NOVEL CUTANEOUS ABSCESS MODEL: MODEL DEVELOPMENT AND EXPLORATION OF RELIABILITY AND VALIDITY OF DETECTING KEY DIAGNOSTIC FEATURES

by

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Abstract

Introduction: The difficulty of differential diagnoses between cellulitis and occult cutaneous abscess remains the main issue in clinical practice. Educational efforts, however, have been invested into building simulation models directed toward the treatment of cutaneous abscesses. The discrepancy between the problem in clinical practice and educational efforts in this area requires simulation models that can provide an opportunity for trainees to practice their diagnostic skills.

Aims: The study focuses on creating a cutaneous abscess model that is detectable by ultrasound and evaluating the reliability and validity of detecting clinical and sonographic features of cutaneous abscess disease on the basis of the model.

Materials and methods: Six identical models were made, each consisting of a water balloon filled with mock abscess and two glue threads inside a pork belly, and radiologist standardized ultrasound images of the model. Reliability and validity of detecting key diagnostic features on the basis of the model by 24 judges were explored.

Results: Cronbach's alpha across all models were 0.89 and 0.87 for clinical and sonographic features, respectively. The intraclass correlation coefficient was 0.71 for both clinical and sonographic features. The correlation between all clinical and sonographic features and corresponding construct were statistically significant ($p < 0.01$). Content validity indices were 0.90 for clinical features construct and 0.85 for the sonographic features construct.

Discussion: The model was constructed from simple, widely available and easy to assemble materials. It is a high fidelity, cost-effective model and can be used as a simulator for diagnosis of cutaneous abscess in medical education. Study data expressed excellent internal consistency and high agreement among judges. The clinical and sonographic features were significantly correlating to the overall corresponding construct. It also reveals strong content validity. The constructed cutaneous abscess model has reliable and valid ability in demonstrating both clinical and sonographic features. Further studies are needed to examine the efficacy of the model for training and correlations with the clinical outcomes in real practice.

Conclusion: The novel high fidelity cost-effective cutaneous abscess model allows for reliable and valid detection of the clinical and sonographic diagnostic features of the cutaneous abscess disease.

Preface

This dissertation is original, unpublished, independent work by the author, A. AlKanhal. All of the work presented in this paper was conducted at the Centre of Excellence for Simulation Education and Innovation (CESEI), Department of Surgery, the University of British Columbia (UBC).

The empirical study presented in Chapter 2 was approved by the UBC Behavioural Research Ethics Board (certificate # H15-01989).

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Acknowledgments

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to the person who sacrifices her life and made me a man .. my mother Munirah

to the most generous and wisest person I know .. my grandma Sarah

to the person that has influenced my life .. my uncle Mohammad

to the reason behind my happiness .. my lovely wife Lubna

Chapter 1: Introduction

The well-known phrase “practice makes perfect” implies that in order for one to become proficient at a certain task, mistakes are inevitable in the learning process and practicing is the best way to learn how to avoid them. This applies to all skills and tasks, and medicine is no exception.

But applying a philosophy of trial and error in medicine is problematic and may result in severe morbidities and even mortalities. Therefore it is essential to provide a safe learning environment to allow medical trainees to learn from their mistakes without harming patients. This is the idea behind simulation.

Medical simulation has become more sophisticated than ever, with a wide variety of models and many improvements made to the materials used to construct them. High and low fidelity simulators have been developed to address different aspects of medical diagnostics and therapeutic approaches so that medical students can learn and perform procedures away from patients and the associated risks, in keeping with the Hippocratic oath to *first do no harm.*

1.1 The Role of Simulation in Medical Education

The Merriam-Webster dictionary defines simulation as “something that is made to look, feel, or behave like something else …” (Merriam-Webster, 2015). This expresses the essence of simulation when applied as a concept of the integration of knowledge, skills and critical thinking

(Rauen, 2004). With the rapid advancements in computer science and virtual reality, a common misconception is to link simulation to technology solely. Rather, simulation is a "technique" that aims to immerse the subject in an environment that mimics real situations (Gaba, 2004). Simulation techniques are utilized ideally and intensively in aviation and the military, and this union facilitated the expansion of simulation into healthcare education (Loftin, 2015). This led to a paradigm shift in medical education and training from the classical Halstedian apprenticeship model of "see one, do one, teach one" to a more comprehensive and standardized method (Wayne et al., 2006). Using simulation became widely accepted by all medical disciplines (Rosen, 2008), and is currently a major requirement for board certification and licensing in some residency programs in order to ensure competency ("Fundamentals of Laparoscopic Surgery," 2015).

Using simulation as a precipitating measure for patient safety was introduced first in 600 B.C. by Sushruta, an Indian doctor who believed that surgical techniques should be practiced on fruits and vegetables before being applied to patients (Swami, 2013). Hence one of the key roles of simulation in medicine is to ensure patient safety.

Baker et al. studied the incidence of medical errors among patients in acute care hospitals in Canada, reporting that out of the annual 2.5 million admissions to hospitals, approximately 185,000 patients who encountered a medical error, and 36.9% of those errors were considered preventable (Baker et al., 2004). Some studies have shown that the lack of psychomotor abilities (i.e. skills) and knowledge are not responsible for most medical errors (Bilotta, Werner, Bergese, & Rosa, 2013; Hobgood et al., 2010). Instead, these errors are related to nontechnical skills

(Lewis, Strachan, & Smith, 2012), like team work, communication skills and critical thinking. These skills are called upon during team interactions that are difficult to teach and assess in real-life situations when in direct contact with patients. Eliminating this burden and providing a safe environment away from patients allows for repetition, standardization of situations for the assessment of trainees, and provides the opportunity for constructive feedback. It also allows the integration of technical skills and teamwork, one of several advantages offered by simulation. Although there are limited studies in the literature that assess the use of simulation for improving patient safety, its impact can be measured in real practice and shows a positive effect on patient care (Bilotta et al., 2013).

Fidelity is a term that represents the degree of reality which simulation reproduces (Beaubien & Baker, 2004). In terms of simulator realism, this could be high or low fidelity. A common misconception in much of the literature is the constant marriage of high fidelity simulation to technology, whereas in reality, fresh human cadavers are considered high fidelity simulators (Grober et al., 2004) despite the absence of technology. This is because the concept of fidelity is extremely subjective. Technology can be an integral part of high fidelity because it provides the best approach for dynamic, immersive team-training scenarios, and by using technology, mannequins can react to several attempted actions by trainees. Disadvantages of the high fidelity simulators are the high startup, maintenance and upgrade costs, in addition to the infection hazards and ethical barriers for fresh animal and human tissue (Grober et al., 2004). However, with good laboratory practice and safety precautions, animal and human cadavers have been used successfully for a long time. Although there are some ethical barriers to using live animals in surgical training, there are fewer concerns with the animal parts. An example of using animal parts is Basic Surgical Technique (BST) program at the University of British Columbia (UBC) (Qayumi et al., 1999).

Learning objectives are the indicator for what type of fidelity should be used to achieve competency (Surgical Simulation, 2014). Low fidelity simulators are better suited to psychomotor skills acquisition, especially for invasive procedure training (de Montbrun & MacRae, 2012). They are cost effective and easy to prepare and maintain, whereas real surgical and clinical instruments can be used solely to train repetitively. An excellent example of this is McGill's Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS), the manual component of Fundamentals of Laparoscopic Surgery (FLS). This simulator uses a physical training box with real laparoscopic instruments to perform five non-procedural specific laparoscopic surgical tasks ("Fundamentals of Laparoscopic Surgery," 2015). This model was extensively validated and proven useful for training, assessments and for ensuring proficiency and is widely accepted by many surgical residency programs, especially in North America. Currently, the American Board of Surgery (ABS) requires FLS certification for graduating residents ("Fundamentals of Laparoscopic Surgery," 2015).

1.2 Skin and Soft Tissue Abscess

As a defense mechanism, our natural immunity responds to any foreign material that invades normal tissue. This response might result in contained inflammatory lesions forming purulent content, lesions known as abscesses (Cheng, DeDent, Schneewind, & Missiakas, 2011). Abscess formation can take place in any part of the human body, in superficial or deep tissue. Cutaneous abscesses, a type of skin and soft tissue infection, are common in clinical practice irrespective of the clinical specialty. In the United States, emergency department (ED) visits for cutaneous abscesses increased dramatically from 1.2 million to 2.6 million between 1996 to 2005 (Taira, Singer, Thode, & Lee, 2009), making skin infections the seventh most common cause of ED visits (Nawar, Niska, & Xu, 2007). Increased hospitalization due to cutaneous abscesses has been reported in Australia, reaching 13,126 admissions in 2007 with 48% increase since 1999 (Vaska, Nimmo, Jones, Grimwood, & Paterson, 2012).

1.2.1 Etiology

Cutaneous abscesses are mainly caused by infections from skin flora or adjacent mucous membranes, depending on the infected site (Moran et al., 2006). Although many microbes contribute to abscess formation, a single isolated pathogen might cause the inflammation and subsequent abscess. Staphylococcus aureus, a normal human skin flora, is the most common cause of infective cutaneous abscess, forming 72% of abscesses caused by one pathogen (Meislin et al., 1977). It is also the predominant organism in subcutaneous abscesses caused by multiple organisms throughout the body, except for the perioral, perineal and perianal areas where anaerobes are more prevalent than aerobic bacteria (Brook & Frazier, 1990). It is also less frequent in injection drug users, as most of the microbes in this group are of oral origin types (Summanen et al., 1995). With bacteria's ability to develop resistances to various kinds of antibiotics, a special strain of Staphylococcus aureus appeared in hospitals starting in 1960, known as methicillin-resistant Staphylococcus aureus (MRSA) (Moran et al., 2006). This difficult to treat strain can result in fatal complications like sepsis and necrotizing pneumonia, and affects people with immunity related risk factors more severely (Singer & Talan, 2014). A genetically different strain, which is less antibiotic resistant but more aggressive, has outreached to the community (known as community-associated MRSA) (Baba et al., 2002). The prevalence of community-associated MRSA in ED visits has reached 51-80%, and this number is increasing dramatically (Schmitz, 2011). It has become the most commonly isolated microbe in patients with cutaneous abscesses in different regions in the United States (Moran et al., 2006).

Skin abscesses can also be sterile, i.e. with no infective pathogen. The incidence of this milder form of abscesses is 5%, and is mainly due to unabsorbed oil-based injection drugs, such as anabolic steroids and penicillin (Zelman, 1978). There is a high tendency for this kind of abscess to turn into a scar rather than remaining as a cavity of abscess.

Skin abscesses can develop even in individuals with no established risk factors other than injuring the skin (Singer & Talan, 2014). There is an increased chance of acquiring cutaneous abscesses in individuals who are in close contact with patients with active infections (Zimakoff, Rosdahl, Petersen, & Scheibel, 1988). Other risk factors are related to immunity status, such as immunocompromised patients (e.g. geriatric and pediatric age groups, patients with diabetes mellitus and immune deficiency diseases), who are at high risk of developing infective cutaneous abscesses (Kars, van Dijk, Salimans, Bartelink, & van de Wiel, 2005). Mycobacteria might form furuncles (infections of hair follicles) in patients who share whirlpool footbaths in nail salons (Vugia et al., 2005). Recurrent cutaneous abscesses might occur in cases of incomplete drainage of abscess, improper antibiotic coverage of the infective pathogen (or pathogens group) or infections caused by MRSA (Duong, Markwell, Peter, & Barenkamp, 2010).

1.2.2 Pathogenesis

Skin is the largest organ in the human body and a basic part of its immune system (Elias, 2007). Breaching or breaking the skin barrier can predispose one to cutaneous abscesses. Starting in the dermis and deeper skin tissues, abscess formation begins with inflammatory response induced by a causative factor. A series of vascular events around the affected site will take place to develop the inflammation process needed for the elimination of the cause of cell injury, removal of necrotic tissue and assistance in tissue repair (Das, 2011). The first vascular response to tissue injury is vasodilatation, which is caused by several chemical mediators released by endothelial tissue (e.g. nitric oxide, prostaglandins, histamine, etc.). Vasodilatation increases the blood flow to the affected site, followed by an increase in the permeability of vasculature. This allows protein leakage to the extravascular space and subsequently increases viscosity of the blood. As a result, leukocytes will accumulate on the vascular endothelium and leave the vasculature to the extravascular space. As this process progresses, more mediators will be produced causing an inflammatory cellular response, which results in the attraction of different immune cells (neutrophils and macrophages) to the affected site (Lowy, 1998). The interaction between the immune system and the cause will accumulate liquefied necrotic tissue (composed of the causative agent, dead white blood cells, necrotic tissue debris and protein elements from the immune reaction), which when combined form pus (Lam, Sweeney, Witmer, & Wise, 1963). In order to prevent these contents from seeding to the rest of the body through the bloodstream, the body reacts by forming a wall of fibrin deposits, known as the abscess wall (Cheng et al., 2009).

This pathophysiology of the abscess is not specific to a certain cause (Tzianabos, Wang, & Lee, 2001); instead, some biological causes (i.e. microbes) might use this defensive response for replication and spreading (Cheng et al., 2010).

1.2.3 Clinical Features and Diagnosis

For any inflammation process, the cardinal four signs were described 2000 years ago by Celsus: *rubor, calor, dolor, tumor* (i.e. redness, hotness, pain and swelling respectively) (Punchard, Whelan, & Adcock, 2004). The loss of function has been added later in 19th century as the fifth sign. Redness and heat are the result of vasodilatation, which is the first vascular response in inflammation. The following vascular permeability increase will cause the swelling, which is the result of protein and fluid leakage from the intravascular to the extravascular space. Pain is triggered by the release of the different chemical mediators. The loss of function might be subjective due to the pain resulting from the inflammation, or might be objective as a result of tissue destruction.

The clinical presentation of a cutaneous abscess is usually a localized, painful and tender site with fluctuating swelling surrounded by an erythematous induration surrounding it (Summanen et al., 1995). Sometimes a cutaneous abscess results from distant bacteria seeding through the blood stream, resulting in systemic manifestations (e.g. fever and chills) that may progress into sepsis.

Induration and swelling around the lesion might make it difficult to establish a diagnosis of underlying abscess collection. In such situations, some physicians will try to insert a needle and aspirate to confirm the presence of an abscess. This invasive method can lead to misdiagnosis if the needle is inserted into an empty space or a wrong location. A noninvasive imaging option is to use bedside ultrasound (US).

1.2.3.1 The Role of Ultrasound in the Diagnosis of Cutaneous Abscesses

Unlike other imaging modalities that use radiation, ultrasound is a unique real-time imaging method that uses sound wave reflections to produce images (Anderson M, 2000). The machine consists of three major components: the transducer (probe), computer processing unit and display monitor. The ultrasound machine sends electric signals to the transducer, resulting in the production of sound waves. The waves travel through acoustic transmission gel, which allows transmission of the sound waves into the soft tissue. The sound waves interact with the soft tissue and reflect waves back to the transducer, which in turn transmits the electrical current to the computer processing unit to produce a cross-sectional image. The more waves reflected from the tissue, the brighter the image will be displayed. Two factors affect the wave reflection: the angle of the transducer being perpendicular to the anatomical structures, and the property of the tissue being hydrophilic and inhomogeneous, e.g. soft tissue (K. Kirk Shung, 1992). Homogenous structures have high permeability, which allows sound waves to travel through without reflection, and as a result, dim or black areas will appear in the image, e.g. bony structures and areas filled with gas such as the lungs and bowel. Clinical descriptions of different reflections displayed on the images are: hyper echoic (i.e. bright echo), hypo echoic (i.e. weak echo), anechoic (no echo which looks black). Structures adjacent to each other with the same echogenicity displayed on the image are described as isoechoic.

The type and frequency of the transducer play a major role in image resolution, depending on the depth and characteristics of the structure being scanned. The frequency of sonographic waves can be a single, fixed frequency (e.g. 10 MHz), or a spectrum of frequencies (e.g. 13-6 MHz). This makes it possible to reach the optimal frequency for any structure or different kinds of structures in the same scanned plane (Whittingham, 1999). The lower frequency waves tend to travel deeper and give better images of deep structures, although they display lower resolution, and are visualized better with a curvilinear transducer to allow for a wider field of view. Conversely, linear transducers with a higher frequency are best used for superficial structures and result in high-resolution images; these are frequently used for skin and soft tissue pathologies.

Sonographic imaging relies on special skills and knowledge that requires special training to be utilized properly. Although it is an operator dependent technique, sonographic imaging has many advantages in addition to the above-mentioned features, making it superior to other imaging modalities in some clinical situations.

The ultrasound machine is a cost-effective, portable tool that can be used at a patient's bedside. It obtains images with a harmless technique that uses the reflection of sound waves. In addition to the diagnostic value of ultrasound, it can also be used to provide guidance for other diagnostic tools or therapeutic injections (Adler & Sofka, 2003; Stefano Bianchi, 2007).

Ultrasonic imaging has a great facility for detecting abscesses of the skin and soft tissue. Squire et al. compared the accuracy of physical examinations and bedside ultrasound to physical examinations alone for detecting cutaneous abscesses in patients presented to ED. The ultrasound's sensitivity for abscesses was 98%, with 88% specificity. In addition, there was a discrepancy between ultrasound and physical examination findings in 18 cases, and this disagreement was correct in favor of ultrasound in 94% of those cases (Squire, Fox, & Anderson, 2005).

Ultrasound is more sensitive than computerized tomography scans (CT-scan) for diagnosing skin and soft tissue infections (R. Gaspari, Dayno, Briones, & Blehar, 2012). It visualizes more detailed descriptive features of cutaneous abscess lesions than CT-scans. The regularity of the lesion wall and shape (usually round or oval, in some cases geographical) can be seen. It can also predict the maturity of the abscess depending on the echogenicity of the contents (Loyer, DuBrow, David, Coan, & Eftekhari, 1996). Other abscess signs include hyper echoic debris, posterior acoustic enhancement and anechoic shadows of gas that can develop with open skin or if the abscess cavity communicates with the bowel or lung (Chau & Griffith, 2005). Swirling Sign indicates the fluid nature of abscess content, and can be seen by gentle compression on the lesion by the transducer (Adhikari & Blaivas, 2012). Inflammatory fluid collection also can be detected with a color Doppler ultrasound, which shows hyperemia in the surrounding tissue (Arslan et al., 1998). Using US as a guide before I&D could be of great value in assessing adjacent neurovascular structures to avoid unexpected complications before surgery.

With the increased hazard of community-associated MRSA, several studies tried to investigate distinguishable sonographic features that could predict the presence of MRSA as the causative pathogen of cutaneous abscesses. In a recent pilot study by Gaspari et al., uncomplicated cutaneous abscesses that underwent incision and drainage were investigated, in those cases in which ultrasound was performed prior to the procedure. Physicians with skin and soft tissue ultrasound experience (blinded to the culture results) reviewed the sonographic images to evaluate the presence of predetermined features of cutaneous abscess. The correlation between the identified, agreed upon sonographic features and the presence of MRSA was calculated statistically. Results showed that the likelihood of the presence of MRSA in a culture is seven times greater in the presence of small, ill-defined edges and irregular shape signs in US (R. J. Gaspari et al., 2015).

A simple yet powerful tool that is widely available, ultrasound is considered a greatly effective device for the diagnosis of cutaneous abscesses. The challenges of correctly managing the diagnosis of cutaneous abscesses could be eliminated by using an imaging modality such as ultrasound, which is safe and can disclose important diagnostic features lying just beneath the superficial layers of skin. Therefore, training healthcare practitioners to properly use this tool in the diagnosis of cutaneous abscesses is essential, especially when a possibility to simulate realistic abscesses exists.

1.2.4 Treatment

Incision and drainage (I&D) is the definitive treatment for cutaneous abscesses. Historically, this was described in writing around 2100 B.C. in Sumerian (Majno, 1977): "If a man, his skull contains some fluid, with your thumb press several times at the place where the fluid is found. If the swelling gives way (under your finger) and (pus) is squeezed out of the skull, you shall incise, scrape the bone and (remove) its fluid….". Obtaining a sample of the abscess material for culture and sensitivity is advisable, although it was not a standard practice prior to the spread of MRSA (Miller et al., 2007). Wound packing after I&D has been proven of no additional benefit (Leinwand et al., 2013), instead, avoiding packing is the more effective and safer procedure.

Since the emergence of community-associated MRSA, antimicrobial therapy has been used to great effect as an adjunctive to I&D, although prior evidence was not in favor of adding antibiotics to the main surgical treatment (Llera & Levy, 1985; Macfie & Harvey, 1977). A retrospective study reviewed patients with MRSA as the cause of skin and soft tissue infections, and 361 of those suffered from cutaneous abscesses (Ruhe, Smith, Bradsher, & Menon, 2007). Patients treated with antibiotics sensitive to the isolated pathogen in obtained cultures had better outcomes than the group with no antibiotic therapy. Other randomized control trials done on adult patients and one targeting the pediatric age group, supported the notion that choosing the right antibiotic coverage decreases the risk of recurrence (Duong et al., 2010; Schmitz et al., 2010).

It is apparent from the above evidence that it is essential to direct more attention towards education about cutaneous abscesses in order to avoid potential direct and indirect complications. Indirect complications, caused by antimicrobial therapy, are complex and multifaceted, making them difficult to control for application in simulation education. However, more emphasis should be laid on direct complications that can result from misdiagnoses owing to inexperience or from surgical intervention with a lack of practiced skills, all of which are possible with simulation.

1.3 Simulation Models of Cutaneous Abscess

All skin infections caused by bacteria begin as cellulitis and progress into an abscess. Cellulitis is treated with antibiotics and doesn't require any surgical intervention, whereas incision and drainage is the main treatment for cutaneous abscesses. Therefore it is crucial to make a definitive diagnosis to differentiate between cellulitis and abscess, to anticipate unneeded surgical intervention. Additionally, false diagnosis and delaying abscess treatment may result in medical complications.

Most skin infections are diagnosed clinically by physical examination, which is not always sufficient to establish a definitive diagnosis without using radiological imaging. Ultrasound, as mentioned, is a safe, cost-effective and widely used tool that can be used bedside. It has proven more sensitive than the CT-scan for diagnosing skin and soft tissue infections (R. Gaspari et al., 2012), and provides more details about the abscess cavity without radiation harm. A study from a regional ED in the United States (Tayal, Hasan, Norton, & Tomaszewski, 2006) studied the effects of US in the management of skin and soft tissue infections over 28 months. After ultrasound imaging, physicians changed their management of cases in about half the patients diagnosed clinically with cellulitis, with ultrasound helping detect underlying occult abscesses in those patients. For these reasons, it is important to emphasize the education and training of residents and doctors on managing cutaneous abscesses to decrease healthcare burdens. As stated earlier, a cornerstone approach for training is simulation.

Although, it has been proven that the diagnosis of cutaneous abscesses is the most challenging issue (Tayal et al., 2006), particularly in training a novice, in simulation a great deal of attention has been devoted to the issue of treatment rather than diagnostic models (McGaghie, Issenberg, Petrusa, & Scalese, 2010). Many synthetic and real tissue models have been described in the literature as simulating cutaneous abscesses. A simulated abscess model created by injecting a mock abscess inside a Word catheter then inserting it into the leg of a fresh cadaveric specimen showed realistic I&D procedure techniques (Fitch, Manthey, McGinnis, Nicks, & Pariyadath, 2008). This model concentrated on the treatment aspect of cutaneous abscesses and used high cost tools to demonstrate a common problem, which might not be feasible for many institutions. Another model used chicken breasts and mock abscesses injected into a water balloon, resulting in a reliable teaching method that can be used in teaching I&D skills (Heiner, 2010). However, it failed to demonstrate realism in terms of diagnostics.

1.4 Problem Statement

The difficulty of differential diagnoses between cellulitis and occult cutaneous abscess remains the main issue in clinical practice. Educational efforts, however, have been invested into building simulation models directed toward the treatment of cutaneous abscesses. The discrepancy between the problem in clinical practice and educational efforts in this area requires simulation models that can provide an opportunity for trainees to practice their diagnostic skills. Given the important role that US imaging plays in the diagnosis of these conditions, using US imaging to supplement the physical simulation will improve the educational modalities and will subsequently lead to improvement in healthcare delivery in this area.

1.5 Context of the Study

The Centre of Excellence for Simulation Education and Innovation (CESEI) has launched a major project to investigate this problem. The hypothesis driving the project is that a high fidelity cost-effective simulation model of cutaneous abscess that is recognized by ultrasound imaging will improve the diagnostic skills of trainees and subsequently will positively affect the clinical outcome of patients with cutaneous abscess. The goals of the CESEI project are: a) to develop a high fidelity cost-effective simulation model of a cutaneous abscess that can be detected with ultrasound imaging; b) to implement the model into the training of physicians, to improve their diagnostic skills, which will subsequently lead to better clinical outcomes for patients. Attaining these goals requires addressing several objectives: 1) development of a high fidelity cost-effective simulation model of a cutaneous abscess that is recognizable by ultrasound; 2) evaluating the reliability and validity of detecting key diagnostic features on the basis of the simulation model; 3) assessing the efficacy of training that utilizes the model; 4) study the clinical outcome of patients treated by physicians who were trained on this simulation model.

1.6 Specific Goals of this Study

This study is aiming to address the following goals:

- To create a high fidelity cost effective simulation model of cutaneous abscess.
- To assess the reliability and validity of detecting key diagnostic clinical and sonographic features on the basis of the simulation model.

1.7 Research Question

The first goal of this study has to do with the development of a simulation model for education. Best practices in simulation development were used to guide the process of developing this simulation model.

The following research questions were formulated to guide the approach to analyses results addressing the second goal of this study:

1) How precisely are the target diagnostic features detected on the basis of the simulation models? Is there a difference in the precision, with which diagnostic features are identified?

2) How accurately are the intended diagnostic features detected? How consistently are judges able to detect the diagnostic features of the model? Are there models that better

portray the intended features? Are there features that are more accurately detected? Which are the features that are more predictive of the diagnostic decision than other?

If this model proves reliability and validity of demonstrating clinical and sonographic features of cutaneous abscess and reveals the potential for use in training, further scientific studies are needed to examine the efficacy of the model for training and correlations with the clinical outcome in clinical practice.

Chapter 2: Method and Procedure

2.1 Model Construction

The model consists primarily of: a pork belly to simulate skin and soft tissue, a water balloon to simulate an abscess wall, mock purulence (described below) and simulated cavity septae, created using thermoplastic glue. Pork belly was chosen for its structural similarity to human skin layers and thickness ratios (Swindle, 2007). The size of each specimen was 7 X 7 inches with full thickness of the belly wall. A pocket was created on the side of the specimen just under the skin layers toward the center of the specimen, using a surgical scalpel (size 10) and a curved Kelly hemostat (Figure 1).

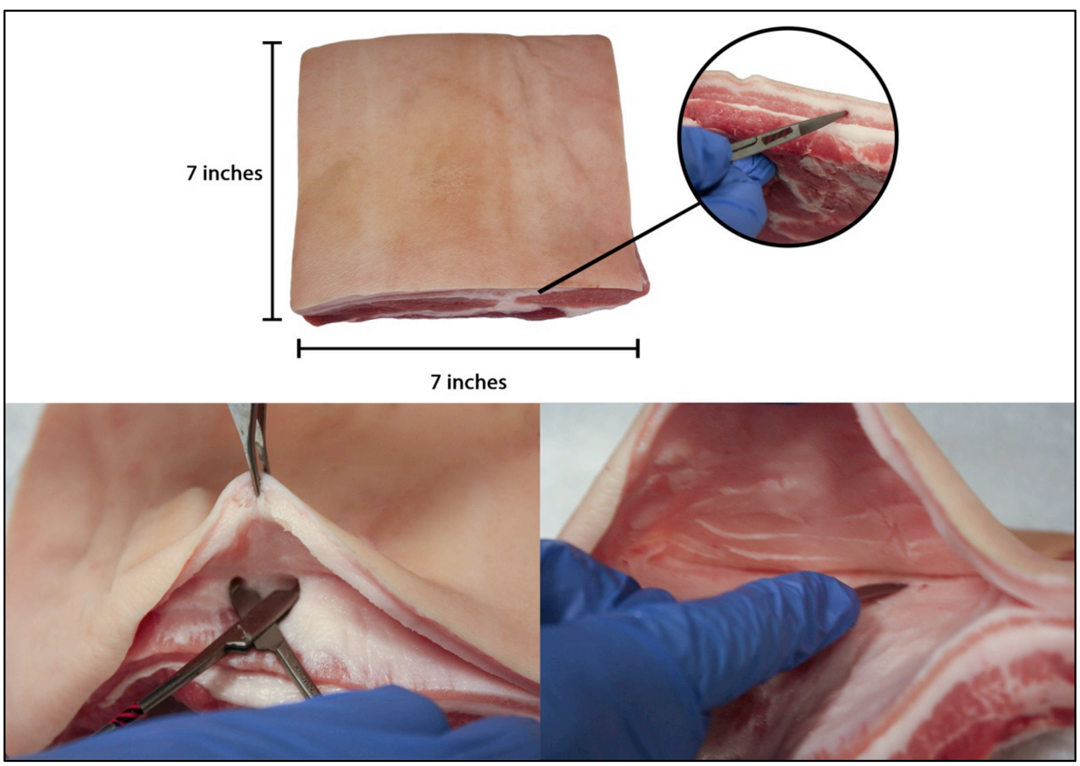

Figure 1: Preparing the abscess cavity on the pork belly

The simulated abscess purulence consists of a mixture of mayonnaise, mustard and water (3:1:1 ratio respectively). To mimic septae of the abscess cavity, a glue gun was used to dispense two thin threads of glue, which were air-dried for 2 minutes (Figure 2).

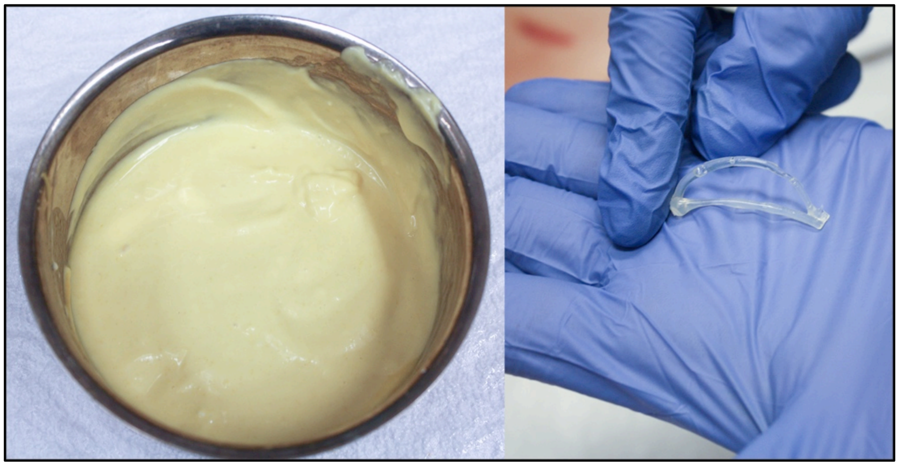

Figure 2: Abscess and septae mock

The dried glue threads were then inserted into the balloon. The neck of the balloon was cut just under the bead to widen the inlet (Figure 3).

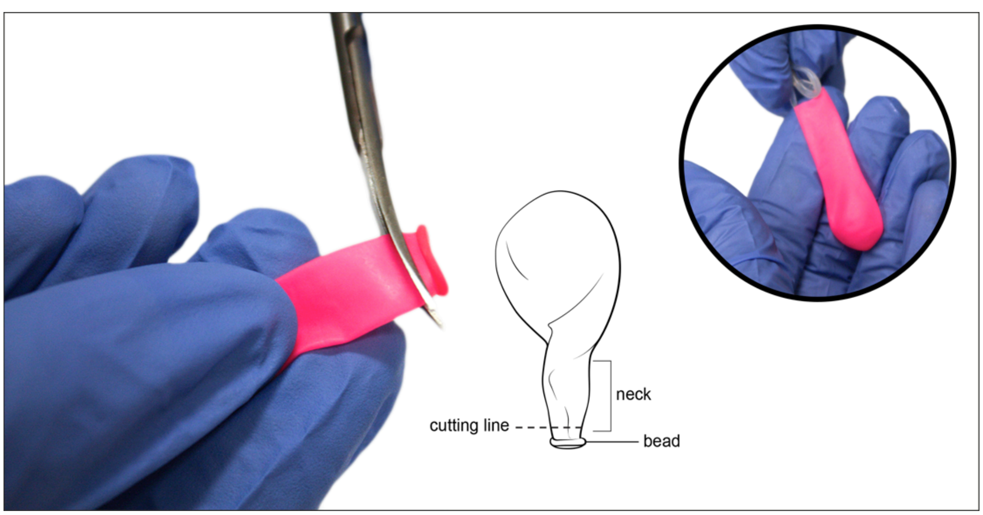

Figure 3: Preparing the abscess wall and inserting the septae mock

To minimize air inside the abscess cavity, a 14-gauge catheter (without the needle) was inserted into the balloon through the neck, a surgical knot tied around the neck of the balloon holding the catheter in place. Air inside the balloon was withdrawn using 10 cc syringes, and then the catheter was clamped with a Kelly hemostat to prevent air from returning into the cavity (Figure 4).

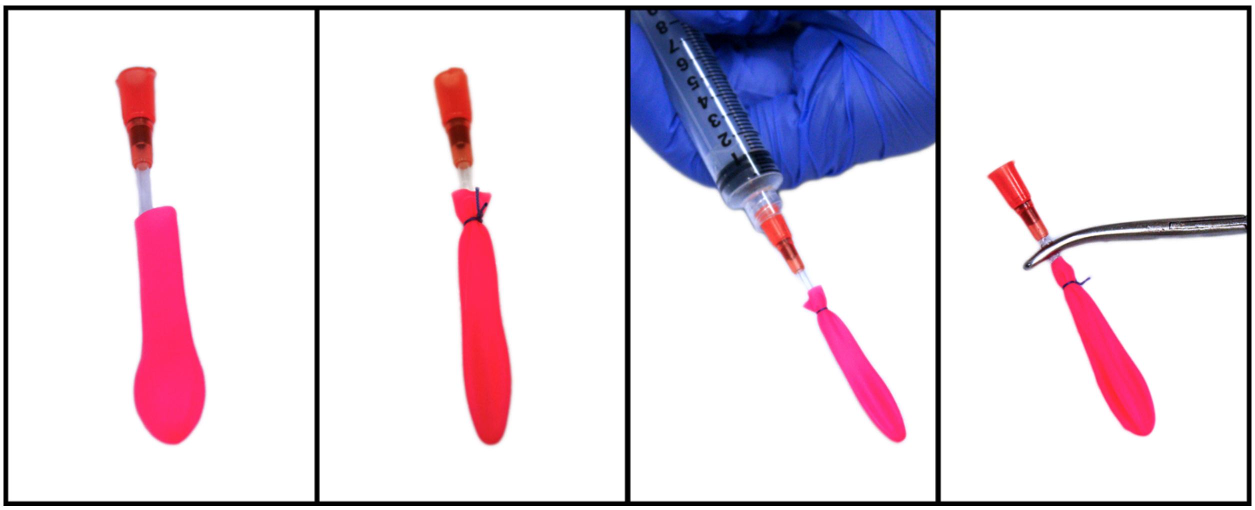

Figure 4: Steps of deflating the balloon and preventing air re-entry.

The balloon was filled with 10 cc increments of the mock purulence using a syringe attached to the catheter. This process was repeated until it was filled with 30 cc. It was important to ensure that the catheter be clamped each time before disconnecting the syringe (Figure 5).

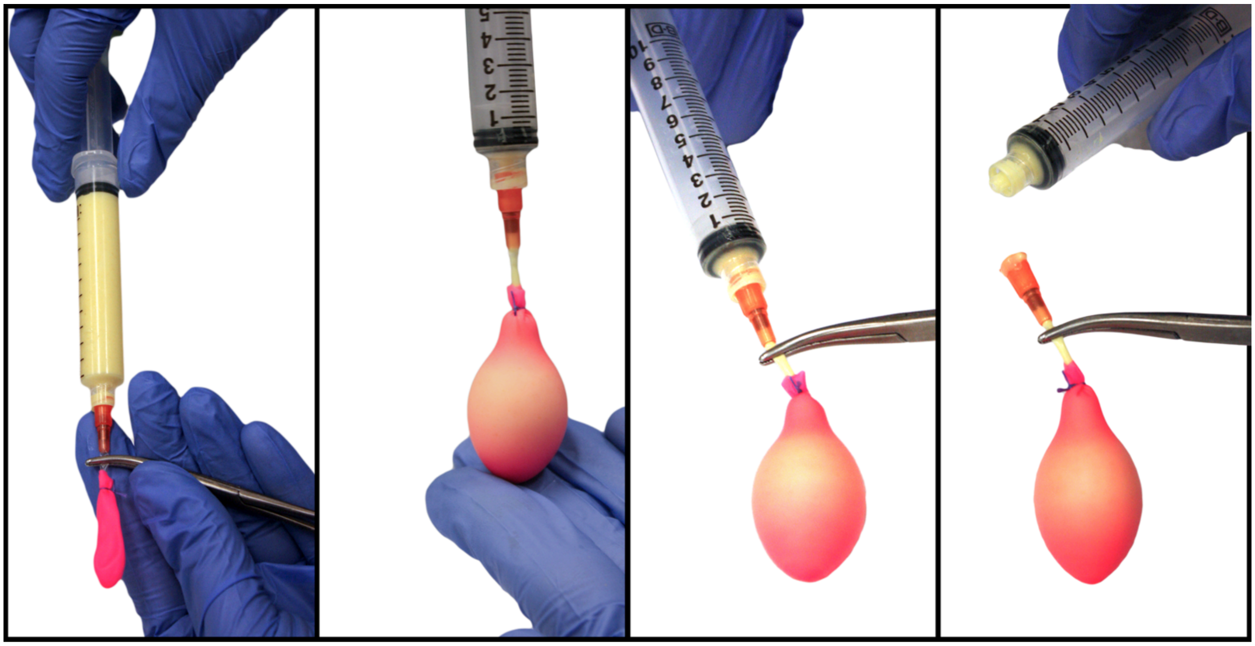

Figure 5: Filling the balloon with the abscess mock. Note that the catheter should be clamped each time before disconnecting the syringe.

To remove the catheter, another surgical knot was placed just below the previous knot simultaneously with pulling the catheter, to prevent leakage and air entry into the abscess cavity (Figure 6).

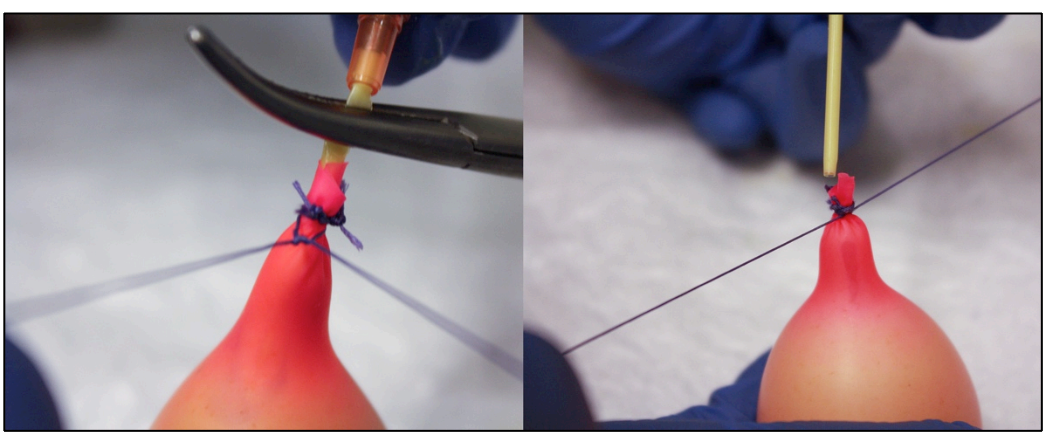

Figure 6: Tying a surgical knot simultaneously with withdrawal of the catheter to prevent air entry inside the balloon.

Finally, the balloon was placed inside the pork belly through the created pocket, and the edge of the pocket inlet was sutured to close the cavity and give a realistic skin tension. The skin of the pork belly was then moulaged with red color (e.g. lip stick) to simulate the erythema around and over the swelling (Figure 7).

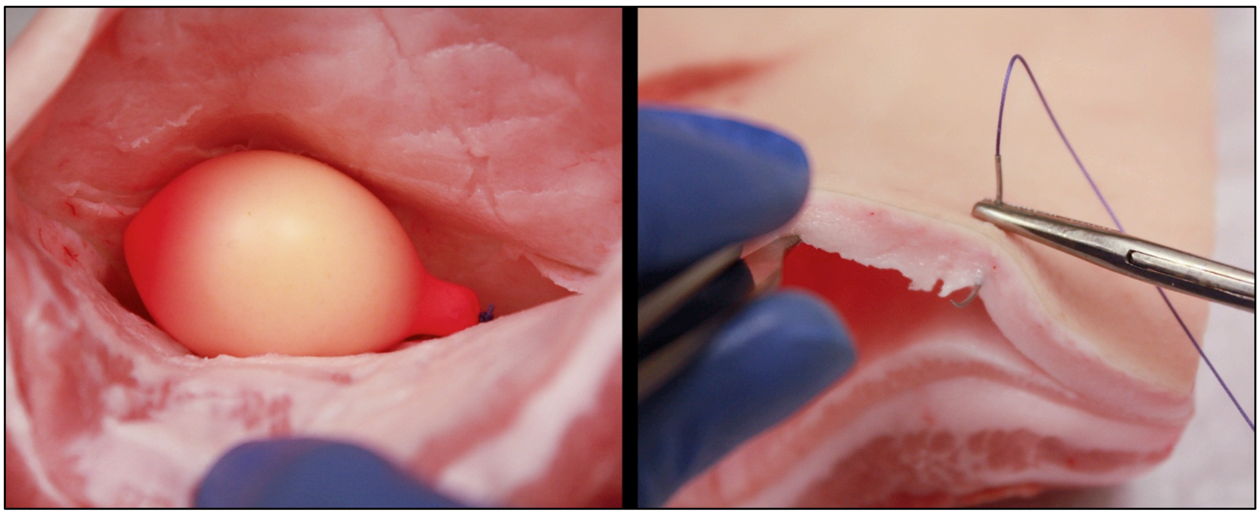

Figure 7: Placing the mock abscess lesion inside the pork belly and suturing the side pocket inlet.

2.2 Ultrasound Imaging of the Models

This study aims to drive this novel model to the next stage of usability as a teaching tool for trainees to practice diagnostic measures of cutaneous abscesses and ultrasound techniques. At the stage of measuring reliability and validity of the model, a radiologist was asked to standardize the ultrasound imaging in order to anticipate the down side of the ultrasound as an operator dependent diagnostic tool. A linear transducer (15-6 MHz) connected to a SonoSite M-Turbo® ultrasound machine capable of easily extracting high quality pictures was used in this study (Figure 8).

Figure 8: Portable Ultrasound machine and the linear transducer used for imaging the models.

The radiologist examined six identical abscess models (labeled with alphanumeric codes) as described earlier and then he chose one image for each model that looked similar to cutaneous abscess seen in real patients. Each image was labeled with the same code used for the corresponding model to be used later in the evaluation form (Figure 9).

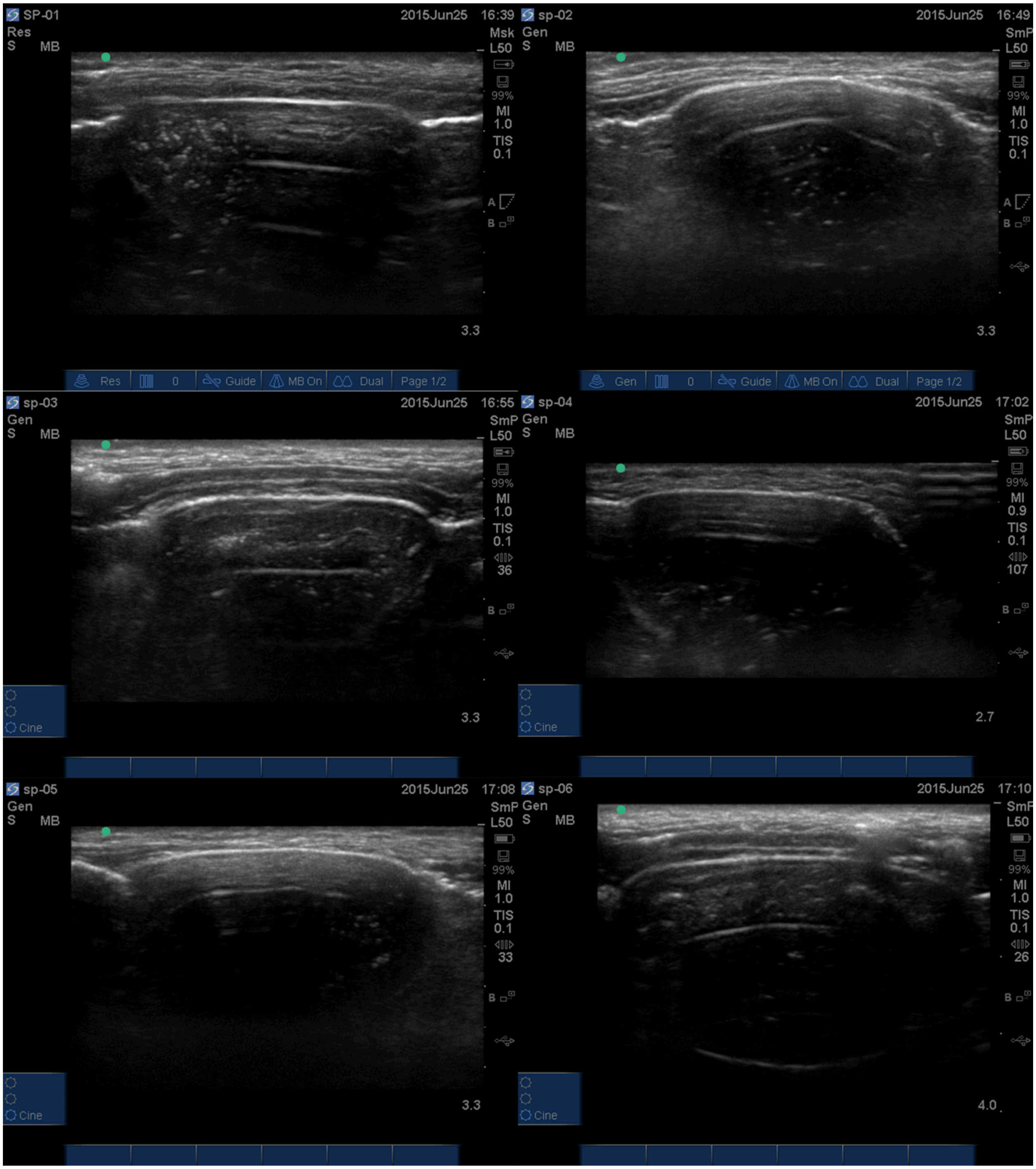

Figure 9: Sonographic images of the six abscess models.

2.3 Participants

Many courses organized by different departments at the University of British Columbia (UBC) and affiliated hospitals are held weekly at CESEI. The research team sent an email to the organizers of these courses to introduce them to the study and the timeline needed to complete the experiment, as well as a call for study participation by the course members. A copy of the consent form was attached along with the email, in order to give the participants enough time to read the consent before making a decision. The participant inclusion criteria were: 1) Medical doctors (staff and residents) familiar with skin and soft tissue infections; 2) Medical doctors who are able to identify cutaneous abscesses by physical examination and ultrasound. Exclusion criteria include: 1) Medical doctors with no prior experience of cutaneous abscesses; 2) Medical doctors who are not confident in assessing ultrasound images of abscesses; 3) Medical doctors who stopped practicing for more than 10 years.

A total of 24 medical doctors volunteered to participate in the study. Written consent forms (Appendix I) were collected after the introductory explanation of the study. The consent forms stated clearly that the participant had the right to withdraw from the study at any time with no obligation or need for justification. Ethical board approval was obtained for this study.

2.4 Instrument and Variables

An electronic form was created to evaluate the cutaneous abscess model for its clinical and sonographic features and realism (Appendix II). A five level Likert-scale (high, medium and low level of agreement and low and high level of disagreement), with a rating of 5 expressing a high level of agreement and number 1 referring to a high level of disagreement, was used to rate five clinical characteristics (redness, swelling, size, shape and consistency) and five sonographic features (well-defined abscess wall, anechoic/hypo echoic cavity, septae, hyper echoic floating debris/gas and posterior acoustic enhancement). The last component was to evaluate realism on a scale from 1 to 10.

2.5 Procedures

The study was conducted in the Centre of Excellence for Simulation Education and Innovation's (CESEI) computer lab. The electronic forms were uploaded onto CESEI's learning management system (LMS) in a web-secured environment. The six models were set beside computers displaying the evaluation form and the corresponding ultrasound image. Participants were divided into four groups (six persons in each group), with each group participating separately. Each participant rotated between the cutaneous abscess models and completed the electronic evaluation forms (each model evaluated six times by a group). At the end of the study, each participant has examined all six models (i.e. each model was examined 24 times in total).

The study and the procedures used were described to the volunteering participants on the day prior to the study. All data generated from the study was stored on CESEI's LMS, which is a secure electronic platform according to UBC and Vancouver Coastal Health (VCH) standards. All personal data of participants was protected, the only identifier being the timestamp of the electronic evaluation form, which was submitted and randomly coded after data collection was completed, and before the analyses.

2.6 Statistical Analyses

To assess reliability in this study, the internal consistency reflecting the extent of relatedness within the diagnostic features (Tavakol & Dennick, 2011), was calculated among 24 judges using Cronbach's alpha. The internal consistency of both constructs (i.e. clinical features and sonographic features) was assessed separately for each of the six independent models. That indicates the extent to which all diagnostic features in a model measure the same corresponding construct. Interrater reliability was assessed by calculating intraclass correlation coefficient (ICC) for the overall scale of each construct and for each feature (e.g. redness) separately. For a content validity assessment, the number of agreements was counted for each construct across all six models to calculate the content validity index (CVI). Calculating the CVI will ensure the degree of appropriateness of the diagnostic features selected for the construct being measured (Polit & Beck, 2006). The correlation between features in each category was calculated, in addition to their relation to the overall scale using the Pearson Correlation Coefficient (*r*). A linear regression was computed to identify the predictors of the measure of each construct.

Chapter 3: Study Results

3.1 Reliability

To assess reliability in this study, Cronbach's alpha a measure of internal consistency was calculated. The result of this statistical analysis showed strong internal consistency (Cronbach's alpha: 0.89 and 0.87 for clinical and sonographic features respectively). Table 1 demonstrates internal consistency for each model. The highest Cronbach's alpha score for clinical features was in Model 1 (Cronbach's alpha = 0.8) and the lowest was in Model 3 (Cronbach's alpha = 0.69). For the sonographic features, the highest internal consistency was in Model 3 (Cronbach's alpha = 0.8), and the lowest was for model 6 with Cronbach's alpha 0.57. Although Cronbach's alpha of the sonographic features in Model 6 showed low levels in comparison to the other models, the overall internal consistency of the sonographic features was not affected after elimination of this model (Cronbach's alpha = 0.84).

Table 1: Internal consistency of the six abscess model

	Clinical Features		Sonographic Features	
	Cronbach's alpha	**SE**	**Cronbach's alpha**	**SE**
Model 1	0.8	0.14	0.75	0.15
Model 2	0.79	0.14	0.7	0.6
Model 3	0.69	0.66	0.8	0.71
Model 4	0.79	0.76	0.63	0.62
Model 5	0.76	0.61	0.76	0.72
Model 6	0.74	0.6	0.57	0.58
Cronbach's alpha	0.89		0.87	

In addition to Cronbach's alpha, the interrater reliability was computed using ICC in order to determine agreement among the judges. The ICC was strong when the data of both clinical and sonographic features were pooled (ICC = 0.71). However, when the ICC for clinical and sonographic features was calculated independently, the interrater reliability was stronger for sonographic features (ICC = 0.74) in comparison to clinical features (ICC = 0.57). Tables 2 and 3 depict the data on clinical (mean = 3.88, SD = 0.44 and ICC = 0.57) and sonographic (mean = 3.63, SD = 0.44 and ICC = 0.74) features and describe specific elements of the construct. By analyzing all the elements of the construct, the highest rate of agreement between judges was on swelling, shape of the wall and cavity content. The lowest rate of agreement was on shape of the abscess lesion and posterior acoustic enhancement.

Table 2: Intraclass correlation coefficient for clinical features

	Mean	SD	ICC
Redness	3.63	0.60	0.45
Swelling	4.04	0.51	0.75
Palpation: size	4.02	0.47	0.5
Palpation: shape	3.94	0.53	0.43
Palpation: consistency	3.75	0.62	-0.005
		Overall ICC	0.57

Table 3: Intraclass correlation coefficient for sonographic features

	Mean	SD	ICC
Wall: well-defined (spherical/oval)	3.81	0.54	0.8
Cavity: anechoic/hypo echoic	3.82	0.48	0.76
Septae	3.40	0.68	0.62
Floating debris/gas:hyper echoic	3.78	0.49	0.56
Posterior acoustic enhancement	3.34	0.56	0.12
		Overall ICC	0.74

The Pearson Correlation Coefficient (*r*) was calculated to assess the relationship between independent categories and the construct. Tables 4 and 5 show highly significant correlations between all features and the corresponding construct ($p < 0.01$). When correlation among clinical features was assessed (Table 4), consistency of the abscess lesion was relatively lower with redness ($r = 0.49$, $p < 0.05$) and swelling ($r = 0.48$, $p < 0.05$). Shape was the only correlation that was not significant in relation to redness ($r = 0.36$). There are three low correlations in sonographic features (Table 4). Cavity of the abscess had lower correlation in relation to septae ($r = 0.42$, $p < 0.05$) and posterior acoustic enhancement ($r = 0.43$, $p < 0.05$). In addition, the degree of significance between floating debris inside the abscess and the abscess wall was relatively lower than the other correlations ($r = 0.47$, $p < 0.05$). From the overall sonographic features, features of the septae did not correlate ($r = 0.28$) with the abscess wall.

Table 4:Pearson Correlation Coefficient of clinical features

	Redness (erythema)	*Swelling*	*Palpation: size*	*Palpation: shape*	*Palpation: consistency*	*Average of Construct*
Redness (erythema)						
Swelling	*0.56***					
Palpation: size	*0.52***	*0.66***				
Palpation: shape	*0.36*	*0.57***	*0.83***			
Palpation: consistency	*0.49**	*0.48**	*0.61***	*0.72***		
Average of Construct	*0.73***	*0.79***	*0.87***	*0.84***	*0.83***	
* p < 0.05, ** p < 0.01						

Table 5: Pearson correlation Coefficient for sonographic features

	Wall: well-defined (spherical/oval)	*Cavity: anechoic /hypo echoic*	*Septae*	*Floating debris/gas: hyper echoic*	*Posterior acoustic enhancement*	*Average of Construct*
Wall: well-defined (spherical/oval)						
Cavity: anechoic/hypo echoic	*0.63***					
Septae	*0.28*	*0.42**				
Floating debris/gas: hyper echoic	*0.47**	*0.6***	*0.61***			
Posterior acoustic enhancement	*0.58***	*0.43**	*0.71***	*0.55***		
Average of Construct	*0.73***	*0.76***	*0.8***	*0.81***	*0.84***	

* $p < 0.05$, ** $p < 0.01$

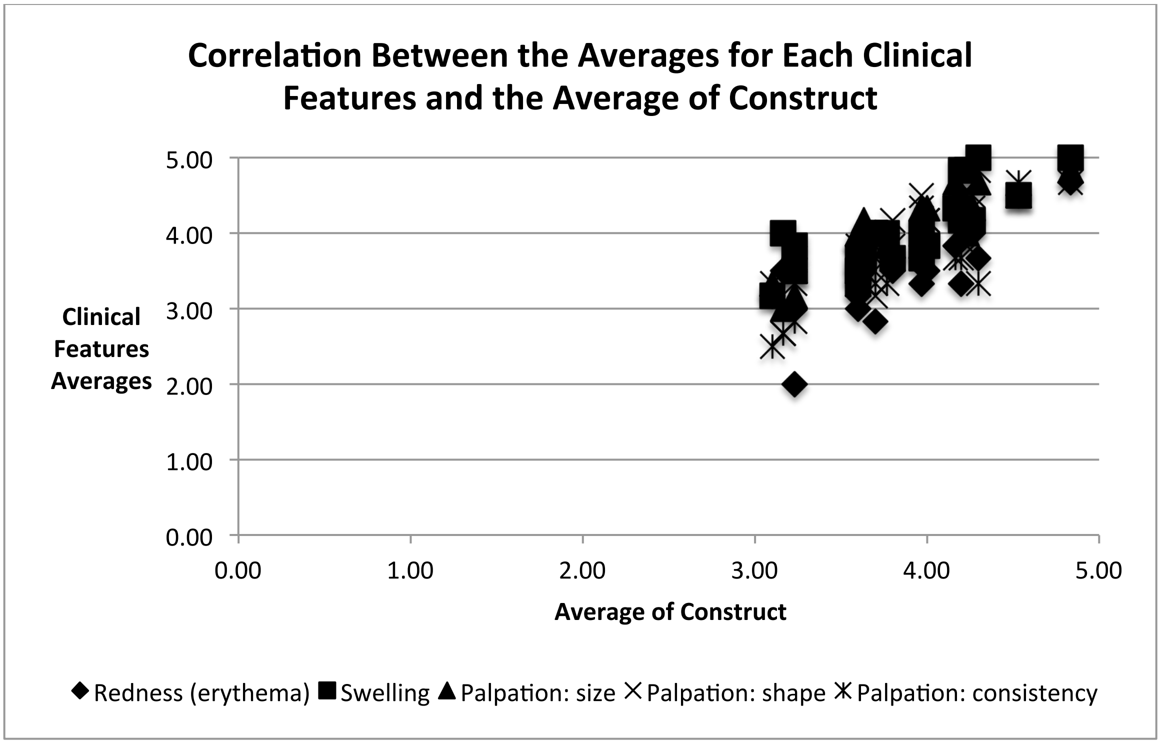

Figure 10: Distribution of each clinical feature in relation to each feature scale (vertical axis), and the overall average of construct. Note the high correlation between the clinical features and the overall scale toward agreement levels.

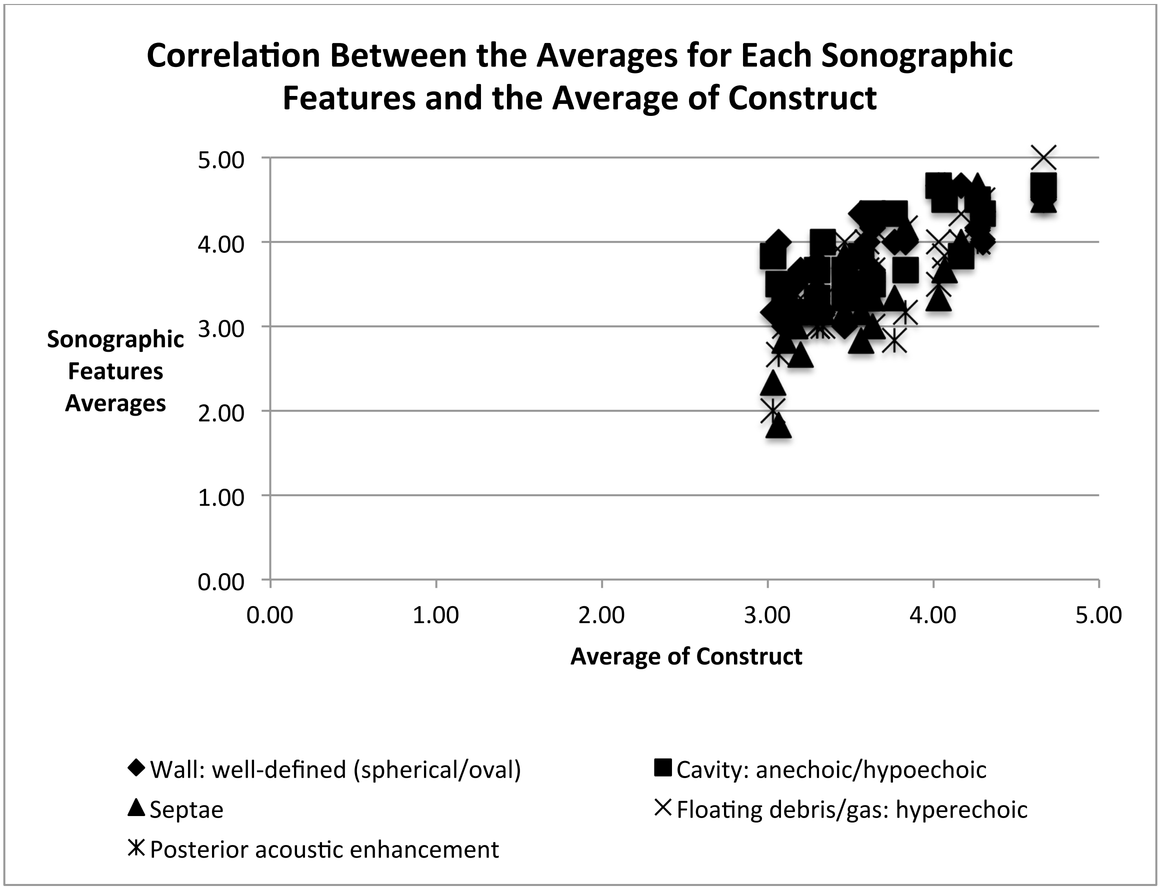

Figure 11: Distribution of each sonographic feature in relation to each feature scale (vertical axis), and the overall average of construct. Similar to the clinical features, a high correlation between the sonographic features and the overall scale is toward agreement levels.

Linear regression was used to identify which features in each construct are more predictive of the outcome scores of each model. For clinical features (Table 7), the strongest predictors for the score on each abscess model were size of the abscess lesion (B = 0.82, SE = 0.1) and shape (B = 0.71, SE = 0.1). However, redness (B = 0.54, SE = 0.11) and consistency (B = 0.59, SE = 0.09) were less predictive. Table 8 demonstrates the results from analyzing the sonographic features. Cavity echogenicity (B = 0.68, SE = 0.12) and presence of floating debris inside the abscess (B =

0.72, SE = 11) were the strongest predictors, whereas the septae had the lowest prediction value (B = 0.5, SE = 0.08).

Table 6: Linear regression of clinical features

	B Coefficient	*Standard Error (SE)*	*Prediction Limits (LCL – UCL)*
Redness (erythema)	*0.54*	*0.11*	*0.32 – 0.77*
Swelling	*0.69*	*0.11*	*0.46 – 0.92*
Palpation: size	*0.82*	*0.1*	*0.62 - 1*
Palpation: shape	*0.71*	*0.1*	*0.51 – 0.91*
Palpation: consistency	*0.59*	*0.09*	*0.41 – 0.77*

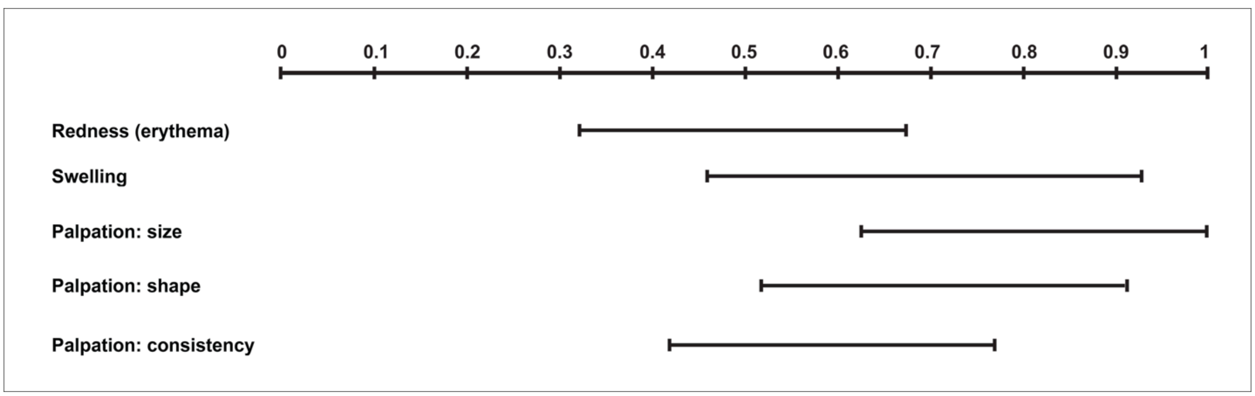

Figure 12: 95% confidence interval around the prediction values among the model clinical features. Note that "swelling" is the strongest predictor in compare to other clinical features.

Table 7: Linear regression of sonographic features

	B Coefficient	*Standard Error (SE)*	*Prediction Limits (LCL – UCL)*
Wall: well-defined (spherical/oval)	*0.58*	*0.11*	*0.34 – 0.82*
Cavity: anechoic/hypo echoic	*0.68*	*0.12*	*0.42 – 0.94*
Septae	*0.5*	*0.08*	*0.33 – 0.67*
Floating debris/gas: hyper echoic	*0.72*	*0.11*	*0.49 – 0.95*
Posterior acoustic enhancement	*0.65*	*0.08*	*0.47 – 0.84*

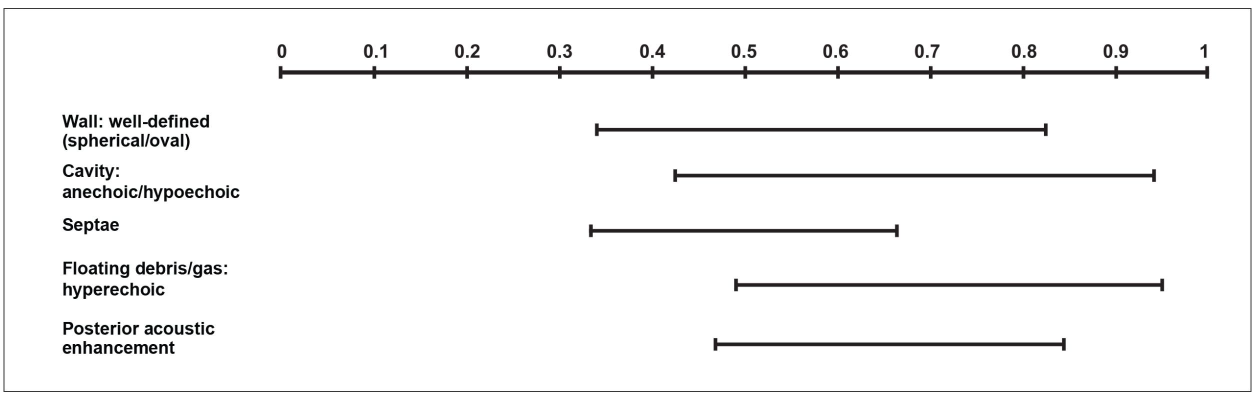

Figure 13: 95% confidence interval around the prediction values among the model sonographic features. Note that abscess cavity and floating debris are the strongest predictor in this construct.

3.2 Validity

To assess whether both clinical and sonographic features that have been used in the evaluation form are relevant in measuring the model, a Content Validity Index (CVI) was computed for each construct (i.e. clinical and sonographic features). The analyses revealed high indices for both clinical features (CVI = 0.90) and sonographic features (CVI = 0.85).

Chapter 4: Discussion

Analysis of the literature reveals the need for a simulation model of cutaneous abscess that would support medical education in the diagnosis of these conditions. A gap exists in the training of successful diagnosis of cutaneous abscesses. In this study, a high fidelity cost-effective simulation model was designed to improve the efficacy of teaching the diagnostic skills of recognizing cutaneous abscess in medical education.

Although the model in this study was constructed from simple, widely available and easy to assemble materials, it utilizes several novel approaches in the design of a simulation model of cutaneous abscess. Homemade tissue phantom from inexpensive gelatin has been used in several studies for vascular access and breast lesion ultrasound-guided procedures (Cheruparambath, Sampath, Deshikar, Ismail, & Bhuvana, 2012; Kendall & Faragher, 2007; Sutcliffe, Hardman, Dornbluth, & Kist, 2013). It was not considered for use in this study's model due to insufficiency in mimicking human soft tissue. Human cadaveric tissue offers the most realistic feel, but it was not considered due to ethical boundaries and high cost. Pork skin tissue has proven to be the most similar to live tissue, human skin, for both its anatomical and physiological features (Sullivan, Eaglstein, Davis, & Mertz, 2001; Swindle, 2007). Thus, pork soft tissue has heterogeneity that can demonstrate different echogenicity in US similar to human soft tissue. As the presence of septae is a cardinal sign for cutaneous abscess in US, thermoplastic glue was chosen for ease of use and elasticity. It can be inserted inside the balloon without breaking or destroying its original shape and it has the ability to re-expand after filling the balloon with mock abscess. To simulate abscess material, a mixture of mayonnaise, mustard and water in a fixed ratio as described earlier was prepared for its similarity to real abscess morphological and sonographic features. A study was conducted at Seattle Children's Hospital in the United States to create a homemade phantom to simulate a superficial soft tissue abscess (Lo, Ackley, & Solari, 2012). The study examined several liquid materials by injecting the liquid into the phantom to simulate abscess formation. They reported that mayonnaise was hyper echoic in ultrasound, which does not mimic a real abscess with different echogenicity on ultrasound images. The study findings demonstrate the opposite, as mayonnaise was found to be the hypo echoic/anechoic element of the abscess material and the goal of adding mustard was to simulate the hyper echoic floating debris. Heiner (2010), described similar findings by using mayonnaise and maple syrup for his skin abscess model for teaching I&D (Heiner, 2010).

This novel simulated abscess model is cost-effective with a maximum cost about $10 CAD, and could be easily reproduced for a large group of trainees. The average time required to construct one model is 20 minutes, with the assistance of a second person to deflate and fill the water balloon. These materials can be reserved in a cooler for up to a week. Although the simplicity in constructing the model from low cost and readily available materials, it provides the immersion of trainees that is needed to mimic real conditions. As per Gaba (2004), the model could be considered as a high fidelity simulator as the anatomy and functionality of the model have a high degree of immersion of subjects.

The innovative ideas of choosing the skin tissue that is closest to human skin, mimicking a cardinal feature of abscess cavity (i.e. septae) and a mock purulence with real abscess US features have been used in constructing the model. All together it successfully demonstrated the clinical and sonographic features of a cutaneous abscess. These put this novel model as a promising tool that can be used as a simulator for diagnosis of cutaneous abscess in medical education.

Reliability refers to the consistency, precision and stability of the model measurements, which indicates getting consistent results when repeating the measurement on different occasions and with different participants (Oermann, 2013). Reliability evidence is concerned with measurement error (McDowell, 2006). These errors can be determined by assessing the internal consistency of the items (to exclude errors related to measurement variability), interrater reliability (errors related to subjects agreement) and test-retest reliability (errors occur from repeating the test in different occasions for different reasons). This approach has been used to prove reliability in several simulators (Hoadley, 2009; Vassiliou et al., 2006). In this experiment, all judges used the same measurements for six identical models to measure the internal consistency and interrater reliability. Cronbach's alpha was 0.89 and 0.87 for clinical and sonographic features respectively. According to George and Mallery (2010), these values indicate "Excellent" internal consistency (George & Mallery, 2010), which suggests the ability of the model in demonstrating clinical and sonographic features of cutaneous abscess is highly precise in distinguishing between participants. Across the six models, Cronbach's alpha was within Excellent, Good and Acceptable levels. Even with the exclusion of Model 6, which showed "Questionable" levels for its sonographic features, the scores for internal consistency without Model 6 did not change. This indicates that all models are consistent and stable and that this minor error is a usual characteristic of any measurement. In addition, the data in this study shows agreement between judges for both constructs (i.e. clinical and sonographic features), which reflects the stability of the measurements, and low variability among judges (ICC = 0.57 – 0.74, 95% CI). The correlation between all measurements and the corresponding construct shows high significant correlations ($p < 0.01$). Thus, this study can offer clear proof of the reliability of the ability of the model in demonstrating both clinical and sonographic features.

Polit and Beck defined content validity as: “the degree to which an instrument has an appropriate sample of items for the construct being measured” (Polit & Beck, 2006). Measuring the validity of any model is a complex process, requiring a series of studies to cover all validity measurements. The simulation model designed for this study was analyzed for validity of content. Content validity can be quantified and measured using the Content Validity Index (CVI). The minimum recommended CVI for 6 to 10 judges is 0.78 (Lynn, 1986). The abscess model revealed high index levels for both constructs (0.9 for clinical construct and 0.85 for sonographic construct) for 24 judges. Considering the results obtained, the content validity of detecting the diagnostic features of cutaneous abscess in this model can be confirmed.

Although data in this experiment expressed clearly the reliability and validity of the model’s ability to demonstrate the diagnostic features of cutaneous abscess, this study also examined the relationship between the items within each construct, for the purpose of identifying and improving the items for future applications of the model. In this context, the ICC was low for redness, shape and consistency of abscess lesion as well as the posterior acoustic enhancement feature in US. In addition, a regression analysis was conducted to identify the strongest and weakest predictors for the overall score of each construct. Size and shape of the abscess lesion, cavity echogenicity and presence of floating debris were the strongest predictors for a score of a corresponding construct. Redness and consistency of the abscess lesion, in addition to the septae in ultrasound images, were the weakest predictors for their constructs. In each experiment, (redness) scores were descending until they reached the lowest score by the last rotation in the experiment. Red lipstick was applied to simulate redness, which slowly diminished from contact with judges' gloves during palpation, until the coloring was barely visible at the end of the experiment. To overcome this problem, waterproof paints should be used to color the area. In addition to redness, a clear discrepancy between judges' agreement on shape and consistency of the abscess lesion were noticed. This may be owing to the amount of the mock abscess material inside the water balloon, which could be decreased to 20 cc instead of the 30 cc used in this study. This will result in a less prominent and more fluctuating simulated abscess lesion.

Only one sonographic feature (posterior acoustic enhancement) was affected by the variation in judges' agreement, likely owing to the glue gun material. Although the glue successfully simulated what it was intended to (i.e. septae), it caused some shadowing behind the abscess lesion in ultrasound images (Figure 5). This is due to the physical characteristics of the glue as a hydrophobic material, which absorbs all the acoustic waves and prevents waves from moving towards the transducer. This appears as a black area (shadow) on ultrasound images (Culjat, Goldenberg, Tewari, & Singh, 2010). Several other studies used other materials as tissue substitutes, materials with the permeability to pass and reflect acoustic waves and appear on ultrasound images with similar heterogeneity to real soft tissue (Denadai et al., 2014; Jussila, 2004; Rock, Leonard, & Freeman, 2010). Examples of these materials are: gelatin, agar and alginate, which all share the physical characteristic of being hydrophilic. This study avoided hydrophilic materials because they would not hold shape when inserted into the water balloon.

Our suggestion is to use shorter and thinner threads of the glue. Finding a hydrophilic substitute to the glue is a better option indeed.

4.1 Summary

Medical simulation has become more sophisticated than ever, with a wide variety of models and many improvements made to the materials used to construct them. So medical students can learn and perform procedures away from patients and the associated risks, in keeping with the Hippocratic oath to *first do no harm.*

The difficulty of differential diagnoses between cellulitis and occult cutaneous abscess remains the main issue in clinical practice. Educational efforts, however, have been invested into building simulation models directed toward the treatment of cutaneous abscesses. The discrepancy between the problem in clinical practice and educational efforts in this area requires simulation models that can provide an opportunity for trainees to practice their diagnostic skills. Given the important role that ultrasound imaging play in the diagnosis of these conditions, using this imaging modality to supplement the physical simulation will improve the educational modalities and will subsequently lead to improvement in healthcare delivery in this area. CESEI has launched a major project to investigate this problem. The hypothesis driving the project is that a high fidelity cost-effective simulation model of cutaneous abscess that is recognized by ultrasound imaging will improve the diagnostic skills of trainees and subsequently will positively affect the clinical outcome of patients with cutaneous abscess. The aim of this study is to create a high fidelity cost effective simulation model of cutaneous abscess model and to assess the reliability and validity of detecting key diagnostic clinical and sonographic features on the basis of the simulation model.

Six identical models consist of a water balloon filled with mock abscess and two glue threads inside pork belly, and radiologist standardized ultrasound images of the model. Reliability and validity of detecting key diagnostic features on the basis of the model by 24 judges were explored.

Internal consistency was assessed by calculation of Cronbach's alpha across all models. Cronbach's alpha was 0.89 and 0.87 for clinical and sonographic features respectively. This suggests the ability of the model in demonstrating clinical and sonographic features of cutaneous abscess is highly precise in distinguishing between participants. The agreement among judges was assessed by calculation of intraclass correlation coefficient was 0.71 of both clinical and sonographic features, which reflects the stability of the measurements and low variability among judges. The correlation between all clinical and sonographic features and corresponding construct were highly significant ($p < 0.01$), that indicates the relation between each feature and the overall corresponding construct. Validity was assessed for validity of content to determine if the variables of both constructs are relevant in measuring the model diagnostic features. Content validity indices (CVI) were 0.90 for clinical features construct and 0.85 for sonographic features construct.

The innovative ideas of choosing the skin tissue that is closest to human skin, mimicking a cardinal feature of abscess cavity (i.e. septae) and a mock purulence with real abscess sonographic features, have been used in constructing the model. Overall, the model successfully demonstrated the clinical and sonographic features of a cutaneous abscess. This novel model is a promising tool that can be used as a simulator for training in diagnosis of cutaneous abscess in medical education. Study data shows high internal consistency and high agreement between judges. All clinical and sonographic features were significantly correlating to the overall corresponding construct. It also reveals strong content validity. The ability of the constructed cutaneous abscess model to demonstrate both clinical and sonographic features is reliable and valid. The efficacy of the model for training, and correlations with the clinical outcome in real practice are questions for further studies.

4.2 Conclusion

- The developed high fidelity cost-effective model can be used as a simulated teaching tool to demonstrate clinical and sonographic features of cutaneous abscess disease.
- This novel cutaneous abscess model reliably demonstrates clinical and sonographic features of cutaneous abscess disease.
- The model shows high content validity for both clinical and sonographic features.

4.3 Recommendations

4.3.1 Improvement of the Model

To improve on the cutaneous abscess model, future studies can attempt to substitute the thermoplastic glue utilized in this study by a hydrophilic material with sufficient elasticity to provide better ultrasound imaging while also maintaining its shape without breaking.

4.3.2 Future Plans

Since the reliability and content validity of detecting the diagnostic features of cutaneous abscess based on the model has been established in this study, we recommend moving the model to the next step toward usability as a standard of training. We propose further development of this scientific study as suggested by Kirkpatrick four steps for training evaluations to evaluate the efficacy of the model (Orlando & Pennsylvania, 2009; Rouse, 2011). These levels are: reactions (learner satisfaction), learning (knowledge and skills acquisition), transfer (applying the acquired knowledge and skills to clinical practice) and results (patient outcomes).

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