

AN INVESTIGATION OF THE USE OF SIMULATION-BASED MEDICAL EDUCATION
FOR TRAINING CENTRAL VENOUS CATHETERIZATION IN MEDICAL RESIDENTS

BY

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DISSERTATION

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ABSTRACT

Severe complications occur in 2.9% to 3.7% of hospitalized patients, and medical errors account for more than 1 million injuries and up to 98,000 hospital deaths each year. Medical procedures are the second most common cause of iatrogenic patient complications, leading to increased length of stay and healthcare costs. This simulated training program aims to standardize the education and training of central line training across multiple residencies and specialties. A simulated-based curriculum was designed to improve clinical knowledge, behavioral and technical competencies. An n=299 procedural checklists were reported; 11960 steps were completed correctly, 167 steps were done incorrectly, and 47 steps were omitted. The investigation yielded a 23% delta in self-efficacy pre/post-CVC simulation, and 60% acknowledged they had sufficient education before the simulation. 80.2% stated they perceived an increase in skillset after the simulated training, and 95.24% said they could identify a change in practice. 88% of the faculty surveyed stated they noticed improved skills post-simulation, and 84% stated they would like more simulation-based medical education procedural labs for the residents. Through triangulation of quantitative and qualitative data tools, the investigation results proved that a structured central venous catheterization curriculum does yield positive outputs regarding self-efficacy, improved procedural psychomotor skills, and faculty perceived technical improvements regarding central venous catheter placement.

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CHAPTER 1: INTRODUCTION

Significance

Medical educators have a shared responsibility toward the public perception of competency with their respective learner groups. The public deserves the best-trained physicians documentable by competency-based medical education (CMBE) and forecasted throughout medical training. Each evolution must provide a tangible metric gauging how a future physician progresses beyond the current standard structure of a process-based curriculum (Carraccio et al., 2002). The existing structure of medical education is defined as the training experiences by simple exposures to content for a predetermined period, which is mainly defined as a process-based system of learning (Carraccio et al.; Gottlieb et al., 2022). In contrast, a competency-based system of learning represents the desired outcome of training, the work driving the educational process (Carraccio et al.; Gottlieb et al.). Further, administrative burdens on clinical faculty have substantially grown, forcing faculty to manage programs rather than mentor residents instead. A recent study reporting administrative tasks related to compliance is a significant factor in faculty burnout amongst programs (Nasca et al., 2012). Early in the 21st century, responsibility and accountability became the driving force behind the American Board of Medical Specialties (ABMS) and the Accreditation Council for Graduate Medical Education (ACGME) to inaugurate a competency-based training program for all physicians (Carraccio et al.).

One clinical procedure that warrants such oversight toward clinical competency and the shared responsibility towards the public is the placement of a central venous catheterization. This clinical procedure is crucial for the proper application of high-rate intravenous therapy (IV) and for monitoring fluid load pressure on the right side of the heart. Instead of placing the catheter in the arm (peripheral), the catheter is placed in the jugular vein in a patient's neck. Physicians

insert more than five million central venous catheters every year (McGee & Gould 2003). McGee and Gould state that central venous catheterization allows the measurement of hemodynamic variables that cannot be measured accurately by noninvasive means and will enable the delivery of medications and nutritional support that cannot be given safely through peripheral venous catheters (p. 1123). The authors further explain that the placement and use of central venous catheterization can be associated with adverse events that are expensive to treat and can be hazardous to patients. More than 15 percent of patients who receive central venous catheterization will have complications, and these are divided into three categories: mechanical, infectious, and thrombotic (McGee & Gould). Mechanical complications occur in 5 to 19 percent of patients, infectious complications occur in 5 to 26 percent, and thrombotic (clotting) occurs in 2 to 26 percent of placed or attempted placement of central venous catheterization (p. 1123). Of the 5 million central venous catheters placed in patients, 750,000 (15%) will develop a complication. These staggering numbers demand further training modalities to ensure positive patient outcomes and improve clinical performance.

Research Questions

This investigation will be utilizing these three research questions:

1. How can a standardized procedural curriculum, including a procedural checklist, redress cognitive and behavioral deficiencies in the training of medical residents?
2. How can the self-efficacy of medical residents for placing a central line be impacted using simulation?
3. What self-efficacy must measures be used for monitoring medical residents' performance post-training?

Hypothesis

This hypothesis statement will guide this investigation: Initiating a simulated central venous catheterization procedural skills curriculum for medical residents will improve technical and behavioral skills while probing self-efficacy post-simulation.

A series of theories, methodologies, and research implementation plans must be established to investigate the research questions and either prove or disprove the hypothesis.

Overview of Theory

The theories utilized in this investigation are deliberate practice, knowledge, and experiential learning theory (ELT). Ericsson, Prietula, & Cokely, 2007 provide an established learning theory that learners who are consistently engaged in concise procedural training programs have significantly better educational outcomes when compared to their peers. Cope and Kalantzis (2016) opine that simple tools such as checklists and post-feedback surveys provide insights on whether a transfer of learning occurred and whether the learner progressed in a level of competency. Kolb's ELT (1984) is simply learning by doing. This is important as it is evident from the previous publications that learners who are continuously exposed to concise training programs with direct observational checklists and post-feedback surveys are consistently documented as succeeding minimum requirements for clinical competency (Ericsson, Prietula, & Cokely, 2007; Cope & Kalantzis, 2016; Kolb, 1984).

Summary of Methods

A mixed-methods approach to the investigation was selected as the stated hypothesis is to create a simulated central venous catheterization procedural skills curriculum for medical residents that will improve self-confidence and technical and behavioral skills. The investigation will assess how to create a procedural curriculum, implement the simulated event, learners'

perception of the education and self-efficacy, and evaluate the learners' technical and behavioral performance rated on a checklist. These variables lend themselves to a mixed-methods research approach due to both qualitative (learners' perceptions) and the quantitative scoring (procedural checklist) of clinical and behavioral performance.

Research Plan

The research plan for this investigation is aided by utilizing an instructional design methodology ADDIE. The ADDIE is an acronym for; analysis, design, development, implementation, and evaluation (Mayfield, 2011). From this tool, faculty were able to identify that the placement of central venous catheterization required more training due to the substantial risk of adverse outcomes. A core group of faculty gathered and agreed upon a procedural checklist, a post-simulation self-efficacy survey, and deliberate feedback. The learners would volunteer to attend a simulated lab session once a month that consisted of an introductory PowerPoint presentation, a self-guided central venous catheterization placement in the lab, direct oversight from a faculty member in which they would receive directed feedback about the procedure, and an anonymous self-efficacy survey upon completion of the simulation. Learners were allowed to repeat the simulation as many times as requested and could use any educational material available to cognitively prime for the simulated encounter. After several months of simulations, the data would be aggregated and examined for trends. This could then shape the continuation of the simulation and later be assessed as a metadata analysis for historical or longitudinal curriculum assessment. Finally, an electronic faculty survey was distributed to determine if an improvement in skills was observed. This was captured by distributing a Qualtrics survey to the departments where residents who attended the voluntary simulation lab were contained.

CHAPTER 2: LITERATURE REVIEW

Medical Simulation

Medical simulation attempts to imitate the live clinical environment by providing a safe learning environment non-patient-facing for novice clinicians to hone skills (Issenberg et al., 1999). Medical simulations are used for education, assessment, research, and clinical system integration (McGaghie et al., 2016). Simulation in medicine aims to train physicians in low-risk, high-reward environments that improve patient outcomes (Issenberg et al.). Additionally, simulation is utilized by entry-level medical and health professionals for orientation and training. There are several types of medical simulations: task trainer, a manikin-based, standardized participant (SP), virtual reality (VR) or augmented reality (AR), in situ, and tissue-based (McGaghie et al.).

Medical school is generally a four-year curriculum divided into pre-clinical and clinical sections. Graduates are then conferred as medical doctors and become resident physicians in programs ranging from three to seven years, depending on specialty. In residency and fellowship programs, the physician practices medicine under the supervision of an attending physician. During their training, several multimodal activities are introduced, including simulated encounters. Through simulations, health care workers can learn by practicing skills and experiencing mistakes before interacting with an actual patient (Salas et al., 2005). Several areas within the health care industry are currently using simulation-based training to help individuals and teams improve patient safety (Salas et al.). Simulation-based medical education (SBME) can also be a valuable tool in mitigating ethical tensions and practical dilemmas (Ziv et al., 2003). Further discussions of medical error and risk reduction strategies have highlighted simulation as an essential tool in improving the safe delivery of medical care (Salas et al.).

Simulation is a novel solution for training medical professionals in technical and non-technical skills (Ziv, Ben-David, & Ziv, 2005). Simulation can serve as a safe alternative to direct patient care that provides a realistic training experience. Ziv, Ben-David, & Ziv state that simulation-based medical education (SBME) aligns with and complements traditional and non-traditional training programs such as lectures, problem-based learning (PBL), and bedside teaching on clerkships and residencies. The defined goals of SBME are to reduce the occurrences of error during medical treatment, improve medical care, and improve patient safety by enhancing competence and performance in clinical skills, practical procedures, teamwork, patient management, and clinical decision making (Ziv, Ben-David, & Ziv). They further recommend that the effectiveness of improving patient care should measure by successful SBME programming.

Each medical school is governed by the Association of American Medical Colleges (AAMC), and residencies are governed by the Accreditation Council of Graduate Medical Education (ACGME). Both institutions provide guidelines for national instruction of medical professions, but the implementation is varied at the institution level due to local and fiscal resources. The core of SBME can be found in the instructional design of the programming, and the curriculum should then drive the level of fidelity of the SBME within the structure of the local institution (Ziv, Ben-David, & Ziv).

Definitions of Simulation-Based Medical Education

The simulation study in medical education is relatively new compared with the military and commercial aerospace operations, as these have well-documented outcomes. Several definitions were acquired from simulation-based medical education journals and the theory they apply. Further, the selected definitions are not necessarily confined to medical simulation alone

but a proposed methodology for educating learners to a level of proficiency. Two selected definitions are as follows:

“Through simulations, health care workers can learn by practicing skills taught and experiencing mistakes before interacting with an actual patient. Several areas within the health care industry are currently using simulation-based training to help individuals and teams improve patient safety” (Salas et al., 2005, p. 354).

“Simulation-based medical education (SBME) can be a valuable tool in mitigating these ethical tensions and practical dilemmas. Recent discussions of medical error and risk reduction strategies have highlighted simulation as an important tool in improving the safe delivery of medical care. Nevertheless, medicine has lagged other high-technology, high-risk professions in simulation, such as aviation, in which sophisticated technical and behavioral skills are necessary” (Ziv et al., 2003, p. 784).

From these definitions, it is sufficient to say the aerospace and military industries have led the way for the medical industry to use simulation as a form of education and assessment (Liu, Macciarella, & Vincenzi, 2009). “Commercial aviation and the military have invested heavily in simulation-based training because it offers a realistic, safe, cost-effective, and flexible environment to learn the requisite competencies for the job” (Salas et al., 2005, p. 365).

Best Practices of Simulation-Based Medical Education

McGaghie et al. state there are twelve SBME best practices:

1. feedback
2. deliberate practice
3. curriculum integration
4. outcome measurement

5. simulation fidelity
6. skill acquisition and maintenance
7. mastery learning
8. transfer to practice
9. team training
10. high-stakes testing
11. instructor training
12. educational and professional context

Through these twelve practices, residents are trained and assessed for personal performance, limitation of error, and better patient outcomes (McGaghie et al.). Before the adoption of SBME, healthcare professionals were left to hone their needed skillset on patients (Issenberg et al.). Subsequently, the governing bodies of medicine have not fully adopted simulation as an official means of assessing skill attainment or mastery (Moreira, Doty, & Gallahue, 2019). Macgregor et al. (2012) claim that the American Board of Surgery (ABS) does not require any certification for robotic surgery. “Despite its increasing use in surgical practice, no formal certification exists to show competency in robotic surgery” (Macgregor et al.). Compared to the aerospace community, if a learner fails to achieve proficiency during simulated encounters, they are not allowed to return to active status (Liu, Macciarella, & Vincenzi, 2009).

The second definition relates SBME to enhancing technical, behavioral, and social skills (Ziv et al.). The enhancement of technical skills aligns with the first definition; the behavioral and social skills were not addressed. Nonetheless, Ziv et al. posit that SBME can provide an ethical evaluation of the best standards of care and training, error management, patient safety, patient autonomy, social justice, and resource allocation (Ziv et al.). Ziv et al. propose the

overreliance on technological medicine, which may threaten humanistic care. The use of simulation, they add, may also have a risk of subjecting the less fortunate to more levels of novice care. “The basic bioethical principle of distributive justice requires that citizens equally share risks of medical innovation, research, and practitioner training. Yet, academic health systems (AHSs) are in urban areas (only 2 of more than 115 AHSs are not within a metropolitan statistical area [MSA]), and they provide disproportionate amounts of care to the poor” (Ziv et al., 2003, p. 785). Furthermore, ethical SBME advancement at the American College of Surgeons (ACS) only recently, in conjunction with the Subcommittee on Advanced Trauma Life Support (ATLS) and the Committee on Trauma, approved an alternative non-cadaveric model for use during the ATLS Surgical Skills Practicum (ATLS, 2001).

Central to both definitions is the performance measurement; what do they hope to achieve during a simulation? Salas et al. insist that education is hindered without assessment and feedback. Simulation-based training becomes merely a simulation (Salas et al. Salas et al. warn that it is the focus of methodology that drives simulation outcomes in any such environment. Additionally, they claim that personnel or system assessment can be obtained using simulation (Salas et al.).

Educational Frameworks in Simulation-Based Medical Education

Medical education today crosses three distinct areas: undergraduate (medical school), postgraduate (residency), and continuing professional development (attending physician) (Swanwick, 2013). Within each region, learners are provided SBME to assess technical and non-technical skills for competency. Per Ziv, Ben-David, & Ziv, faculty provide goals, set the standard for a learner goal by level, and provide feedback on individual or group performance. This framework allows learners to make mistakes in a safe and private environment that gives

room for metacognition to improve their skillset. In short, Ziv, Ben-David, & Ziv stipulate that this provides insight into how medical errors could occur and how to mitigate the effects. This methodology allows learners to learn through their errors with the simulation lab rather than honing a skillset in direct patient care (Ziv, Ben-David, & Ziv).

Unfortunately, medical error has become prominent in healthcare. Donaldson, Corrigan, and Kohn (2000) estimate that as many as 98,000 people die in any given year from medical errors that occur in hospitals. For perspective, that is more than those who die from motor vehicle accidents, breast cancer, and AIDs (Donaldson, Corrigan, & Kohn). New evidence suggests that medical error is the third leading cause of death in the United States, ranging from 210,000 to 440,000 annually (Hopkins, 2016). Further, Ziv, Ben-David, & Ziv posit that most of these errors occur in intensive care units (ICUs), operating rooms, and emergency departments, highlighting the need for expansive training modalities within patient care management. SBME could be the training methodology for improving patient outcomes but redesigning the education as a mistake-driven educational method (Ziv, Ben-David, & Ziv). Ziv, Ben-David, & Ziv have outlined an educational framework around error management that includes several stages (p. 194):

1. Identification and acknowledgment of mistakes performed by individuals or teams.
2. Analyze errors to discover the root causes and course of events that led to their occurrence (at individual, team, and system levels).
3. Determination of changes and corrections to be implemented.
4. Internalization and implementation of the lessons learned.

Additionally, teaching error management skills allows learners to work through each of the aforementioned stages, where experiencing mistakes in a simulated fashion is encouraged. Ziv,

Ben-David, & Ziv further developed a list of education techniques aimed the developing error management skills that consist of personal experience, peer to peer learning, and small group discussion (p.195):

1. A clinical encounter with a simulated patient or manikin.
2. A personal reflection on how the trainee handled the case and their notion of possible causes for errors and suggestions for corrections.
3. Students' and professionals' observation of peers coping with a similar scenario to their own.
4. A feedback meeting with the simulated patient who acted out the case (if applicable).
5. A personal one-on-one review of the audiovisual documentation of the educational session with experts in communication skills and specific clinical domains. The study focuses on the individual's performance, both in instances of positive coping and particularly when errors have occurred.
6. Group discussions were facilitated by an SBME teacher based on video recordings of the participants while handling the simulated case.

This framework affords the learners time to reflect upon simulated events. Personal and group feedback is imperative for growth and could deliver a patient perspective not easily captured while rounding with actual patients.

Best Practices for Curriculum Design in Simulation-Based Medical Education

Sanchez & Kumar (2020) speculate that simulation provides a learning environment that allows novice clinicians to integrate theoretical knowledge by participating in realistic scenarios. SBME substitutes actual patients for mannequins or task trainers to decrease the chances of

harming patients when practicing clinical skills or procedures (Sanchez & Kumar). The authors also propose a six-step methodology for curriculum development in simulation:

1. Needs assessment
2. Learner analysis
3. Establishment of learning objectives
4. Selective instructional methods
5. Assessing learning
6. Evaluation of simulation activities

The needs assessment is the first step in the process as it identifies the issues or needs that a particular group is looking to improve (Sanchez & Kumar). Specifically for medical simulation, the needs assessment focuses on the procedural or clinical skills that require enhancement and identifying the simulated setting needed to improve the skillset (Sanchez & Kumar).

The authors provide that learner analysis provides the background of the target audience. This is extremely important to include early in the design process as care delivery varies depending on the provider. For example, training for physicians and nurses is changed due to the scope of practice. Swanwick (2013) provides that each specialty is limited to specific medical interventions documented by their professional license. Such the training methodology will need to be augmented toward the specialty.

The authors related that the establishment of learning objectives and selective instructional methods are the expected result after a simulated educational experience and the methodology and environment in which the experience was conducted. They affirm that these areas are the most confusing for educators, as they misalign goals and learning objectives which could skew the environment or instructional methodology selected. Goals are the results

expected as a long-term target at the end of the entire training experience; learning objectives are the specific actions of the immediate educational activity. The authors confirm that these terms can be misinterpreted, and the expectations from SBME activities do not align with the need's assessment.

The final phase in SBME curriculum design is the assessing learning and evaluation of simulation activities. Again, there is a bit of confusion when aligning these initiatives as they are similar but diverge into different arenas. Assessing learning is essentially the tracking of a learner's progress with specific values (Sanchez & Kumar). The publication suggests using assessment tools that include confidence, performance, self-perception, checklists, pre and post-tests, knowledge tests, and group evaluation to capture both quantitative and qualitative responses. The assessment of simulation activities is subdivided into two rationales, formative and summative evaluation. Formative evaluation aids the faculty in assessing a learner or group's knowledge, skills, and critical thinking, while simultaneously evaluating the overall effectiveness of the instructional methodology through immediate and continuous feedback (Sanchez & Kumar). Summative evaluation is conducted at the end of the SBME activity, providing a grade to the learner and evaluating whether the learning objectives were met. The main disadvantage of a summative verse's formative evaluation is that the summative does not provide any modifications due to the finality of the grade (Sanchez & Kumar). The feedback found in the formative assessment allows the learners to adjust strategies in compliance with directed feedback.

Foundations of Medical Education

Swanwick (2018) states that the growing concerns about patient safety have influenced how medicine is practiced and how physicians are now publicly accountable for errors. This has

shifted toward problem-based learning within medical schools to mirror clinical interactions (Swanwick). This course change has included the expansion of technology and the macro-policy concerns around developing new physicians with an ever-aging population. In short, the world dynamic is changing for the face of healthcare. An increasing elderly population with complex healthcare needs is mounting toward an insurmountable health inequality gap. This author also confirms that two things are needed to improve our medical education institutions, scholarly medical educators and educational scholars.

Simulation-based medical education deploys three components of curriculum development: organizational analysis, task analysis, and person analysis (Nyein & Gregory, 2020). Organizational analysis is a process in which an assessment of the larger contexts, groups, and organizations are to be integrated (Nyein & Gregory). This is a very high-level overview of the curriculum development that ensures alignment with the organizational needs and goals while cementing buy-in from stakeholders and other leaders. For example, human-patient simulators can provide a realistic training experience for learners. Unfortunately, these types of technology are prohibitively expensive, and the organization could find a lower fidelity modality that fits more into the budgetary plan (Nyein & Gregory). To conduct a well-balanced organizational analysis, the designer should use a succinctly designed interview template with one-on-one structured focus groups with corporate leaders, faculty, curriculum directors, peers, and patients (Nyein & Gregory).

The goal of the curriculum design task analysis is to inform curriculum development; simply. This serves to identify what learners need to learn (Nyein & Gregory). The task analysis is where the faculty can band together and identify the specific knowledge, skills, attitudes, and

other characteristics (KSAOs) required to perform the tasks of a physician in training. Nyein & Gregory provide the example of training for robotic surgeons:

“In performing robotic surgery, surgeons need to know not only the anatomy of a human body but also the different functions of robotic arms and how to use them. Therefore, one of the objectives in this simulation may be for learners to become proficient in using all robotic arms. Second, task analysis is beneficial in developing the content of the simulations. For instance, understanding how a decision is made to perform an emergency cesarean section can help create the conditions of a realistic simulation scenario” (p. 1).

The person analysis is the final step for assessing who needs training and if the learners are ready for training (Nyein & Gregory). This step is more specific as it considers the learner’s perspective on self-awareness of task readiness, not simply a group or organizational analysis. There could be a bell curve of task readiness within any organization within learner groups (Nyein & Gregory). The person analysis is designed to elicit feedback on which learner is proficient with KSAOs and whether the individuals require remediation or advancement of skillset (Nyein & Gregory).

Main Findings in Simulation-Based Medical Education

Medical educators have designed strategies for conducting, maintaining, and enhancing technical and non-technical skills with simulation. The most critical part stressed by the literature is the design and implementation of a needs assessment (Nyein & Gregory, 2020; Swanwick, 2013; Sanchez & Kumar, 2020). Without a thorough needs assessment, training gaps in clinical knowledge and skills could be realized, leading to patient safety concerns (Nyein & Gregory).

For the simulation curriculum development process, a robust needs assessment ensures that this gap is mitigated (Nyein & Gregory).

At the heart of the issue of SBME is the enhancement of healthcare teams and patient outcomes. Simulation training is extensively used to improve the fundamental drivers of quality and safety of healthcare delivery regarding the improvement of teamwork KSAOs such as communication and conflict resolution (Nyein & Gregory). McClusky & Smith (2008) state that any skills curriculum design should objectively discover the trainee's proficiency. A too advanced curriculum may provide less than desired outcomes and foster perceptions of resentment and mistrust among faculty and learners. Nuzhat, Salem, Al Shehri, & Al Hamdan (2014) proclaim that using SBME in various learning outcomes can be achieved with high-fidelity simulators. Still, the practicality of this type of learning experience is not easily reproducible in small centers with limited funding opportunities. Specifically, technology-enhanced simulation sessions such as communication, diagnostics, procedural, self-confidence, integration of basic and clinical sciences, and teamwork are all improved (Nuzhat, Salem, Al Shehri, & Al Hamdan).

Definitions of Simulation Fidelity

The definitions supplied are from simulation-based education publications within medicine, military, and aerospace disciplines. The chosen descriptions are:

1. "Two major dimensions underpinned the large variety of definitions and constructs for fidelity—that of structural fidelity (how the simulator appears) and functional fidelity (what the simulator does)" (Hamstra et al., 2014, p. 388).
2. "The fidelity questions refer to how similar a training situation must be, relative to the operational situation, to train most efficiently" (Hays & Singer, 2014, p. 58)

3. “Simulation fidelity is an umbrella term defined as how the simulation replicates the actual environment” (Liu, Macciarella, & Vincenzi, 2009, p. 62).

Hamstra et al. identify the correlation between simulator fidelity and instructional design (ID). Hamstra et al. illustrate that high-technology simulation has risen in popularity in medical education, and simulator fidelity has emerged as a potentially significant instructional design feature, if greater fidelity will enhance learning. The same study indicates that instructional designers must select the appropriate fidelity and methodology for the selected instruction. Too much or little simulation fidelity distracts the learner and wastes valuable resources. This publication states that it may be more productive from an educational standpoint if we consider the fidelity of the simulation scenario relative to clinical task demands (functional fidelity) rather than the physical resemblance to the human patient (structural fidelity). Simulation fidelity should be independent of the learning methodology, the importance of learning objectives, and task demands for practical transfer skills. Additional research is needed to ascertain if fidelity in simulation is more effective or distractive for simulation education (Hamstra et al.).

Hays and Singer (2012) state that fidelity describes the characteristics that must be incorporated into the training system to maximize training effectiveness. Like the previous authors, Hays and Singer correlate the design methodology to the degree needed to portray the necessary training landscape accurately. Decisions on training fidelity have customarily been made assuming that the transfer surface is essentially the same for all tasks. Further, the authors cannot precisely define fidelity but rely on the amount of ‘realism’ needed to ensure a positive learning environment. These authors also agree that more research is required to determine an official taxonomy of fidelity. This is additional evidence of the necessary balance of engineering simulation, cost, and transfer of training value (Hays & Singer).

Liu, Macciarella, and Vincenzi (2009) begin by stating that simulation fidelity is one subject that has been determined to have a solid link to transfer of training. With budget limitations in mind, the issue becomes one of identifying the degree of fidelity necessary to achieve maximal transfer of activity to keep the cost of the training system as low as possible (Liu, Macciarella, & Vincenzi). Continuing with a theme, these authors also equate applying the appropriate level of simulation fidelity for the learning objectives and assessment.

Additionally, all the papers conducted a meta-analysis of simulation fidelity and, through their detailed research, could not precisely define fidelity. In contrast, they supply the necessary details to create a synthesis definition. Hays & Singer state that fidelity in simulation should provide a level of operational environment realism that defines the prescribed learning objectives and is guided by assessment methodology. The chosen fidelity should be cost independent and rely more on the method than technology (Liu, Macciarella, & Vincenzi). Simulation fidelity methodology should be guided by transferring learned skills from the simulated to operational environments (Hamstra et al.). Further development of technology in SBME has allowed designers to look at how to leverage fidelity to immerse a learner or group into a clinical situation in a high-reward, low-risk environment.

Virtual Reality (VR) for Simulation Education

Since the early nineteenth century, VR has been used (History of Virtual Reality, 2016). “If we focus more strictly on the scope of virtual reality to create the illusion that we are present somewhere we are not, then the earliest attempt at virtual reality is surely the 360-degree murals (or panoramic paintings) from the nineteenth century. These paintings were intended to fill the viewer’s entire field of vision, making them feel present at some historical event or scene” (History of Virtual Reality, 2016, p. 1). Since then, educators have searched for more efficient

ways to deliver content to learners. VR has revolutionized medical school and residency training in medicine, and one of the first courses students are exposed to is gross anatomy (Satava, 1993). It covers the full anatomical landmarks of body position, physiology, structure, and innervation. Before advances in technology, students would painstakingly take to one of the bibles of human anatomy, the Netter Atlas of Human Anatomy (Netter, 2011). This book was illustrated and composed by Dr. Frank Netter, who took years to hand-draw thousands of human body structures and condense them into only 640 pages. The book had many clinical correlations between pathological imaging and differential diagnosing (Netter). It was wonderfully illustrated, but it was only available in a 2D image set until recently.

Dr. Satava (1993) states, ‘virtual-reality surgical simulator signals the beginning of an era of computer simulation for surgery. The surgical resident of the future will learn new perspectives on surgical anatomy and repeatedly practice surgical procedures until they are perfect before performing surgery on patients.’ Further, VR represents the foundation for an educational base as important to surgery as the flight simulator is to aviation (Satava). Adopting best practices from the aerospace community, Satava insists this practice is essential to educate today’s learners. The medical community must adhere to the changing technologies and utilize the best resources available to sustain a viable product for the future. “Surgical training systems based on virtual reality (VR) and simulation techniques for tissue deformation may represent a more cost-effective and efficient alternative to traditional training methods.

Additionally, VR is a technology that can teach surgeons new procedures and determine their competence level before they operate on patients” (Kühnapfel, Çakmak, & Maaß, 2000).

Objectively determining a level of competence is central to the use and education of VR in medical simulation. Without objective data points, assessors would not have a computational

analysis to juxtapose learners to benchmarks (Kühnapfel, Çakmak, & Maaß). Furthermore, VR medical simulator definitively demonstrates what proficiency resembles in an acute clinical setting (Satava).

VR operations are not without challenges, mainly costs associated with hardware, software, and system maintenance personnel. Changes in technology and access to computers have significantly reduced the costs of purchasing a VR medical, or educational system. For instance, a Netter in 1997 price about \$250.00. Now with the VR included is only \$46.00. Further, more extensive advanced technology such as a LAP MENTOR (n.d.) costs about \$80,000 but is only needed for training surgeons in minimally invasive laparoscopic surgeries (MIS). With the invention of the iPhone, now VR medical imaging and simulation can fit in your hand for only \$35 (3D4Medical, n.d.). Partnering with Stanford anatomists, 3D4Medical has taken the next step in the evolution of sharable technology. A student can purchase the application on any device and access thousands of images, scans, dissections, and clinical interventions related to human anatomy (3D4Medical). What once took a semester of study can now be accessed in weeks.

In contrast, Ziv et al. (2003) propose the overreliance on technological medicine, which may be a threat to humanistic care. While VR intends to mimic human anatomy and clinical situations, it is not perfect in form. “One of the main problems with virtual reality is motion sickness brought on by poor design or ergonomics, which affects people differently” (History of Virtual Reality, 2016, p. 2). Additionally, traditional anatomy labs allow the learner to view natural variations within aspects of human anatomy (vessels, ligaments, etc.), but this can be accounted for within simulation.

VR simulation has become increasingly important in many scientific and technological disciplines owing to the wealth of computational power (Szekely & Satava 1999). Calculation of the behavior of these computational models is increasingly replacing experiments on real-world objects—for example, in the car industry (tests based on simulated crashes) or in the development of nuclear weapons—and is becoming an indispensable tool in the development of new products and procedures (Szekely & Satava). Per Szekely and Satava, the most common uses for VR in medicine are:

- Simulated three-dimensional reconstruction of organs from radiological cross-sections are an essential diagnostic tool that provides clinicians with a more naturalistic view of a patient's anatomy.
- Preoperative planning using a computer, including a realistic outcome prediction, has become an integral part of the intervention in specific disciplines, such as radiation therapy, craniofacial surgery, or neurosurgery.
- Computerized three-dimensional atlases of human anatomy, physiology, and pathology are about to revolutionize the teaching of these subjects.

These endeavors illustrate the future of VR in medical simulation, but we must not forget the human element in the physician/patient relationship. It must be emphasized that this new technology is only a vehicle. The methodology, not the technology, will drive the outcomes of the educational platforms of the future.

Simulation as Education for Central Venous Catheterization Procedures

To demonstrate how impactful simulation is for a specific procedure, we can analyze the pre/post-training simulation for central venous catheterization (Barsuk et al., 2009). A central venous catheterization is a widespread procedural skill taught to medical students, residents, and

fellows (Barsuk et al.). Central venous catheterization is introduced to medical students within clinical rotations beginning in the third year, shifted towards a competency-based assessment as a baseline for placing a line in a patient during the first year of residency, and subsequent enhanced training progressing through residency into fellowship.

In medicine, patients can deteriorate rapidly in acute and critical care situations, such as sepsis (a possible fatal bacterial blood infection), poor access due to dehydration, insufficient blood pressure monitoring, need for large quantities of fluids, medications, or blood to be infused rapidly, or hypotensive patients leading toward hypovolemic shock (very low blood pressure and need more fluids or blood) (Albrecht et al., 2004). Several pharmaceutical interventions or management plans are possible but require distinct delivery routes (Albrecht et al.). One route of fluid and medication administration is central venous catheterization. A central venous catheterization is placed in the internal jugular or subclavian veins (Albrecht et al.). Unfortunately, severe or fatal iatrogenic (illness caused by exam or treatment) complications occur in 2.9% to 3.7% of hospitalized patients. Medical errors account for more than 1 million injuries and 98,000 hospital deaths each year (Barsuk et al.). Medical procedures are the second most common cause of iatrogenic patient complications, and these complications often lead to increased length of stay and healthcare costs (Barsuk et al.).

The Ausmed (2020) image (figure 1) below illustrates how a central venous line is placed. Central venous catheters may be placed for lack of peripheral venous access, hemodynamic monitoring, administration of medications that would induce phlebitis through a peripheral IV, or rapid volume administration (Albrecht et al.). A large central vein is cannulated using a needle (Albrecht et al.). Once the vein is cannulated, a guidewire is advanced into the vein, and a catheter is then advanced over the wire and positioned adequately into the vein

(Barsuk et al.). This procedure is invasive and carries the risk of serious complications such as significant bleeding, infection, venous thrombosis, arterial cannulation, and pneumothorax (Barsuk et al.).

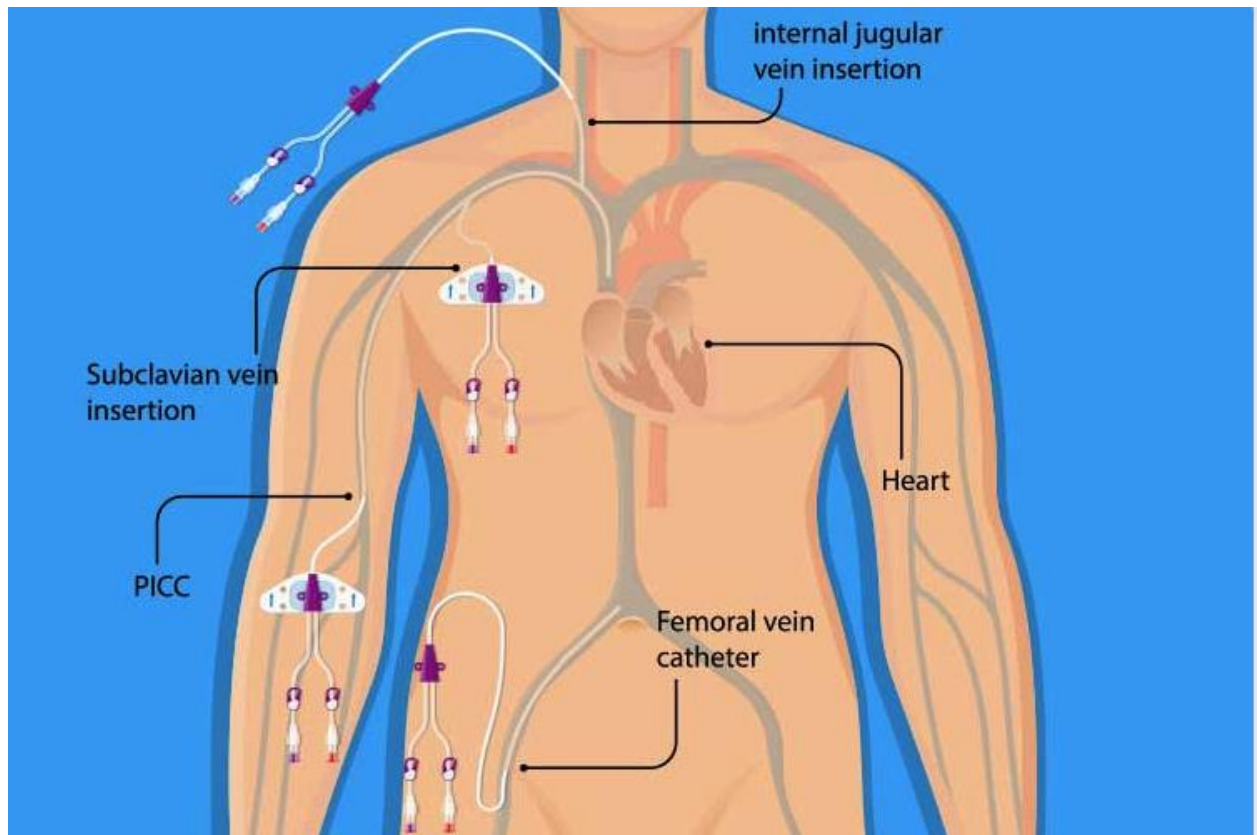


Figure 1

Ausmed. (2020). Caring for patients with central venous catheters. Retrieved March 19, 2021, from <https://www.ausmed.com/cpd/articles/-central-venous-catheters>

Central line insertion experience must complete many residency training programs and acquire hospital credentials once they graduate from these programs (Barsuk et al.). This procedure is commonly performed by critical care medicine, pediatrics, anesthesiology, internal medicine and pediatrics, surgery, and emergency medicine residents (Albrecht et al.). Historically, procedural skills, such as central line insertion, have been taught by the “see one, do

one, teach one” method (Barsuk et al., 2009; Cohen et al., 2010). Using this traditional method, trainees learn procedures through the observation of their peers. Barsuk et al. and Cohen et al. studies show that complications can be reduced with operator experience and ultrasound. However, they claim that educational programs in central line placement are often not rigorously assessed.

Simulation-based training for residents for central venous catheterization should be conducted at the beginning of their intensive care units (ICUs) rotations as additional training due to the number of central venous catheterizations placed within the ICUs (Cohen et al.). At the beginning of their academic year, residents who cannot participate may need to be scheduled for individualized training utilizing mastery learning (Barsuk et al.). The objectives of this type of training are three-fold:

- Educate new providers on the sterile technique during central line placement utilizing mastery training at the beginning of their residency.
- Utilize group training to review and practice central line placement.
- Decrease iatrogenic complications and improve patient outcomes.

Barsuk et al. posit that designing a simulated training program for central venous catheterization should account for several factors. The type of environment can influence training. Central venous catheterization can be placed in several different areas of the hospital, and these areas have different levels of sterility (Barsuk et al.). Additionally, Liu, Macciarella, & Vincenzi add that if a provider visits satellite care centers, these areas may not have the same type or style of central venous catheterization kit, leading to cognitive imbalance (Liu, Macciarella, & Vincenzi). Barsuk et al. explain that the assistants located in each area will have different levels of education and involvement with this procedure (Barsuk et al.). These

transactional boundaries can further impact patient care and positive outcomes. The ideal way to overcome highly interdependent group tasks is to incorporate interprofessional educational simulations (Liu, Macciarella, & Vincenzi). Having operational team members train in simulated environments will help mitigate provider boundaries and illuminate individual challenges with such a high-risk procedure (Liu, Macciarella, & Vincenzi).

Cognitive Functionality in Simulation

Kappers (2011) describes three aspects of shape discrimination and perception studies in her article. The three aspects proposed are perceptions of shape, curvature, and one hand/finger versus two hands/fingers performance. This directly correlates to the placement of a central venous catheterization as the physician is interchanging instruments with both hands continuously, threading guidewires into cannulated vessels, and seamlessly monitoring patient comfort and hemodynamics. Due to the expansiveness of fine motor, clinical decision-making, and recall inputs, this procedure spans the realm of executive cognitive functionality (Reason, 1990).

The first topic is the perception of shape by touch, and Kappers defines the cutaneous and kinesthetic senses. The cutaneous sense of touch relies on inputs from receptors in the skin. Kinesthetic sense relies on sensors located in muscles, tendons, and joints. Both senses combine to form haptic perceptions (Kappers). Haptic perception of touch is critical in the design structure of clinical education (Kappers). Choosing the correct material that will simulate the texture and layering is essential in educating physicians on the process of inserting a central line (Barsuk et al.). Without both cutaneous and kinesthetic senses, the proper finder needle depth would lead to the perforation of unintended arteries and nerves (Kappers).

Perception of curvature by touch is the second aspect that Kappers explores. The studies examined used unimanual exploration and showed small finger movements for small stimuli, and more significant stimuli triggered actions in the arm and shoulder. Kappers ties back to clinical simulation with the economy of motion. The economy of movement lessens time under anesthesia in these specialized cases. The fewer moves made by the surgeon to complete the task, the safer outcome for the patient (Kappers). In the clinical simulation, we try to use the exact instrumentation used in actual procedures, but occasionally, surgeons do not use the precise instrument called for in that procedure. Either through bad habits or poor design, a different tool is handed into the surgical field (Issenberg et al.).

Performance of one hand/finger versus two hand/fingers is the final topic. Kappers describes the task loads that can be distributed into different hemispheres. She explains how using one hemisphere versus two hemispheres can be impactful when exploring unilateral or bilateral performance. It speaks to the Seldinger technique of threading objects in opposite directions while maintaining the positional vector of cannulation (Warrington, Penoyer, Kamps, & Van Hoeck, 2012).

Definition of Error

Reason (1990) states that human error is neither as abundant nor as varied as its vast potential might suggest. He argues that errors are much rarer than correct actions. Still, they also tend to take a surprisingly limited number of forms, surprising, that is, when set against their possible variety (Reason). “Moreover, errors appear in similar guises across a wide range of mental activities. Thus, it is possible to identify comparable error forms in action, speech, perception, recall, recognition, judgment, problem-solving, decision making, concept formation and the like” (Reason, p. 2). Error is directly linked to human intention (Reason). “The term

‘error’ can only be meaningfully applied to planned actions that fail to achieve their desired consequences without the intervention of some chance or unforeseeable agency” (Reason, p. 3).

Reason declares that there is no universally decided classification system of human error, but they can be divided into several taxonomies (Reason). “Errors may be classified at three levels: behavioral, contextual, and conceptual. But only the last provides a good foundation, since there is no direct mapping of the surface forms of error onto their underlying cognitive mechanisms” (Reason, p. 4). Behavioral classification is concerned with recoverability, human and machine attribution, and design versus operator responsibility (Reason). The contextual variety is the relationship between error type and the task or situation provided (Reason). Conceptual classification is tied to the cognitive stages or mechanisms involved (Reason). “Error forms are recurrent varieties of fallibility that appear in all kinds of cognitive activity, irrespective of error type” (Reason, p. 6). Per Reason, human error type is related to the origin of the error and the stages involved in producing and executing a sequence of actions. Error types are differentiated per the performance levels at which they occur. On the other hand, error forms are pervasive varieties of fallibility that are evident at all performance levels (Reason).

Shappell and Wiegmann posit that we can divide errors into types and forms from one's intention. Shappell and Wiegmann (2000) aptly distinguish between errors (classes) and violations (states). Error types are skills-based, decision (rule), and perceptual (knowledge) (Shappell & Wiegmann). Violations, form types, are routine and exceptional (Shappell & Wiegmann, 2000). In general, errors represent individuals' mental or physical activities that fail to achieve their intended outcome (Reason). Human beings make errors by their very nature, so these unsafe acts dominate most accident databases (Shappell & Wiegmann). On the other hand, Violations refer to the willful disregard for the rules and regulations that govern flight safety

(Shappell & Wiegmann). The bane of many organizations, the prediction, and prevention of these appalling and purely “preventable” unsafe acts, continues to elude managers and researchers alike (Shappell & Wiegmann). When our actions do not mirror the desired intention, the error is described as a slip or lapse, but it is a mistake if the plan does not yield the specific intention (Reason). Reason alludes to three defined human error types: skills-based, rule-based, and knowledge-based. Skills-based errors are defined as slips in which one’s actions deviate from current intention due to execution failures (Reason). Rule-based mistakes are actions aligned with preferences but do not achieve their intended outcome due to incorrect application of a rule or inadequacy of the plan (Duke University, n.d.). Knowledge-based mistakes are intended actions but do not achieve the intended outcome due to knowledge deficits (Duke University).

There is a distinction between error types and error forms (Reason). Error types can be distinguished according to the performance levels at which they occur. On the other hand, error forms are evident at all levels of human performance and appear to originate in universal cognitive processes (Reason). Violations (forms) are broken into routine and exceptional subcategories (Shappell & Wiegmann). Regular violations tend to be habitual and often tolerated by governing authorities (Reason). Unprecedented violations are isolated departures from an authority, not necessarily indicative of an individual’s typical behavior pattern nor condoned by management (Reason).

Although human error can be viewed as overly negative (Reason), we can use the combined knowledge of taxonomy and origin to positively impact human/machine interactions (Shappell & Wiegmann). At the skill-based level, human performance is governed by stored patterns of preprogrammed instructions represented as analog structures in a time-space domain

(Reason). Reducing the number of steps required can reduce errors or slips by limiting the algorithmic information recalled for programming a system (Duke University). The individuals' intention can be carried out with tremendous success if the overall sequence is shortened, or the system used is specified (Duke University). Shappell & Wiegmann claim that rule-based errors are intentional behaviors that proceed as intended, yet the plan proves inadequate or utilizes the wrong strategy. These errors are typically associated with the misclassification of situations leading to applying the wrong rule or incorrect procedures recall. Reducing the amount given to one individual or team can reduce the likelihood of error (Duke University). Once the group formulates a plan of action, more attention provided to the desired outcome will reduce system errors (Duke University). The knowledge-based level comes into play in novel situations for which activities must be planned online, using conscious analytical processes and stored knowledge (Reason). To mitigate knowledge-based errors in the operational environment between humans and machines, we increase our access to resources (Reason). Automating processes will reduce human error in the forum (Duke University).

“We cannot change the human condition, but we can change the conditions under which humans work” (Reason, p. 5). By increasing our expertise, Reason claims, we can shift of mitigation of error from reactive to proactive (Duke University). Designing better systems that are resistant, not infallible, but appropriate to an ever-changing landscape. The simple solutions that maximize our potential to reduce human error are automation, standardization, algorithmic checklists, reduction in sequence, and a redundant systems approach (Duke University).

Gaps in Medical Education

Bates, Lovato, & Buller-Taylor, (2008) concluded that there are seven critical gaps in medical education:

1. increased demand for medical education
2. integration of internationally educated medical graduates into the physician workforce
3. lengthened postgraduate training demands
4. retention of physicians
5. shortage of physicians
6. shortage of primary care physicians
7. diversity in medicine.

There are multiple stakeholders in healthcare, physicians, nurses, other health professionals, patients, and hospital systems. With an aging population of baby boomers and generations X and Y, the United States needs more healthcare professionals (Buja, 2019). Unfortunately, demand is not keeping up with supply, and this can be evident by entering any emergency department and being subjected to waiting for hours on end. Without enhancing the efficiency that physicians are educated, the demand for quality healthcare from physicians will become overwhelming, and with the surge of COVID-19 brought it to the forefront. Orru et al. (2021) state that health care workers (HCWs) during the pandemic were affected by professional burnout and secondary traumatic stress (STS). “In the frontline HCWs, different sources of psychological distress have been reported, such as uncertainty of the disease progression (short- and long-term effects), treatment, lack of personal protective equipment (PPE), physical exhaustion, overwhelming workload, concerns about the direct exposure to COVID-19 at work. In particular, the latter is associated with the fear of getting infected or spreading the infection among colleagues and family’s members” (Orru et al., p. 18). This phenomenon has contributed to the increased need to replenish and strengthen our HCWs.

Medical school applications are up 18% in 2021 and have been dubbed the “Fauci Effect” due to the recruitment and applications the year before matriculation (Murphy, 2020). Murphy equates the stream in medical school applications in two areas: the healthcare challenges in response to the pandemic and an unfriendly economic climate for other professions forced to shut down during infection surges. This issue with the wave is that medical universities are not dynamic enough to increase enrollment on a whim (Bates, Lovato, & Buller-Taylor). Increasing enrollment is tethered to increasing faculty, staff, and clinical rotational spaces that were already limited before the pandemic (Buja).

Additionally, there has been an increase of foreign medical graduates competing with US medical students for spots in residencies (Murphy). This further complicates medical education as each learner must complete a predetermined number of patients, educational, and supervised interactions when rotating within the hospital (Murphy). This increase places further time constraints on faculty-learner interactions that could be solidified in the simulation lab.

There has been a further increase in lengthening postgraduate training programs (Bates, Lovato, & Buller-Taylor). Any increase in learning time delays the physician's entry into the workforce. According to Bates, Lovato, & Buller-Taylor, “While this phenomenon appears to result from student preference, the highly specialized environment of academic teaching centres may model extended training and subspecialization as desirable to trainees” (p. 51).

The retention of physicians has also been noted, especially in underserved settings. Per Bates, Lovato, & Buller-Taylor, medical schools have designed educational programs and telehealth encounters to reach underserved areas of the nation. Unfortunately, physicians tend to move from job to job, and the International Medical Graduates (IMGs) have a known rapid turnover rate (Bates, Lovato, & Buller-Taylor). These constant migrations can serve as an

additional shortfall in physician retention is immensely seen in rural settings. Buja states that physician loan reimbursement and community involvement sometimes drive physician recruitment, but this is mainly seen when the physician is originally from a similar area.

Transitioning toward the curriculum designed to educate further generations of physicians, there is an ongoing argument for moving past the principles advocated by Flexner and Osler towards a new focus of integrated curriculums within medical education. Buja wrote:

“Flexner recommended that medical schools be university-based, have minimum admission requirements, implement a rigorous curriculum with applied laboratory and clinical science content, and have faculty actively engaged in research. Osler championed bedside teaching, bringing medical students into direct contact with patients, and learning medicine from these direct experiences under the guidance of faculty clinicians” (p.2).

These theories established the two-stage learning methodology of preclinical (M1/2 years) non-patient facing and clinical (M3/4 years) patient-facing in medical school. The move from the post-Flexnerian and Oslerian curriculums was promoted to shift from passive learning lectures to more active learning team-based learning (TBLs), problem-based learning, self-directed learning, flipped classrooms, and fully online learning since the inception of COVID-19 (Buja). Buja states the goal of merging this gap in medical education was to produce physicians who can deliver an individualized plan of healthcare, manage the is reflective of mastery learning of basic physiology, be aware of current evidenced-based practiced medicine, conduct artful patient communication, and share decision-making with the healthcare team, patient, and family. Moreover, the shift has encompassed a competency-based education instead of cognitive knowledge where the learner could learn for the test, not successful management of the patient's outcomes (Murphy).

Baja notes a direct link between how medical student is evaluated and how they function within the setting. The current medical education landscape has removed traditional grades from all medical schools, moved into a pass/fail prescription, and left a gap regarding the methodology of assessment (Murphy). Without grades, how are the students measured? Simulation could be the solution for evaluation. Simulation can elicit the learned behaviors, cognitive skills, and psychomotor skills for what we benchmark as the essence of a physician. Baja confirms that “there is a broad consensus that a good doctor manifests a combination of humanistic and scientific attributes and capabilities” (p. 10). Additionally, there are seven key roles of the ideal physician (Baja):

1. Communicator
2. Collaborator
3. Manager
4. Health Advocate
5. Scholar
6. Professional
7. Medical Expert

These roles cannot be assessed within a traditional summative examination; and rather these characteristics can be directly observed and enhanced with simulation-based medical education and deliberate-recursive feedback toward a masterly level of skills.

While SBME is evidenced in medicine, the documented outcomes from training in the live clinical environment need further investigation. According to McGaghie (2010), SBME needs to adapt to the same rigorous clinical research standards. McGaghie further denotes that most SBME effects are not captured in the hospital setting and provides a framework for

mitigating such loss of data. Medical educational research could follow the same guidelines as clinical research projects by adopting a similar structure. This process is aligned from a benchwork to bedside methodology that captures a physician's knowledge, skills, and professional attributes and follows the T1-T3 clinical trial phases (McGaghie).

T1- Translational Science: illustrates a learner's knowledge and skill improvement in a simulation laboratory.

T2- Translation Science: yields measurable results for clinical skills and knowledge of physicians at all levels and are transferred and utilized in inpatient care settings.

T3- Translation Science: demonstrates the improvement of the health of individuals or populations as an overall result of SBME.

The literature review suggests that researchers could be tracking patient outcomes about specific procedural outcomes, such as length of stay, complications during a procedure, and infection occurrence, and comparing them with training outcomes within a simulation. This can then be combined with historical data on cost-benefit analyses that can portray a monetary saving to patients and the hospital system.

SBME is still in its infancy but gaining traction. Patients are becoming more technologically savvy and investigating physicians' backgrounds regarding medical care. Hospital systems could provide extensive experiences on the hours of simulated training efforts by physicians and the patient safety measures taken by the system to show why patients should choose their method over another transparently. This could be done with the assistance of SBME research in quality improvement and patient safety initiatives investigated in the simulation center. Here, providers can partner with intra/inter-professional collaborators to reduce or eliminate medical errors plaguing modern medicine. Key to this initiative is having a foundation

for defining an error, a system to conduct root cause analyses, simulation labs to recreate the error for investigation and mitigation, and steadfast administration to deploy resources for both physicians and patients to limit sentinel events from occurring. This work could be a framework that is the groundwork for other types of invasive clinical procedures, which provides context for clinical educators to limit negative impacts on patients.

It is at this juncture that simulation-based medical education is to perform a direct shift from summative examinations that could be highly gamified by learners who have taken several courses of mastering the execution of exams can now be observed in a safe environment, with no harm to patients and allow to emulate what they have learned. This is a monumental shift from the traditional pedagogy of medical education and impacts how medical students are evaluated.

CHAPTER 3: METHODOLOGY

Ericsson, Krampe, and Tesch-Römer (1993) established the theoretical framework of deliberate practice. Specifically, Ericsson, Krampe, and Tesch-Römer define “expert performance as the result of an individual’s prolonged efforts to improve performance while negotiating motivational and external constraints” (p. 363). Moulaert, Verwijnen, Rikers, and Scherpbier (2004), explain that two distinct motivations are prevalent to mastery skill obtainment motivation and external information. Suppose a learner is motivated and provided time to utilize outside educational resources (journals, books, videos, etc.). In that case, they can achieve proficiency through deliberate practice with the appropriate training materials, along with the time necessary to obtain and hone, both the learner and faculty side to provide feedback and be assessed for transfer of learning (Moulaert et al.).

Ericsson, Prietula, and Cokely (2007) clearly state the historical evidence that experts are made, not born. Further, their conclusions are based on rigorous research that looked at exceptional performance using verifiable scientific methods and reproducible (Ericsson, Prietula, & Cokely). “The longer physicians have been out of training, for example, the less able they are to identify unusual diseases of the lungs or heart. Because they encounter these illnesses so rarely, doctors quickly forget their characteristic features and have difficulty diagnosing them. Performance picks up only after the doctors undergo a refresher course” (Ericsson, Prietula, & Cokely, p.8).

Additionally, invasive procedural training is inherently different than non-invasive. That is to mention the risks involved for the patient if an error is made. Counter to this argument, a procedure could be performed correctly, and if an unanticipated outcome could arise, leading back to the proceduralist to recall the training to resolve the issue. Simply, the research states that

learners who consistently engage in more concise training their performance is significantly better than their counterparts (Ericsson & Harwell, 2019).

The instructional methodology for incorporating deliberate practice draws on Bloom's Taxonomy. Armstrong (2016) provides a revised version of the taxonomy with emphasis on four cognitive processes:

1. factual knowledge
2. conceptional knowledge
3. procedural knowledge
4. and metacognitive knowledge.

The design framework proposed begins at the lowest level of the pyramid (figure 2) (Armstrong). Learners are provided a stepwise PowerPoint overview, created by faculty members, of the central venous catheterization procedure and advised to utilize any reputable medical resource for training. At the onset of the procedure, learners must provide an informed consent statement to the faculty member. This provides insight to faculty that the learner understands (second block of the pyramid) the ideas or concepts and can logically describe the risks, benefits, and mitigation techniques. Finally, the learner will demonstrate how to place a central venous catheterization in a low-fidelity simulator, allowing them to apply their new technique (third block of the pyramid) or be reintroduced to the procedure.

Bloom's Taxonomy

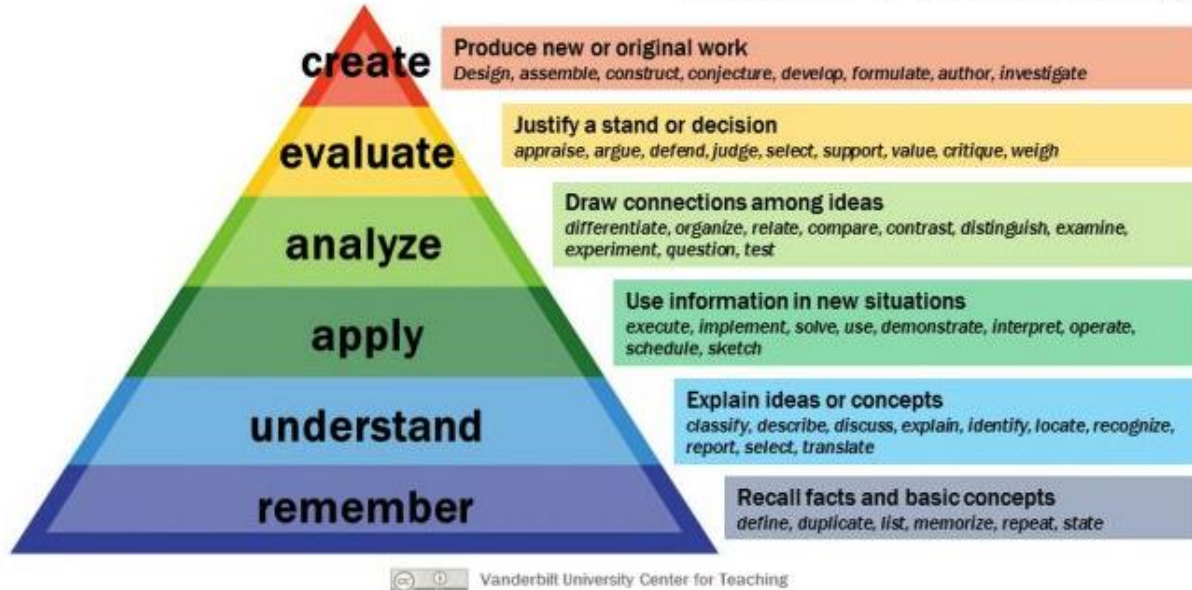


Figure 2

Armstrong, P. (2016). Bloom's taxonomy [Online image]. Vanderbilt University Center for Teaching. <https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/>

A Curriculum Model Investigating Simulation-Based Medical Procedures

Creating an adult learning curriculum is required for the theory of deliberate practice to be actionable and subsequently investigated. Furthermore, the tools for capturing learner outputs must be created and verified with procedural experts. The below logic model (figure 3) for such an investigation outlines an overall study design process.

SBME Curriculum & Research Design Logic Model



Figure 3

Custom Designed Logic Model for the investigation

McClusky & Smith (2008) devised a five-module iterative training curriculum that they posit improves proficiency levels through evidenced-based techniques for individual or group assessment ranging from:

- cognitive functionality
- psychomotor
- behavioral skills
- toward automated proficiency

The framework selected for this investigation is based on McClusky & Smith due to a structured, module-driven curriculum theme that dominates the literature in this domain. Such a model, it was found, contributed to a reduction in time for both educators and learners alike and could thus reduce formalized training curriculums. This collective curriculum design aligns with

the evidence in the literature reviewed for designing simulation-based medical education activities, allowing for reproducibility amongst other specialties.

Module one of the McClusky & Smith training curriculum consists of determining knowledge acquisition based on designing the cognitive components to identify skill level (McClusky & Smith). The goal of the cognitive stage is to capture what the learners understand before the physical application of knowledge. Module two provides the psychomotor assessment and initial acquisition of procedural content. At this stage, the faculty assesses which skills need to be improved upon, which is driven by reviewing the cognitive module (McClusky & Smith). The final skill assessment is meant to be assessed on a low-fidelity simulator that can capture the participants' movements and is directly observed by faculty on the efficiency, economy, and effectiveness of movements within the scope of patient safety and clinical outcomes (McClusky & Smith).

It should be noted that the psychomotor assessment proposed by McClusky & Smith's curriculum model is not present in a vacuum; instead, the instructional methodology of "chunking" can be observed (McClusky & Smith). The chunks of the procedure, mainly the components and subcomponents of the procedure, are divided and trained toward mastery level competency (McClusky & Smith). Module three involves integrating knowledge and psychomotor skills and provides meaningful feedback to the learner to shape behaviors associated with clinical training and patient outcomes (McClusky & Smith).

There are two-part tasks in this mode. First, the learner is provided with a clinical case requiring intervention. The learner then offers oral instructions to faculty and is advised to proceed if the answer is satisfactory (McClusky & Smith). Next, the learner can move to module four, a supervised real-world training application. Second, the learners must demonstrate

proficiency in specific tasks within a supervised real-patient encounter (McClusky & Smith). It is important to note that the assessment of participants in this model is not to be reduced due to restrictions of direct observation; in fact, more stringent faculty oversight is needed, and a designated faculty member needs to be appointed to only observe the learner in this setting (McClusky & Smith). Finally, once the learner has successfully matriculated through the other four modules, module five is mastery. Mastery in this curriculum model implies that learning is an ongoing process that is never completed (McClusky & Smith). This model is premised on the fact that even the most senior physicians attend grand rounds presentations by residents, fellows, and other attendings. In medicine, knowledge is ever-evolving and revisiting simulated skills only enhances one's skill set and provides optimum patient care, outcomes, and safety.

Curriculum Designs/Theories

This curriculum design model by McClusky & Smith also encapsulates a blend of Kolb's (1984) Experiential Learning Theory with adaptive flexibility (Mainemelis, Boyatzis, & Kolb, 2002). Further, Cope and Kalantzis (2016) suggest that learning designs focus on the knowledge approach by knowing meaning and action. Cope and Kalantzis identified four ways of knowing; experiencing, conceptualizing, analyzing, and applying. Sharing is a knowledge process where learning immersion of real experiences and exposure to evidence-based data (Cope & Kalantzis). This theory is well suited for clinical training.

Learners are exposed to live clinical training and then hone skills. They have seen others apply in a safe, high reward environment, the simulation center. Conceptualization allows the learner to generalize concepts and provide a synthesis that moves away from world experience and is rooted in further chunking like data towards a common goal (Cope & Kalantzis).

Conceptualization broaches well into the curriculum design proposed by McClusky & Smith as it

provides the learner with an iterative process towards the improvement of cognitive, technical, and behavioral skills without reliance on a solely linear pathway. All three improvements can be made simultaneously. Analysis indeed provides the examination of the functional elements presented to the learners through the lens of the curriculum (Cope & Kalantzis). Simple tools such as checklists and post feedback surveys can provide in-depth insights on if the curriculum has achieved the learning objectives and hence offered a transfer of learning to the pupil. The final knowledge process evidenced by Cope and Kalantzis is “applying,” where the learners can showcase the obtained knowledge in a designated setting, providing further indications that curriculum and assessment designs were correctly implemented. This is where the concept of a simulation lab is paramount. The creation of simulations can provide a real example of a clinical encounter where a novice learner can make mistakes and learn from past experiences without endangering patients.

Kolb’s (1984) Experiential Learning Theory is described as learning by doing. Thus, the experiences of learners including in the context of case studies and a simulation of a procedural event, it is hypothesized could yield improved learner outcomes when compared to traditional medical instructional methodologies. Kolb’s Experiential Learning Theory (figure 4) is divided into four modes concrete experience (CE), abstract conceptualization (AC), reflective observation (RO), and active experimentation (AE). These four experiences are woven into the foundation of the curriculum’s creation. Learners are exposed to the procedure through several means: apprenticeship, online, medical student interactions, etc., provide a defined process by seasoned faculty, allowed time to absorb a checklist, and deliberate observed practice within a safe and controlled simulated setting in the lab.

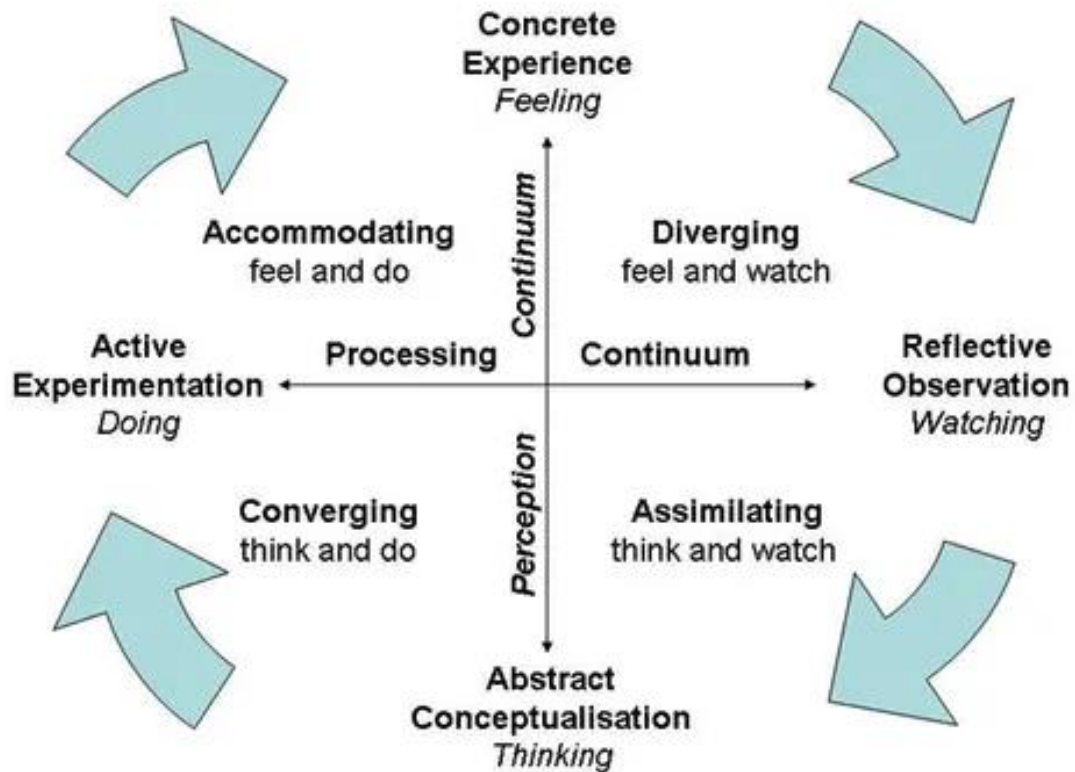


Figure 4

Kolb, D. A. (1984). *Experience as the source of learning and development*. Upper Sadle River: Prentice Hall.

Kolb describes how learners will naturally choose their preferred learning pathway and provides four learning styles: Diverging, Assimilating, Converging, and Accommodating. Diverging combines CE/RO, which relates to a sense of watching first rather than doing (Kolb). These learners, it is posited, gather large amounts of information and use their imagination to solve problems cognitively before physical action (Kolb). Diverging learners, it is claimed, prefer to work in larger groups, are very open to feedback and ideas, and have an open mind to new ways of completing tasks (Kolb). Assimilating synthesizes AC/RO to provide learners with

a concise and logical approach to ideas and concepts more than the social constructs of the learning environment (McLeod, 2017). Converging learners, McLeod found gravitate towards doing and thinking by combining AC/AE. He claims this type of learner prefers to solve problems and make decisions by experimenting with new ideas and are attracted to technical tasks, while being less concerned with social or interpersonal interactions (McLeod). McLeod concludes that the true hands-on learners are titled under the accommodating framework utilizing a CE/AE. They assimilate others' knowledge, then proceed with their informed suspicion (McLeod).

For this dissertation, the instruments selected to assess the various learning theories presented above align with a hybrid of the Learning Style Inventory. The Learning Style Inventory is designed to allow learners to select which resources best fit their learning styles. Learners, in this model of assessment, it is posited can choose to use resources outside of the faculty provided PowerPoints, which aligns with a conceptualizing/experiencing (AC-CE) experience, or simply attend labs without cognitive priming that correlates with an acting/reflecting (AE-RO) style of training by doing (Mainemelis, Boyatzis, & Kolb, 2002). “The assumption is that the more balanced a person is in their dialectic preference, the more they will experience a creative tension or attraction to both poles opening a wider space for flexible adaptation and development of learning skill” (Mainemelis, Boyatzis, & Kolb, p. 8).

These theories presented above will underpin investigating a case study related to how deliberate experiential practice can influence the placement of a central venous catheter within a simulated environment.

Hypothesis and Research Questions

Hypothesis:

Initiating a simulated central venous catheterization procedural skills curriculum for medical residents will improve technical and behavioral skills while probing self-efficacy post-simulation.

Research questions:

1. How can a standardized procedural curriculum, including a procedural checklist, redress cognitive and behavioral deficiencies in the training medical of residents?
2. How can the self-efficacy of medical residents for placing a central line be impacted using simulation?
3. What self-efficacy measures must be used for monitoring medical residents' performance post-training?

Methodology Review

Creswell and Creswell (2017) state that research approaches should be based on the nature of the research problem, the framework of inquiry title research designs, and the data collection, analysis, and interpretation called research methods. The decision to move forward with a specific research approach should also involve the researchers' personal experiences and be tailored to the audience for the study (Creswell & Creswell). For this investigation, a mixed-methods approach is warranted, and the following definitions and explanations are illustrated for additional context while simultaneously providing an argument supporting the selected methodology. The authors offer three research approaches; qualitative, quantitative, and mixed methods and state that mixed methods lie within the middle of qualitative and quantitative

investigations (Creswell & Creswell). The qualitative research approach relies on analyzing words using open-ended questions rather than numbers (Creswell & Creswell).

Conversely, framing an investigation to review more numeric values would fall under quantitative research. Creswell & Creswell (p. 4) provide complete definitions for each of the three research approaches:

1. Qualitative research is an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. The research process involves emerging questions and procedures, data typically collected in the participant's setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data.
2. Quantitative research is an approach for testing objective theories by examining the relationship among variables. These variables, in turn, can be measured, typically by instruments, so that numbered data can be analyzed using statistical procedures.
3. Mixed methods research is an approach to an inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may include philosophical assumptions and theoretical frameworks.

Qualitative Research

Qualitative research can be used the understanding people's beliefs, attitudes, experiences, behavior, and interactions (Pathak et al., 2013). Modestly, it generates non-numerical data points. The history of qualitative research has initially been viewed in

psychological studies when researchers found it overwhelming to evaluate human behavior in numeric (Pathak et al.). Specifically, in clinical research, the qualitative methods approach can help view data points more extensively while strengthening clinical trials by enhancing user involvement (Pathak et al.). Pathak et al. speculate three broad categories of qualitative research interests in new age clinical research, such as an observational study, interview studies, and textual analysis from various written records.

Further, the authors opine that qualitative research can contribute to healthcare research, as these research participants have an empowering experience in the study. This is tied to the relationship of the researcher and participant, which can be less formal than in quantitative research, leading to enhancement of social parameters that are additive to the quantitative measures within the study. Creswell and Poth (2018) drill down on qualitative research approaches by describing an investigational subset titled ground theory research. Grounded theory could be used when a theory is not available for explanation or to understand a process (Creswell & Poth). This investigation hopes to illustrate how a detailed framework for performing a central venous catheterization could facilitate a change in practice for medical residents. This may help other specialties understand a complex process for catheter insertion. Additionally, Merriam and Tisdell (2016) state that are having an interest in improving one's practice is at the core of qualitative research. Hence, developing a training program to improve technical and behavioral skills demands that a methodology include qualitative variables.

For this investigation, the study utilizes a direct observation approach. Observation can be defined as a systematic process of collecting information in each environment (Queirós et al., 2017). Data is simultaneously collected with the occurrence of the simulated event, which provides the researcher with an unobtrusive, flexible method to elicit the discovery of knowledge

obtained by the participant groups through deliberate practice. Further, the groups are provided a structured survey that falls under the heading of structured interviews for qualitative research. The structured interview provides insights into the comparative responses of participants (Queirós et al.). The downside to these approaches is the faculty time invested into the process, the rigidity of reproducible results, and the historically low response rate known for survey data (Baruch & Holtom, 2008).

Queirós et al. review that qualitative methodology produces in-depth and illustrated information to understand various dimensions of the problem under analysis. Queirós et al. have identified a list of seven types of qualitative methodologies:

1. Observation
2. Ethnography
3. Field research
4. Focus groups
5. Case studies
6. Structured interviews
7. In-depth interviews

Queirós et al. provide an illustrated description of the advantages and disadvantages of qualitative research methodologies in the table below (Figure 5).

Table 2: Comparison among qualitative methods

Method	Advantages	Disadvantages
Observation	- Collect data simultaneously with the event occurrence - Unobtrusive way, which is not dependent on upon someone's response - Flexible and oriented to knowledge discovery	- Very time consuming - Dependent on the observer's impartiality - Requires significant preparation - Difficult to collect data in real time
Ethnography	- Based on observation and interviews with the direct involved authors - Provide in-depth findings - Suitable to explore new lines of research	- Very time consuming - Difficult to get concise and precise conclusions - Researcher needs to have a deep knowledge of the problem domain
Field research	- Adequate to get very detailed data - Emphasizes the role and relevance of social context	- Difficult to generalize and get data from a very large number of people or groups - Dependent on the observer's impartiality - Documenting observations may become a challenging process
Focus groups	- Adequate to get detailed information about personal and group	- Hard to control and manage - Difficult to get the participation of

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	- Offer opportunity to seek clarification - Lower costs and time when compared to individual interviews	- people - Can be no representative of all population
Case studies	- Provide detailed information about individuals - Offer a good opportunity for innovation and change current theoretical assumptions - Can be a good alternative or complement to focus groups	- Difficult to establish cause-effect connections - Hard to generalize from a small number of case studies - Ethical issues, especially of confidentiality, may appear - Difficult to create a case study that suits all subjects
Structured interviews	- Well-structured and easy to compare respondent's answers - Can reach a large sample - Easy to replicate - Conducting an interview is fairly quick to conduct	- Very rigid - Low flexibility in the response's choice - Difficult to obtain detailed data - Preparing an interview can become time consuming
In-depth interviews	- Adjusted to get detailed and insightful information on a given domain - Need only fewer participants to provide useful and relevant insights - Can be performed in informal environments	- Time consuming and relatively high costly - Longer verification process to extract compared information - Participants should be carefully chosen to avoid bias - Not generalizable

Figure 5

Queirós, A., Faria, D., & Almeida, F. (2017). Strengths and limitations of qualitative and quantitative research methods. European Journal of Education Studies.

Quantitative Research

Quantitative Research includes both experiments and other systematic methods that emphasize, control, and quantified performance measures (Hoy & Adams, 2015). Central to the deployment of quantitative research are the connections between empirical observation and mathematical expressions of relations (Hoy & Adams). Simply, quantitative researchers are concerned with the development and testing of hypotheses and the further generation of models and theories that will explain behavior. Sukamolson (2007) states there are six main types of research questions suited to quantitative research (p. 9):

1. The first is when we want a quantitative answer. For example, 'If the students have their choice, how many of them choose to study Experiential English I?' or 'How many English teachers in the Language Institute would like to teach Experiential English courses instead of Foundation English courses?' We need to use quantitative research to answer this kind of question is obvious. Qualitative, non-numerical methods will not provide us with the numerical answer we want.
2. Numerical change can likewise only accurately be studied using quantitative methods. For example, 'Are the numbers of students in our university rising or falling?' or 'Is achievement in English of our students going up or down?' We would need to do a quantitative study to find out the answer.
3. Quantitative research is helpful in conducting audience segmentation. It is done by dividing the population into groups whose members are similar and distinct from other groups. Quantitative analysis is used to estimate the size of an audience segment as a follow-up step to a qualitative study to quantify results obtained in a qualitative research and verify data obtained from a qualitative study.

4. Quantitative research is also helpful to quantify opinions, attitudes, and behaviors and find out how the whole population feels about an issue. For example, when we want to find out the exact number of people who think a certain way, set baselines (e.g., to measure consumer attitudes regarding an issue before a campaign), and ensure that the students can share some comments or ideas to a new course.
5. Quantitative research is suitable for explaining some phenomena. For instance, ‘What factors predict the general English proficiency of the fourth-year students?’ or ‘What factors are related to changes in student English achievement over time?’ This kind of question can be studied successfully using quantitative methods, and many statistical techniques have been developed to make us predict scores on one factor or variable (e.g., student English proficiency) from scores on one or more other factors or variables (e.g., learning habits, motivation, attitude).
6. The final activity for which quantitative research is especially suited is testing hypotheses. We might want to explain something, for example, whether there is a relationship between students’ achievement and their self-esteem and social background.

Questions one through four could be typecast as descriptive research as researchers attempt to describe a situation or premise. Examples five and six provide more of an inferential research methodology as the researchers try to explain a phenomenon instead of a simple description. The issue with quantitative research is that while the variables are being collected, the data might not support or identify the hypothesis. Additionally, the descriptive research aspect dovetails into a qualitative methodology, which may yield additional data points not readily recognizable to the quantitative researcher. Finally, once the data collection process has concluded and the team

transitions to analytics, the data points collected might not be able to support the original goal of the investigation. The research team will then have to restart the investigation to capture the correct data points to prove the hypothesis. This could waste much valuable time allotted for the investigation timeline. This would be highly detrimental to the proposed central venous catheterization investigation as the research participants are only provided a small number of educational hours outside of clinical duties. Further, the attitudes and behaviors would be lost in a solely quantitative methodology as this investigation has an informed consent process.

In contrast, Sukamolson (p. 10) provides suggestions on when not to use quantitative methods:

1. The first situation where quantitative research will fail is when we want to explore a problem in depth. Quantitative research provides information in breadth from a large number of units. But when we want to explore an issue or concept in-depth, quantitative methods are too shallow. To get really under the skin of a phenomenon, we need to go for ethnographic methods, interviews, in-depth case studies, and other qualitative techniques.
2. As mentioned earlier, quantitative research is well-suited for testing theories and hypotheses. What quantitative methods cannot do very well is develop hypotheses and theories. The hypotheses to be tested may come from a literature review or theory but can also be created using exploratory qualitative research.
3. If issues are particularly complex, an in-depth qualitative study (a case study, for example) is more likely to pick up on this than a quantitative study. This is partly because there is a limit to how many variables can be looked at in any one quantitative study. In quantitative research, it is the researcher who defines the variables to be studied. In qualitative research, unexpected variables may emerge.

4. Finally, while quantitative methods are better at looking at cause and effect (causality, as it is known), qualitative methods are more suited to the meaning of events or circumstances.

The primary downside to utilizing a quantitative research methodology is the time invested in producing quantifiable outputs from the participants. The investigator should discover which research methodology to use when producing the hypothesis that aligns with the variables needed for analysis.

Queirós et al. research provide six types of quantitative research:

1. Field Experiments
2. Simulation
3. Surveys
4. Correlation Study
5. Multivariate analysis

Queirós et al. provide an illustrated description of the advantages and disadvantages of quantitative research methodologies in the table below (Figure 6).

Table 3: Comparison among quantitative methods

Method	Advantages	Disadvantages
Field experiments	- Works in natural setting - Larger scale research - Subjects are not influenced by the observations of the experiments	- Difficult to control variables - Difficult to replicate the same conditions of the study - Ethical problems can arise
Simulation	- Used to study complex systems - Compress a time frame, which allows to study the behavior of the system more quickly - "What-if" questions can be tested and answered	- Model building requires deep knowledge of the field - Time consuming and expensive - May require specialized hardware and software tools
Surveys	- Low development time - Cost-effective - Easy data collection and analysis using statistical methods - Can reach high audiences - High representativeness - Not affected by the subjectivity of the researcher	- Reliability of data is very dependent on the quality of answers and on the survey' structure - Rigidity of the structure - Don't capture emotions, behavior and changes of emotions of respondents

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Correlational study	- A lot of information and different domains can be explored - Degree of association between two variables can be easily calculated - No manipulation of behavior is required	- No direct cause and effect can be inferred - May lacks internal/external validity - Doesn't provide a conclusive reason for the existence of a correlation between two variables
Multivariate analysis	- Several statistical tests and techniques can be used - A lot of information and different domains can be explored - Technical rigor of the process	- Complex of the employed techniques - Requires the use of specialized statistical software

Figure 6

Queirós, A., Faria, D., & Almeida, F. (2017). Strengths and limitations of qualitative and quantitative research methods. European Journal of Education Studies.

Mixed Methods Research

Halcomb and Hickman (2015) state that the term mixed methods research is broadly accepted to refer to research that incorporates qualitative and quantitative data within a single study. Halcomb and Hickman provide eight critical considerations in planning and undertaking mixed methods research are presented here for the novice researcher (p. 4):

1. examine the rationale for using mixed methods
2. explore the philosophical approach

3. understand the various mixed-method designs
4. assess the skills required
5. review project management considerations
6. plan and justify the integration of qualitative and quantitative aspects
7. ensure that rigor is demonstrated
8. disseminate mixed methods research proudly.

Simply, researchers whose investigations are afforded multiple perspectives provide a more detailed understanding than a single methodology. Further, several types of mixed methods designs are found in the literature (p. 8):

1. Convergent parallel
2. Sequential explanatory
3. Embedded/nested

Convergent parallel compels the researcher to obtain different but complementary data points to answer a single research question in which the data is collected and analyzed independently. An example could be an unstructured email survey to a board participant base to gather feedback on a process. The sequential explanatory methodology has two different ways to collect data; quantitative and qualitative versus qualitative and quantitative (Halcomb & Hickman). The qualitative data are collected to explain the quantitative findings. This is more of a dominant quantitative trait.

Conversely, qualitative methodology builds from quantitative data sets in which the findings are more generalizable. An example could be the research team conducting a series of interviews to uncover experiences, perceptions, and expectations of a university program—this capture of both qualitative perceptions and further alignment with quantitative programmatic vital

indicators. Embedding or nesting allows the research team to obtain different data sets to answer a complementary set of research questions. An example could be using embedded surveys in a randomized control trial to elicit feedback on the overall program. The pros of using a mixed-methods design are the shared understanding of the contradictions between quantitative results and qualitative data sets (Halcomb & Hickman). Mixed methods also foster scholarly interactions as there could be a large multidisciplinary team of investigators (Halcomb & Hickman). Finally, a hybrid data investigation provides the researcher with added flexibility for outcomes (Halcomb & Hickman).

In research investigations, the planning of outcomes only provides a possible snapshot of the outputs, and with mixed variables, the results may not necessarily produce expected outcomes. Therefore, additional flexibility is appreciated as the investigators may not be able to restart the entire study. The cons of using a mixed methodology are that a single researcher is rarely formalizing the study. Additionally, considerable time must be spent to find individuals with backgrounds in finding individuals with both quantitative and qualitative backgrounds. A further negative connotation for a mixed methods research approach is the sheer size of the data collected and the additional ‘mixing’ of each data point for analysis.

DeCuir-Gunby and Schutz (2017) further support a mixed methods research approach in health sciences. It allows the research team to examine complex problems in education from a single study by providing evidence to triangulate findings from multiple sources. For instance, this investigation utilizes two data collection tools: a structured procedural checklist and a self-efficacy survey. The mixture of these data collection tools can be used to challenge the validity of either data set. Simply, if the research participant state in the self-efficacy tool that they learned a change of practice of catheter insertion techniques, it should also be shown or

triangulated in the quantitative procedural checklist that they achieved a level of competency.

Additionally, the most significant consideration for utilizing a mixed methods investigation is the time and resources, as it can consume much of both, limiting the overall investigation (DeCuir-Gunby and Schutz).

Research Approach

For this study, the stated hypothesis is that creating a simulated central venous catheterization procedural skills curriculum for medical residents will improve self-confidence and technical and behavioral skills. The investigation will assess how to create an effective procedural curriculum and how to implement a simulated event and learners' perception of their educational experience and self-efficacy. It will also assess the learners' technical and behavioral performance rated on a checklist. These variables lend themselves to a mixed methods research approach due to both qualitative (learners' perceptions) and the quantitative scoring (procedural checklist) of clinical and behavioral performance.

Since a mixed methods research approach has been selected, the next step is choosing a design approach in which there are three core designs of mixed methods research: sequential explanatory design, sequential exploratory design, and concurrent triangulation design (Figure 7) (Warfa, 2016).

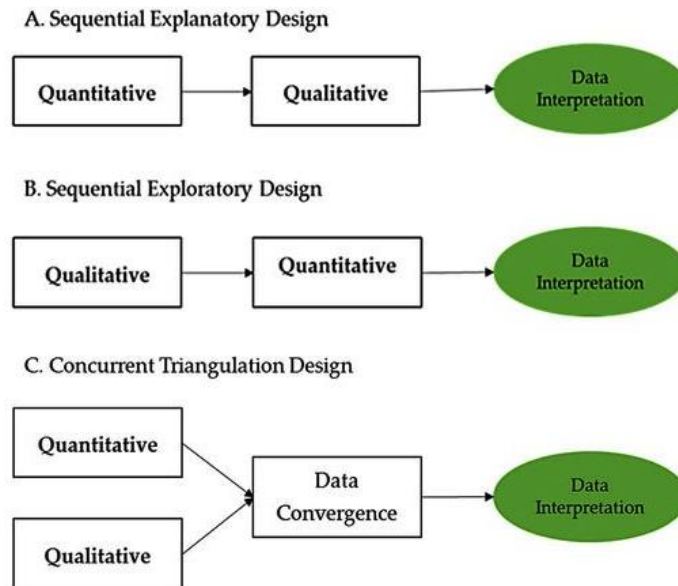


Figure 7

Warfa, A. R. M. (2016). *Mixed-methods design in biology education research: Approach and uses*. *CBE—Life Sciences Education*, 15(4), rm5.

Ivankova et al. (2006) state that when designing a mixed methods investigation in two consecutive phases, the investigator should provide weight to quantitative and qualitative data collection and analysis, the sequence of the data collection, and the stages of the research process at which time the two data sets are linked, and results are integrated. Further, Warfa (2016) provides a stepwise approach to designing these consecutive phases and begins with a sequential explanatory design. Two phases define the sequential explanatory design research approach: an initial phase of quantitative data collection and analysis followed by the qualitative data collection and analysis (Warfa). The strengths of both sequential designs (exploratory and explanatory) are the ability to (Warfa):

1. contextualize and generalize qualitative findings to larger samples (in the case of sequential exploratory)

2. enable one to gain a deeper understanding of findings revealed by quantitative studies (in the case of sequential explanatory
3. collect and analyze the different methods separately

The challenge with these types of mixed method investigations is the time committed to complete both data collection phases. Purely, this design suggests collecting data at two different time points, and the analysis of the primary data source may further delay the collection of the second data source after preliminary analysis (Warfa).

Conversely, concurrent designs allow the investigator to collect data in a single phase. This approach enables both data sets to merge during analysis, providing the investigator insights on convergence, divergence, or contradictions (Warfa). Concurrent design is not without weakness and has two primary areas of opportunity. The single data collection precludes follow-up on any data that may prove interesting or confusing, as the single-stage collection has concluded (Warfa). Second, integrating the data sets could become an impediment if the outcomes are contradictory or diverge (Warfa). On the other hand, the strength of the concurrent designs is in the single stage of data collection, which provides a shorter time frame, making concurrent methods more efficient and further allowing triangulation from the combination of variables (Schoonenboom & Johnson, 2017; Warfa).

Sullivan et al. (2008) suggest that many procedural specialties rely on a traditional apprenticeship model for skill acquirement. This type of instruction is highly variable and critically dependent on the supervising physician. Further, this style might not guarantee adequate exposure to all the necessary skills to safely and effectively provide high-quality care to a patient in need (Sullivan et al.). Due to time constraints, faculty are challenged to develop stepwise procedural checklists to offer insights into novice physicians' cognitive, technical, and

behavioral skillsets regarding invasive clinical procedures. Sullivan et al. utilize an instructional design framework encompassing all three variables titled cognitive task analysis (CTA). A CTA captures information beyond traditional task analysis by assessing cognitive decisions made during procedural tasks and allows faculty to break down the entire procedure into discrete steps that learners can easily understand (Sullivan et al.).

Mengshoel (2012) states that concurrent triangulation designs should be based on different paradigms that have both ontological and epistemological implications. Further, Doyle et al. (2009) agree that when an investigator has both quantitative and qualitative phases of research co-occurring, the preferred methodology should be a concurrent triangulation design. After reviewing the available variable and the collection tools needed for analysis, the literature supports a mixed methods concurrent triangulation design protocol to provide the best interpretation of the procedural checklist and the self-efficacy survey.

Limitations

A mixed-methods concurrent triangulation design is the selected methodology with these investigations now defined. This involves the two data sets chosen for the study, the procedural checklist and the self-efficacy survey. Both data sets are collected simultaneously, then can be converted into a singular dashboard for analysis.

The limitations of this design are the amount of time needed to collect both data sets from participants during and after the simulation. Additionally, there could be a lack of uniform analysis for triangulation, such as the uncertainty of the outputs. Direct observational checklists are, in their nature, subjective and could be perceived as biased. Furthermore, the subsequent self-efficacy survey might not be completed or rushed by the physician returning to clinical duties. Another drawback could be that the researcher is not an expert in both types of analysis.

This could lead to a lack of understanding by the reader or an incorrect application of combining the results.

Additionally, learners might not have an ideal self-perception of their skill set. Performing the task several times in the simulation lab could foster a false sense of competency, which could be translated into the survey. This limitation could be mitigated by utilizing some parametric and non-parametric statistical analysis where warranted. Although these limitations could skew the data sets, the robustness of both groups provides a strong case focusing this type of investigation.

Implementation Plan: A Mixed Methods Concurrent Triangulation Design

Integrating a simulated procedural skills curriculum allows senior administrators and faculty to investigate the transfer of technical skills to the operational environment. Further, this curriculum aims to standardize training protocols, enhance human performance, reduce clinical errors, and provide better patient outcomes through validated metrics. One standardized interprofessional training methodology needed to be created to investigate human performance, which provides safe and effective patient care. The simulated interprofessional clinical procedural curriculum's goal is to enhance human performance and reduce error for required clinical procedures utilized across a range of medical specialties and providers. Simulated clinical training can improve both clinical knowledge and performance for basic competence (Issenberg et al., 1999). Employing validated checklists across a sizeable medical continuum may further provide insights to standardize additional essential clinical procedure competencies, reduce errors, enhance technical performance, and lead to positive patient outcomes (Berg et al., 2013; Berg et al., 2013; Riesenbergs et al., 2013).

The primary objectives of the simulated curriculum that were implemented are:

1. Utilized procedural checklists to ensure standardization of procedural skills across medical specialties, specifically, thoracentesis, paracentesis, airway management, and lumbar puncture.
2. Demonstrate clinical knowledge relevant to procedures through explaining indications, contraindications, patient preparation methods, sterile techniques, pain management, proper techniques for handling specimens and fluids obtained, and test results.
3. Ability to clearly explain to the patient all facets of the procedure necessary to obtain informed consent, then competently perform each essential procedural skill according to the validated checklist.
4. Provide a safe environment for novice providers to rehearse, then enhance performance through simulated procedures.
5. Augment simulated procedural training toward mastery-level learning.

CVC Simulation Lab Curriculum

The first session begins with a flipped classroom-style deployment of training PowerPoint for the procedure. Next, learners must demonstrate clinical knowledge by role play assessment for informed procedural consent, utilizing a three-level approach, indications, contraindications, and troubleshooting. Finally, each learner will rotate through the simulated encounter, which provides an overview and demonstration, first-person orientation, and skill rehearsal, then a direct observational assessment of the simulated procedure.

The central venous catheterization procedure was identified by clinical faculty across several different specialties that perform this procedure as the content of the proposed curriculum. There was an evident deficiency amongst the residency populations per faculty oversight. The simulation department was contracted to design, implement, and analyze a standardized central

venous catheterization procedural curriculum based on evidenced medical practice and the feedback from practicing clinical faculty. The curriculum design framework was based on an instructional design methodology (elaborated below), followed by creating a forty-two stepwise procedural checklist and accompanied by a self-efficacy survey post-simulation. The overall design process spanned roughly twelve months as several clinical faculty needed to be interviewed. The procedural checklist was voted upon based on personal clinical knowledge and evidence-based medical practice. Additionally, the flow of the selected simulation activity needed to be outlined using the instructional design methodology described below and how the learners would receive and provide feedback. A PowerPoint presentation was created reviewing the overall steps of the procedure (Appendix C) and would be shown before each simulation as a cognitive primer. Learners were not limited to this reference alone and were encouraged to research any evidence-based connection they found helpful. Once the curriculum design was constructed and the data collection tools were aligned, an implementation phase was launched with several chief residents (residents at the end of their clinical training) to assess any gaps in the training. After three sessions, the pilot program was concluded, and the entire curriculum was launched.

Instructional Design Methodology

Sullivan et al. (2008) suggest that many procedural specialties rely on a traditional apprenticeship model for skill acquirement. This type of instruction is highly variable and critically dependent on the supervising physician. Further, this style might not guarantee adequate exposure to all the necessary skills needed to provide high-quality care safely and effectively to a patient in need (Sullivan et al.). Due to time constraints, faculty are challenged to develop stepwise procedural checklists to provide insights into novice physicians' cognitive,

technical, and behavioral skillsets regarding invasive clinical procedures. Sullivan et al. suggest utilizing an instructional design framework encompassing all three variables titled cognitive task analysis (CTA). A CTA captures information beyond traditional task analysis by assessing cognitive decisions made during procedural tasks and allows faculty to break down the entire procedure into discrete steps that learners can easily understand (Sullivan et al., 2008). Specifically for the central venous catheterization curriculum design, the instructional design tool titled ADDIE was deployed as a CTA.

The ADDIE (figure 8) pictured below is an acronym for; analysis, design, development, implementation, and evaluation (Mayfield, 2011). Mayfield proposed using the ADDIE development process umbrella rather than a specific stepwise framework for designing training programs. This design is intentional to be provide subject matter experts (SMEs) flexibility to interject steps for the training, thus removing any bias and solely relying on the group to determine the flow of the training by utilizing a tool.

Figure 1 A graphical representation of the ADDIE process

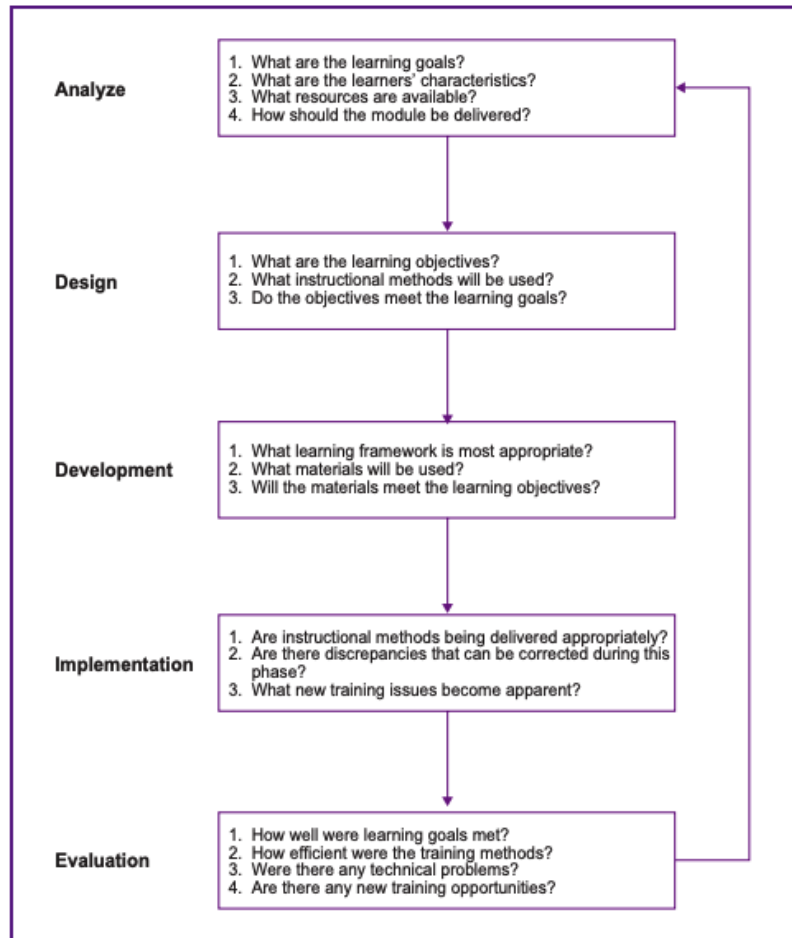


Figure 8

Mayfield, M. (2011). *Creating training and development programs: using the ADDIE method. Development and Learning in Organizations: An International Journal*, 25(3), p. 21.

Shibley et al. (2017) provide further evidence of the use of a blended ADDIE checklist design methodology that removes the dependency of the sole instructor on the day of the lab and shifts the design to focus more on the standardization of a checklist for superior outcomes. For the specific structure of the procedural checklist, the framework of the ADDIE was followed, beginning with the learner analysis. Step one is the analysis stage where the faculty identified learner characteristics, determined the SMEs needed for a procedural checklist (quantitative) and

self-efficacy survey (learner perception/quantitative) creation, provided the learning objectives for the procedure, and strategized the fidelity on which is the best medium of instruction. This stage provided the overall goals, resources, and fidelity needed to achieve competency (Mayfield, 2011). Next is the design phase, where the training strategy is fully defined and how the instructional methodologies will accomplish the learning objectives.

Data Collection Tools

The investigation utilized two primary data collection tools, a forty-two-step procedural checklist (quantitative) and a self-efficacy survey (qualitative). The identified faculty used a modified Angoff methodology of selecting SMEs to code a procedural checklist and self-efficacy survey to capture both variables. Shulruf et al. (2016) concede that the Angoff methodology utilizes a judge-based system of aligning the process of completing a task and the minimal passing threshold/level (MPL) needed for competency. Twelve attending physicians were allowed to define, in a stepwise manner, how a central line procedure should commence individually so as not to bias the group of experts. Next, the list of tasks was placed in order by a voting structure of the same experts to create a linear process for the procedure. This voting structure as a binary zero or one selection of place or moves the procedural item. The twelve faculty would vote by raising a card with zero or one. If a consensus was not able to be reached due to working or placement of task, a further open vote would commence aligning the faculty by majority. Once aligned, the checklist was again voted upon by the individual experts separately as to the final order of the course. Further, a capture system needed to be developed and again utilized a modified Angoff judging system, which moves the investigation into the development phase. The checklist employed a three-metric faculty selection feature for easy grading during direct observation: done, not done, done incorrectly. These three metrics were

again deliberated and selected for additional insights into the clinical decision-making of the learners across the forty-two-step checklist (Appendix B). Still, within the development phase, the same faculty SMEs provided feedback on learner perceptions that would need to be captured. A post-simulation self-efficacy survey was created similarly (Appendix A). After both capture systems are agreed upon, the investigation marches towards the implementation phase. There is a series of “dry-runs” in the implementation phase before learner participation. This is a crucial step in the methodology. It can reveal any unforeseen errors in the learner’s experience and is a simple assessment mechanism for the faculty to observe how the simulation will unfold (Shulruf et al.). Once correctly aligned with several “dry-runs,” the learners are brought into a practical simulation session, and the proper investigation initiates. The final stage in the instructional design methodology is evaluation. This stage provides the convergence and possible triangulation of the two data sources. Both data sources are evaluated for outliers, completeness, and changes in the delta. Additionally, the intersection of the qualitative data could provide valuable insights into perceived learner confidence regarding cognitive, behavioral, and technical abilities when combined with the checklist. Learners are provided with direct observational feedback upon completion of the simulation and allowed to begin again. Central venous catheterization training sessions are held monthly and can accommodate up to twenty learners simultaneously, with four to five faculty conducting the direct observation. This proposed new curriculum is designed to fill gaps in resident medical education regarding procedural skill performance while enhancing communication skills, clinical knowledge, and overall provider confidence, keeping patient safety a priority with consistent longitudinal training throughout multiple specialties. Finally, a faculty observational post-simulation survey was created to assess if any change in procedure or skillset was noted (Appendix C).

Data Analysis

Since the simulation lab is a formal learning environment to train medical residents in central venous catheterization, learners will be allowed readings, lectures, exploring analytical models, and can appreciate the time to work through the process analytically (Kolb, 1984). Learners may choose to be primed with any outside learning materials they select on the line placement. Further, all participants are provided a PowerPoint overview of the procedure, directly observed while placing a line in a safe, simulated setting, then provided just-in-time feedback. This methodology will utilize a mixed-methods concurrent triangulation design with a

- Forty-two-step checklist encompassing cognitive, psychomotor, and behavioral characteristics.
- Learner participants will complete the line placement and then submit a qualitative survey regarding self-efficacy, change in practice (what, why, and why not), usefulness in specific medical practice, and facilitator performance.

The checklist was created using a modified Angoff methodology by gathering subject matter experts from six different clinical specialties that commonly perform this procedure. A binary scoring system was deployed to facilitate the logical order, type of information, and clinical decision-making for the design of the checklist.

They provide an instructional design framework for all the learner types found within medicine. The fluidness of the procedure was also noted in the curriculum design theory, as the nature of the patient's presentation could change the course of the flow. Patients requiring a central venous catheter need large amounts of fluids, medications, blood, or internal pressure monitoring. They could be in a state of trauma, which provides little time for systematic instrument setup, which circles back to the experimental learning theory involving chunking

recall, clinical decision making on which side to place the line, executive psychomotor functionality, and behavioral interactions with the informed consent of an invasive procedure. Synthesizing experimental deliberate practice theories with just-in-time feedback should provide faculty with evidence that a transfer of learning towards mastery level execution was accomplished.

Investigational Study Control

The investigation will utilize a faculty survey response to direct learner observation as a control group. A survey was distributed to faculty members whose departments voluntarily encouraged residents to participate in the simulation lab (Appendix C). This allows the faculty members who are the medical residents' direct clinical supervisors in training to observe any changes in skillset pre/post CVC simulation. The faculty is ultimately responsible for improving clinical abilities within their medical specialties. The questions assess if an educational intervention was warranted, what (if any) changes in technique or clinic practice were observed, and if they would appreciate more simulation-based medical education modules to improve other skills within their medical specialty.

Evidenced Strengths and Opportunities

While a mixed-methods investigation is warranted by the goals/outputs designed by the proposed curriculum, the subjectivity of the faculty and study participants could produce confounding variables. One such variable is a learner who performs well in the simulation lab but not within direct patient care, and the reverse may also be true. Further, patient presentation and anatomy variability may present a considerable challenge. For example, a very sick, dehydrated patient would have all their veins compressed, and would be challenging to gain central venous access due to a pathological condition. Also, learners cannot always be under

direct supervision due to the sheer number of patients needing central venous access. A learner could perform poorly with the catheter placement, and the patient could have other medical management problems that supersede the review of the line placement.

On the other hand, continuous practices have shown positive patient outcomes (Issenberg et al., 1999; Berget al., 2013; Berg et al., 2013; Riesenberget al., 2013). The key to the success of the placement of a central line is a deliberate practice in a safe, low-risk, high-reward environment such as the simulation lab. Here learners can continuously hone a skill without impacting patients, leading to improved clinical outcomes.

Project Timeline

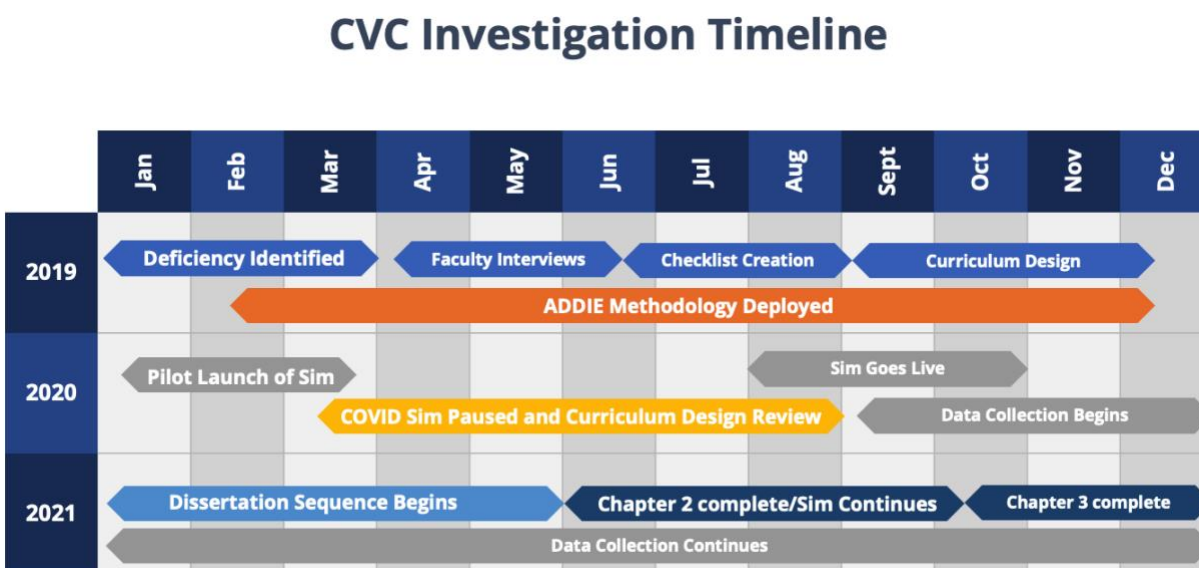


Figure 9: Investigation Timeline

Institutional Review Board

After several conversations with both the OSF Saint Francis hospital system and the University of Illinois College of Medicine at Peoria IRB departments, it was determined that this investigation does not reach the level of human subject research. The determination was made due to the lack of identifiable features within the study design. Both data analysis tools do not

collect names, dates of birth, residency specialty, or any other identifiable characteristics. A waiver of human subject research has been requested from both IRB boards, and documentation is found in Appendix D.

CHAPTER 4: RESULTS

The investigation recorded 310 procedural checklists and 83 submitted self-efficacy surveys. Of the submitted checklists, 11 were excluded due to incomplete or missing most of the steps not captured, leaving 299 procedural checklists analyzed. Of the 83 self-efficacy checklists, only 63 submitted a fully completed survey or submitted one. Twenty-five faculty observational surveys were returned and completed.

Procedural Checklist Data Results

Table 1 below illustrates a full breakdown of the 42-step procedural checklist, which is completed by clinical faculty members across the specialties that utilize CVCs. The faculty are asked to attend a training course to review the procedural checklist and watch a core faculty member place the catheter in the simulation lab. These faculty members then attend and observe residents outside of their own specialty to limit inter-rater reliability issues. Within table 1, there are three columns of data to be extracted. First is if the participant completed the step correctly (green), next was the step done incorrectly (yellow), and finally, the step was not completed at all (red). From table 1, we have n=299 total participants completing 11960 the green shaded steps correctly, 167 steps done incorrectly in yellow, and 47 steps not done at all in red.

PROCEDURE CHECKLIST			
Sterile Barrier Preparation and General Line Insertion	Completed	B Done Incorrectly	C Not Done
Obtains Informed Consent			
Benefits (medication, fluids, CVP Monitoring)	299		
Risks (Pneumothorax, arterial puncture-bleeding, Infection, thrombosis)	299		
Describes the additional interventions that would address complications	299	2	
Non-sterile set up			
Put on surgical cap and mask before opening the CVC bundle	299	1	1
Opens CVC bundle wrapper on sturdy work surface without touching materials (CVC kit, Chlorhexidine, or drape) inside blue wrapper	299	1	
Puts on sterile gloves, separates inner bundle materials, locates Chlorhexidine.	299		
Indicates on self the area to be prepped with Chlorhexidine	299	4	
Opens Chlorhexidine, vigorously scrubs the setup table for 30 SECONDS , in 3 planes (horizontal, vertical and diagonal-10 sec each) Dry time 2 minutes	299	10	
Discards gloves	299	1	2
Open and drop sterile probe cover onto sterile field	299	1	1
Barrier Protection phase-doctor, patient, probe			
Opens second pair sterile gloves and gown, placing on counter top	299	6	3
Performs hand hygiene (15 Seconds for Alcohol Sanitizer, 30 seconds for hand washing-soap/water)	299	1	
Barrier doctor: Puts on sterile gown by opening gown with the fold toward themselves, <i>hands must remain inside sleeves</i>	299	6	
Puts on sterile gloves by inserting white sleeve collar inside glove first, then sliding hand through white collar into glove.	299	5	
Barrier patient: Drape applied transversely across table then pulled over the head/superior part of the table and then over the "body" (rest of table).	299	1	
Barrier US Probe: Verbalizes this step. [skill practiced at US station]	299		
Set up CVC Kit			
Prepares order of use- lidocaine syringe, finder needle, wire, scalpel, dilator, CVC catheter. Obtains needleless caps, saline, 2nd Chlorhexidine, Tegaderm	299	4	
Flushes ports with sterile saline to purge air and verify patency	299	1	
Clamps each port or attaches needleless caps. (ok to keep brown port off)	299	1	1
Unclamps and removes cap from the brown port to accommodate wire	299	1	2
Procedure			
Verbalizes placing patient in 10-15 degrees Trendelenburg position	299	9	6
Anesthetizes skin (foam pad) with 1% lidocaine beginning with a small surface wheal and then anesthetizing deeper tissues.	299	2	
Puncture foam pad with introducer needle.	299	1	
Removes the syringe from the needle (or uses syringe port for wire)	299	2	1
Advances guidewire through introducer needle no more than 20 cm [2 black lines on guidewire]	299	5	
Removes the needle while maintaining hold of guidewire	299	6	
Uses the scalpel to nick the foam in order to advance the dilator.	299	9	3
Advances the dilator over the guidewire to dilate the skin [foam pad] using no more than half the dilators length, then removes dilator.	299	13	
Advances the triple lumen over the wire, pulling back the guidewire as the catheter is moved forward.	299	20	1
User never lets go of the guidewire.	299	21	
Advances the line to approximately 14-16 cm for the right side 16-18 cm on the left side.	299	10	
Once the line is in place, removes the guidewire in its entirety.	299	3	
Verbalizes: Draws blood and flushes each port to ensure there is blood flow	299	4	
Cleanses skin of any blood with 4x4 gauze and 2nd Chlorhexidine stick	299	10	
CVC Completion			
Secures the lines place (Stat Lock is preferred).	299	2	4
Places antibiotic (Chlorhexidine) disk.	299	2	12
Places large Tegaderm over line (or verbalizes this).	299	1	4
Discards sharps	299	1	2
Orders a CXR to confirm location.	299		2
Notifies nurse that line is ok to use when no pneumothorax is seen and tip of CVC visualized at the SVC/RA junction.	299		2

Table 1

42-Step Procedural Checklist-Full List

A further breakdown of the frequency of done steps incorrectly is found within the procedural checklist. The most consistent steps incorrectly correlate to the physical procedure, specifically the participant ‘Advances the triple lumen over the wire, pulling back the guidewire as the catheter moves forward and User never let’s go of the guidewire’ respectively. This step is difficult because both hands move the guidewire and the catheter in opposite directions. This takes considerable concentration and could pose a high-risk moment for the patient if not completed correctly. Third on the list of “done incorrectly” missed items was ‘advancing the dilator over the guidewire to dilate the skin using no more than half the dilator's length, then removes the dilator.’ There was a three-way tie for the fourth-most step completed incorrectly, ‘Opens Chlorhexidine, vigorously scrubs the setup table for 30 SECONDS in 3 planes (horizontal, vertical and diagonal-10 sec each) Dry time 2 minutes, Advances the line to approximately 14-16 cm for the right side 16-18 cm on the left side, and Cleanses skin of any blood with 4x4 gauze and 2nd Chlorhexidine stick.’

The final column (illustrated in table 2 below) in red indicates a step not performed at all. The most omitted step was ‘Cleanses skin of any blood with 4x4 gauze and 2nd Chlorhexidine stick. This is a clinical knowledge error titled a lapse. There are two main types of antiseptic agents used in procedures, chlorhexidine, and iodine. While both clean the target area well, they are applied in different methods. Iodine is applied by making larger concentric circles, moving any bacteria away from the target site. Chlorhexidine is a scrubbing application that goes directly over the target area by moving the head back and forth for thirty seconds. The second most omitted step was ‘Verbalizes placing the patient in 10-15 degrees Trendelenburg position.

Finally, there was a tie for the third-most missed step of ‘Secures the lines place (Stat Lock is preferred) and Places large Tegaderm over the line (or verbalizes this).’

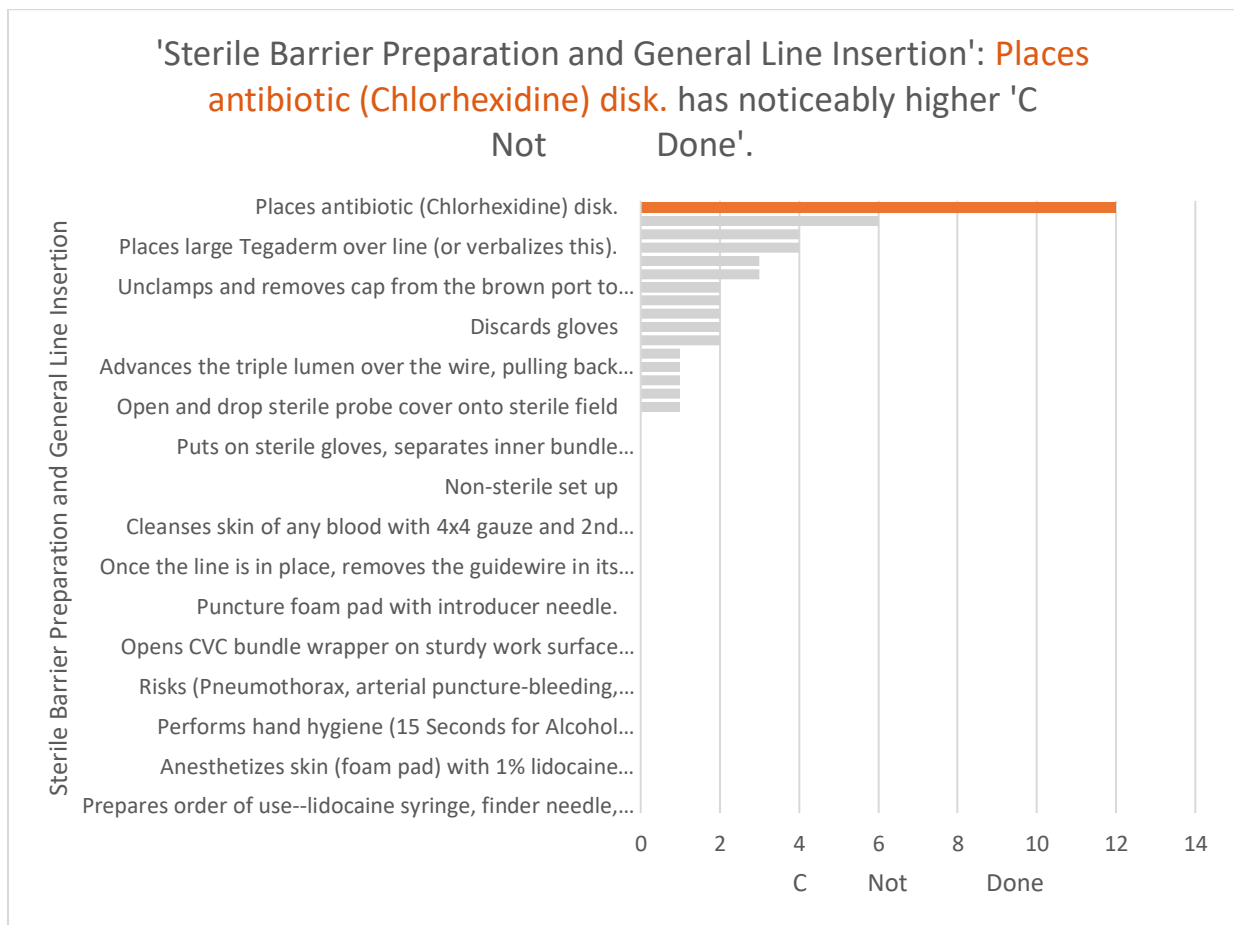


Figure 10

42-Step Procedural Checklist Results

The totals of all error rates can be visualized in Table 3 below. The peaks in blue are steps done correctly. The white valleys are steps done incorrectly or omitted.

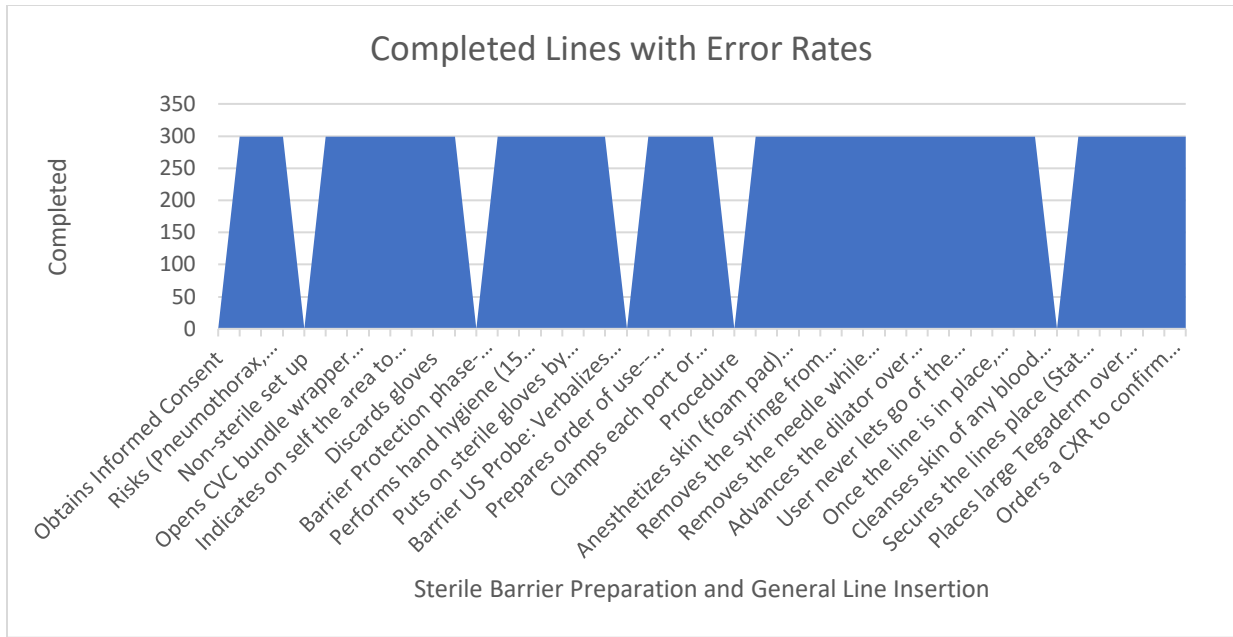


Figure 11

42-Step Procedural Checklist Results

Post Simulation Self-Efficacy Survey Results

The post-simulation self-efficacy survey (Appendix A) yielded 63 participant responses. The survey analyzed the participants' perspectives across four questions ranging from identification of practice change after the simulation with examples, ability to apply the content, the participant perception of faculty instruction to improve participant performance, and self-efficacy of the procedure.

Figures 10 and 11 below illustrate the participants' level of self-efficacy and if the faculty helped the participant see how to improve or sustain good performance. Figure 8 demonstrates a 23% change in self-efficacy pre/post-CVC simulation. Less than 60% of the participants felt they had sufficient education with CVCs before the simulation, and 80.2% stated they perceived an increase in skillset.

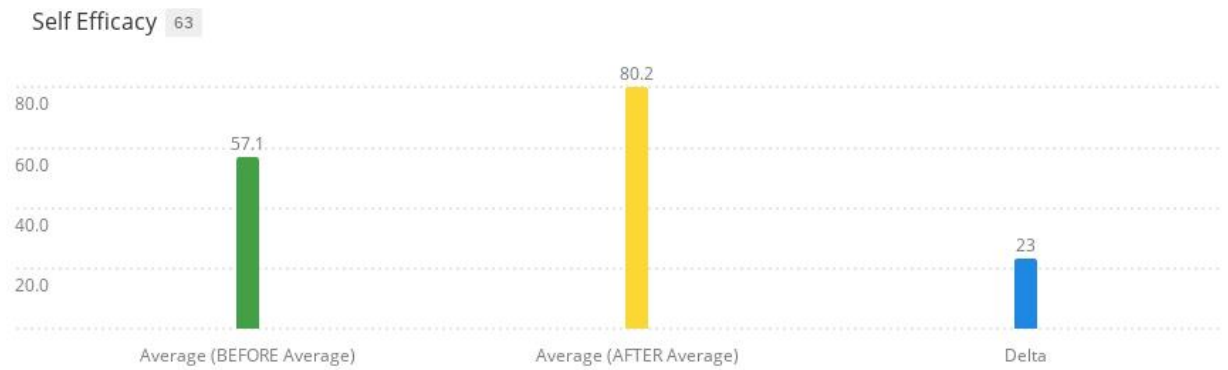


Figure 12

Self-Efficacy Survey Results

Learner: The facilitator helped me see how to improve or sustain good performance. 63



Figure 13

Self-Efficacy Survey Results

Additionally, the participants were queried whether they could identify a change in practice after completing the simulation. Figure 12 below exemplifies that 95.24% of the 63 responses noted they could identify a difference in their specific practice of placing a CVC.

Learner: I can identify a change in practice - something I would do differently next time I encounter similar situation(s). 63



Figure 14

Self-Efficacy Survey Results

Diving deeper into the self-efficacy survey, participants were asked to specifically identify what change in practice they would make after completing the training. Figure 13 and 14 demonstrate the two most significant changes in practice; the distance of catheter insertion based on either right or left side of the neck and improved hand-eye coordination with the probe and needle tip.

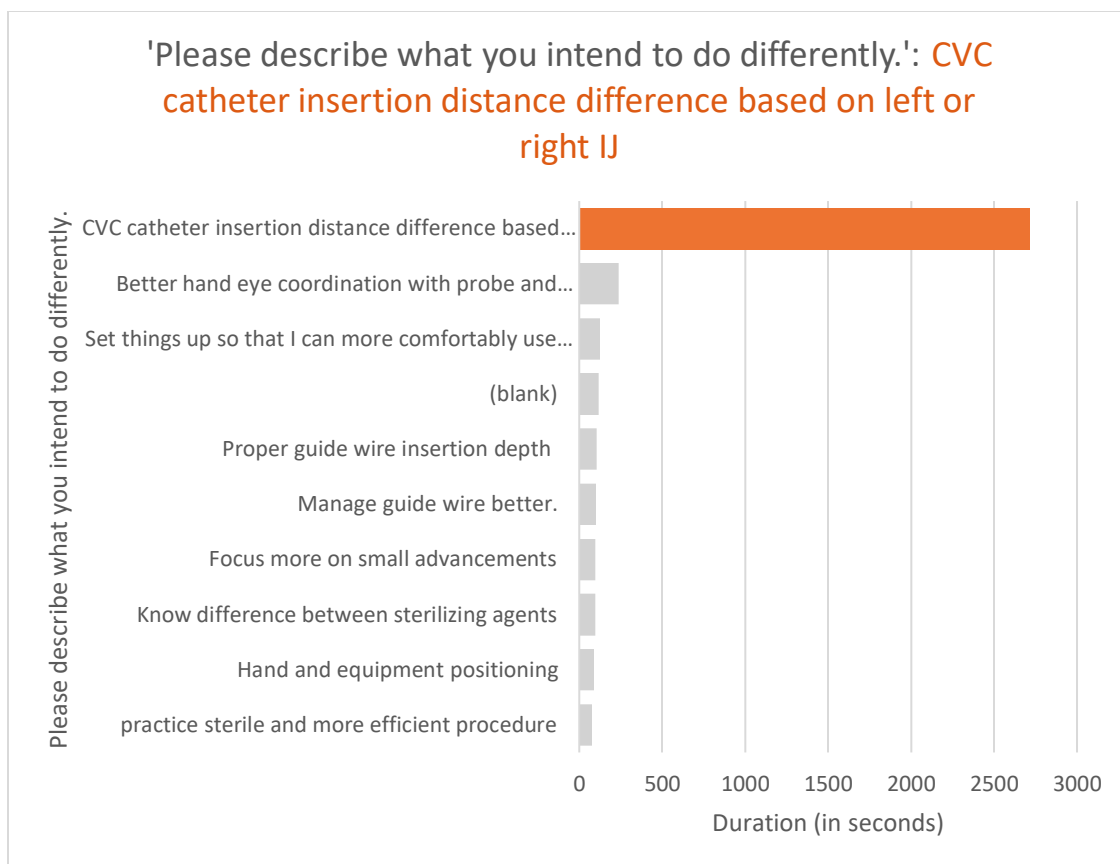


Figure 15

Self-Efficacy Survey Results

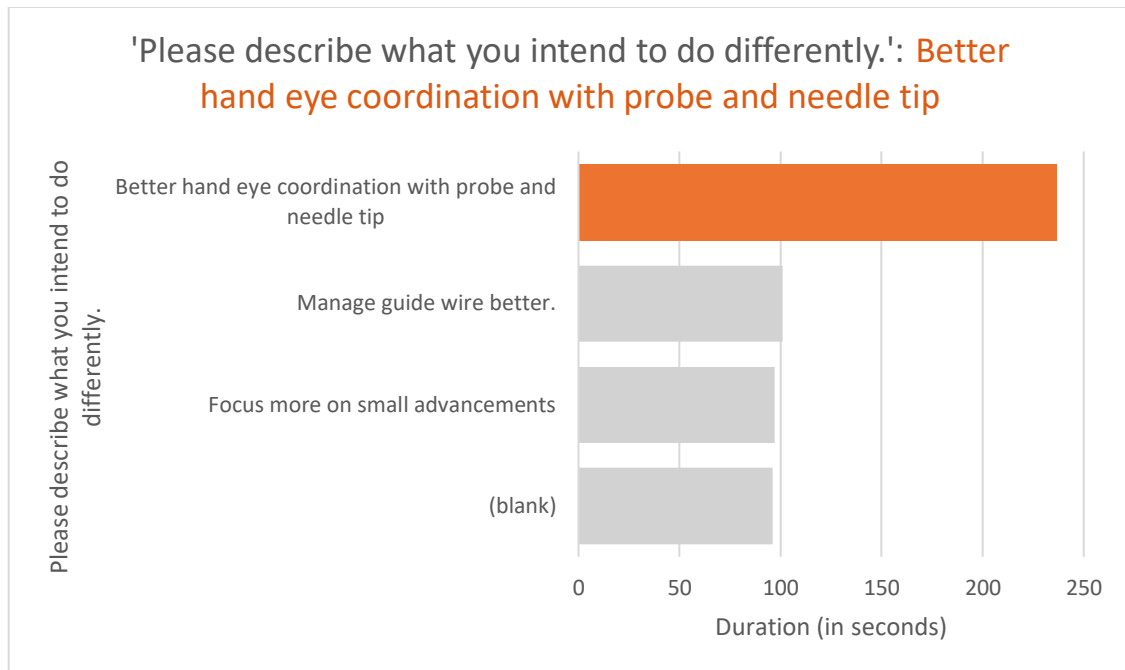


Figure 16

Self-Efficacy Survey Results

The final assessment captured within the self-efficacy survey was allowing the participants to relay their ability to apply the content learned before and after the simulation, which is presented in figure 15 and 16 below.

The scatterplot shows a positive correlation between the participants' ability to apply the content from before the simulation to after the simulation. The increase of the y-axis evidences this while the x-axis is also increasing.

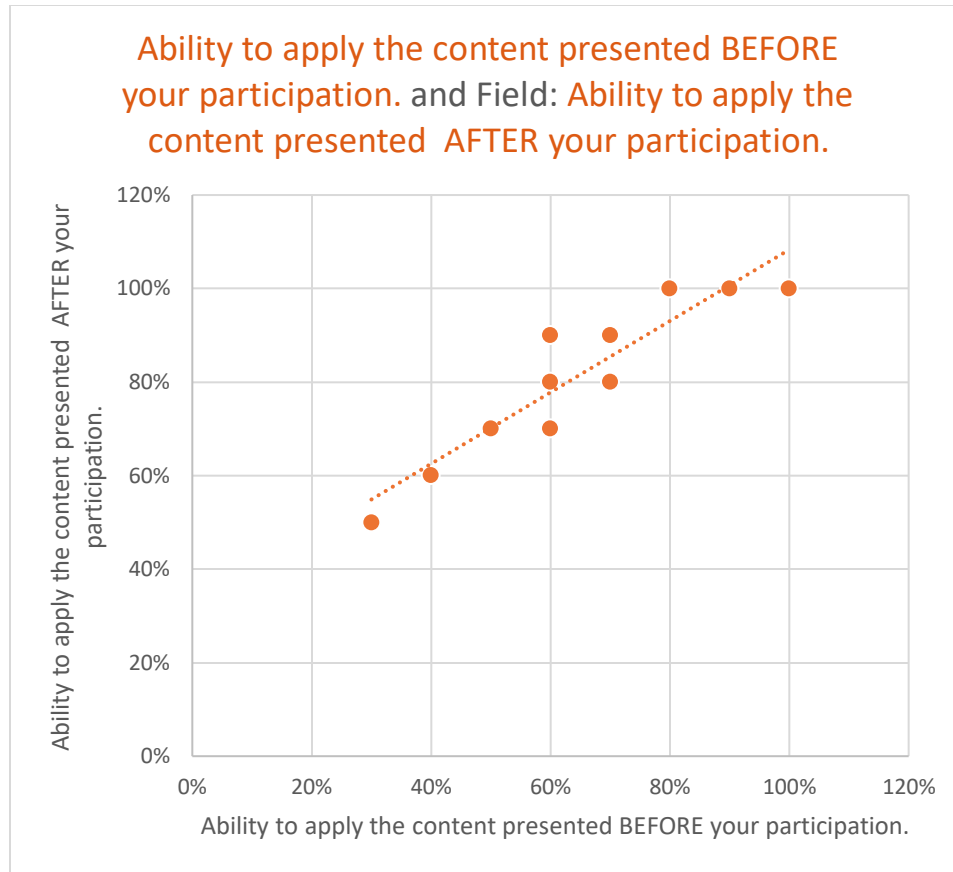


Figure 17

Self-Efficacy Survey Results

Figure 16 provides a simple bar graph to emphasize further an increase in participants' positive perception of their ability to apply the content is more significant after the simulation when compared to before receiving the content. Simply, Figure 16 illustrates a three-fold improved frequency of the ability to apply the lab content after participation.

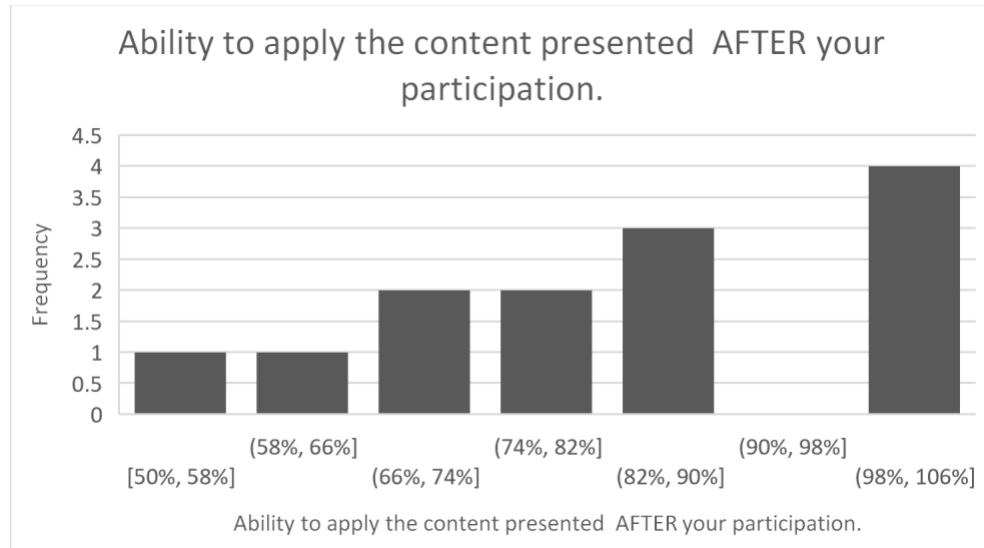


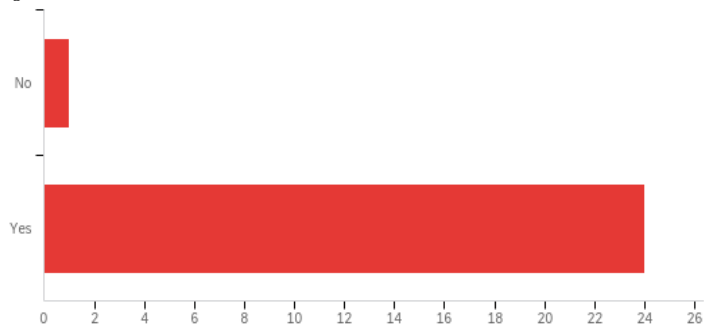
Figure 18

Self-Efficacy Survey Results

Faculty Observational Survey

The final data collection tool utilized was a faculty observational survey to supply a control group of noticed varied abilities between participants and non-participants within the residencies. The electronic survey was sent out to faculty members of all the residency groups and yielded n=25 responses (Graph 1-5). 96% of the faculty who responded to the survey allowed time for their residents to attend the volunteer CVC simulation lab.

I provided my residents time to attend the CVC simulation lab. 96% yes

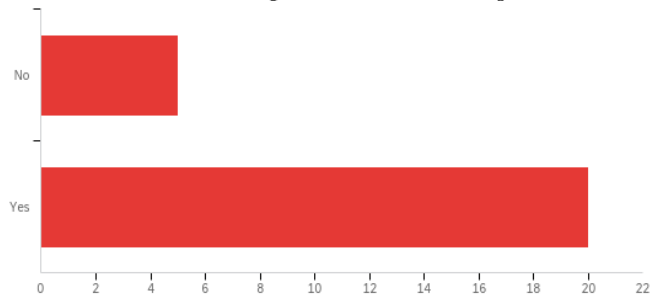


Graph 1

Faculty Observational Survey Results

80% of the faculty that responded to the survey stated that they noticed their residents needed additional practice with CVC line placement.

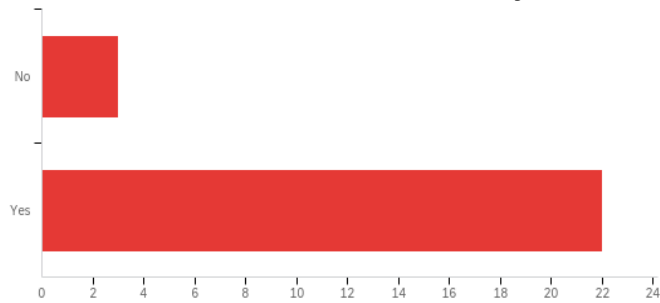
Before attending the CVC simulation lab, my residents needed additional practice with CVC line placement. 80% yes



Graph 2

Faculty Observational Survey Results

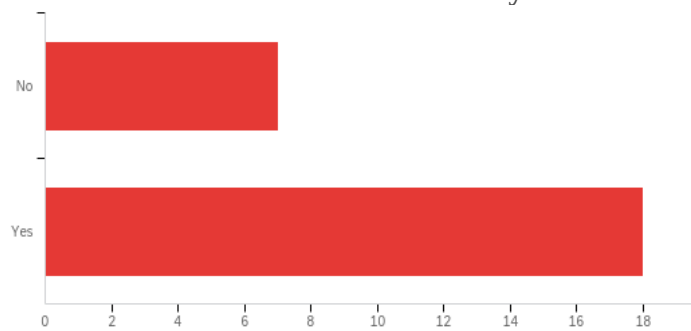
88% of the faculty respondents stated they noticed an improvement in skills from the residents.
After attending the CVC simulation lab, I noticed an improvement in skills from my residents that attended. 88% yes



Graph 3

Faculty Observational Survey Results

72% of the faculty respondents stated they noticed a change in practice of care.
After attending the CVC simulation lab, I noticed a change in practice of care from my residents that attended. 72% yes

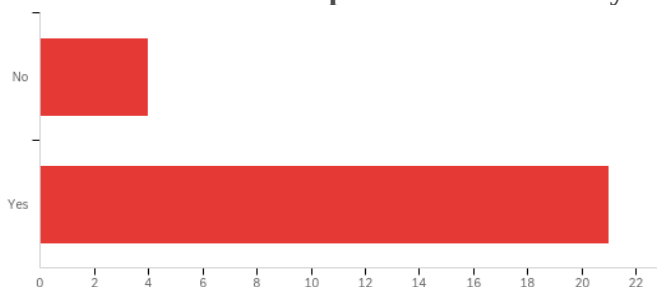


Graph 4

Faculty Observational Survey Results

84% of the faculty respondents stated they would like more simulation-based medical education labs like the CVC.

I would like more of the residents I supervise to attend simulation-based medical education labs like the CVC to improve skillsets. 84% yes



Graph 5

Faculty Observational Survey Results

These findings contribute to simulation-based medical education by providing an encouraging relationship of self-efficacy post-simulation, a perceived improvement from faculty, and in-depth insight into tailoring clinical procedural training by assessing learners with a checklist. Specifically, there are several positive correlations toward improving skillset, positive changes in medical practice, improvement of technical skills, and solidification by faculty oversight. The procedural data clearly shows that more education is needed in the physical procedure of the CVC, as this is where the most errors occur. By combining the done incorrectly and not done columns, the data totals 214 errors. Of these errors, 126 occurred in the procedure section of the checklist, accounting for almost 60% of all errors. Digging deeper into the items missed, the data do not show the significance of the outcome. Omitting or completing the thing incorrectly could lead to severe infections, increased length of stay, increased severity of admittance (ICU, SICU, MICU), and financial burden to the patients. Further, 96% of the participants noted they would make a change in practice to improve patient outcomes, and their perceived self-efficacy was enhanced by 23% pre- to post-simulation. 83% of faculty surveyed

reported an improvement in the skill set of the residents who volunteered to attend the simulation, confirming a triangulation of three data points: procedural, self-efficacy, and direct faculty observation. The positive triangulation proves a positive linkage between deliberate practice and improved skillset within the scope of simulation-based medical education of CVCs. Moreover, similar types of simulation-based medical education could be produced using the same conceptual framework to provide curriculum and assessment tools to improve clinical procedural skills further and hopefully improve patient safety and reduce human error.

CHAPTER 5: DISCUSSION

Procedural Checklist Analysis

Through triangulation of quantitative and qualitative data tools, the investigation results proved that a structured central venous catheterization curriculum yields positive outputs regarding self-efficacy, improved procedural psychomotor skills, and faculty perceived technical improvements regarding central venous catheter placement. According to the procedural checklist, many of the 42-steps were done correctly and precisely. The results show a divide between clinical knowledge and psychomotor skills. This is observed by the sheer number of items missed more frequently in the physical procedure than in the clinical knowledge portion. Specifically, there is a three to one error rate within the physical procedure compared to clinical knowledge. The data support further training sessions regarding technical skills involving the movement of the catheter over the wire, never letting go of the wire, and placement of the dilator. These lend themselves to more psychomotor skills and can be remedied with further skills labs. The clinical knowledge errors were evidenced by the lack of opening the chlorhexidine scrub and applying it correctly. This is a clinical knowledge error of not understanding how the antiseptic cleanser is opened and used.

Moreover, the chlorhexidine application was the most ‘not done at all’ step. Securing the catheter and placing a large Tegaderm over the line was the third most omitted step, further strengthening the evidence for reviewing clinical applications of antiseptic procedures and tools. Without checking these steps, the patient is at greater risk for a line-born infection. Curiously, the second most omitted step was patient placement. Typically, a patient receiving a CVC is placed in a Trendelenburg position, simply angling the bed ‘head down.’ This is needed to engorge the internal jugular vein to locate it more quickly and provide greater circumference for

catheter placement. This step would need to be made by using an operating room table. The simulation lab uses a simple four-post table that is an adjustable up/down table, and Trendelenburg is not possible with this equipment and is a verbalized step. On a positive note, of the 12427 steps completed by the 299 participants, the overall error rate of steps completed correctly versus not done or done incorrectly is 0.017%. This illustrates that learners present to the simulation lab with a solid understanding of catheter placement. Unfortunately, the errors committed could prove catastrophic for the patient as they lend themselves to complications such as perforation, catheter dislocation, or infection. Some of the conditions that could cause these errors are lack of supervision, lack of training, and distraction. These complications may result in a surgical procedure to remove a foreign body if the wire retrogrades into the vessel or vessel/surrounding structure repairs and prolonged infection resulting in an ICU stay. These complications have a considerable cost of service passed onto the patient, further burdening an already turbulent hospital admittance.

The standardized procedural curriculum redressed residents' cognitive and behavioral deficiencies for research question one by providing the learners with an itemized list of procedural errors they could review to improve capacity. Likewise, learners and faculty can review each participant's checklist and advise other training methodologies tethered to each mistake committed. Finally, the learner was allowed to repeat the simulated procedure with faculty members if requested, utilizing the checklist for statistical improvement. These checklists were not added to the results, as we could assume that the repeated attempts at the same skill would show an improvement in a short time and might lead to improved confidence, which may be unfounded. The behavior deficiencies were not evident with the data collection tools. The primary section for behavior characteristics is found at the beginning of the procedural checklist

under informed consent. Within this section, the participant would describe the procedure to the faculty member (posing as a patient), outline why the procedure is needed (benefits) if there are any risks involved, and any mitigation techniques for the stated risks. Surprisingly, only two noted errors were categorized as ‘done incorrectly.’ This low indicator could be influenced by speaking with patients daily using the career or faculty/peer oversight with patient interactions.

Self-Efficacy Analysis

While the self-efficacy surveys lacked the depth of response rates (n=63), they did yield some surprising results. 80.2% of the participants stated they perceived an increase in skillset, but only 23% reported a change in self-efficacy. Self-efficacy refers to the participant's perceived ability level they can master, and skillset refers to self-concepts which are the mental perceptions about learning in general. This is an important point but needs further context. Residents arrive at training programs from medical universities worldwide, and each of these universities provides a similar educational experience but is not identical. This point can be evidenced by the 60% of the respondents feeling they had a proper education regarding CVCs before attending the simulation lab. Contrary, 40% perceive that they did not have a formal education in the procedure. If this is the case, then why only a 23% delta in self-efficacy, which is nearly half? This could be due to the type of residency program, how many catheters are placed within the specialty, faculty oversight, and peer-to-peer instruction. Further, the learner could have a false sense of accomplishment after participating in the lab. This could pose adverse outcomes for patients and needs a longitudinal study to prove results over time effectively.

Additionally, 95.24% of the participants noted they could identify a change in their specific practice of catheter placement, precisely estimating the difference in catheter insertion depth and improvements in hand-eye coordination. Again, this is an interesting data point compared to the

level of psychomotor errors noted within the procedural checklist. This could be due to the amount of time spent analyzing the patient anatomy.

Before any procedural step up, the learners are informed, per the self-guided PowerPoint, to review the patient's anatomy several times with ultrasonography. While most anatomy is similar (Netter), there can be various pathologies present, which provide an added level of complexity for the proceduralist. One such example can be the patient's body mass index (BMI). An individual with either large or small BMIs will influence the approach angle of needle insertion, needle/guidewire/dilator/catheter placement depth, and method of securing to skin. Regarding the self-efficacy datapoint (Table 13), there was statistical significance with the application of participants applying the content learned during the simulation lab post-simulation. This added evidence supports a positive outcome for the dedicated hypothesis to improve skillset with deliberate practice.

Regarding research question two, how can the self-efficacy of medical residents be impacted using simulation is by the positive frequency of the bar chart (Table 14). The survey was designed to capture the participants' perception of self-skills improvement, and there was an overwhelming improvement pre- to post-simulation. Further (Figure 9) illustrates that 63% of the participants felt the faculty helped them see how to improve or sustain good performance.

Faculty Observational Analysis

The last data collection tool utilized was an electronic faculty observational survey distributed after the simulation to assess if any procedural or delivery of care was noticed while interacting with patients. Of the n=25 faculty respondents, 80% of the faculty noted the residents would benefit from additional training, and 96% provided dedicated time to attend the sessions. The survey does support the hypothesis, with 88% of the faculty noting an improvement in skills

with their residents. Additionally, 72% observed a change in care practice after attending the simulation, leading to 84% stating they would like more simulation-based procedural labs for the residents. These metrics corroborate the self-efficacy percentages and provide solid evidence of a transfer of learning and improvement of skills on Bloom's Taxonomy (Figure 2). The taxonomy states that a learner will progress up the pyramid by the recall of facts (asynchronous PowerPoint), explaining ideas or concepts (informed consent), using the information in situations (placement of the catheter), drawing connections (depth of needle/catheter to anatomy), justify a decision (confirm placement with chest Xray), and create new work by noting a change in the delivery of care (Armstrong, 2016). The data produced by the investigation could be the starting point for a longitudinal assessment of improved skillset over time. The curriculum could be modified to include most clinical procedures and improved upon by reviewing each participant's actions over time and without anonymity.

The third and final research question posed by investigating what measure must be used for monitoring is the post-simulation direct observational survey completed by faculty members. Statistically, many faculty respondents were optimistic about the training curriculum and requested extra curricula be created for other commonly performed procedures. Without this 360-degree feedback loop, it could be impossible to track if the learning supplied within the simulation was captured and applied in direct patient care.

Limitations

There are several limitations of the outputs for this investigation, primarily the link to direct patient care. Instead of a participants' anonymous skills review within the simulation lab, taking the verified results and monitoring residents in need could provide insights for additional training. This would allow faculty to review a resident's skillset over time and in the clinical

environment, leading to improved patient care and safety. In medical education, the goal is to improve clinical outcomes for patients and reduce the likelihood of medical errors. All three data capture tools are designed to assess a learner's behavioral, medical knowledge, and technical skills at a singular moment in time. The tools might simply need to utilize more frequently and presented within direct patient care settings. This could provide additional insights into how residents perform in the clinical setting, not solely in the simulation lab. Instead, collecting learner data over a complete residency program could provide further insights into resident success or why some residents do not matriculate. This can be demonstrated by McGaghie's (2010) suggestion of designing simulation-based medical and educational curricula after benchmark research, as the reproducibility is more consistent. Clinical educators should be tracking patient outcomes about specific procedural outcomes, such as length of stay, complications during a procedure, and infection occurrence, and comparing them with training outcomes within a simulation. This can then be combined with historical data on cost-benefit analyses that can portray monetary savings to patients and the hospital system. This would benefit the learner and significantly improve learning outcomes across residency programs.

Similarly, the investigation does not provide research into patient outcomes. Tracking patients pre/post-placement of a central line could guide additional modules needed for education or the costs associated with clinical errors. The mapping of clinical errors was not considered for this study as the IRB would have considerable oversight of the identifiable residents and the patients they treated. If there was an error noted, the investigation could retrospectively review if the learner was a volunteer participant in the simulation and, if so, what were the outputs from the three data tools. Furthermore, the costs brought onto the patient could be calculated if an error occurred by reviewing the additional length of stay, materials needed to provide further

care, escalation of care delivery costs, and contrast this total toward patients without complications and the overall cost of the simulated training. This would give a cost-benefit analysis that would showcase the tangible value added to the hospital system, resident educational programs, and patient cost savings.

Another limitation of the investigation is the interrater reliability of the faculty facilitators and the possible bias within each survey. One could pose the theory that each simulation facilitator may grade slightly or vastly differently than a counterpart. This could skew the data in various ways and introduce several confounding variables. The self-efficacy must be taken as an honest self-comparison pre/post simulated learning. To limit this type of data error, faculty could watch a recording of the resident performing the simulation from an overhead camera. This would allow several faculty to review a single procedure, and the average of the scores may lead to better outcomes. A learner could provide a false sense of self-perception after the learning endeavor and thus continue this incorrect behavior to direct patient care by providing care with an unfounded sense of confidence. This perception could be mitigated by having each learner perform the procedure several times and then, immediately after the simulation, proceeds to place a line under faculty supervision. Currently, learners can place a line with considerable time in between the simulation lab and direct patient care. This time-lapse could decrease the transfer of learning.

A last noted limitation is the reproducibility of the entire investigation. Learners are continuously exposed to embedded specialty training scenarios, patient interactions, and external asynchronous education. This proved to be confounding to provide a proper control group without measuring patient outcomes and randomly assessing non-volunteering residents across each specialty. This ideal way to provide an observable control group was to give the faculty

survey and trust that there was no reliability or bias interjected. A strict training methodology would need to be established across all the residency programs to improve reproducibility. Currently, each department uses any instructional design methodology, which produces additional confounding variables. Streamlining the use of a single instructional design methodology can improve clinical outcomes by reducing the variability of instruction across medical specialties.

Implications

Assessment and research within simulation-based medical education have three significant implications for improving medical education and patient outcomes. Primarily, simulation-based medical education has improved visibility as the primary source for enhancing performance, limiting error, and improving quality of care and patient safety (Issenberg et al., 1999). Second, the evidence is accumulating in the recent literature that encourages simulation-based medical education to be a practical approach for educating technical skills to enhance performance and improve competency (Laack et al., 2017). Third, simulation-based medical education has been connected to excellent learning outcomes compared with other instruction modalities that augment human performance, limitations, and error (Laack et al., 2017).

To overcome the challenges of human error in healthcare, we will have to acknowledge the scope of the concern. Makary & Daniel (2016) assessed several studies and concluded that initial human error reports might have been significantly underestimated. After extrapolating regional data and applying it nationally, Makary & Daniel (2016) concluded that 135,581 patients die from poor care due to human error each year. This number is equivalent to 325, 747-400 passenger jets crashing with total loss of life every single year. Easing an issue of this magnitude, through a systematic approach toward standardized simulation-based medical,

educational curricula should be required to comprehend the nature of the error, the effects on human performance, and its impacts on patients.

Recommendations for Future Research

As the investigation has evidenced, utilizing a standardized simulation-based procedural curriculum has statistically significant positive results measured in performance improvements, self-efficacy, and faculty observational assessment. The coupling of several forms of educational modalities could be the key to the future mapping of resident matriculation. How can we provide safe, effective patient care while assessing which residents may or may not matriculate through the entire residency? How do we define clinical competence, and how will that definition evolve? This question has lingered with the clinical faculty for some time. New technology and innovations constantly evolve this definition, leading to the increasing difficulty in defining it. Clinical competency should be simply safe and effective care and can be measured by utilizing simulation to discover training deficiencies, then improve them before transitioning to direct patient care. With the inception of a global pandemic, how has the training curriculum for medical residents been impacted, and how can we mitigate any further disruptions. The onslaught of COVID-19 has drastically reduced resident-patient interactions as social distancing, and copious amounts of personal protective equipment (PPE) may have furthered the divide in instructional medical management. Could the use of simulation-based medical education provide a bridge to cover the gap created by reduced training opportunities through synchronous and asynchronous procedural modules? Indeed, it can help implement new forms of assessment, embedding sensors that ensure economy of motions, the introduction of peer-reviewed asynchronous videos, and detailed “think-aloud” patient care algorithms. It is no surprise that as ICU and emergency departments swelled with patients, the time allotted for skill development

was significantly reduced or, in some cases, eliminated. In medical education, patients come first beyond all other endeavors, including simulation, standardized exams, and lectures. Almost overnight medical education seemed to cease. It is hoped that simulated curriculums for invasive procedures such as the CVC will provide the benchmark for patient outcomes. Rest assured that there was no shortage of patients who needed large amounts of fluids, medications, or blood by placing a CVC during the pandemic. The opportunity for training programs in the simulation was reduced to provide the framework for safe and effective care for vulnerable patients.

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APPENDIX A: SELF-EFFICACY POST SURVEY

Self-Efficacy Post Survey

1. As a result of participating in the central venous catheterization Training Session, I can identify a change in practice, i.e., something I would do differently next time I encounter a similar situation.
 - a. If yes, please describe
 - b. If not, please describe why no opportunity for change was identified and/or barriers to implementation.
2. Please rate your level of agreement with the following statements regarding the central venous catheterization training session. (5-point Likert scale)
 - a. I was completely absorbed, and time passed quickly
 - b. I intend to use what was presented when I am in my patient care setting
 - c. The material covered was relevant to my work.
3. Please rate your level of agreement with the following statements describing facilitator behavior. (5-point Likert Scale)
 - a. The facilitator maintained an engaging context for learning central venous catheterization line placement.
 - b. The facilitator helped me to see how to improve or sustain good performance.
4. Regarding in central venous catheterization training session, rate your ability to apply the content presented before and after your participation. (0%-100% slider confidence metric)
 - a. Before (0 not confident at all, 50 somewhat confident, 100 completely confident with 10% intervals).

- b. After (0 not confident at all, 50 somewhat confident, 100 completely confident with 10% integrals).

APPENDIX B: PROCEDURAL CHECKLIST

Sterile Barrier Preparation and General Line Insertion

Key: A = Done Correctly B = Done Incorrectly C = Not Done

Obtains Informed Consent			
Benefits (medication, fluids, CVP monitoring.)	A	B	C
Risks (Pneumothorax, arterial puncture-bleeding, Infection, thrombosis)	A	B	C
Describes the additional interventions that would address complications	A	B	C
Non-sterile set up.			
Put on surgical cap and mask before opening the CVC bundle.	A	B	C
Opens CVC Bundle wrapper on sturdy work surface without touching materials (CVC kit, Chlorhexidine, or drape) inside blue wrapper.	A	B	C
Puts on sterile gloves, separates inner bundle materials, locates Chlorhexidine.	A	B	C
Indicates on self the area to be prepped with Chlorhexidine	A	B	C
Opens Chlorhexidine, vigorously scrubs the setup table for 30 SECONDS in 3 planes (horizontal, vertical, and diagonal - 10 sec each) dry time 2 minutes.	A	B	C
Discards gloves.	A	B	C
Open and drop sterile probe cover onto sterile field.	A	B	C
Barrier Protection phase-doctor, patient, probe.			
Opens second pair sterile gloves and gown, placing on countertop.	A	B	C
Performs hand hygiene.			
(15 Seconds for Alcohol Sanitizer, 30 seconds for hand washing-soap/water)	A	B	C
Barrier doctor: Puts on sterile gown by opening gown with the fold toward themselves, <i>hands must remain inside sleeves.</i>	A	B	C
Puts on sterile gloves by inserting white sleeve collar inside glove first, then sliding hand through white collar into glove.	A	B	C
Barrier patient: Drape applied transversely across table then pulled over the head/superior part of table and then over the "body" [rest of table].	A	B	C
Barrier US Probe: Verbalizes this step. [skill practiced at US station]	A	B	C
Set up CVC kit.			
Prepares order of use--lidocaine syringe, finder needle, wire, scalpel, dilator, CVC catheter. Obtains needleless caps, saline, 2nd Chlorhexidine, Tegaderm.	A	B	C
Flushes ports with sterile saline to purge air and verify patency.	A	B	C
Clamps each port or attaches needleless caps. (Ok to keep brown port off)	A	B	C
Unclamps and removes cap from brown port to accommodate wire.	A	B	C
Procedure.			
Verbalizes placing patient in 10-15 degrees Trendelenburg position.	A	B	C
Anesthetizes skin [foam pad] with 1% lidocaine beginning with a small surface wheal and then anesthetizing deeper tissues.	A	B	C
Puncture foam pad with introducer needle.	A	B	C
Removes the syringe from the needle (or uses syringe port for wire).	A	B	C
Advances guidewire through introducer needle no more than 20 cm [2 black lines on guidewire]	A	B	C
Removes the needle while maintaining hold of guidewire.	A	B	C
Uses the scalpel to nick the foam in order to advance the dilator.	A	B	C
Advances the dilator over the guidewire to dilate the skin [foam pad] using no more than half the dilators length, then removes dilator.	A	B	C
Advances the triple lumen over the wire, pulling back the guidewire as the catheter is moved forward.	A	B	C
User never let's go of the guidewire.	A	B	C
Advances the line to approx to 14-16cm for right side 16-18cm on the left side.	A	B	C
Once the line is in place, removes the guidewire in its entirety.	A	B	C
Verbalizes: Draws blood and flushes each port to ensure there is blood flow.	A	B	C
Cleanses skin of any blood with 4 x 4 gauze and 2nd Chlorhexidine stick.	A	B	C
CVC Completion			
Secures the line in place (Stat Lock is preferred).	A	B	C

Places antibiotic (Chlorhexidine) disk.	A	B	C
Places large Tegaderm over line (or verbalizes this).	A	B	C
Discards sharps.	A	B	C
Orders a CXR to confirm location.	A	B	C
Notifies nurse that line is ok to use when no pneumothorax is seen, and tip of CVC visualized at the SVC/RA junction.	A	B	C

APPENDIX C: FACULTY OBSERVATIONAL SURVEY

Faculty Observational Survey

1. I provided my residents time to attend the CVC simulation lab.
 - a. Yes
 - b. No
2. Before attending the CVC simulation lab, I notice that my residents needed additional practice with CVC line placement.
 - a. Yes
 - b. No
3. After attending the CVC simulation lab, I noticed an improvement of skills from my residents that attended.
 - a. Yes
 - b. No
4. After attending the CVC simulation lab, I noticed a change in practice of care from my residents that attended.
 - a. Yes
 - b. No
5. I would like more of the residents I supervise to attend simulation-based medical education labs like the CVC to improve skillsets.
 - a. Yes

APPENDIX D: CENTRAL VENOUS CANNULATION PRESENTATION

Central Venous Cannulation



Created by: Joseph R Peters, D.O., RDMS, FACEP, FACOEP, FACOI

Emergency/Internal Medicine Attending

Core Faculty, Emergency Medicine Residency

Director, Emergency Medicine Residency Ultrasound Education

OSF St. Francis Medical Center

University of Illinois College of Medicine, Peoria, IL

Adapted by: Elsa Vazquez Melendez, MD, FAAP, FACP 8/29/2019

CVC Benefits



- Reliable vascular access
- Ability to infuse multiple medications
- Ability to infuse high flow fluids
- Safe administration of vasoactive drugs
- Hemodynamic monitoring

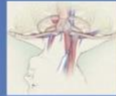
OSF CVC Criteria for Need

1. **Blood Sampling**- in a patient with documented poor vascular access, as evidenced by multiple documented unsuccessful IV sticks and multiple lab draws per day
2. **CVP Monitoring**—must have defined parameters for CVP and CVP reading is guiding treatment
3. **Chemotherapy** - Includes biotherapy for transplant patients
4. **IV Fluid Therapy**— in a patient with documented poor vascular access, as evidenced by multiple documented unsuccessful IV sticks, or a patient who needs rapid fluid therapy
5. **IV Medication Therapy**—caustic medications, vasopressors, medications with a pH <5 or >9
6. **TPN**
7. **Hemodialysis**
8. **CRRT/Apheresis**
9. **Other**

CVC Risks

- Infectious

- CLABSI:
Central line Associated
Bloodstream Infection.
 - 90% of catheter related blood stream infections occur with CV lines.
 - Prolongs hospitalization by mean of 7 days.
 - Estimates of attributable cost per blood stream infection, \$3700-29,000



- Mechanical

- Pneumothorax
- Hemorrhage
- Arterial puncture
- Air Embolism
- Venous thrombosis and/or embolism

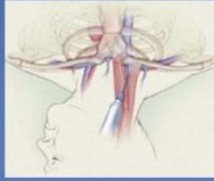
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- Soufir L et al, Attributable morbidity and mortality of catheter-related septicemia in critically ill patients: a matched, risk-adjusted, cohort study. Infection Control Hosp Epidemiol. 1999;20(6):396-401

Making Healthcare Safer



- Quality matters...
- *Quality* is not a department...
- Quality begins with individual effort...
- *CDC in 2011 published guidelines for the prevention, training and management of CLABSI with the goal eliminating it from all patient-care areas.*
- **Simulation training (or refresher) for all ICU residents, regardless of the level of training helped decreased significantly the rate of CLABSIs and other complications.**

CVC 6 Point Safety Bundle



- **Summary: Risk reduction.**

- 1) Hand hygiene.
- 2) Maximal barrier protection for patient, practitioner, US probe.
- 3) Patient skin antisepsis.
- 4) Catheter site selection—high lines preferred over low lines.
- 5) Daily review of need for central line.
- 6) Real-time ultrasound guidance for IJ central lines.

#1 Hand Hygiene

CVC 6 point Bundle



Two options.

- Soap and Water.
 - **30 seconds** of vigorous scrubbing required.
- Alcohol based cleanser.
 - **20 seconds** of vigorous scrubbing required.



- IHI 100,000 Lives
- O'Grady et al, Guidelines for the prevention of intravascular catheter-related infections. Center for Disease Control and Prevention. MMWR Recomm Rep. Aug 9 2002;51 (RR-10):1-29

#2 Barrier Protection

CVC 6 Point Bundle



— Patient:

- Must be completely draped, head to toe.
- Only skin exposed is the area of work.



— Practitioner:

- All hair covered.
- Protective eyewear.
- Mask covers nose and mouth tightly.
- Sterile gown and gloves.



— US Probe:

- Placement of sterile sheath before use.



- *IHI 100,000 Lives*
- Mermel LA et al, The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. *Am J Med.* Sep 16 1991;91(3B): 1975-2055.
- Raad II et al, Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infect Control Hosp Epidemiol.* Apr 1994; 15(4 Pt 1):231-238.

#3 Skin Antisepsis

CVC 6 Point Bundle



- **Chlorhexidine** has been proven to provide better skin antisepsis than other agents.
 - Skin must be scrubbed for **30 seconds**.
 - Scrub in 3 planes, 10 seconds each.
 - Scrub *both IJ and SC* regions.
 - Area must **dry for 2 minutes** prior to procedure.



- *IHI 100,000 Lives Campaign*

#4 Site Selection



- **High lines** preferred to *low lines* to reduce infection.
- Great majority of infections occur at site of insertion.



- *IHI 100,000 Lives*
- Mermel et al. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. *Am J Med.* Sep 16 1991; 91(3B): 197S-205S
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#5 Daily Review



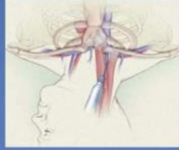
- **Need to maintain CV line:**

- Risk of infection occurs over time.
 - The longer in place, the greater infection risk.
- Assessing the daily need for the line prevents delays in CVC removal.

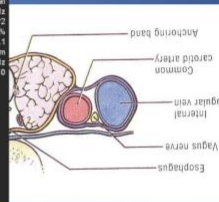


- *IHI 100,000 Lives*
- O'Grady et al. Guidelines for the prevention of intravascular catheter-related infections. Centers for Disease Control and Prevention. MMWR Recomm Rep. Aug 9 2002; 51(RR10):10

#6 Ultrasound IJ



- **Real-Time Ultrasound Guidance IJ CVC:**
 - To reduce the mechanical complications.



Types of Catheters



Triple Lumen vs Cordis?



- **Cordis:**

- *Short and wide = Rapid Fluid Infusion*
 - Conduit to pass Swan-Ganz catheter. (Introducer)
 - Cordis size range from 4 to 11 French(Fr).
 - A “French” refers to the size of the outer lumen.
 - Fr = 1/3 of a millimeter (9 Fr is 3mm outer lumen).
 - Standard size is 8.5 – 9.0Fr and 11cm length.



- **Double/Triple/Quad Lumen catheters:**

- *Multiple Medications*
- *Secure IV Access*
- *Hemodynamic Monitoring*
 - 7.0-8.5 Fr. Is standard. Longer length than Cordis ranging 16-20cm.
 - The more lumens, ***the smaller the internal diameter of each lumen.***
 - Triple lumens have more narrow lumens than double lumens.



CVC Checklists

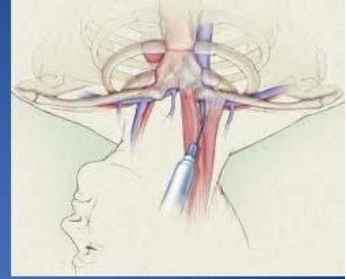


CVC Checklists:



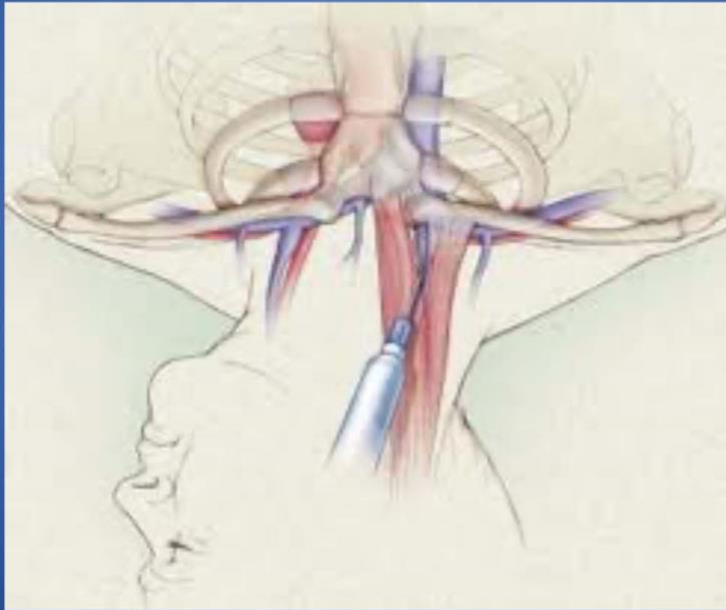
- **Review the chart, things to consider.**
 - Coagulopathy?
 - Hypercoagulable state--clot in the vein?
 - Severe Thrombocytopenia?
 - Abnormal Anatomy?
 - Scarring--multiple lines in the past.
 - Tumor in vicinity.
 - Trauma.
 - Skin infection present.
 - Latex Allergy?
 - Medication Allergy?

CVC Checklists:



- **Review the chart, things to do.**
 - Informed Consent.
 - *Pre US* the region of choice to search for best anatomy
 - ***Time Out Procedure*** with your staff.
 - Perform Central Line.
 - Post Procedure housekeeping.
 - Clean area.
 - Chlorhexidine disc.
 - Sterile dressing.
 - CXR for eval for pneumothorax and good line position.
 - Discard sharps.
 - Procedure note.

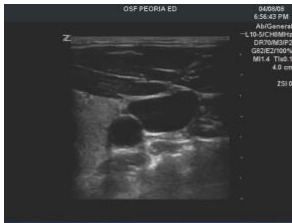
CVC



Organization, the key to success

- Steps for CVC success:
 - 1) Gather supplies.
 - 2) *Set up—2 phases.*
 - » Non-sterile
 - » Sterile.
 - 3) Barrier Protection.
 - » Patient, doctor, US probe
 - 4) *CVC insertion.*
 - 5) Post Procedure housekeeping
 - » Antibiotic disc
 - » Sterile dressing
 - » CXR

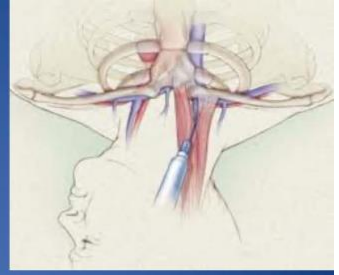




- **Gather supplies**

- Gown, hat, mask, gloves (2 pair).
- *CVC bundle* = CV Kit, Pt drape, Chloraprep.
- Ultrasound Probe Cover/gel.
- Stat Lock/Antibiotic disc/Large Tegaderm.
- Sterile saline
- Needle-less caps (3)
- **Work Surface**

CVC The Set Up



- **US Equipment**

- Direct line of sight.

- Poor position prohibits safe technique and success.



- **Preparation.**

- **Non sterile phase: After consent obtained.**

- Pre-ultrasound neck to plan approach.
- Protective eyewear, mask, hat must be placed on *first*.
- Open CVC Bundle package touching the outside of blue wrapper only.
- Don sterile gloves and separate the 3 inner components, which include:
 - Drape, ChloroPrep scrub, CVC kit.
- Sterilize the pt's skin wearing the sterile gloves used to open the bundle.

- **Sterile phase:**

- Barrier protect yourself.
 - » Open the sterile gloves (#2) and the gown, set aside.
 - » **Perform HAND HYGIENE** *then* don gown and gloves (#2).
- Drape the patient *after* you gown.
- Barrier protect US probe *after* you drape the patient.
- Open and prepare central line for insertion.



Gowning

- Open the gown with the fold side toward you!
 - Inside of the gown will be facing toward you.
- Gown without exposing your hands!



Gloving

- Gloving:
- Keep hands inside the sleeves
- Don the sterile gloves by inserting the white collar on the sleeve into the glove first
- Then sliding hand through it into glove.



Draping

- *Drape is placed transversely across patient's body first and then pulled superiorly over the head and then inferiorly over the body.*
- Only skin exposed is area the line is inserted.



Probe Cover

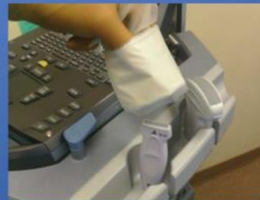
- Sterile packet contains probe cover, rubber bands, sterile gel.



- Place *pocket* into palm and fingers under folds.



- Add sterile gel inside mouth of cover.
- Grasp US probe with mouth of sterile probe cover, lift.



Probe Cover

- Lift US probe off cart and carefully slide sleeve over cord.



- Apply rubber bands to secure it.



- Rest sterile probe on patient until it is needed.



- [illegible]



CVC The Set Up



- **Goal:** Layout everything you need in order you need it.



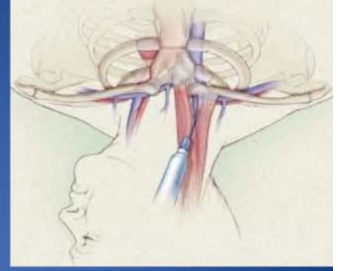
CVC Set Up



- Draw up Lidocaine



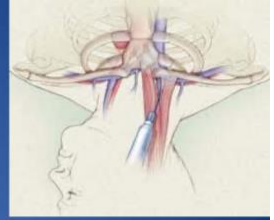
CVC Set up



- “Finder needle”
 - Attach to syringe with bevel aligned with the numbers.



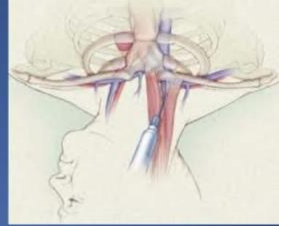
CVC Set Up



- **Normal Saline to flush the catheter.**
 - Flush all three ports to purge air and verify patency.
 - Apply needless caps to all ports except brown port.
 - **Brown:** the distal port used to pass the wire.



CVC Set Up



- Keep “*Sharps Container*” within reach.
 - Away from the area you are reaching to avoid inadvertent needle sticks.



CVC Set Up

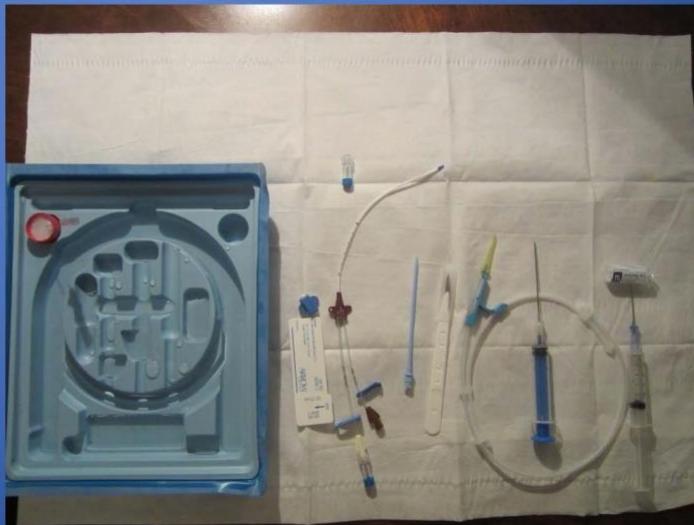


- ***Layout kit in the order needed!***

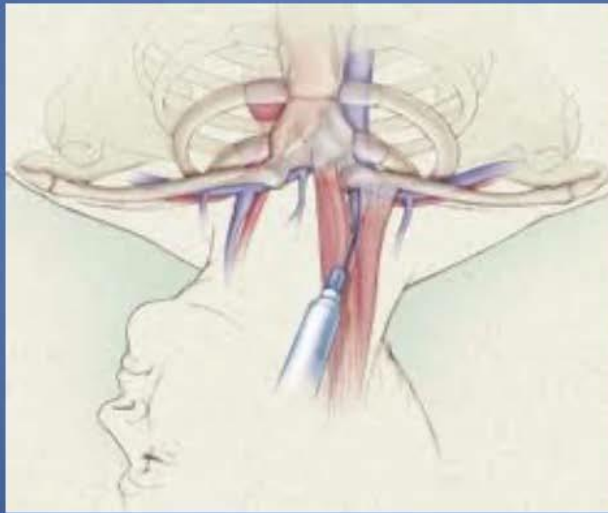
- Keeps you organized, reminding you of the order of the procedure.
- No searching of what you need next, prevents you from sticking yourself.

- **Right to Left toward kit**

- Lidocaine needle
- Finder needle
- Wire
- Scalpel for skin nick
- Dilator
- Flushed catheter
- Lock (optional)
- Suture
- Sterile dressing
- Needle holder away

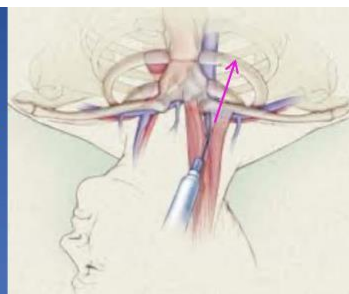


CVC The Procedure

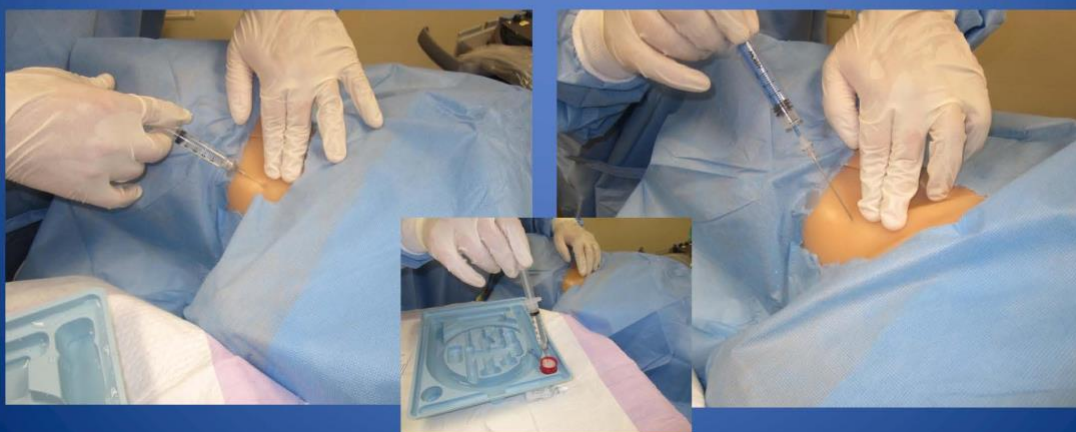




CVC IJ Procedure

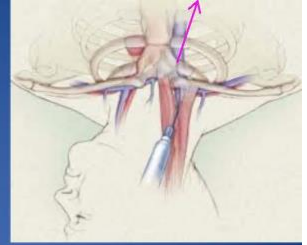


- Apex of the Sternocleidomastoid (SCM) bifurcation.
 - Palpate the Carotid pulse medially.
 - Anesthetize lateral to the palpable pulse.
- “Finder needle”
 - Enter skin at the bifurcation of the SCM in the direction of the ipsilateral nipple.





CVC IJ Procedure



- Aspirate as you advance until you obtain a flash.



CVC SC Procedure

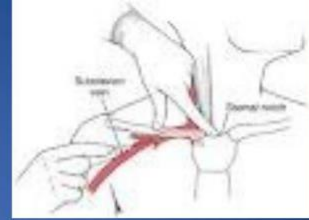


- “1/3 – 2/3” landmark
 - “Angle of the Clavicle”
 - Anesthetize skin and cortex.





CVC SC Procedure



- **“Angle of the Clavicle”**

- Start 1-2cm lateral to the clavicle!
- Keep the syringe *horizontal*
- Walk the “Finder needle” under Clavicle.
- Aspirate while advancing the needle toward the sternal notch
- Obtain flash of blood





CVC Procedure

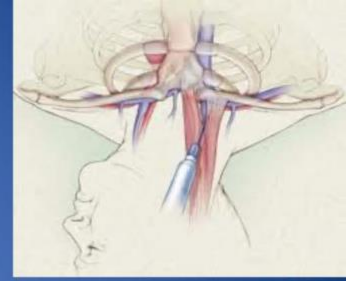


- **Note:**
 - Sometimes flash obtained withdrawing needle!
 - Due to the needle initially passing through both walls of the vessel while advancing the needle.
 - On entry, needle tip pressure pushes the anterior wall against the posterior wall and penetrates both walls. Called “**Double Walling**” the vessel.
 - As such the needle passes through both walls and no blood flash is obtained on entry.
 - On withdrawal, the walls separate again and the needle tip is pulled into the open lumen of the vessel allowing blood aspiration.





CVC Procedure



- Disconnect the syringe
 - Don't dislodge the needle from the vein!





CVC Procedure



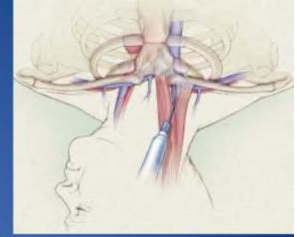
- **Thread the wire**

- It should always advance with ease.
- Advance no more that 20 cm. Watch monitor for PVCs
- **Never, ever let go of the wire once it is in the body.**

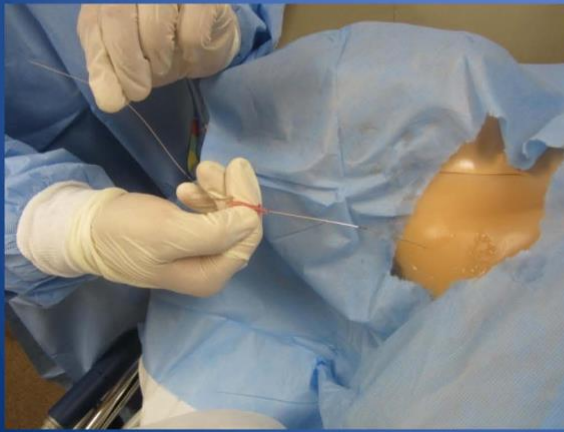




CVC Procedure



- Remove the needle
 - Always control the wire.
 - **Never, ever let go of the wire.**

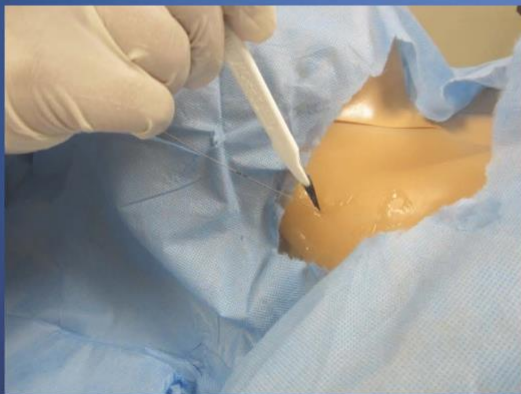




CVC Procedure



- Nick the skin at the wire entry to make room for the dilator.
- Pass the dilator over the wire into the skin.
 - Control the wire!
- Remove dilator leaving the wire in place.





CVC Procedure



- Pass the saline flushed catheter over the wire
 - Always controlling wire so you don't push it into the body.
- *The catheter is not advanced into the body at this point but stopped short of skin.*
- The wire is then pulled out of the body a little at a time, back through the catheter, until it comes out of the open brown port.





CVC Procedure

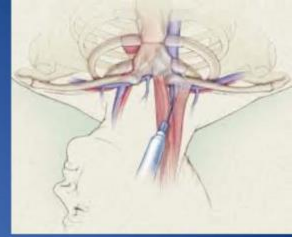


- Wire grasped distally with non dominant hand.
- The catheter is then advanced into the body to 15cm with dominant hand.





CVC Procedure

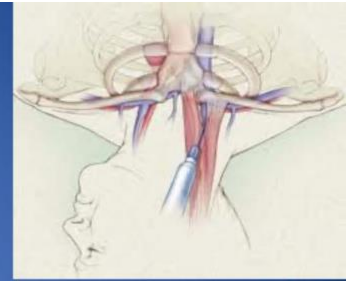


- Wire removed.
- The brown port is capped.
- All ports aspirated to evaluate port function and purge air.
- All ports flushed with saline.





CVC Procedure



- **Secure Catheter**

- Statlock preferred
- Suture
 - Try not to strangulate skin with your knots.
 - Suture both the hub and the lock.
 - When passing needle through the holes place it through backward so not to stick yourself with the sharp point.
- Chlorhexidine disc.



CVC Procedure

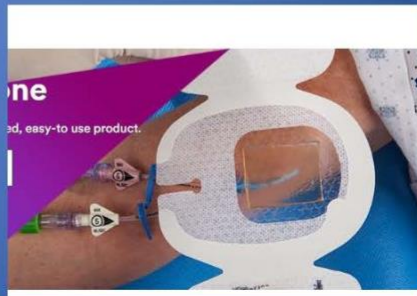
Antimicrobial Dressing

- The largest research study about BioPatch was published by Timsit et al. Chlorhexidine-impregnated sponges and less-frequent dressing changes for prevention of catheter-related infections in critically ill adults: a randomized controlled trial. JAMA. 2009 Mar 25;301(12):1231-41.

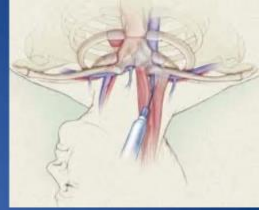
Use of a 1-piece chlorhexidine gluconate transparent dressing on critically ill patients

- CONCLUSION: A low rate of catheter-related bloodstream infections can be maintained, nurses' satisfaction achieved, and cost savings realized with the new dressing.

Pfaff, B., Heithaus, T., & Emanuelson, M. (2012). Critical care nurse, 32(4), 35-40.



CVC Procedure

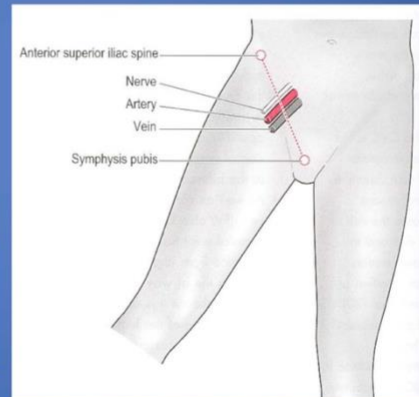
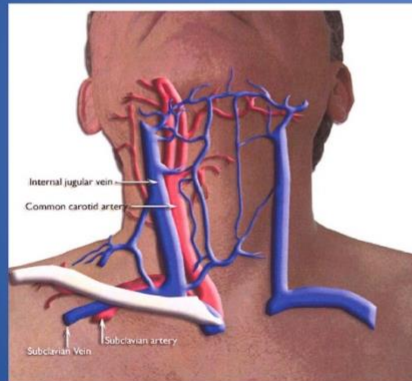


- **Chest Xray:**

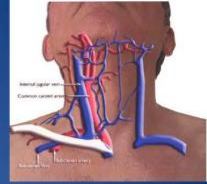
- Good line position cath tip at SVC/RA junction.
- Evaluate for Pneumothorax.



Ultrasound Guided Venous Access



US Guided CVC



- *Vital skill for both EM and CC physicians.*

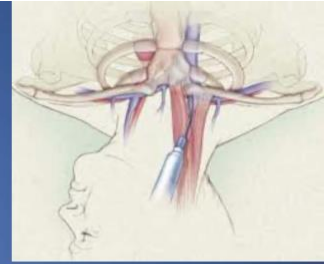
- Landmark technique

- Risks-pneumo/hemothorax, arterial puncture.
 - Anatomic variation.
 - Traumatized anatomy.

- Ultrasound Guided Technique

- Reduces the mechanical complications.
 - Allows accurate location of the IJ.
 - Identifies anatomic variation or disease.

IJ Anatomy



- **Why use the IJ?**

- *“High Line”*

- Less infection

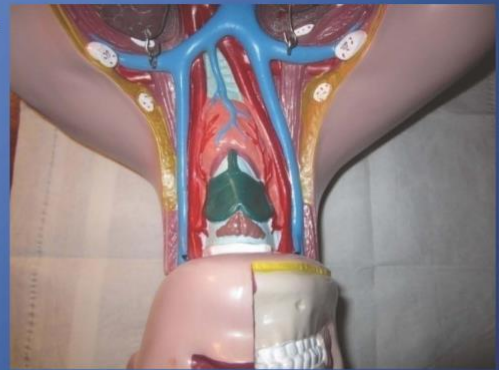
- **Compressibility**

- Differentiates vein from artery.
 - Rules out clot in the vessel.

- **Straight.**

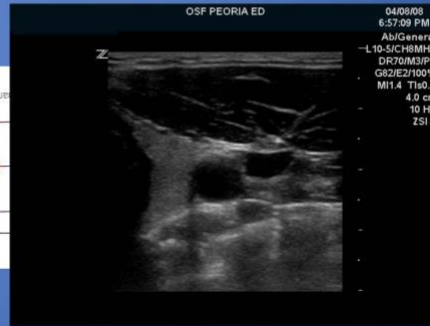
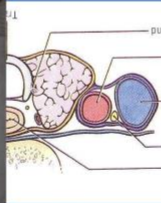
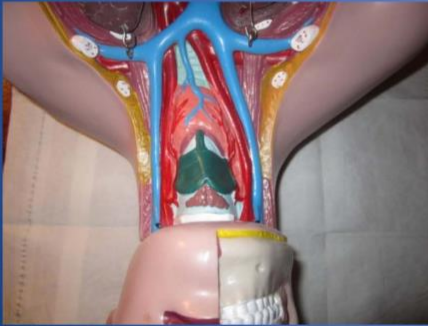
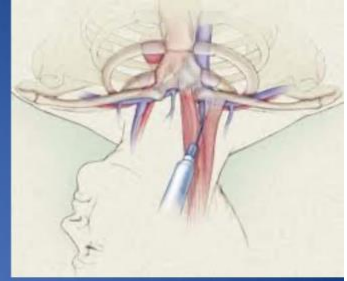
- **Easily visualized with US.**

- **Distant from the Lung.**

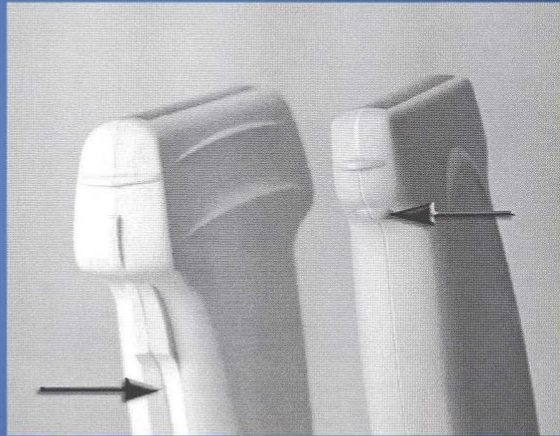


US CVC Anatomy

- IJ and Carotid

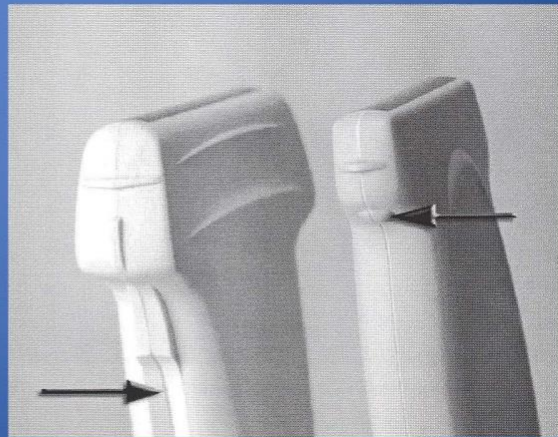


Ultrasound Basics



“Depth Gain & Probe Orientation”

- Adjust the **depth** to 4cm.
- Set the **gain** to what is pleasing to your eye.
- Maintain the probe indicator to your **left**.



Transverse needle insertion

- Insert tip of the needle just below the skin and find it with the US beam.
 - It will look like a bright dot.

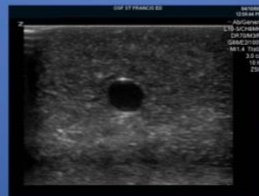


US Venous Access



- **Overshoot**

- **The US beam is 1mm thick!**
- Overshooting the beam will make the *barrel* of the needle appear as the *tip*.
- The needle tip will enter the lung before you recognize the mistake if you don't keep the tip localized.



Transverse needle insertion

- Once the needle tip is visualized advance a mm at a time.
- Find the tip again with the probe by angling the probe away from the entering location.
- Continue this process all the way into the vein and flash obtained.



Central Venous Access

- **IJ Approach—Transverse**
 - Needle approaching the vessel



Central Venous Access

- **IJ Approach—Transverse**
 - Needle in vessel with flash.



CVC Review



- **Summary of CVC 6 point bundle**

- Hand hygiene.
- Maximal barrier protection for practitioner and patient.
- Patient skin antisepsis.
- Catheter site selection.
- Daily review of need for central line.
- Real-time ultrasound guidance CVC.

APPENDIX E: INSTITUTIONAL REVIEW BOARD DOCUMENTATION



Peoria Institutional Review Board
One Illini Drive
Peoria, Illinois 61605

FWA 00005172

IRB #00000688
IRB #00000689

DATE: January 26, 2022

TO: ANTHONY DWYER, MS
FROM: University of Illinois College of Medicine at Peoria IRB 1

STUDY TITLE: [1819930-1] AN INVESTIGATION OF THE USE OF SIMULATION-BASED MEDICAL EDUCATION FOR TRAINING CENTRAL VENOUS CATHETERIZATION IN MEDICAL RESIDENTS

IRB REFERENCE #:
SUBMISSION TYPE: New Project

ACTION: ACKNOWLEDGED
APPROVAL DATE: January 26, 2022
EXPIRATION DATE:
REVIEW TYPE: Administrative Review

Thank you for your submission of New Project materials for this research study. University of Illinois College of Medicine at Peoria IRB 1 has ACKNOWLEDGED your submission, however, **the IRB will not provide a formal written determination after a project has already been initiated/completed.**

The Not Research/Human Subject Research Determination request is to done prospectively per the OSF and the Peoria IRB process whereby the Project Leader does NOT attempt to determine this for themselves. The process requires the IRB to make this determination by reviewing the completed Determination of Human Subjects Research Form.

In Section 3 of the above-mentioned form, the answer indicates that the project has already been conducted. The project was initiated and completed with no prior letter of determination confirming IRB oversight was not required.

If you have any questions, please contact Mindy Reeter at 309 680 8631 or mreeter@uic.edu. Please include your study title and reference number in all correspondence with this office.

cc: