O. Props – see "USS CASE 1 IMAGES" folder
(basic airway and code blue cart is assumed)
a.) ECGs: sinus tachycardia 160-180s
b.) X-rays: normal chest X-ray
c.) special airway equipment (laryngeal mask airway [LMA])
d.) bedside echocardiogram images- right ventricular strain with fast, organized cardiac activity, no pericardial fluid

P. Distractors –none

VIII. Simulation Personnel and Assigned Roles (Faculty, Actors, etc)

J. Roles – paramedic x 1-2, nurse x 1, critical care medicine consultant
K. Who may play them – other residents, other students, actors
L. Action Role – supportive (see narrative)

Case Narrative (describes what the learner will experience)

P. Paragraph narrative overview of case and how case starts-

At 10pm, EMS brings in a 43 year old woman who stood up from bed, collapsed and had a brief seizure. Her husband performed CPR and called 911. The patient has been undergoing CPR for approximately 6 minutes at time of arrival in the Emergency Department.

Q. Patient information-

1. Name/Age/Sex: Lisa R. 43 year old female
2. Mode of arrival: EMS
3. Accompanied by: husband (can be in waiting area until later)
4. Triage Note: n/a
20. Chief Complaint: [cardiac arrest]
21. Past Medical History: **minor right foot surgery 2 weeks ago**
22. Medications and Allergies: aspirin, vitamins, no known allergies
23. Family and Social History: n/a
24. Patient's Initial Exam:

Vital signs: heart rate: **no pulses without CPR**
blood pressure: **no pulses**
respiratory rate: **0**
oxygen saturation: **no waveform**
temperature: n/a
Airway: **no gag, pooled secretions**
Breathing: **no spontaneous respirations**
Circulation: **no pulses, warm extremities**

Secondary Exam: middle-aged female, **CPR in progress**
HEENT: **pooled secretions**
Neck: no JVP noted
Lungs: **no spontaneous breath sounds**
Cardiac: **no heart sounds**
Abdomen: no distention
Extremities: warm. **short-leg cast or splint on right**
Neurologic: **GCS 3**. pupils 7mm

Additional information:
Fingerstick blood sugar: normal
EKG: **rapid narrow complex rhythm 160-180s**
CXR: normal
Bedside echocardiogram: right ventricular strain with fast, organized cardiac activity, no pericardial fluid
PCP: Dr. Jeff Cooper

R. Flow diagram with branch points, times of expected interventions and reactions from Sim Man with notes (see Appendix A + B)

Case progression:

1. Despite "standard" PEA treatment (intravenous fluids, epinephrine, etc), progression to shockable pulseless rhythm (fast VT).

2. Defibrillation of fast VT results in transient return to sinus tachycardia 170-190s with blood pressure of 60 / 30 mmHg

3. Recurrent pulseless fast VT despite anti-arrhythmics

4. Appropriate regiment of Intravenous thrombolytic administration and CPR for 10-15 minutes results in stable sinus tachycardia with gradual improvement

Optional: Inability to intubate -> LMA

S. Distracters in case: n/a

T. Trends needed: (see Appendix B)

IX. Instructors Notes (what the instructor must do to create the experience)

J. Tips to keep scenario flowing in lab and via computer
- presentation of patient in extremis with persistently unstable rhythm without a definitive precipitant should keep the case moving quickly and with learner stress.
- lulls in activity may be broken with entry of agitated spouse

K. Tips to direct actors- as above

L. Scenario programming- see Appendix B

13. Optimal management path
14. Potential complications path(s)
15. Potential errors path(s)
16. Program debugging

X. Debriefing Plan

D. Method of debriefing

1. This is a simulation scenario faithful to a true PE / PEA patient who was resuscitated with excellent functional recovery. It may highlight the relevance of proper ACLS and aggressive critical interventions in Emergency Medicine

2. Debriefing Topics

a.) didactic content

- ACLS algorithms
  - check responsiveness, pulselessness

- activate emergency response system
- early rhythm analysis

- airway management
  - indications and technique of endotracheal intubation
  - indications and technique of LMA use

- PEA
  - assessment of "electrical" cardiac activity
  - assessment of "mechanical" cardiac activity
  - differential diagnosis (reversible causes)
    - -hypovolemia
    - -hypoxia
    - -hydrogen ion
    - -hyper- or hypo-kalemia
    - -hypothermia
    - -tablets
    - -tamponade
    - -tension PTX
    - -thrombosis (coronary)
    - -thrombosis (PE)
  - use of epinephrine (not vasopressin)
  - specific interventions
    - -sodium bicarbonate
    - -fluid bolus
    - -needle decompression: bilateral
    - -pericardiocentesis: use kit
    - -thrombolytics
    - -rewarming: target 92deg F
  - continuing (prolonged) resuscitative efforts
    - -hypothermia
    - -PE

- emergency ultrasonography in PEA
  - -FAST
  - -cardiac and pericardial window
  - -pneumothorax views

- massive pulmonary embolism
    - presentation
        -identified or unknown risk factors for clot
        -may have profound hemodynamic instability
    - evaluation
        -role of bedside echocardiography to assess RV strain
        -CT angiogram
        -angiography
    - treatment
        -cardiac arrest
            -thrombolytic therapy with ACLS (may take up to 30 minutes for restored circulation)
            -consider bilateral thoracotomy with pulmonary vessel massaging to make clots peripheral as a temporizing measure
        -hemodynamic instability (present or impending)
            -thrombolytic therapy with ACLS (some regimens studied include:
            [0.6mg/kg tPA IV over two minutes] or
            [100mg tPA IV over 2 hours] or
            [250,000 units streptokinase IV over 30 minutes, then 100,000 units/hr x 24hrs]
            -vasopressors (norepinephrine, isoproterenol)
            -anticoagulant therapy (heparin without bolus)
    -disposition
        -operating room for bypass
        -angiography for evaluation and intervention
        -critical care unit if unstable
        -telemetry unit if stable

b.) teamwork behaviors
    -leadership
        -resuscitation leadership establishment
        -role and responsibility assignment
    -collaboration
        -recognition and integration of team input
        -error recognition and correction
    -communication
        -callouts of critical information
        -callbacks for confirmation of information
    -situational awareness
        -continued patient reassessment
        -plan development and execution
        -task prioritization
        -workload assessment
        -team member cross-monitoring
        -requests for assistance
    -professionalism

XI. Pilot Testing and Revisions

G. Numbers of participants- 3-5 learners (1-2 leaders)
H. Performance expectations, anticipated management mistakes
-incorrect rhythm recognition
-resistance to administration of thrombolytic therapy
-premature termination of resuscitative efforts

XII. Authors and their affiliations

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Arun Nagdev, MD; RIHMSC, Rhode Island Hospital

XIII. Additional Debriefing Materials:

Goldhaber SZ, Nadel ES, King ME et al. Case 17-2004: A 42-year-old woman with cardiac arrest several weeks after an ankle fracture. *N Engl J Med* 2004; 350(22): 2281-90.

Janata K, Holzer M, Kurkciyan I et al. Major bleeding complications in cardiopulmonary resuscitation: the place of thrombolytic therapy in cardiac arrest due to massive pulmonary embolism. *Resuscitation* 2003; 57(1): 49-55.

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Sharma, S. Pulmonary embolism. In eMedicine Specialties > Medicine, Ob/Gyn, Psychiatry, and Surgery > Pulmonology. Tino G, Talavera F, Anders GT et al. (eds), eMedicine Web site. Updated June 2, 2006. Available at: http://www.emedicine.com/med/topic1958.htm Accessed December 11, 2005.

Tang A, Euerle B. Emergency department ultrasound and echocardiography. *Emerg Med Clin North Am* 2005; 23(4): 1179-94

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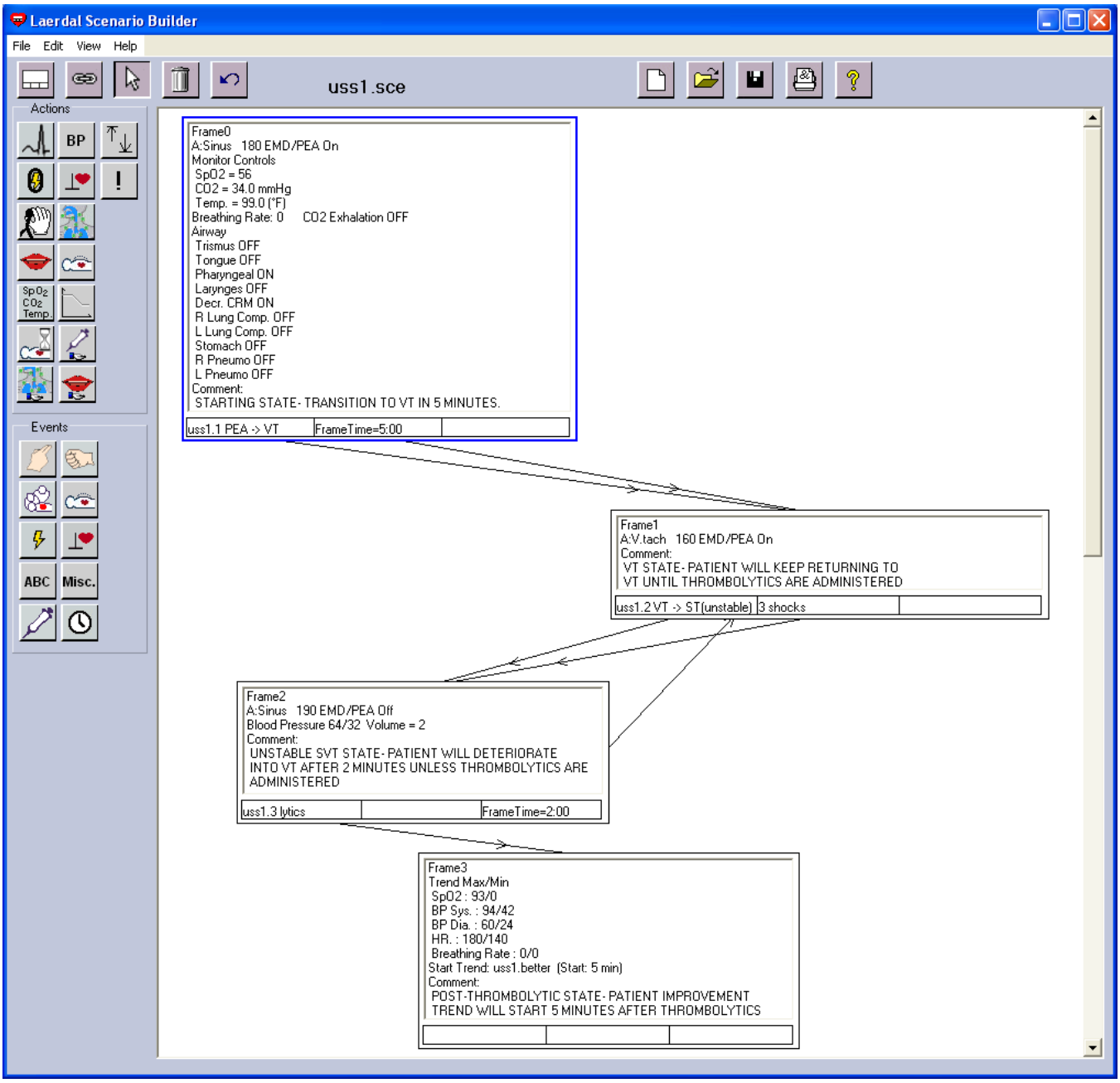

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