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Abstract

Embedded soft tissue foreign bodies are common complaints of patients presenting to rural urgent care centers. The removal of soft tissue foreign bodies present challenges for the healthcare provider when objects are radiolucent and cannot be identified on readily available diagnostic imaging modalities such as plain radiographs (X-rays). Ultrasound has been introduced in the literature as a useful adjunct to X-rays for the localization and removal of soft tissue foreign bodies. The purpose of this research utilization project was to report the use of bedside ultrasound by healthcare providers as an adjunct to X-ray for the localization and removal of foreign bodies in soft tissue wounds among patients presenting to an urgent care setting. A total of 45 patients' medical records were selected for this retrospective chart review. Patients' ages ranged from two to 88 years with a mean age of 39 years. The selected patients in the chart review underwent soft tissue foreign body removal with the use of X-ray alone (N=24), ultrasound and X-ray (N=8), and without the use of X-ray or ultrasound (N=13). Medical records of the three groups of patients were compared for the following variables: time from the onset of the foreign body removal procedure to patient discharge; the location of the foreign body and time of removal to discharge; and types of foreign body material and time for removal to discharge. X-ray alone detected 10 of 24 soft tissue foreign bodies with a removal time to patient discharge of 22 minutes. X-ray and ultrasound in parallel detected all 8 soft tissue foreign bodies with a removal time to patient discharge of 19 minutes. Without diagnostic imaging 13 soft tissue foreign bodies were detected with blind probing by the provider with a removal time to patient discharge of 16 minutes. Pertinent comparisons also yielded pain as the most common presenting symptom associated with an embedded soft tissue foreign body while the finger was the most commonly affected anatomical location. Wooden foreign body material required the greatest extraction time compared to metal and glass. In this research utilization project, the implementation of ultrasound as an adjunct to X-ray for the localization and removal of soft tissue foreign bodies had favorable outcomes when used to remove both radiolucent and radiopaque objects compared to X-ray alone in the urgent care setting.

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List of Abbreviations

CAT Scan.. Computed Axial Tomography

FB... Foreign Body

MRI...Magnetic Resonance Imaging

US ....Ultrasound

X-ray ....Plain Radiographs

Chapter 1

Introduction

Scope of the Problem

Traumatic wounds and lacerations account for approximately 7.1 million visits to United States emergency departments each year (Niska, Bhuiya, & Xu, 2010). A majority of these visits (2.8 million) are from young males with complaints of upper extremity lacerations and other wounds excluding the head and face (Niska, et al., 2010). When the objects responsible for creating these wounds are composed of material that shatters or splinters, such as glass or wood, the risk increases for fragments of foreign bodies to become embedded within the wound (Capellan & Hollander, 2003; Halaas, 2007; Winland-Brown & Allen, 2010). Complications from traumatic wounds occur when penetrating soft tissue foreign bodies are missed during the initial wound evaluation (Levine, Gorman, Young, & Courtney, 2008).

Early detection of foreign bodies in soft tissue wounds has proven difficult as nearly 38% are missed during initial examination by healthcare providers (Blankenship & Baker; 2007; Boyse, Fessell, Jacobson, Lin, van Holsbeeck, & Hayes, 2001; Dean, Groncsewski, & Constantino, 2003; Jacobson, Powell, Craig, Bouffard, & van Holsbeeck, 1998; Manthey, Storrow, Milbourn, & Wagner, 1996; Schlager, 1997; Tibbles & Porcaro, 2004). Puncture wounds by far are the most difficult to explore and as many as 95% of foreign bodies isolated in these types of wounds consist of glass, metal, plastic, or wooden objects (Aras, Miloglu, Barutcugil, Kantarci, Ozcan, & Harorli, 2010; Manson, Ryan, Ladner, & Gupta, 2011; McDevitt & Gillespie, 2008). Delayed removal of foreign bodies can result in osteomyelitis, cellulitis, necrotizing fasciitis, peripheral nerve damage, tendon damage, and granuloma development (Lyon, Brannam, Johnson, Blaivas, & Duggal, 2004; Salati & Rather, 2010). As a result, undetected foreign bodies in soft tissue wounds are the second highest cause of malpractice suits against healthcare providers (Blankenship & Baker, 2007; Boyse et al., 2001; Dean et al., 2003; Gibbs, 2006; Graham, 2002).

Factors contributing to the missed foreign bodies include small size and radiolucent material composition such as wood, plastic, and other organic material. Dried wood has only a 15% visibility on plain radiographs (X-ray) which decreases as time progresses from the initial injury (Boyse, et al., 2001; Flarity & Hoyt, 2010). Organic material such as splinters, thorns and other vegetative material embedded in soft tissue for greater than 48 hours becomes saturated with body fluids rendering them indistinguishable from surrounding tissue on X-ray (Gibbs, 2006; Peterson, Bancroft, & Kransdorf, 2002; Shepherd, Lee, & McGahon, 2007). Glass fragments less than 2mm prove difficult for visualization on X-ray with detection rates of 61%-83% (Orlinsky & Bright, 2006; Steele, Tran, Watson, & Muelleman, 1998; Tuncer, Ozcelik, Mersa, Kabakas, & Ozkan, 2011).

Analysis of Current Practices

Traditionally, healthcare providers have ordered plain radiographs (X-rays) as the standard of care for first line screening of a suspected soft tissue foreign body without regard to the material composition of the foreign body (Friedman, Forti, Wall, & Crain, 2005; Gibbs, 2006; Manthey et al., 1996; Teng & Doniger, 2012; Tibbles & Porcaro, 2004). Plain radiographs have proven to be an effective tool in detecting 80% of soft tissue foreign bodies, most of which are composed of radiopaque material, such as metal, stone, and glass (Jacobson et al., 1998; Tibbles & Porcaro, 2004). Incidentally, 85% of soft tissue foreign bodies composed of radiolucent material, such as wood, plastic, and thorns, are missed leading healthcare providers to search for other imaging modalities as an adjunct to plain radiography (Jacobson et al., 1998; Tibbles & Porcaro, 2004).

Several diagnostic methods for locating foreign bodies in soft tissue exist, including X-ray, ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI) (Lyon et al., 2004). Although radiopaque foreign bodies such as metal, gravel, and glass are easily detected by plain radiographs, radiolucent foreign bodies in wounds such as wood, plastic, and vegetative material are not (Blankenship & Baker, 2007; Manthey et al., 1996). Both radiopaque and radiolucent foreign bodies can be detected by CT and MRI but they are limited by cost, increased radiation exposure, and availability (Lyon et al., 2004). In addition, an MRI cannot be performed if there is suspicion for metallic foreign bodies (Lyon et al., 2004).

Discussion of Practice Innovation

Ultrasonography has been introduced as an adjunct to the conventional plain radiographs for detecting and removing both radiopaque and radiolucent foreign bodies in soft tissue wounds (Blankenship & Baker, 2007; Turner, Wilde, Hughes, Meilstrup, & Manders, 1997). Ultrasound technique uses a high-frequency transducer to penetrate soft tissue for the localization and evaluation of foreign bodies (Boyse et al., 2001; Mills & Butts, 2009). By scanning the tissue in both longitudinal and transverse orientations, bright hyperechoic foci can be visualized indicating the presence of with wooden, glass, and metal foreign bodies (Boyse et al., 2001).

In several studies, ultrasound was found to have a sensitivity of 90% and a specificity of 96% in the localization of foreign bodies in soft tissue without exposing the patient to ionizing radiation (Bray, Mahoney, & Campbell, 1995; Jacobson, Powell, Craig, Bouffard, & van Holsbeeck, 1998). Ultrasound not only gives the exact size and depth of the foreign body but also allows for examination of nearby tendons, vessels and muscles (Lyon et al., 2004). Other benefits include the ability of the healthcare provider to use ultrasound at the bedside to assist with removal of the foreign body from soft tissue wounds without painful probing and exploration (Friedman et al., 2005; Lyon et al., 2004).

Basic ultrasound principles can be employed by healthcare providers with relatively no ultrasound equipment experience (Hill, Conron, Greissinger, & Heller, 1997). According to a prospective study conducted by Orlinsky, Knittel, Feit, Chan and Mandavia (2000), emergency physicians attending a two day ultrasound course had an 82% accuracy rate in identifying foreign bodies in unfrozen chicken thighs compared to 83% accuracy of radiologists and 85% accuracy of experienced sonographers (Mills & Butts, 2009; Orlinsky et al., 2000).

Table 1.1

Definitions

Computed Axial Tomography (CAT) Scan	A computer generated analysis of the attenuation of X-ray beams passed through the body creating a cross sectional representation of anatomy (Fauci, Braunwald, Kasper, Hauser, Longo, Jameson, et. al., 2008).
Magnetic Resonance Imaging (MRI)	A type of diagnostic radiography that uses atomic nuclei in a magnetic field to create images of tissues and organs (Venes, 2001).
Non-Radiopaque Foreign Body/Radiolucent Foreign Body	A foreign body that is transparent to X-rays or allows penetration by X-ray and thus is not displayed on plain radiographs.
Radiopaque Foreign Body	A foreign body that is impenetrable to X-rays and thus is easily displayed on plain radiographs (Venes, 2001).
Soft Tissue Foreign Body	An object of metal, glass, wood or other material that penetrates, punctures or is embedded in the soft tissue/skin (Venes, 2001).
Ultrasound	A machine that uses an attached transducer (probe) to create sound waves that are transmitted through body tissues and reflected back to the transducer (probe) displaying images on the monitor screen (Witt & Gilmore, 2007; Yen & Gorelick, 2002).

Ultrasound and X-ray Equipment Costs

The expense of conducting bedside ultrasound is comparable to X-rays when equipment and facility requirements are taken into consideration. Ultrasound equipment ranges in price from $50,000 to $200, 000 depending upon the functional capabilities of the machine (Witt & Gilmore, 2007). Additional charges for ultrasound gel, image software, various size probes and sterile probe supplies are also incurred with the purchase of ultrasound equipment (Witt & Gilmore, 2007).

The initial cost of X-ray suite equipment starts at upwards of $100,000 or greater based on facility operational needs and equipment features. Additional expenses include consultation with a medical physicist regarding on site shielding requirements and engineering plans for the dedicated office space housing the X-ray machine as specified by South Carolina Department of Health and Environmental Control regulations. Other costs independent of the X-ray machine include lead aprons, picture archiving and communication system (PACS), a film reader and film cassettes.

Implications for Nurse Practitioner Practice

Since 1975 nurse practitioners have been providing emergency care in an efficient and cost effective manner (Campo, McNulty, Sabatini, & Fitzpatrick, 2008; Cole, & Ramirez, 2000). In 2008 the Emergency Nurses Association (ENA) developed entry level competencies of care for nurse practitioners in emergency or urgent care settings with ordering and interpreting radiographs, injection of local anesthetics, and removal of foreign bodies from soft tissue listed among these competencies (ENA, 2008). A majority of nurse practitioners employed in the emergency or urgent care settings are board certified family nurse practitioners who have completed an accredited family nurse practitioner program, attended continuing education workshops and received on the job training (Cole & Ramirez, 2003). Currently no specific regulations exist delineating what procedures are taught in family nurse practitioner programs (Cole & Ramirez, 2003). In a survey of 71 nurse practitioners in the emergency setting, Cole and Ramirez (2000) found that 69 out of 71 nurse practitioners reported performing foreign body removal from soft tissue wounds, and 59 that the majority of their education in performing this procedure was obtained through on the job training (Campo et al., 2008; Cole & Ramirez, 2000). In another study conducted by Cole and Ramirez (2003), 55.4% of family nurse practitioner program directors rated bedside ultrasound as unimportant to teach family nurse practitioner students while 71.1% rated foreign body removal from soft tissue as an important procedure to be taught (Cole & Ramirez, 2003).

Wound management ranks among the top ten procedures performed by nurse practitioners in an emergency care setting (Campo et al., 2008; Flarity & Hoyt, 2010). Among the most important aspects of wound management include the history and physical exam, wound exploration, identification of underlying structures and potential foreign bodies harbored in the wound bed (Flarity & Hoyt, 2010). With the use of ultrasound guided localization and removal of foreign bodies embedded in soft tissue, underlying anatomical structures are readily visible at the bedside for identification by the provider (Blankstein et al., 2000; Bradley, 2012; Callegari et al., 2009).

In many instances independent practice of nurse practitioners in the emergency setting can be intimidating especially with decreased comfort levels and inadequate educational preparation in procedures such as wound management and the use of bedside ultrasound (Campo et al., 2008). Proper educational preparation of nurse practitioners in the form of residency programs leads to confidence and professional development (Campo et al., 2008). Residency programs have the capability of providing novice nurse practitioners with the refined procedural skills, such as ultrasound and suturing, that they need for entry into independent practice.

The use of bedside ultrasound gives providers an additional assessment tool to expedite patient care especially in the setting of wound debridement with the potential of an embedded radiolucent foreign body (Callegari et al., 2009; McGuinness, Snaith, Wilson, & Wolstenhulme, 2011). Other implications for practice include decreased patient anxiety and pain along with increased provider confidence related to the foreign body removal process as bedside ultrasound allows for direct visualization, smaller incision sites, and the elimination of blind probing during wound exploration.

Statement of Purpose

The purpose of this research utilization project is to report the use of bedside ultrasound by healthcare providers as an adjunct to X-ray for the localization and removal of foreign bodies in soft tissue wounds among patients presenting to an urgent care setting.

Framework Model of Research Utilization

Initially published in 1976, the Stetler-Marram Model for Research Utilization centered its focus on “research-as-a-process” including the individual practitioner’s critical thinking skills, reflective ideology, and the resulting application of research findings into clinical practice (Melnyk & Fineout-Overholt, 2005; Stetler, 2001). The model has undergone two revisions (1994, 2001) since the first publication but the components of critical thinking and decision making skills among individual practitioners have remained a mainstay for promoting evidence based practice research utilization (Melnyk & Fineout-Overholt, 2005; Stetler, 2001). Since this model is practitioner oriented, it was chosen to guide the implementation for the change of clinical practice proposed by this research utilization project.

The refined Stetler Model addresses five phases: preparation, validation, comparative evaluation/decision making, translation/application, and evaluation for implementing changes in clinical practice settings (Melnyk & Fineout-Overholt, 2005). In preparation for research utilization, the purpose of phase one of Stetler's Model is to define a clinical practice need and desired outcomes in conjunction with systematically locating the best relevant evidence to support the needed change in practice (Melnyk & Fineout-Overholt, 2005). Phase two focuses on validating and critiquing the chosen evidence in order to determine if sufficient credible evidence exists to recommend a change in practice (Melnyk & Fineout-Overholt, 2005). For phase three, criteria specific to the change in practice is determined and according to these criteria the evidence is evaluated for its applicable use in clinical practice (Melnyk & Fineout-Overholt, 2005). Phase four translates the evidence based findings for use in persuading others regarding a need for change in practice (Melnyk & Fineout-Overholt, 2005). During phase four the current clinical practice is assessed for change and the formal implementation of the planned change occurs (Burns & Grove, 2005). In the final phase of Stetler's Model, the planned change is evaluated according to cost-benefit analysis and the achievement of goals set forth in phase one (Melnyk & Fineout-Overholt, 2005).

Project Question

Is ultrasound useful as a clinical tool in addition to wound exploration and X-ray to ensure complete removal of soft tissue foreign bodies?

Project Outcomes

1. Ultrasound may be used for complete removal of soft tissue foreign body as evidenced by real time pre and post removal imaging.

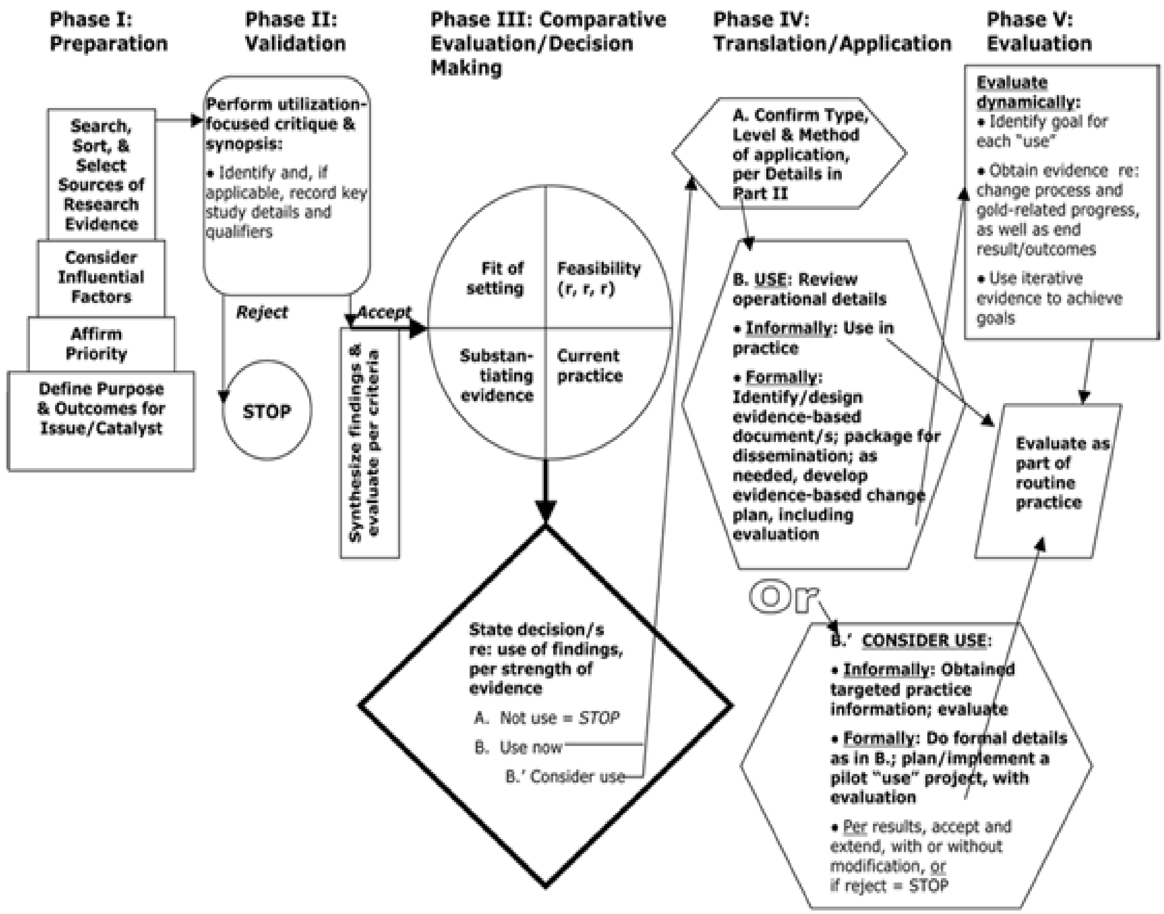

Figure 1.1 *Stetler Model*

Retrieved from: http://www.ktdrr.org/ktlibrary/articles_pubs/ktmodels/figures1-6.html#figure5ste

2. Ultrasound has the potential to become an alternative imaging approach to plain radiographs for locating radiolucent foreign bodies, such as wood, plastic, and other vegetative materials, in soft tissue.

Summary

Common complaints for patients presenting to urgent care include an embedded soft tissue foreign body after a work injury; stepping on glass, a splinter or toothpick; and various other encounters of soft tissue puncture wounds, penetrating wounds and traumatic lacerations. Even though plain radiographs detect a majority of these foreign bodies, some materials go undetected placing patients at high risk for complications. By using bedside ultrasound as an adjunct to plain radiographs for the identification and removal of foreign bodies, patients become more involved in their plan of care and experience less pain and anxiety during the removal process (Shiels, 2007). In the following chapter, an analysis of the literature and evidence supporting the practice innovation surrounding the use of bedside ultrasound as an adjunct to plain radiographs for the localization and removal of soft tissue foreign bodies will be presented.

Chapter 2

Literature Review

A comprehensive search of the literature was performed using the research question as a framework for search terms. The purpose of this search was to identify high quality evidence in the form of meta-analysis, randomized control trials, systematic reviews, quantitative or qualitative research studies, practice guidelines, reports from expert consensus and peer reviewed clinical articles to demonstrate the use of ultrasound as an additional assessment tool for localization and removal of soft tissue foreign bodies in wounds.

Databases searched include: CINAHL, Cochrane Library, PubMed/MEDLINE, Ovid, and Web of Science. Other online searches performed include the following: American College of Emergency Physicians (ACEP), American College of Radiology (ACR), American Institute of Ultrasound in Medicine (AIUM), Google Scholar, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), National Guidelines Clearing House (NGC), United States Preventative Task Force (USPTF), and Agency for Healthcare Research and Quality (AHRQ).

Literature Search Strategies

Initially for the literature search broad key terms were used followed by title searches and author searches. Using the broad search terms of foreign body removal, many articles retrieved did not specifically include foreign bodies in soft tissue. Various articles were retrieved pertaining to foreign bodies located in other anatomical spaces besides soft tissue.

Several search term combinations were used and included the following: ultrasound, foreign body, extraction, laceration, puncture, soft tissue, X-ray, radiolucent, and radiopaque. In addition, other synonym key words searched were ultrasound guided procedures, examination, removal, skin, plain radiographs, radiography, sonography, ultrasonography, and wounds.

Narrowing the literature search to the search terms of ‘ultrasound, foreign body, and soft tissue’ yielded more articles pertinent to the research question. Limiting the search terms to ‘penetrating, puncture, laceration, and soft tissue foreign bodies’ further narrowed the results. As supporting articles were retrieved, the reference citations were examined for additional evidence.

After review of bibliographic references from articles retrieved in the search process, several authors were noted to have performed extensive research on the use of ultrasound guidance for removal of foreign bodies from soft tissue. A subsequent search was performed using the authors’ last name yielding numerous other research studies.

Several common themes were identified throughout the literature review and include the following: indications for the use of ultrasound guided soft tissue foreign body removal; detection of soft tissue foreign bodies with ultrasound; the use of ultrasound versus plain radiographs (X-rays), computed tomography (CT), and magnetic resonance imaging (MRI) for the detection of radiolucent soft tissue foreign bodies; soft tissue foreign body imaging characteristics emitted by ultrasound frequency; precise localization of radiolucent soft tissue foreign bodies with the use of ultrasound; and the cost effectiveness and risk assessment associated with the use of ultrasound versus other diagnostic modalities to detect and remove soft tissue foreign bodies. A majority of the literature did not specifically address the procedure for bedside ultrasound guided removal of soft tissue foreign bodies.

Literature Inclusion and Exclusion Criteria

Inclusion criteria for the literature search addressed those items less than 20 years old and written in the English language. Since many of the in vitro research studies addressing ultrasound and the localization of radiolucent foreign bodies were performed in the 1990s, a 10 year limitation of the literature was not feasible. Articles referencing the use ultrasound guided removal of soft tissue foreign bodies were first available in the late 1990s.

The population of interest included adults and children, both males and females in all ethnic groups, ages 5 and above. Children were included since the results of ultrasound localization and removal of soft tissue foreign bodies in this population can be extrapolated to the adult population. Children in particular benefit from the ultrasound guided procedure because they can participate in the real time procedural guidance hence causing decreased anxiety (Cohen, 2008).

Articles over 20 years old were excluded. Furthermore, studies pertaining to animal bites or foreign bodies in the breast, ear canal, esophagus, eye, genitals, nose, peritoneum, trachea, and rectum were excluded. Many of these anatomical locations inhibit examination by ultrasound, create the potential for significant scarring, or demand emergent specialist referral.

Limitations of Literature Review

Limitations of the literature review include a paucity of evidence in the form of meta-analysis, systematic reviews and randomized controlled trials to support the ultrasound guided removal of foreign bodies in soft tissue; many studies were greater than 10 years old; 34 of the articles retrieved to support the research question were case studies and six were literature reviews from peer reviewed sources. In addition, a majority of the randomized controlled studies selected for review were in vitro and not specifically conducted using live, human skin tissue.

However, extending the literature search to include acute wound management strategies and ultrasound policy guidelines resulted in relevant evidence based resources. Several sources cited the association of wound location and retained foreign bodies in traumatic lacerations with increased risk of infection (Hollander, Singer, Valentine, & Shofer, 2001; Nicks, Ayello, Woo, Nitski-George, & Sibbald, 2010; Zehtabchi, Tan, Yadav, Badawy, & Lucchesi, 2012). Other articles addressed the significance of thorough wound exploration in the setting of small penetrating wounds and the benefit of bedside ultrasound as an additional assessment tool to detect potential tendon injuries obscured by foreign bodies (Tuncali et al., 2005; Wu, Roque, Green, Drachman, Khor, Rosenberg, & Simpson, 2012).

Synthesis of Literature

Articles chosen for analysis were ranked according to the Melnyk and Fineout-Overholt (2005) hierarchy of evidence (Figure 2.1). The rating system for the hierarchy of evidence includes levels of evidence I through VII with level I representing the highest quality of evidence in the form of systematic reviews or meta-analyses of randomized controlled trials and level VII indicating the lowest quality of evidence in the form of expert opinion (Melnyk & Fineout-Overholt, 2005).

Guidelines

The National Guideline Clearinghouse (NGC) guideline summary for the American College of Radiology (ACR) appropriateness criteria for acute trauma to the foot (2010) recommends X-ray for the initial diagnostic study of acute penetrating trauma to the foot and ultrasound for radiolucent foreign bodies. In addition if initial X-rays are negative, ultrasound is recommended as the next best study for penetrating trauma with a foreign body (NGC, 2010).

Indications for the use of Ultrasound Guidance

Mechanism of injury, wound characteristics, location and patient perception of retained foreign bodies have been an indication for meticulous wound exploration during the initial physical exam performed by the healthcare provider (Bray, Mahoney, & Campbell, 1995; Capellan & Hollander, 2003; Friedman, Forti, Wall, & Crain, 2005; Nicks, et al., 2010; Orlinsky & Bright, 2006; Ozsarac, Demircan, & Sener, 2011; Steele, Tran, Watson, & Muelleman, 1998; Zehtabchi et al., 2012). In their prospective patient series, Avner and Baker (1992) questioned the accuracy of visual wound exploration by providers for detecting all glass fragments embedded deep in a laceration. Furthermore, a cross sectional study conducted by Hollander et al. (2001) determined that the increased risk for infection in traumatic lacerations was associated with patient age, medical history of diabetes mellitus, laceration width, and foreign body contamination. However, the best form of imaging modality to assist providers in identifying underlying foreign bodies in soft tissue wounds remains to be debated.

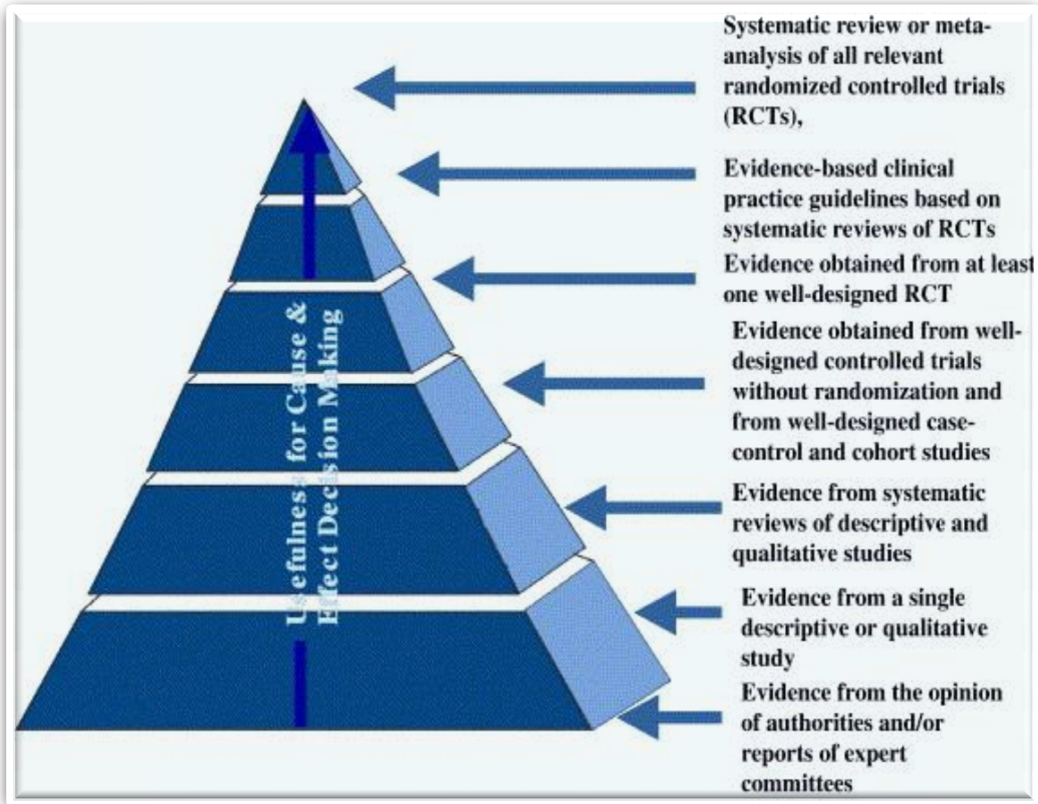

Figure 2.1 *Hierarchy of Evidence*

Adapted from: Fineout-Overholt, E., Melnyk, B, & Schultz, A. (2005). Transforming Healthcare from the Inside Out: Advancing Evidence-Based Practice in the 21st Century. *Journal of Professional Nursing*, *21*, 335-344.

Friedman et al. (2005) conducted a prospective cohort study in a pediatric emergency department to investigate bedside ultrasound or a combination of ultrasound and patient perception of a foreign body as a screening tool for the detection of foreign bodies in wounds. A total of 105 patients with 131 wounds were evaluated with foreign bodies removed from 12 wounds (Friedman et al., 2005). The wounds containing foreign bodies were isolated to the hands or feet with ultrasound detecting six out of nine radiopaque foreign bodies while plain radiographs detected eight (Friedman et al., 2005). Ultrasound detected two of three radiolucent foreign bodies while plain radiographs were unsuccessful at detecting any of the radiolucent material (Friedman et al., 2005). Subsequently, a repeat ultrasound was performed revealing the third radiolucent foreign body. Significant results were found with the specificity of bedside ultrasound alone compared to the specificity of ultrasound and plain radiographs in parallel or the use of plain radiographs alone for the detection of foreign bodies in wounds (Friedman et al., 2005). However, the highest sensitivity resulted with the use of bedside ultrasound and plain radiographs in parallel (Friedman et al., 2005). Beneficial evidence gathered from this study was the potential application of bedside ultrasound as an adjunct screening tool prior to plain radiographs for the detection of foreign bodies in wounds.

In a prospective study using six cadavers, Crystal, Masneri, Hellums, Kaylor, Young, Miller, and Levsky (2007) explored use of beside ultrasound in order to detect various small foreign bodies in traumatic lacerations that might have been missed during the initial wound exploration. In a total of 150 extremity wounds, researchers randomly inserted various foreign materials consisting of metal, plastic, glass, wood and in some cases no foreign body (Crystal et al., 2007). The emergency physician sonographers were blinded to location, type, and number of foreign bodies (Crystal et al., 2007). Sonographic detection of foreign bodies by the physicians yielded an overall sensitivity of 52.6% and specificity of 47.2% (Crystal et al., 2007). The authors concluded that ultrasound for the detection of foreign bodies is rarely used alone but instead is often used in conjunction with the provider's physical exam and plain radiographs (Crystal et al., 2007).

Historically, research has shown that small penetrating and puncture lacerations to the hand, wrist, and forearm can disguise deeper structural injuries or harbor fragments of foreign bodies (Tuncali, Yavuz, Terzioglu, & Aslan, 2005; Tuncer, Ozcelik, Mersa, Kabakas, & Ozkan, 2011). In a prospective study, Soubeyrand, Biau, Jomaah, Pradel, Dumontier, and Nourissat (2008) explored the efficacy of ultrasound for the detection of deep structural or neurovascular injury as a result of penetrating lacerations to the volar surface of the hand. The ultrasound examinations were performed prior to surgical exploration of the 30 wounds (Soubeyrand et al., 2008). Ultrasound located 17 tendon tears (Se 100%; Sp 100%; PPV 100%; NPV 100%), 14 arterial injuries (Se 87.5%; Sp 100%; PPV 100%; NPV 96.7%), and 12 nerve injuries (Se 75%; Sp 90.8%; PPV 66.7%; NPV 93.7%) (Soubeyrand et al., 2008). However, ultrasound missed two arterial injuries and four nerve injuries detected during surgical exploration (Soubeyrand et al., 2008). During surgical exploration ultrasound was employed for post procedure imaging and detected three foreign bodies prior to wound closure (Soubeyrand, et al., 2008).

Detection of Soft Tissue Foreign Bodies

Bray et al. (1995) randomly inserted various foreign bodies composed of wood, metal, and glass into 15 cadaver hands to determine the sensitivity and specificity of ultrasound detection of foreign bodies in the hand. X-rays performed prior to ultrasound examination revealed all metal foreign bodies, 50 out of 54 glass foreign bodies, and none of the wooden foreign bodies (Bray et al., 1995). Ultrasound detected 156 of 166 foreign bodies in the cadaver hands resulting in a diagnostic sensitivity of 94% and a specificity of 99% (Bray et al., 1995). In this study the researchers noted the diagnostic sensitivity for both X-ray and ultrasound detection of glass was 93% with ultrasound capable of detecting those glass foreign bodies not visualized on X-ray (Bray et al., 1995). This prospective study advocated for the use of ultrasound and X-ray in combination for detecting foreign bodies in the hand instead of blind probing during wound exploration (Bray et al., 1995).

A retrospective study of 23 patients in an outpatient orthopedic clinic was conducted by Shrestha, Sharma, Mohammad, and Dhoju (2009) to detect radiolucent soft tissue foreign bodies in extremities with the use of ultrasound. Nineteen patients were found to have the characteristic ultrasound hypoechoic appearance of a foreign body while all plain radiographs were negative for foreign body (Shrestha et al., 2009). The material of the foreign body identified consisted of wood (12), plant thorn (4), bamboo twig (2), and granuloma (1) (Shrestha et al., 2009). The authors concluded that plain radiography lacks sensitivity to detect radiolucent foreign bodies and ultrasound is superior with greater sensitivity and specificity for the identification of radiolucent foreign bodies in soft tissue of the extremities (Shrestha et al., 2009).

Levine, Gorman, Young and Courtney (2008) performed a retrospective case series of patients diagnosed with foreign body in a wound over a period of four years in two separate emergency departments. A majority of the patients were males with a total of 490 patients selected according to certain inclusion criteria (Levine et al., 2008). Most complaints were lacerations with foreign bodies or stepping on an object with wood, metal, glass and ceramic being among the top three materials responsible for the injury (Levine et al., 2008). Plain radiographs were determined to have a sensitivity of 75.5% for glass, 98.6% for metal, and 7.4% for wood (Levine et al., 2008). Approximately 90% of these foreign bodies were removed in the emergency department with limited specialist consultation (Levine et al., 2008). Post removal imaging by X-rays were completed (Levine et al., 2008). Recommendations from this study included the use of ultrasound to achieve greater sensitivity in the detection of wood foreign bodies (Levine et al., 2008). No comparison of ultrasound and plain radiography for the detection of wooden foreign bodies in wounds was addressed in this study.

A retrospective cohort study by Rubin, Chezar, Raz, and Rozen (2010) investigated the management of 96 adult patients that received a nail puncture wound to the plantar surface of the foot while wearing rubber soled shoes. All patients underwent X-ray and 22 patients had ultrasound examinations of their injured foot (Rubin et al., 2010). The X-rays detected a metal foreign body in one patient while ultrasound indicated 9 foreign bodies (Rubin et al., 2010). The authors recommend ultrasound examination of all patients presenting with nail puncture wounds through shoes (Rubin et al., 2010).

In another retrospective study conducted by Salati and Rather (2010), 61 cases of missed foreign bodies in the hand were treated from 2003 to 2009. Patients related various complaints from non-healing, draining wound, pain, foreign body sensation, hematoma and paresthesias (Salati & Rather, 2010). Among the 61 patients, 34 had no previous medical treatment, 18 had X-rays and wound care, and 9 had wound care without X-rays (Salati & Rather, 2010). Most significant was the fact that 37 patients (61%) had wooden splinters retained in their hands and X-ray only detected two (3%) wooden foreign bodies while ultrasound detected 35 (97%) (Salati & Rather, 2010). However, ultrasound did not detect any of the four stone fragments and only detected one of 13 metallic fragments and one of 7 glass pieces in the hands of patients (Salati & Rather, 2010).

Several in vitro studies have been conducted regarding the use of ultrasound for the identification of radiolucent and semi-radiopaque foreign bodies embedded in turkey, cow tongue, cadaver extremities, pork shoulder and chicken models in which the sensitivity for ultrasound detection ranged from 85-100% (Harcke & Levy, 2003; Harcke, Levy, & Lonergan, 2002; Hill, Conron, Greissinger, & Heller, 1997; Jacobson, Powell, Craig, Bouffard, van Holsbeeck, 1998; Manthey, Storrow, Milbourn, & Wagner, 1996; Mizel, Steinmetz, & Trepman, 1994; Oikarinen, Nieminen, Makarainen, & Pyhtinen, 1993; Turkcuer, Atilla, Topacoglu, Yanturali, Kiyan, Kabakci, et al., 2006; Turner, Wilde, Hughes, Meilstrup, & Manders, 1997). Turkcuer et al. (2006) conducted a randomized, blinded descriptive in vitro study in which rubber and wooden foreign bodies were inserted into chicken thighs for the comparison of plain and soft tissue radiographs with ultrasound for accurate detection of non-radiopaque foreign bodies. Their hypothesis stated that soft tissue and plain radiographs could be eliminated for the examination of non-radiopaque soft tissue foreign bodies and replaced with high-frequency ultrasound (Turkcuer et al., 2006). Forty foreign bodies of rubber shoe sole (20) and toothpick wood (20) were inserted into 40 chicken thighs with another 40 chicken thighs used as the control group with similar tissue damage (Turkcuer et al., 2006). Two veteran radiologists were blinded to the chicken thigh preparation and each other's interpretation of the diagnostic imaging studies (Turkcuer et al., 2006). Plain radiography detected no wooden foreign bodies in 20 model preparations and two false positive wood foreign bodies from the control group while two out of 20 rubber foreign bodies were detected in the model preparations with two false positive rubber foreign bodies detected from the control group (Turkcuer et al., 2006). The same results were obtained with soft tissue plain radiographs. Ultrasound detected 17 of 20 wooden foreign bodies (85%) in 20 chicken thighs with four false negative wooden foreign bodies from the control group while 19 out of 20 rubber foreign bodies were detected in the 20 chicken thighs with four false positive detected in the control group (Turkcuer et al., 2006). Ultrasound was found to have 90% sensitivity and 80% specificity for rubber and wood foreign bodies in the model preparations of chicken thighs. The authors suggest that plain radiographs should not be used to detect non-radiopaque foreign bodies and ultrasound should be considered as an option (Turkcuer et al., 2006).

Hill et al. (1997) and Jacobson et al. (1998) conducted randomized, controlled cadaver studies to explore the efficacy, sensitivity and specificity of ultrasound for detecting radiolucent foreign bodies in the legs and feet. Ultrasound results revealed a 93% sensitivity for wood and 73% sensitivity for plastic with an overall sensitivity of 83% and specificity of 59% in the Hill et al. (1997) study. Jacobson et al. (1998) found a sensitivity of 86.7% and a specificity of 96.7% for ultrasound detection of 2.5mm pieces of wood which increased to a sensitivity of 93.3% and a specificity of 96.7% for the detection of 5.0mm wooden foreign bodies.

Manthey et al. (1996) challenged the ability of ultrasound to detect soft tissue foreign bodies in the distal extremities. In their randomized, blinded descriptive study, the researchers randomly inserted various foreign bodies consisting of metal, wood, plastic, cactus, needles, glass and gravel into 60 chicken thighs in order to mimic puncture wounds in the hand (Manthey et al., 1996). Another 60 chicken thighs were used as a control group. All chicken thighs received X-rays and ultrasound imaging with radiologists blinded to type and number of foreign bodies along with their preliminary ultrasound read (Manthey et al., 1996). The X-rays were interpreted after completion of the ultrasound analysis and detected 98% of the radiopaque foreign bodies (Manthey et al., 1996). Results of this study yielded a sensitivity of 43% and specificity of 70% with a 50% false negative rate and 30% false positive rate for ultrasound detection of foreign bodies (Manthey et al., 1996).

Precise Localization of Soft Tissue Foreign Bodies

Gibbs (2006) conducted a retrospective study to determine the efficacy of ultrasound in locating soft tissue foreign bodies. A total of 20 patients were selected based on chart review from April 2001 to February 2005 (Gibbs, 2006). Plain radiographs (X-ray) were used for the initial imaging screening in 17 out of the 20 patients detecting eight foreign bodies composed of metal and inorganic material (Gibbs, 2006). X-ray did not detect wood or glass in nine patients. All 20 patients underwent ultrasound examination revealing eight organic, eight inorganic and four metallic foreign bodies (Gibbs, 2006). In addition, ultrasound was used to assist with the removal of foreign bodies in 11 patients allowing for precise localization and faster removal times compared to X-ray (Gibbs, 2006). In fact, Gibbs (2006) describes a 20 minute failed removal attempt by a physician probing for glass foreign bodies in the hand as demonstrated on X-ray. Other applications of ultrasound guided foreign body removal include post procedure imaging, smaller incision sites, and the elimination of blind probing resulting in fewer complications and faster recovery for the patient (Gibbs, 2006).

A retrospective review of 20 patients conducted by Rockett, Gentile, Gudas, Brage, and Zygmunt (1995) demonstrated the efficacy of ultrasound in the localization of wooden soft tissue foreign bodies in the foot prior to surgical removal. Plain radiographs (X-rays) performed prior to ultrasound failed to reveal any of the wooden foreign bodies in 20 patients (Rockett et al., 1995). At the time of ultrasound examination, the anatomical location of suspected point of foreign body entry was marked and then scanned in transverse and longitudinal planes (Rockett et al., 1995). Positive ultrasound findings of wooden foreign bodies in 10 patients were then marked by the ultrasonographer in anticipation of surgical excision (Rockett et al., 1995). Surgical pathology results correlated with the positive ultrasound findings of wooden foreign bodies (Rockett et al., 1995).

Several case studies demonstrate the effectiveness of bedside ultrasound for the localization of radiolucent wooden foreign bodies retained in soft tissue wounds (Borgohain, B., Borgohain, N., Handique, & Gogoi, 2012; Bu, Overgaard, Viegas, 2008; Dean, Gronczewski, & Constantino, 2003; Firth, Roy, & Moroz, 2011; Graham, 2002; Harris, 2010; Hung Y.T., Hung, L.K, Griffith, Wong, & Ho, 2004; Sidharthan & Mbako, 2010; Teng & Doniger, 2012). Wooden foreign bodies have the potential to cause infectious complications due to their ability to enhance bacterial growth within the wound

(Sidharthan & Mbako, 2010). Wood also has the ability to splinter creating draining sinus tracts and migrating into tendons and joint capsules (Borgohain, et al., 2012; Bu, et al., 2008; Graham, 2002; Harris, 2010; Sidharthan, & Mbako, 2010).

A majority of the patients detailed in the case reports had plain radiographs completed at the time of presentation to a healthcare provider which were all interpreted as negative for foreign body (Borgohain et al., 2012; Bu et al., 2008; Firth et al., 2011; Graham, 2002; Harris, 2010; Hung et al., 2004; Sidharthan & Mbako, 2010). In addition, five patients had wooden foreign bodies that were missed on initial examination by a healthcare provider and they were discharged home with oral antibiotics only to return with complaints of foul smelling wound, drainage, non-healing wounds, pain with weight bearing activities, and difficulty walking (Borgohain et al., 2012; Graham, 2002; Harris, 2010; Sidharthan & Mbako, 2010). Based on the patients' complaints along with a high clinical index of suspicion and wound characteristics, providers in these case studies employed the use of ultrasound which successfully localized wooden radiolucent foreign bodies for removal.

Imaging Characteristics

Davae, Sofka, DiCarlo, and Adler (2003) retrospectively reviewed sonographic examinations from 1998 to 2001 with possible soft tissue foreign bodies. A total of 25 patients underwent ultrasound for possible foreign body but only 12 were included in this study (Davae et al., 2003). Ultrasound was performed by experienced radiologists and detected all foreign bodies in patients that had subsequent surgical exploration (Davae et al., 2003). Material composition of the foreign bodies identified included glass (2), wood (3), cactus spur (1), metal (1), rose thorn (1), fish spine (1), and suture (1) and there were two false positive results (Davae et al., 2003). Ultrasound imaging revealed a hypoechoic halo in eight of the 10 patients and hyperemia with power doppler in all of the patients with proven foreign bodies as correlated with histopathology (Davae et al., 2003). Under power doppler the hyperemia was a consistent ultrasound finding for foreign body and can represent inflammation (Davae et al., 2003). The authors relate that their facility conducts ultrasounds routinely if plain radiographs are negative for foreign body but the provider remains with a high index of clinical suspicion for the existence of a soft tissue foreign body (Davae et al., 2003).

There are characteristic sonographic images for type and age of foreign body which can assist the provider in accurately identifying a soft tissue foreign body for removal (Gibbs, 2006). Several authors suggest using a high-frequency linear array transducer (7.5MHz or higher) and scanning in two planes creating longitudinal and transverse images for increased localization of the foreign body (Blankenship & Baker, 2007; Gibbs, 2006; Teng & Doniger, 2012). Orientation of the ultrasound probe parallel to the foreign body has proven to display the greatest signal for visualization of the foreign body (Bradley, 2012; Turner et al., 1997).

Superficial foreign bodies composed of organic materials can present with many different images on ultrasound based on the time progressed from initial injury (Gibbs, 2006). In the beginning of the acute phase of injury, the organic material, such as wood, displays as a bright hyperechoic structure with clean shadowing but over time as the material decomposes and absorbs body fluids, the foreign body is not as bright and a hypoechoic ring develops which can benefit from color doppler imaging for better visualization (Gibbs, 2006). Metal foreign bodies appear as reverberation or “comet tail” artifact while glass appears as more scattered “comet tail” artifact (Blankenship & Baker, 2007; Schlager, 1997; Teng & Doniger, 2012).

Imaging Modalities Cost Comparison and Risk Factors

Several imaging modalities exist for the identification and localization of soft tissue foreign bodies. Diagnostic imaging available for selection consists of computed tomography (CT), fluoroscopy, magnetic resonance imaging (MRI), plain radiography (X-ray), and ultrasound. Ultrasound and fluoroscopy are the only two bedside modalities that exist to visualize and guide the removal of soft tissue foreign bodies under real time conditions.

Any form of diagnostic imaging is subject to vary in cost due to insurance regulations, patient co-payments and claim reimbursements. However, CT and MRI account for the most expensive forms of diagnostic imaging. CT costs average $1500 to $2000 while MRI averages $2000 to $4000 (Sistrom & McKay, 2005; Williams, Rousseau, & Glaudemans, 2005). Extremity x-rays average around $65 to $75 to several hundreds of dollars depending on the number of image views associated with the procedure and the facility location (outpatient diagnostic centers versus not-for –profit and for-profit hospital systems) (Sistrom & McKay, 2005). In addition, ultrasounds average approximately $200 to $400 (Sistrom & McKay, 2005). Other charges related to fees for radiologist interpretations and supplies associated with the diagnostic imaging procedures also may be incurred.

Computed tomography (CT) is best utilized during the initial presentation of the injury when the foreign body is composed of radiolucent material or if the foreign body is surrounded by air or embedded in or behind bone (Aras et al., 2010; Pattamapaspong, Srisuwan, Sivasomboon, Nasuto, Suwannahoy, Settakorn, et al., 2012; Shepherd, Lee, & McGahon, 2007; Sidharthan & Mbako, 2010). Metallic foreign bodies create artifact making them difficult to detect with CT (Aras et al., 2010). In a case report Dumarey, De Maeseneer, & Ernst (2004) demonstrated CT to be ineffective at locating fragmented splinters of wood adjacent to larger wooden foreign body structures. In this case ultrasound was completed prior to the CT which identified the splinter fragments avoiding a second surgical procedure for the patient (Dumarey et al., 2004). Furthermore, another study by Al-Zahrani, Kremli, Saadeddin, Ikram, Takroni, & Zeidan (1995), demonstrated CT to be only 70% effective in diagnosing foreign bodies. Other potential risks associated with CT include the high amount of ionizing radiation especially for young patients; increased expense of imaging and insurance requirement of pre-authorization prior to conducting the study; and potential complications from contrast dye (Bernardy, Ullrich, Rawson, Allen, Jr., Thrall, Keysor, et al., 2009; Bierig & Jones, 2009; Soudack, Nachtigal, & Gaitini, 2003).

Magnetic Resonance Imaging (MRI) has limited use for foreign body identification. MRI is best used to identify retained wood in fat or to diagnose complications such as cellulitis or necrotizing fasciitis resulting from foreign bodies (Shepherd et al., 2007). MRI is contraindicated when the material composition of the foreign body is unknown or if the foreign body is metallic (Aras et al., 2010; Sidharthan & Mbako, 2010). In addition, certain patients are prohibited from undergoing an MRI and include those with implanted pacemakers, aneurysm clips and other medical devices or embedded metallic fragments of any kind (American College of Radiology, 2011). MRI is almost three times as expensive as ultrasound and also requires pre-authorization from most insurance companies prior to ordering the exam (Bernardy et al., 2009; Soudack et al., 2003). Furthermore, an MRI often uses intravenous gadolinium and requires cooperation from the patient lying still on the exam table for long periods of time which usually results in the need for procedural sedation of pediatric patients and some adult patients with intense claustrophobia (Firth et al., 2011; Graham, 2002; Harris, 2010; Read, Conolly, Lanzetta, Spielman, Snodgrass, & Korber, 1996; Sidharthan & Mbako, 2010).

Plain radiography (X-ray) is often the preferred initial radiographic imaging for suspected foreign body due to its availability and cost (Aras et al., 2010; Blankenship & Baker, 2007; Peterson, Bancroft, & Kransdorf, 2002; Shepherd et al., 2007; Teng & Doniger, 2012). X-ray commonly allows for visualization of radiopaque foreign bodies such as metal, gravel, and glass (Teng & Doniger, 2012; Turkcuer et al., 2006). However, X-ray has been reported to detect only 15% of radiolucent wooden foreign bodies (Ando, Hatori, Hagiwara, Isefuku, & Itoi, 2009; Graham, 2002; Lee, Chung, & Kam, 2008; Shepherd et al., 2007). X-ray has also been shown to have limitations in the detection of foreign bodies less than 5mm in size (Peterson et al., 2002; Teng & Doniger, 2012). Risks pertaining to using X-ray include the exposure to ionizing radiation which is unnecessary if the foreign body composition is known to be radiolucent (Friedman et al., 2005).

Similar to ultrasound, fluoroscopy can be used in real time to visualize and remove retained foreign bodies (Shepherd et al., 2007). Results from a prospective, randomized masked investigation by Wyn, Jones, McNinch, and Heacox (1995) indicate that fluoroscopy has the greatest sensitivity for identifying radiopaque materials deeply embedded in soft tissue but only limited detection of wood and plastic radiolucent foreign bodies. Considerable risks are encountered with the use of fluoroscopy. Not only can patients experience high doses of ionizing radiation based on the length of the procedure but providers and medical staff are also exposed (American College of Radiology, 2008; Shiels, 2007).

Bedside ultrasound has the unique ability to detect and locate foreign bodies in superficial soft tissue wounds and lacerations regardless of material composition, presence of infection, size of foreign material, or age of injury (Ozsarac, Demircan, & Sener, 2011). Other advantages of ultrasound include the lack of ionizing radiation; the ability to localize and remove soft tissue foreign bodies with real time guidance; allows visualization of nearby important anatomical structures during the removal procedure; capable of identifying size, shape and depth of the foreign body; decreased incision size and time for removal; safer for patients; and it is relatively inexpensive (Aras et al., 2010; Blankstein, Cohen, Heiman, Salai, Diamant, Heim, & Chechick, 2001; Dean et al., 2003; Konez et al., 1999; Orlinsky, Knittel, Feit, Chan, & Mandavia, 2000; Teng & Doniger, 2012). Ultrasound also can produce pre and post removal images to ensure complete foreign body removal while providing reassurance to the patient and provider in those circumstances where the foreign body has the potential to splinter or fragment during the removal process (Sidharthan & Mbako, 2010; Young, Shiels, Murakami, Coley, & Hogan, 2010). Furthermore, ultrasound is the only form of imaging modality that is safe for pregnant patients.

Ultrasound Guided Removal Procedure

Several studies were located in which researchers performed ultrasound guided removal of soft tissue foreign bodies (Bradley, 2012; Callegari, Leonardi, Bini, Sabato, Nicotera, Spano, et al., 2009; Lee, Chung, & Kam, 2008; Levsky, McArthur, & Abell, 2007; Manson, Ryan, Ladner, & Gupta, 2011; Paziana, Fields, Rotte, Au, & Ku, 2012; Young, Shiels, Murakami, Coley, & Hogan, 2010). These studies defined various techniques for ultrasound guided removal of superficial and deep soft tissue foreign bodies. Two studies cited the use of ultrasound in combination with fluoroscopy for ultrasound guided removal of soft tissue foreign bodies (Bradley, 2012; Young et al., 2010).

In a single-blinded, randomized, crossover study, Manson et al. (2011) randomly assigned 14 emergency medicine residents to use either ultrasound or plain radiographs in order to remove metal pins from pig's feet. Ultrasound guided removal was dynamic in nature with the resident physician directly viewing the foreign body with ultrasound while inserting hemostats into the soft tissue for retrieval of the metallic pin (Manson et al., 2011). Three veteran emergency physicians, who were blinded to imaging methods and resident identity, were asked to evaluate the cosmetic outcome post foreign body removal (Manson et al., 2011). Findings revealed all 28 foreign bodies successfully located and removed from the pig's feet with no significant difference between imaging modalities, removal time or cosmetic outcomes (Manson et al., 2011).

In a prospective study, Bradley (2012) described his evaluation of 350 patients for suspected foreign bodies located in penetrating wounds using ultrasound. The author, who is a radiologist trained in ultrasound guided removal procedures, interpreted 63 ultrasounds as negative, thus 287 ultrasounds were positive for various foreign bodies (Bradley, 2012). A total of 27 patients were referred to surgeons due to location of foreign body or unsuccessful extractions and eight additional foreign bodies were left in wounds since no symptoms were exhibited (Bradley, 2012). The author removed a total of 252 (88%) foreign bodies of which 45 superficial foreign bodies were localized by ultrasound and the skin marked for incision site guidance (Bradley, 2012). Dynamic or continual ultrasound guidance was used to successfully remove 207 foreign bodies that were deeply embedded within the wounds with fluoroscopy used in 19 cases after ultrasound (Bradley, 2012). After conducting his study, the author realized that by localizing and mapping superficial foreign bodies with ultrasound instead of continuous guidance saved procedural time (Bradley, 2012).

Another descriptive study by Callegari et al. (2009) presented the technique of ultrasound guided removal of soft tissue foreign bodies and its superiority to standard surgical intervention. A total of 62 patients with 95 foreign bodies received both X-ray and ultrasound evaluation (Callegari et al., 2009). X-ray successfully detected 76 of the foreign bodies composed of metal, glass, and stone while ultrasound detected foreign bodies in 94 cases regardless of foreign body material composition (Callegari et al., 2009). In one case the foreign body was indistinguishable from surrounding tissues on ultrasound requiring radioscopy (Callegari et al., 2009). Under continuous sterile ultrasound guidance, performed by a radiologist, 94 foreign bodies including glass, metal, vegetable, plastic, and stone were removed under real time guidance using surgical forceps from 62 patients within a total procedure time of 15-30 minutes (Callegari et al., 2009). The authors relate ultrasound guided removal of foreign bodies can be safely employed in practice by reducing incision sizes, allowing for adequate visualization of surrounding anatomical structures, minimizing bleeding and complications (Callegari et al., 2009). However, certain foreign body characteristics and locations may still require surgical consultation.

In a retrospective study of 11 adolescent patients with 76 self-embedded foreign bodies, Young et al. (2010) reported the use of ultrasound or a combination of ultrasound and fluoroscopy in order to identify and guide the removal of 68 foreign bodies in the interventional radiology suite. In 43 cases ultrasound was used exclusively for the dynamic guidance of soft tissue foreign body removal (Young et al., 2010). The authors reported the use of ultrasound guided removal of foreign bodies enhances the patient's self-esteem due to minimal incision size resulting in reduced scarring (Young et al., 2010). The time associated with ultrasound guided foreign body removal was not addressed in this study. However, the authors did mention intravenous sedation was required in seven cases but no details were provided regarding the removal procedure or patient monitoring time (Young et al., 2010).

Three case studies demonstrated the detection, localization and ultrasound guided removal of soft tissue foreign bodies (Lee et al., 2008; Levsky et al., 2007; Paziana et al., 2012). Paziana et al. (2012) presented two case studies of ultrasound guided removal of thorns and wooden splinters using a portable ultrasound. Both patients had previously undergone plain film X-ray exams with negative results (Paziana et al., 2012). Prior to foreign body removal, emphasis was placed on the importance of foreign body identification in relation to nearby important anatomical structures by scanning in both longitudinal and transverse planes (Paziana et al., 2012). The authors also detailed their ultrasound guided removal technique of the wooden foreign bodies under direct real-time, visualization using careful blunt dissection (Paziana et al., 2012).

The remaining two case studies demonstrate ultrasound guided foreign body removal with the use of a finder needle in order to mark the orientation and path of the retained foreign body (Lee et al., 2008; Levsky et al., 2007). In the Levsky et al. (2007) case study, the patient experienced a puncture wound to the plantar surface of her toe after stepping on a sewing needle, leaving a broken piece of the needle embedded in her toe. The first attempt by the authors using ultrasound guidance and a finder needle to locate the foreign body at the entry point of the puncture wound was unsuccessful (Levsky et al., 2007). During the second attempt the authors moved the finder needle approximately 5mm from the initial injury site and only then were they able to locate the orientation of the foreign body (Levsky et al., 2007). Interestingly, this case study demonstrated that foreign bodies have the potential to migrate from the initial site of injury and if the authors had blind probed the original puncture site without the use of ultrasound and a finder needle, serious complications could have occurred (Levsky et al., 2007).

Ultrasound Limitations

The literature cited several limitations regarding the use of ultrasound for the detection, localization and removal of soft tissue foreign bodies. One common limitation cited throughout the literature is the operator skill required to accurately diagnose soft tissue foreign bodies by meticulously scanning the area parallel to the foreign body and in both longitudinal and transverse orientations (Blankenship & Baker, 2007; Bonatz, Robbin, & Weingold, 1998; Boyse et al., 2001; Bray et al., 1995; Callegari et al., 2009;

Gibbs, 2006; Graham, 2002; Hill et al., 1997; Lee et al., 2008; Levine & Leslie, 1993; Levsky et al., 2007; Paziana et al., 2012; Read et al., 1996; Teng & Doniger, 2012). Many studies exploring the use of ultrasound for the detection and localization of soft tissue foreign bodies used animal and cadaver models which do not provide actual skin or live anatomical features; lack tissue interfaces; and show no inflammation or edema (Bray et al., 1995; Crystal et al., 2009; Dean et al., 2003; Mizel et al., 1994; Teng & Doniger, 2012). False positives captured on ultrasound are often attributed to air surrounding the injury, scar tissue from previous removal attempts, calcifications, sesmoid bones in the hand, fresh hematomas, and pus (Aras et al., 2010; Blankenship & Baker, 2007; Bonatz et al., 1998; Boyse et al., 2001; Bray et al., 1995; Davae et al., 2003; Dean et al., 2003; Gibbs, 2006; Graham, 2002; Hung et al., 2004; Jacobson et al., 1998; Manthey et al., 1996; Orlinsky et al., 2000; Saboo et al., 2009; Teng & Doniger, 2012) False negatives result from a small foreign body located near bone or tendon or beneath subcutaneous gas (Boyse et al., 2001; Bray et al., 1995; Davae et al., 2003; Gibbs, 2006; Hung et al., 2004; Manthey et al., 1996; Rockett, Gentile, Gudas, Brage, & Zygmunt, 1995; Saboo et al., 2009).

Ultrasound is most effective at identifying nonradiopaque superficial foreign bodies and its accuracy decreases below two centimeters deep when using high-frequency probes (Aras et al., 2010; Blankenship & Baker, 2007; Boyse et al., 2001; Callegari et al., 2009; Dean et al., 2003; Gibbs, 2006; Lee et al., 2008; Teng & Doniger, 2012; Turkcuer et al., 2006). In addition the size of the ultrasound transducer can make imaging of certain anatomical locations, such as the web space of the hand, toes and fingers difficult (Blankenship & Baker, 2007; Bray et al., 1995; Graham, 2002; Teng & Doniger, 2012).

Soft tissue air has been identified throughout the literature as distorting artifact in images resulting in false positive interpretations by ultrasonographers. In a prospective randomized study, Lyon, Brannam, Johnson, Blaivas, and Duggal (2004) implanted metal, glass and bone fragments into turkey models in order to investigate the effect of soft tissue gas on the localization of foreign bodies under real time ultrasound examination. The foreign body fragments were randomly inserted into turkey breasts along with random insertion of 10 milliliters of air in half of the foreign bodies (Lyon et al., 2004). Three physicians, who were blinded to the location, material composition and injection of air, scanned the turkey breasts without interacting with each other (Lyon et al., 2004). The physicians each located all 48 foreign bodies without any affects from the injected soft tissue air resulting in a sensitivity of 100% (Lyon et al., 2004). The researchers did acknowledge that the soft tissue gas distorted the characteristic echo patterns emitted on ultrasound from the foreign bodies, however the sonographers in this study were able to adjust the gain and probe angle for better visualization (Lyon et al., 2004).

An in vitro comparative study conducted by Aras, Miloglu, Barutcugil, Kantarci, Ozcan and Harorli (2010) investigated the sensitivity among plain radiography (X-ray), computed tomography (CT) and ultrasound in the detection of foreign bodies in a sheep's head. Several foreign body materials composed of metal, glass, wood, stone, acrylic, graphite, and plastic were inserted in the sheep's head (Aras et al., 2010). Six independent observers blinded to the material composition of the foreign bodies rated visibility of the foreign body related to each imaging modality on a four-point scale (Aras et al., 2010). The authors concluded that ultrasound identifies foreign bodies that are non-radiopaque and located in superficial tissue better than CT or plain radiography (Aras et al., 2006). However, ultrasound is a poor imaging modality for visualizing foreign bodies in air, such as the sinus cavity (Aras et al., 2006).

Several authors addressed the concerns surrounding inadequate training surrounding ultrasound detection and localization of soft tissue foreign bodies. In a prospective non-randomized study by McGuinness, Snaith, Wilson, and Wolstenhulme (2011), 86% of participants indicated, by electronic questionnaire, that they received adequate training in a two day basic ultrasound course and have developed further ultrasound skills through continuing education. Nienaber, Harvey, and Cave (2010) determined the accuracy of six emergency physicians and 14 emergency medicine trainees in identifying soft tissue foreign bodies with the use of bedside ultrasound. The experienced physicians and novice trainees had varying degrees of ultrasound training ranging from a one to five day course with some having extensive clinical experience with the use of ultrasound (Nienaber et al., 2010). Prior to initiating this study a 20 minute ultrasound tutorial lesson was given regarding ultrasound equipment use for detecting soft tissue foreign bodies (Nienaber et al., 2010). Results determined a comparable accuracy among those experienced physicians and the newer trainees for detecting soft tissue foreign bodies using ultrasound with emergency physicians having an overall sensitivity of 96.7% and specificity of 70% while the newer trainees achieved an overall sensitivity of 85.7% and specificity of 82.9% (Nienaber et al., 2010).

In a prospective study, Orlinsky et al. (2000) evaluated the performance of three emergency medicine residents, inexperienced in ultrasound, compared to an ultrasound proficient radiologist and two certified ultrasound technicians in detecting radiolucent foreign bodies randomly inserted into chicken thighs. A two day ultrasound course was provided for the three emergency medicine physicians prior to the study (Orlinsky et al., 2000). Furthermore, all study participants received a one hour training course on soft tissue foreign body detection (Orlinsky et al., 2000). The results for the emergency physicians revealed an accuracy rate of 80%, sensitivity of 74% and specificity of 87% for the ultrasound detection of radiolucent foreign bodies (Orlinsky et al., 2000). In comparison, the radiologist had an accuracy rate of 83%, sensitivity 83% and specificity 83% while the ultrasound technologists had an accuracy rate of 85%, sensitivity 85%, and specificity 85% (Orlinsky et al., 2000).

Literature Recommendations

Evidence based practice recommendations were graded based on the Strength of Recommendation Taxonomy (SORT) developed by the Family Practice Inquiries Network and several United States family practice and primary care journal editors (Ebell, Siwek, Weiss, Woolf, Susman, Ewigman, et al., 2004). In consensus with the AHRQ key elements for grading evidence, the SORT criteria focuses on quality, quantity and consistency presented in the literature to guide evidence based practice recommendations (Ebell et al., 2004). The SORT grades of recommendation range from A to C.

Table 2.1

SORT Grades of Recommendations

GRADE A	Recommendation based on high quality evidence. Types of Studies: • Systematic review or meta-analysis of randomized controlled trials • Randomized Controlled Trials • High Quality Diagnostic Cohort Studies
GRADE B	Recommendations based on inconsistent or limited-quality evidence Types of Studies: • Systematic Reviews or Meta-Analysis of lower-quality studies • Lower quality clinical trials • Retrospective Cohort Study • Case control Study • Cohort Study of treatment
GRADE C	Recommendations based on expert opinion, case studies, usual practice. Types of Studies: • Expert opinion • Case Series • Consensus Guidelines

Adapted From: A Synopsis of SORT Retrieved From:
http://www.stfm.org/fmhub/fm2004/February/Barry141.pdf

The following recommendations were consistent throughout the literature review:

1) In traumatic wounds where there remains a high clinical index of suspicion for foreign bodies after wound exploration and negative X-rays, ultrasound should be employed as the next diagnostic imaging modality for detecting soft tissue foreign bodies especially for those composed of radiolucent material (Bray et al., 1995; Davae et al., 2003; Friedman et al., 2005; Graham, 2002; Jacobson et al., 1998;

Levine et al., 2008; Mohammadi, Ghasemi-Rad, & Khodabakhsh, 2011; Read et al., 1996). GRADE A

2) A negative physical examination with visual wound exploration alone and radiology studies alone are inadequate to rule out the presence of a soft tissue foreign body thus a combination of both assessment skills and diagnostic imaging should be utilized (Callegari et al., 2009; Levine et al., 2008; Ozsarac, Demircan, & Sener, 2011; Steele et al., 1998; Tuncer et al., 2011; Wedmore, 2005). GRADE B
3) Ultrasound guided soft tissue foreign body removal is a safe procedure which allows the provider to adequately visualize size, depth, and surrounding anatomical structures in relation to the foreign body (Blankstein et al., 2000; Blankstein et al., 2001; Boyse et al., 2001; Bradley, 2012; Callegari et al., 2009; Jacobson et al., 1998; Lyon et al., 2003; Paziana et al., 2012; Rockett et al., 1995; Soubeyrand et al., 2008; Teng & Doniger, 2012; Young et al., 2010). GRADE B
4) Compared to plain radiographs, ultrasound is capable of real time three dimensional localization of soft tissue foreign bodies allowing for precise guided removal with smaller incision sites, decreased removal attempts, and post procedure imaging (Bonatz et al., 1998; Callegari et al., 2009; Dean et al., 2003; Lyon et al., 2003, Ng, Songra, & Bradley, 2003; Ozsarac et al., 2011; Paziana et al., 2012; Shrestha, et al., 2009; Sidharthan & Mbako, 2010; Teng & Doniger, 2012; Turner et al., 1997) GRADE B
5) Wound exploration by providers with blind probing is not recommended for lacerations or penetrating wounds of the hand due to the potential for damaging

underlying tendons, nerves and vascular structures (Bray et al., 1995; Tuncer et al., 2011). GRADE B

6) Evidence exists for the use of ultrasound in patients with complaints of a skin puncture or penetrating wounds to the foot when X-rays are negative (American College of Radiology, 2010; Crankson, Oratis, & Al Maziad, 2004; National Guideline Clearing House, 2010; Peterson et al., 2002; Rubin, 2010). GRADE A
7) Ultrasound should be the imaging modality chosen when wounds are contaminated with a known radiolucent foreign body (American College of Emergency Physicians, 1999; Blankstein et al., 2001; Davae et al., 2003; Gibbs, 2006; Levine et al., 2008; Peterson et al., 2002; Turkcuer et al., 2006; Turner et al., 1997). GRADE C
8) The routine use of plain radiographs to detect radiolucent foreign bodies is unnecessary when ultrasound is available as an imaging modality (Friedman et al., 2005; Manson et al., 2011; Turkcuer et al., 2006) GRADE A
9) In order to reduce patient exposure to ionizing radiation, ultrasound or MRI should be the imaging modality of choice when these diagnostic tests will yield similar quality results to other imaging methods (CT or X-ray). (American College of Radiology, 2010; Joint Commission on Accreditation of Healthcare Organizations, 2011). GRADE A

Future Research

Future research recommendations include an investigation of the efficacy of ultrasound guided removal of soft tissue foreign bodies compared to plain radiographs in conjunction with an exploration of the advantages ultrasound demonstrates for the detection of radiolucent foreign bodies versus plain radiographs (Manson et al., 2011). Additional research studies are needed to examine the improvement in cosmetic outcome when using ultrasound guidance for foreign body removal from soft tissue taking into account both procedural time and number of attempts of foreign body removal (Manson et al., 2011).

Several authors indicated the need for future research based on their findings or limitations of their studies. Friedman et al. (2005) stated the need for future studies to explore the correlation between patient perception and retained foreign bodies in wounds. Topics for future research suggested by Schlager et al. (1994) were based on the procedural benefits of using ultrasound in the emergency department such as reduced monetary and time spent by patients and decreased liability for providers.

Currently, no specific definition exists that delineates the parameters of clinical wound exploration (Orlinsky & Bright, 2006). All providers have varying methods to which they approach wound exploration, irrigation and closure (Pfaff & Moore, 2007; Wedmore, 2005). In particular, for the management of plantar puncture wounds, existing literature is controversial and lacks evidence based recommendations (Capellan & Hollander, 2003; McDevitt & Gillespie, 2008). Additional research is needed regarding best imaging modality for suspected soft tissue foreign bodies; blind probing exploration for foreign bodies; wound irrigation and treatment as these wounds tend to lead to osteomyelitis and even amputation in certain patients (American College of Emergency Physicians, 1999; Cappellan & Hollander, 2003).

Summary

The use of bedside ultrasound challenges the reliability of plain radiographs (X-ray) for the localization and removal of radiolucent foreign bodies in soft tissue such as rubber, wood, plastic and other vegetative material. Jacobson et al. (1998) determined ultrasound to have a sensitivity of 90% and specificity or 96.7% for locating wooden soft tissue foreign bodies as small as 2.5mm while Rockett et al. (1995) proved ultrasound could detect foreign bodies as small as 1mm. The literature review indicates ultrasound has the potential for use as an additional assessment tool to aid the provider in detection, localization and removal of soft tissue foreign bodies during the exploration of wounds.

Chapter 3

Methods

Research utilization serves to disseminate evidence based practice changes that improve patient outcomes and provide quality, cost-effective healthcare services. As evidenced by evaluating the literature (Chapter II), ultrasound has the potential to serve as an adjunct to plain radiograph (X-ray) for the localization and removal of soft tissue foreign bodies and is relatively inexpensive compared to CT scans or MRI. The American College of Emergency Physicians (ACEP) ultrasound guidelines recommend the use of procedural ultrasound due to its safety, efficacy, and ability to improve the quality of patient care (ACEP, 2008). Furthermore, the use of ultrasound for the localization and removal of foreign body decreases risk of complications associated with blind removal procedures allowing for diagnostic accuracy (ACEP, 2008).

Research has shown that ultrasound is beneficial for the localization and removal of radiolucent soft tissue foreign bodies which are not detected on X-ray (ACEP, 1999; Blankstein et al., 2001; Davae et al., 2003; Friedman et al., 2005; Gibbs, 2006; Levine et al., 2008; Manson et al., 2011; Peterson et al., 2002; Turkcuer et al., 2006; Turner et al., 1997). Current practice at the urgent care facility setting of this project is to obtain X-rays prior to the removal procedure of soft tissue foreign bodies regardless of material composition. In order to implement evidence based practice recommendations from the literature review and provide the best patient outcomes, a research utilization project was developed with the assistance of Stetler's Model to report the use of bedside ultrasound by healthcare providers as an adjunct to X-ray for the localization and removal of foreign bodies in soft tissue wounds among patients presenting to an urgent care setting.

Framework: Stetler Model

In order to fulfill the first phase of Stetler's Model, preparation, a diagnostic evaluation of the practice setting occurred prior to initiation of the practice innovation (Burns & Grove, 2005; Melnyk & Fineout-Overholt, 2005). Current practice for the localization and removal of soft tissue foreign bodies at the urgent care was examined in order to identify needs for practice change. After discovering numerous evidence based resources pertaining to the use of ultrasound for localization and removal of soft tissue foreign bodies, Stetler's phase two was used to validate and summarize the evidence in an organized evidence table (Melynk & Fineout-Overholt, 2005). In phase three of Stetler's model, the individual practitioner comparatively analyzed the information and based on evidence rating recommended a change in practice to other colleagues (Melynk & Fineout-Overholt, 2005). In this proposal, a change in practice from using plain radiographs (X-rays) only for first line treatment of soft tissue foreign bodies was countered by the use of ultrasound as an adjunct therapy for improved patient outcomes.

Research Design

A retrospective chart review of patients presenting to a rural urgent care establishment in South Carolina during January 2011 to July 2013 with a diagnosis of embedded soft tissue foreign bodies was conducted. Chart selections were based on electronic medical records searches using primary International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes reflecting soft tissue foreign body and Current Procedural Terminology (CPT) codes for foreign body removal procedures.

Since soft tissue foreign bodies can present in open wounds depending upon the mechanism of injury, the ICD-9 codes associated with open wounds to the extremities were also included in the chart review. IRB approval from the University of South Carolina was obtained with a consent waiver issued.

Table 3.1

ICD-9 Diagnosis Codes/ CPT Codes

ICD 9 Diagnosis Codes		CPT Codes Foreign Body Removal
729.6	Residual foreign body in soft tissue	10121 Incision and removal of foreign body, subcutaneous tissues complex
881.00	Open wound of forearm	
882.0	Open wound of hand	
882.1	Open wound of hand complicated	
883.0	Open wound of fingers	20520 Incision and removal of foreign body, muscle simple
883.1	Open wound of fingers complicated	
884.0	Open wound arm mult/nos	
884.1	Open wound arm nos-complicated	20525 Incision and removal of foreign body, muscle complex
891.0	Open wound knee, leg, ankle	
891.1	Open wound knee, leg, ankle complicated	
892.0	Open wound of foot	
893.0	Open wound of toe	
894.0	Open wound of leg NEC	
912.6	Superficial foreign body of upper arm/shoulder	
913.7	Superficial foreign body of elbow, forearm, wrist	
914.6	Superficial foreign body of hand	
914.7	Superficial foreign body of hand infected	
915.6	Superficial foreign body of fingers	
917.7	Superficial foreign body of foot and toes	

Research Setting and Population

The project was conducted at a rural urgent care establishment in South Carolina which provides treatment to approximately 12,000-13,000 patients per year. Soft tissue foreign body removals account for approximately 20 to 30 patient visits per year. The urgent care is staffed by a physician, nurse practitioner, registered nurses, certified radiology technologists, and ancillary personnel. Diagnostic services available at this facility include: laboratory, CT scan, ultrasound, and X-ray. All procedural ultrasound guided soft tissue foreign body removals were conducted by a nurse practitioner with the assistance of an ultrasound technologist. Both pre and post foreign body removal ultrasound images were interpreted by a physician. All X-rays were evaluated by the urgent care provider with final interpretation performed by a board certified radiologist subcontracted through a local radiology group.

Patients were included in the retrospective chart review if they met the diagnostic criteria of embedded soft tissue foreign body associated with in office removal procedures from January 2011 to July 2013. Charts of adults and children presenting to the urgent care were reviewed for ICD-9 codes of open wounds, residual foreign bodies or superficial foreign bodies (See Table 3.1). These charts were cross-referenced to the CPT codes of foreign body removal procedures performed in the urgent care (See Table 3.1).

Patients excluded from this retrospective chart review were those presenting to the urgent care with foreign bodies located in the face, ear canal, nose, trachea, esophagus, breast, genitals, peritoneum, or rectum. Rationale for excluding these anatomical locations included the inability to use ultrasound for detection of foreign bodies in certain body parts, high risk of scarring, or the need for emergent specialist referral. In addition, patients with foreign bodies deeply embedded adjacent to tendons or other neurovascular structures and within bone required specialist consultation and thus were not included in the chart review. Patients with prescribed anticoagulant therapy were also excluded due to their potential for high risk of bleeding and post-surgical complications.

Data Collection

A total of 45 charts met the above-mentioned inclusion and exclusion criteria. Documentation of the specific aspects of the foreign body removal procedure was collected from the medical records which included (a) the foreign body location, (b) initial symptom presentation, (c) type of foreign material, (d) time from procedure onset to discharge, and (e) whether the foreign body was initially visualized on plain radiograph (X-ray), ultrasound or both. Demographic variables assessed were age, race, and gender. All patients were de-identified for the purposes of data collection.

The selected patients' charts were divided into the following groups: (a) Patients that received both ultrasound and X-ray for soft tissue foreign body localization and removal (n=8), (b) Patients that received X-ray only for soft tissue foreign body localization and removal (n=24), and (c) Patients that received neither X-ray nor ultrasound for soft tissue foreign body localization and removal (n=13).

Description of Treatment Utilization Patterns

Pa**tients who Received both Ultrasound and X-ray.** A selection of patients received X-rays of the extremity containing a suspected embedded foreign body prior to localization of the soft tissue foreign body using bedside ultrasound. X-rays were reviewed by the nurse practitioner using E-Film software on a PACS system with dictated interpretation provided by a radiologist. The presence of a foreign body on ultrasound was compared to the X-ray findings prior to patients undergoing the removal procedure.

Patients who only Received X-ray. Several patients did not undergo ultrasound to localize and remove soft tissue foreign bodies. These patients presented with soft tissue metallic foreign bodies and received X-ray only to determine depth and anatomical landmarks prior to the removal procedure. Since a majority of the metallic foreign bodies were protruding from the skin surface or were readily identifiable on routine X-ray, ultrasound assisted removal was not indicated.

Patients who Received Neither Ultrasound nor X-ray. Certain patients received neither ultrasound nor X-ray for the identification and location of their embedded soft tissue foreign body. Under these circumstances a select few patients refused imaging prior to having their soft tissue foreign body removed. Others had readily identifiable foreign bodies protruding from the skin surface or easily visualized by the healthcare provider just below the epidermis. Children comprised most of the patient records not receiving any form of imaging due to radiation exposure risks and their uncooperative nature during the foreign body removal process.

Ultrasound Soft Tissue Foreign Body Removal Process

In order to identify the proper treatment methods, the medical records were reviewed for information related to the foreign body removal procedure. The ultrasound guided foreign body removal procedure was documented in all charts along with an interpretation of any diagnostic imaging used for the localization and removal of soft tissue foreign bodies.

Documented Procedure Description. After localization of the foreign body using bedside ultrasound and cleansing the region with antiseptic solution, patients presenting with embedded soft tissue foreign bodies were injected with local anesthesia into the adjacent tissue and an incision was made with an 11-blade scalpel along the ultrasound guided path of the foreign body. Using blunt dissection, the foreign body was carefully removed and subsequent irrigation of the wound bed was performed. Based on incision size and location, sutures were used to re-approximate the epidermis with allowance for wound drainage. Other wounds were left to heal by secondary intention after the removal of the foreign body. Prophylactic antibiotics and tetanus (if not up to date) were administered.

Data Analysis

Data analysis was conducted to determine the usefulness of bedside ultrasound as an additional assessment tool for the localization and removal of soft tissue foreign bodies. Records of the three groups of patients (those with foreign body removal using both ultrasound and X-ray, X-ray alone, and neither ultrasound nor X-ray) were compared for the following variables:

1. Time from the onset of the removal procedure to patient discharge
2. The location of the foreign body and time of removal to discharge
3. Types of foreign body material and time for removal to discharge
4. Pertinent comparisons were also made regarding symptoms and type of foreign body material along with the presence or absence of the foreign body material on X-ray compared to ultrasound.

Strategies to Reduce Barriers/Increase Support

No specific evidence based guidelines exist to instruct providers in the removal of soft tissue foreign bodies leaving each individual provider to formulate his or her own plan of care. As conveyed in the literature review, ultrasound has proven beneficial in assisting the provider in localizing and removing soft tissue foreign bodies allowing for real-time visualization not only of the foreign body itself but the surrounding neurovascular structures as well.

Initiating a new practice change often comes with apprehension from healthcare providers in particular and can best be addressed by peer influence, strong evidence based research, and versatile proposed interventions (Melnyk & Fineout-Overholt, 2005). Important potential stakeholders for this research utilization project included physicians, nurse practitioners, nurses, radiology technicians, office administrators and other non-licensed members of the healthcare team. Conducting this retrospective chart review allowed for the identification of evidence based research implemented into practice without significant deviations to the provider's standard of care for soft tissue foreign body removal.

Chapter 4

Results

Sample Description

A total of 940 charts from January 2011 to July 2013 consisting of patients presenting to the urgent with the complaint of a laceration, open wound or an embedded soft tissue foreign body were reviewed. Forty-nine charts were excluded due to foreign bodies located in the face, ear, nose, esophagus, and pharynx. Of the 891 charts remaining, 681 patients were excluded for a diagnosis of lacerations to extremities without the presence of a soft tissue foreign body. Two charts were excluded for patients requiring specialist referral due to a foreign body located adjacent to a nerve or tendon. Another 145 charts were excluded for a diagnosis of laceration to the head, face or scalp. In addition, another 18 charts were coded as foreign body removal related to tick insect material and thus were excluded (Figure 4.1).

The remaining 45 medical records met the inclusion criteria for analysis. Patient ages ranged from 2 to 88 years with a mean age of 39 years. More than half of the identified medical records were comprised of male patients (69%) with the age range of 52-61 years (26%) compared to female patients (31%) with the age range of 2-21 years (Table 4.1).

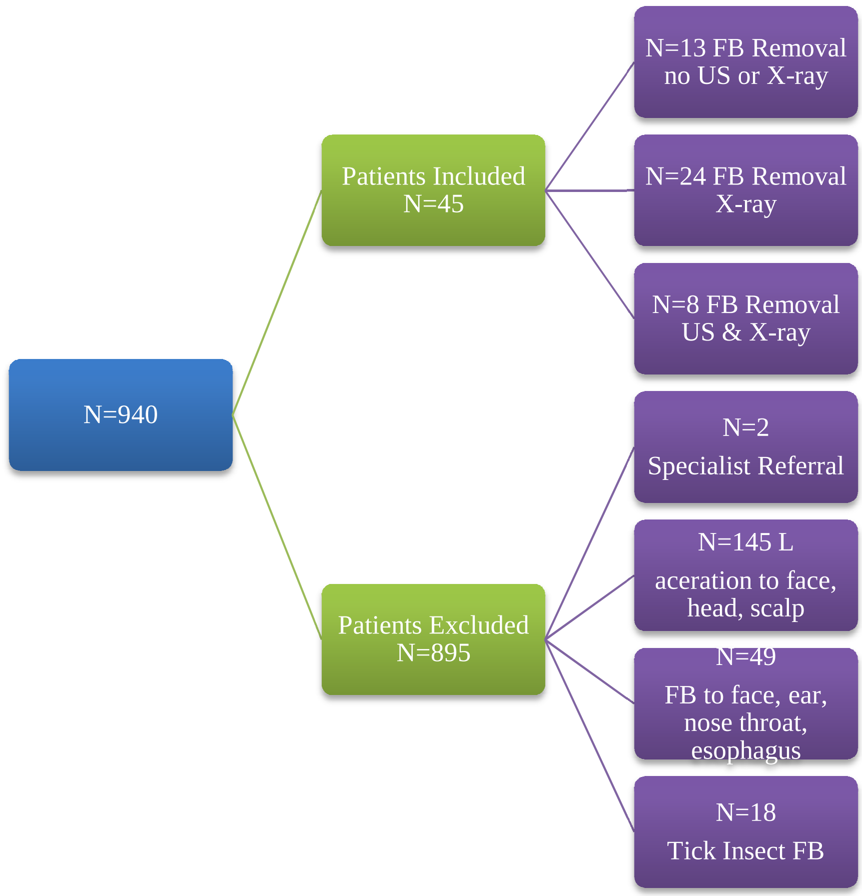

Figure 4.1 *Inclusion and Exclusion Criteria*
FB=foreign body, US=ultrasound

Table 4.1

Sample Characteristics

Sample Characteristics								
	Female		Female Total	Male			Male Total	Grand Total
Age (yrs)	African American	Caucasian		African American	Caucasian	Hispanic		
2-11	3		3	1	2		3	6
12-21		3	3		6		6	9
22-31				1	3		4	4
32-41		1	1		1	1	2	3
42-51		1	1		5		5	6
52-61		2	2	3	4	1	8	10
62-71	1		1	1	1		2	3
72-81		1	1		1		1	2
82-91		2	2					2
Grand Total	4	10	14	6	23	2	31	45
%			31%				69%	

Summary of Patient Characteristics

Patients underwent soft tissue foreign body removal with the use of X-ray alone (53%), ultrasound and X-ray (18%), and without the use of X-ray or ultrasound (29%). The most common presenting symptom associated with an embedded soft tissue foreign body was pain and the most common affected anatomical location was the finger (Table 4.2)

Table 4.2

Presenting Symptoms and Anatomical Location Soft Tissue Foreign Body

	Patient Complaint Characteristics		
	Description	**N**	**Percentage**
Diagnostic Imaging	X-ray Alone	24	53%
	X-ray & Ultrasound	8	18%
	No Imaging	13	29%
Symptom	Pain	28	62%
	Redness	3	7%
	Swelling	14	31%
Anatomic Location	Arm	4	9%
	Finger	19	42%
	Foot	10	22%
	Hand	10	22%
	Leg	2	4%
Foreign Body Material	Glass	2	4%%
	Metal	15	33%
	Wood	23	51%
	Other	5	11%

Other Foreign Body=graphite, granulation tissue, plant thorn, catfish spine

A majority of patients (53%) received X-rays alone prior to their soft tissue foreign body removal procedure. Of those patients receiving X-rays alone, 10 yielded positive interpretations for the presence of a radiopaque foreign body material. The remaining 14 X-rays were interpreted as negative for foreign body with radiolucent foreign body and granulation tissue materials subsequently removed during the office visit.

Patients receiving both X-ray and ultrasound represented 18% of the sample population. These individuals first received an X-ray of their affected extremity for a complaint of retained soft tissue foreign body. After completion of X-rays, ultrasound was used to identify and locate the soft tissue foreign body to assist in the removal procedure. Seven of the eight patients had a negative X-ray for foreign body with subsequent positive ultrasound findings of radiolucent materials and glass fragments. One patient had a positive X-ray for metallic foreign body, which was also identified on ultrasound prior to removal. The following sample cases represent the findings discovered during the retrospective chart review. Ultrasound was used by the urgent care nurse practitioner in each case to locate and remove soft tissue foreign bodies.

Case 1. A 41-year-old female presented with a complaint of swelling to her right arm after hitting her arm on a wooden porch railing. Upon physical examination she was noted to have edema and a palpable foreign body on the dorsal surface of her right forearm. A two view right forearm X-ray was interpreted as negative for foreign body, fracture or effusion by the radiologist. Ultrasound performed during the same visit revealed a wooden splinter, which was removed without complications.

Case 2. An 88-year-old female presented with a complaint of swelling to the left foot after stepping on a toothpick in her kitchen. On physical exam the patient was noted to have pain on palpation of the plantar surface of her left foot with mild edema. A three view left foot X-ray was interpreted as negative for foreign body, fracture or effusion by the radiologist. Ultrasound performed in office revealed a wooden toothpick piece, which was removed without complications.

Case 3. A 31-year-old male presented with a complaint of swelling to his right forearm after lifting and stacking wooden pallets at work. A two view right forearm X-ray was interpreted by the radiologist as negative for foreign body, fracture or effusion.

Ultrasound performed at the same visit located a wooden splinter on the dorsal aspect of the patient's right forearm. The splinter was removed without difficulty and the patient was discharged home.

Case 4. A 39-year-old male presented with a complaint of pain to the bottom of his right foot after walking on a wooden pier. A three view X-ray was interpreted by the radiologist as negative for foreign body. Ultrasound completed at the same visit was positive for wooden fragments on the plantar surface of the patient's right foot. The wooden fragments were removed without complications.

Case 5. A 57-year-old female presented with a complaint of redness to her left hand after accidentally stabbing herself with a pencil. A three-view left hand X-ray was interpreted as negative for foreign body, fracture or effusion by the radiologist. Ultrasound performed in office during the same visit revealed wooden pencil fragments to the palmer surface of the patient's left hand. The wooden fragments were removed without complications and the patient was discharged home.

Case 6. A 36-year-old male presented with a complaint of a laceration to the right lower leg after a glass windowpane fell and shattered on his leg. A two view right tibia/fibula X-ray was interpreted as negative for foreign body, fracture or effusion by the radiologist. Ultrasound performed during the same visit revealed several retained glass fragments within the laceration. The glass foreign material was removed and the laceration was repaired without complications.

Case 7. A 14-year-old female presented with a complaint of pain and a wooden foreign body sensation to the posterior left thigh after sitting on wooden bleachers. A femur X-ray was interpreted as negative for foreign body by the radiologist. The patient underwent ultrasound examination in office, which revealed a wooden splinter in the left posterior thigh. The splinter was removed without complications and the patient was discharged home with her mother.

Case 8. A 19-year-old female presented with a complaint of pain and a pellet foreign body to the left hand after being shot in the hand with a pellet gun. A three-view left hand X-ray was interpreted as positive for metallic foreign body material without fracture or effusion by the radiologist. Ultrasound was performed during the same visit to assist with foreign body removal. The metallic foreign body and neighboring neurovascular structures were identified on the palmer surface of the patient's left hand and the metallic pellet foreign body was removed successfully without complications.

Analysis

Foreign body removal using X-ray alone. Prior to soft tissue foreign body removal, 24 patients received X-rays alone of their affected extremity (Table 4.3). The average time from the foreign body removal procedure to patient discharge using X-rays alone was 22 minutes.

Table 4.3

Foreign Body Removal X-ray Alone

Gender	Age (years)	Anatomical Location	Presenting Symptom	X-ray Interpretation	FB Material Retrieved	Time
Male	67	Hand	Swelling	Negative	Wood	15
Male	22	Finger	Swelling	Positive	Metal	19
Female	83	Finger	Pain	Negative	Wood	20
Male	51	Finger	Swelling	Negative	Wood	8
Male	30	Foot	Swelling	Negative	Wood	10
Male	13	Finger	Pain	Positive	Metal	33
Male	60	Finger	Pain	Negative	Wood	13
Male	20	Foot	Swelling	Negative	Wood	30
Female	77	Hand	Pain	Negative	Wood	25
Male	45	Finger	Swelling	Negative	Wood	30
Male	44	Foot	Pain	Negative	Wood	30
Male	52	Hand	Pain	Positive	Metal	28
Female	50	Finger	Pain	Positive	Metal	20
Male	7	Foot	Redness	Negative	Wood	27
Male	11	Arm	Pain	Positive	Graphite	15
Male	43	Finger	Pain	Positive	Metal	26
Female	9	Foot	Pain	Negative	Glass	20
Male	60	Hand	Pain	Positive	Catfish Spine	15
Male	13	Finger	Pain	Positive	Metal	15
Male	44	Finger	Pain	Positive	Metal	19
Female	17	Foot	Pain	Negative	Granulation Tissue	20
Male	20	Foot	Pain	Negative	Wood	33
Male	56	Finger	Pain	Positive	Metal	27
Male	19	Finger	Pain	Positive	Metal	40

Time=Time from removal of foreign body to patient discharge in minutes

Foreign Body Removal using both X-ray and Ultrasound. Eight patients underwent soft tissue foreign body removal with the use of ultrasound after receiving an X-ray of their affected extremity (Table 4.4). The time from the onset of the foreign body removal procedure to patient discharge averaged 19 minutes for this group.

Table 4.4

Foreign Body Removal X-ray and Ultrasound

Gender	Age (yrs)	Anatomical Location	Presenting Symptom	X-Ray Interpretation	Ultrasound Interpretation	Foreign B body Material	Time
Female	41	Arm	Swelling	Negative	Positive	Wood	15
Female	88	Foot	Swelling	Negative	Positive	Wood	15
Male	31	Arm	Swelling	Negative	Positive	Wood	27
Male	39	Foot	Pain	Negative	Positive	Wood	23
Female	57	Hand	Redness	Negative	Positive	Wood	20
Female	19	Hand	Pain	Positive	Positive	Metal	15
Male	36	Leg	Pain	Negative	Positive	Glass	20
Female	14	Leg	Pain	Negative	Positive	Wood	14

Time=Time from removal of foreign body to patient discharge in minutes

Foreign Body Removal without Diagnostic Imaging. Thirteen patients presenting with a complaint of soft tissue foreign body did not receive X-ray or ultrasound prior to undergoing the removal procedure (Table 4.5). The average time from the onset of the foreign body removal procedure to patient discharge was 16 minutes for this group.

Table 4.5

Foreign Body Removal No Diagnostic Imaging

Gender	Age	Anatomical Location	Presenting Symptom	Foreign Body Material	Time
Female	59	Hand	Swelling	Plant Thorn	16
Male	56	Finger	Swelling	Granulation Tissue	15
Female	9	Hand	Pain	Wood	18
Male	53	Hand	Swelling	Wood	27
Female	71	Finger	Pain	Metal	10
Male	60	Finger	Redness	Wood	30
Male	53	Hand	Swelling	Wood	27
Male	3	Foot	Swelling	Wood	8
Male	77	Finger	Pain	Metal	15
Female	2	Finger	Pain	Wood	10
Male	14	Finger	Pain	Metal	13
Male	23	Finger	Pain	Metal	10
Male	66	Arm	Pain	Metal	13

Time=Time from removal of foreign body to patient discharge in minutes

Foreign Body Anatomical Location and Time of Removal to Discharge. All of the patient's charts selected during the review process represented soft tissue foreign body material present in extremity locations (Table 4.6). A majority of the soft tissue foreign bodies present were located in the finger with the foot and hand following as the next most common anatomical locations. The average time for removal of the soft tissue foreign body to patient discharge was greatest for the foot and least for the lower leg.

Table 4.6

Foreign Body Anatomical Location and Average Time of Foreign Body Removal to Patient Discharge

Anatomical Location	N	Average Time
Arm	**4**	**17.5**
Finger	**19**	**19.6**
Foot	**10**	**21.6**
Hand	**10**	**20.6**
Leg	**2**	**17**

Type of Foreign Body Material and Time of Removal to Discharge. Several different types of soft tissue foreign bodies were retrieved during the removal process described in the retrospective chart review. A majority of the patients presented with wooden soft tissue foreign bodies followed by metal as the second most common retained foreign body (Table 4.7). The average time from the soft tissue foreign body removal procedure to patient discharge was greatest for wooden foreign bodies, followed closely by metal and glass. Removal of other foreign materials consisting of graphite, granulation tissue, plant thorns or catfish spine required the least amount of average time.

Table 4.7

Foreign Body Material and Average Time of Foreign Body Removal to Patient Discharge

Foreign Body Material	N	Average Time
Glass	2	20
Metal	15	20.2
Wood	23	20.7
Other	5	16.2

Other=graphite, granulation tissue, plant thorn, catfish spine

Summary

Results of the retrospective chart review indicate that wood was the most common soft tissue foreign body yielded during patient presentation. X-rays failed to identify foreign bodies in all of the cases where wood or glass was suspected as the cause of patient symptoms. Ultrasound located all foreign bodies regardless of foreign body material type, presenting symptom or anatomical location.

When ultrasound was used in combination with X-ray, the patient was treated and discharged home in an average of 19 minutes compared to 22 minutes with X-ray alone as the form of diagnostic imaging for retained soft tissue foreign bodies. Those patients that did not receive any type of diagnostic imaging were treated and released in an average of 16 minutes.

The most common anatomical location affected by residual soft tissue foreign bodies was the finger. During the foreign body removal procedure, the foot on average required the longest time from procedure to patient discharge followed by the hand and finger. The forearm and leg locations were close in average removal time to patient discharge and required approximately three minutes less than the foot, hand and finger locations.

Minimal differences existed in the average time of the soft tissue foreign body removal procedure to patient discharge for wood, glass and metal materials. Foreign body material consisting of granulation tissue, plant thorns, catfish spine and graphite exhibited the least amount of time calculated from the removal procedure to patient discharge.

Chapter 5

Discussion

The consequences of failing to identify and remove soft tissue foreign bodies can be devastating to patients. Missed soft tissue foreign bodies have the potential to cause systemic infections leading to costly hospitalization and surgical interventions. As a result, patients can suffer permanent disfigurement from scarring, functional disability, and decreased quality of life.

Plain radiographs (X-rays) have been the preferred first line diagnostic imaging modality for the initial evaluation of patients presenting with embedded soft tissue foreign bodies. X-rays are readily accessible to providers and will display radiopaque materials. However, radiolucent materials such as wood and other organic substances are not detected by X-ray. Ultrasound has proven to be a beneficial adjunct to X-rays for the identification and removal of soft tissue foreign bodies regardless of material composition, presence of infection, or length of time from onset of injury (Ozsarac, Demircan, & Sener, 2011).

A majority of the previous studies relied on in-vitro or cadaver models to explore the use of ultrasound compared to other diagnostic imaging modalities in locating and removing of soft tissue foreign bodies. In addition, few prior studies involved time measurement for ultrasound guided removal of soft tissue foreign bodies compared to other diagnostic imaging methods. This project enhances practice by demonstrating that ultrasound is effective in removing both radiolucent and radiopaque foreign bodies in human soft tissue with minimal time differences from procedure onset to patient discharge from the facility compared to those patients only receiving X-rays or no diagnostic imaging prior to soft tissue foreign body removal.

Outcomes

The purpose of this research utilization project was to retrospectively report on the use of bedside ultrasound by healthcare providers as an adjunct to X-ray for the localization and removal of foreign bodies in soft tissue wounds among patients presenting to an urgent care setting, in order to answer the question: Is ultrasound useful as a clinical tool in addition to wound exploration and X-rays to ensure complete removal of soft tissue foreign bodies? Project outcomes included the following:

1. Ultrasound may be used for complete removal of soft tissue foreign body as evidenced by real time pre and post removal imaging.
2. Ultrasound has the potential to become an alternative imaging approach to plain radiographs for locating radiolucent foreign bodies, such as wood, plastic, and other vegetative materials, in soft tissue.

A total of 45 medical charts were used for this retrospective chart review in which patients presented with embedded soft tissue foreign bodies located in the extremities. The extremities have the greatest tendency to harbor a soft tissue foreign body due to environmental exposures such as a patient walking barefoot and stepping on a wooden splinter or getting pierced in the hand with a plant thorn while gardening. Most of the patients (N=19) treated for embedded soft tissue foreign bodies at the urgent care center complained of a foreign body sensation in the finger. The feet (N=10) and hands (N=10) were the next most common sites with the arms (N=4) and legs (N=2) the least frequent.

Procedure time of removal to patient discharge was comparable regardless of the location of the soft tissue foreign body, however the feet, fingers and hands required the greatest amount of time due to the presence of delicate neurovascular and tendon structures in these anatomical locations.

Indications for Use

Previous studies have reported that as many as 38% of soft tissue foreign bodies are missed on initial wound exploration by providers (Blankenship & Baker, 2007; Davae, Sofka, DiCarlo, & Adler, 2003; Manthey, Storrow, Milbourn, & Wagner, 1996; Salati & Rather, 2010; Sidharthan & Mbako, 2010; Steele, et al., 1998). Foreign body material consisting of wood and glass tends to splinter or shatter, creating the potential to have multiple fragments embedded in a soft tissue wound (Sidharthan & Mbako, 2010). Because of this risk, meticulous wound exploration is essential.

Results of this project revealed that of the 24 patients receiving X-rays alone, 14 patients (58%) had negative X-ray interpretations with subsequent wooden material or granulation tissue removed upon wound exploration. Many studies have suggested that X-rays detect only about 15% of wooden foreign bodies, thus as evidenced in this retrospective chart review another imaging method for detection of radiolucent foreign bodies is warranted (Graham, 2002; Sidharthan & Mbako, 2010).

Another 13 patients presenting with a complaint of soft tissue foreign body did not receive any type of imaging and were found to have eight radiolucent and five radiopaque foreign bodies upon wound exploration by the provider. Blind probing wound exploration is often time consuming for both the patient and provider and requires the extension of wound margins creating greater areas of tissue destruction and significant patient discomfort (Davae, Sofka, DiCarlo, & Adler, 2003; Mills & Butts, 2009). Strong recommendations exist against blind probing of lacerations or penetrating wounds in the hand due to the potential for damaging underlying tendons, nerves, and vascular structures (Bray et al., 1995; Tuncer et al., 2011). Twelve of the 13 patients in this study had foreign bodies embedded in the finger or hand.

The average time from the onset of the soft tissue foreign body removal procedure to patient discharge for those patients receiving X-rays alone was 22 minutes in this project while those patients without diagnostic imaging averaged 16 minutes. Those patients without diagnostic imaging presented with superficial protruding foreign bodies, such as fishhooks, which the provider removed immediately at the bedside and did not require diagnostic imaging.

In his retrospective review, Gibbs (2006) discusses the failed attempt of a physician in locating and removing a glass soft tissue foreign body identified on X-ray after probing the wound for 20 minutes. Successive ultrasound images located the glass foreign body with removal occurring in less than 10 seconds (Gibbs, 2006). The findings of this retrospective chart review are congruent with the literature, and indicate that ultrasound is a valuable diagnostic tool in addition to wound exploration and X-ray for the localization and removal of soft tissue foreign bodies.

Accurate Detection and Precise Localization. In past studies, the use of ultrasound and X-ray in parallel has yielded the greatest sensitivity for the identification and removal of soft tissue foreign bodies (Bray et al., 1995; Friedman et al., 2005; Teng & Doniger, 2012). For this project, eight patients received both X-ray and ultrasound for the detection of soft tissue foreign bodies. Seven of the eight patients had a negative X-ray with wooden or glass fragments identified during the removal process using ultrasound. Similar results were obtained by Rockett, Gentile, Gudas, Brage, and Zygmunt (1995) in their retrospective review of 20 patients presenting with the complaint of wooden soft tissue foreign bodies. All X-rays completed on the 20 patients were interpreted as negative with 10 patients found to have positive ultrasounds for wooden foreign bodies.

For this project, the average time from onset of the foreign body removal procedure to patient discharge averaged 19 minutes for patients undergoing both ultrasound and X-ray for the localization and removal of soft tissue foreign bodies. Similar results were obtained by Callegari et al. (2009) in their descriptive study of 62 patients presenting with suspected retained soft tissue foreign bodies. The authors reported an average removal time of 15 to 30 minutes using ultrasound guidance.

Previous studies have indicated that ultrasound displays wooden foreign bodies with the characteristic hyperechoic foci, while the glass fragments emit a “comet-tail” artifact (Blakenship & Baker, 2007; Gibbs, 2006; Schlager, 1997; Teng & Doniger, 2012). The chart reviews conducted in this project did not specifically provide a description of the soft tissue foreign body image but a review of the obtained images did exhibit these characteristics. Surrounding neurovascular structures were readily identifiable on the saved images by the use of the doppler color flow ultrasound machine feature. Post-removal images were also obtained, ensuring complete removal of the foreign body in each of the cases reported in the retrospective chart review, thus indicating that ultrasound can be used for complete removal of soft tissue foreign bodies.

Comparative Costs and Risks. Routinely, X-rays are the chosen first line treatment modalities for the identification of a soft tissue foreign body due to their availability and inexpensive cost (Pattamapaspong, Srisuwan, Sivasomboon, Nasuto, Suwannahoy, Settakorn, et al., 2012; Shepherd, Lee, & McGahon, 2007). However, if the foreign body is radiolucent, it will not be visualized on X-ray and the patient will be exposed to unnecessary ionizing radiation.

Ultrasound is safe, effective and can provide information regarding the location, size and depth of the embedded soft tissue foreign body (Blankstein et al., 2001; Rockett, et al., 1995). Other advantages of ultrasound include the ability of the provider to create smaller incision sites; visualization of surrounding neurovascular and tendon structures during the removal process; and the availability of pre and post removal imaging without repeated patient exposure to ionizing radiation (Gibbs, 2006; Turner, Wilde, Hughes, Meilstrup, & Manders, 1997).

Several of the studies in the literature review suggested the use of ultrasound instead of X-ray in wounds contaminated with known radiolucent foreign bodies (Friedman et al., 2005; Manson et al., 2011; Turkcuer et al., 2006). The urgent care facility site of this project currently performs X-rays prior to removal of soft tissue foreign bodies regardless of material composition. However, results of this project demonstrated that the use of ultrasound as an adjunct to X-ray did identify all of the radiolucent and radiopaque foreign bodies embedded in soft tissue wounds. Since the sample size of patients undergoing both X-ray and ultrasound for the localization and removal of foreign bodies was relatively small (N=8), there is not sufficient evidence to recommend discontinuation of using X-rays at this time. Further studies with larger sample sizes need to be conducted with a comparison of X-ray to ultrasound findings.

Other forms of diagnostic imaging do exist for the detection of soft tissue foreign bodies. Pattamapaspong, et al. (2012) performed a controlled study using CT and MRI for diagnostic accuracy of detecting foreign bodies in cadaver feet. Results found both diagnostic modalities highly specific for identifying foreign bodies but poorly sensitive. CT and MRI costs vary according to insurance policies and facility payment programs. Average costs of these imaging studies are two to three times that of ultrasound or X-ray and they have limited availability (Jacobson, Powell, Craig, Bouffard, & van Holsbeeck, 1998; Soudack, Nachtigal, & Gaitini, 2003). Other risks include the large dose of ionizing radiation and potentially nephrotoxic contrast dye with the use of CT scans (Bierig & Jones, 2009; Soudack, et al., 2003). None of the patients selected for this retrospective chart review required further diagnostic imaging with CT or MRI.

Operator Skill/Training. Ultrasound allows for localization and removal of the foreign body under real-time guidance at the patients' bedside (Aras, Miloglu, Barutcugil, Kantarci, Ozcan, & Harorli, 2010). The ultrasounds completed for this project were conducted by the urgent care nurse practitioner with assistance from an ultrasound technician. Both pre and post ultrasound guided foreign body removal images were saved and interpreted by the nurse practitioner and the urgent care physician.

Several studies indicate ultrasound guided foreign body localization and removal procedures can be learned in less than one to two days by providers who have little prior formal ultrasound training. Manson, Ryan, Ladner, and Gupta (2011) conducted a single-blinded, crossover, randomized study of the removal of pins in pigs' feet by 14 emergency medicine residents using both ultrasound and X-ray. The emergency medicine residents were in their first and second year of residency with two having completed an ultrasound elective (Manson et al., 2011). The residents were given a 30 minute lecture covering the topic of localization and removal techniques of foreign bodies using ultrasound and X-ray in this study (Manson et al., 2011).

Orlinsky, Knittel, Feit, Chan, and Mandavia (2000) conducted a prospective study to compare the diagnostic accuracy of new emergency physicians without prior ultrasound experience to experienced ultrasound technologists and radiologists using ultrasound for foreign body detection. The new emergency physicians attended a two day ultrasound training course (Orlinsky et al., 2000). Both the new emergency physicians and the experienced ultrasound technologists and radiologists were required to attend a one hour foreign body removal course (Orlinsky et al., 2000). The new emergency physicians had a diagnostic accuracy of 80% compared to 83% for the radiologists and 85% for the ultrasound technologists in identifying toothpick foreign bodies embedded in chicken thighs (Orlinsky et al., 2000).

For the identification and localization of foreign bodies, Gibbs (2006) indicates that most facilities employ the use of a sonographer instead of the physician to perform the ultrasound guided localization of soft tissue foreign bodies. With two ultrasound technicians employed in the urgent care setting of this project, their assistance was used to prep the patient prior to the procedure and provide landmarks related to the soft tissue foreign body location.

Formal ultrasound training should not be downplayed. Those providers performing bedside ultrasound should be encouraged to attend a national ultrasound course and participate in continuing education.

Limitations

This retrospective chart review was conducted at a small, rural urgent care center. Chart selections were based on the ICD-9 codes and CPT codes designated for wounds and residual soft tissue foreign bodies. It is possible that all charts pertaining to soft tissue foreign bodies were not located in the electronic medical record system. Potential missed charts were those coded as cellulitis or pain in limb for the primary diagnoses instead of wounds or embedded foreign bodies.

Other limitations include the small sample size of 45 charts chosen for the retrospective chart review. Only eight patients were noted to receive both X-ray and ultrasound for the localization and removal of soft tissue foreign bodies. In addition, the soft tissue foreign bodies removed were documented as superficial or simple muscle in the procedure section of the charts reviewed.

Implications for Practice

No universally accepted algorithm exists delineating the first line treatment of embedded soft tissue foreign bodies. Treatment is based on individual patient cases and provider preference along with availability of diagnostic imaging resources. The following algorithm (Figure 5.1) is a compilation and expansion of recommendations from the literature and displays the use of X-ray and ultrasound in parallel (American College of Radiology, 2010; Bradley, 2012; Bray, Mahoney, & Campbell, 1995; Callegari, Leonardi, Bini, Sabato, Nicotera, Spano, et al., 2009; Crystal, Masneri, Hellums, Kaylor, Young, Miller, & Levsky, 2007; Davae, et al., 2003; Friedman et al., 2005; Ipaktchi, DeMars, Park, Ciarallo, Livermore, & Banegas, 2013; Lee, Chung, & Kam, 2008; Levsky, McArthur, & Abell, 2007; Manson, Ryan, Ladner, & Gupta, 2011; Oikarinen, Nieminen, Makarainen, & Pyhtinen, 1993; Paziana, Fields, Rotte, Au, & Ku, 2012; Young, Shiels, Murakami, Coley, & Hogan, 2010). It is presented as a guide for providers for the treatment of patients presenting with embedded soft tissue foreign bodies.

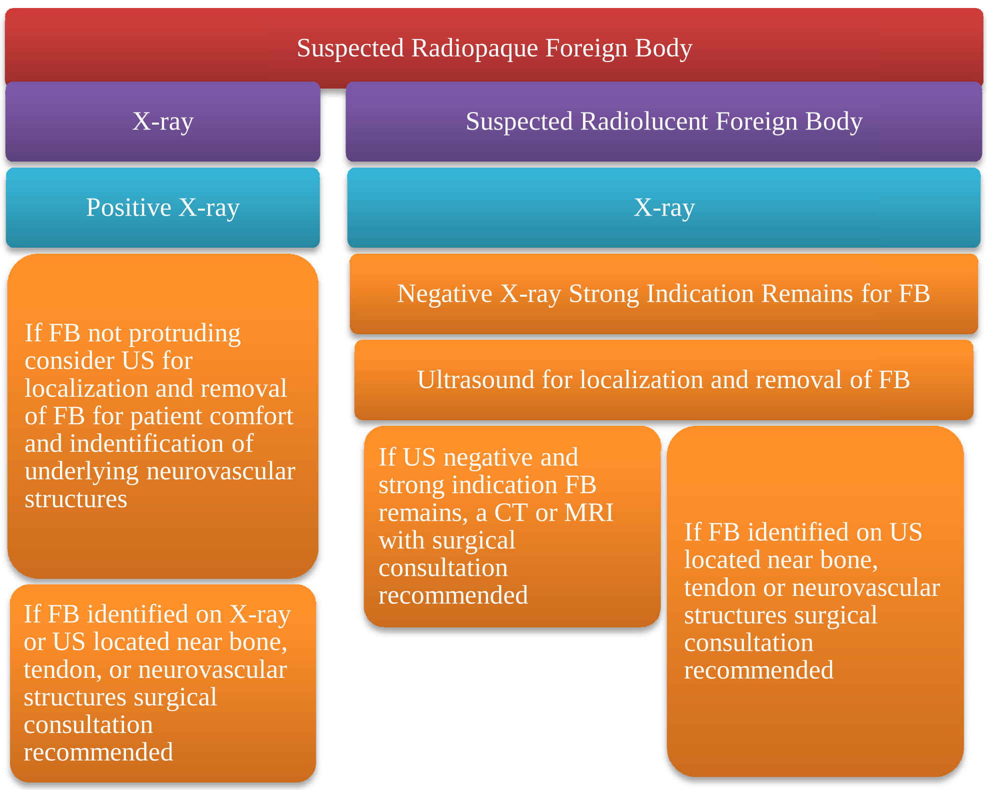

Figure 5.1 *Treatment Algorithm*

Recommendations for Future Research

Future research involving larger and more diverse samples needs to be conducted. A larger patient sample with comparisons among ultrasound and X-ray for soft tissue foreign body procedure removal time analysis also needs to be performed. Other studies with cost comparisons among the different imaging modalities also need to be conducted.

Conclusion

Several professional organizations such as the American College of Radiology (ACR), American College of Emergency Physicians (ACEP), American Institute of Ultrasound in Medicine (AUIM), and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) support the use of ultrasound for the localization of soft tissue foreign bodies due to the minimally invasive nature and lack of exposure to radiation (ACR, 2010; ACEP, 2008; AUIM, 2012; JCAHO, 2011).

The data analysis conducted in this study suggests that ultrasound as an adjunct to X-ray is beneficial for the localization and removal of soft tissue foreign bodies. Furthermore, ultrasound was implemented in the urgent care setting as a clinical tool in addition to wound exploration and X-ray to ensure complete removal of soft tissue foreign bodies as evidenced by pre and post removal imaging.

Results of this research utilization project found that in comparison to X-ray alone, ultrasound used in parallel with X-ray was found superior with regards to soft tissue foreign body localization and procedure removal time to patient discharge from the urgent care facility. However, there was not enough evidence to suggest that ultrasound become the sole diagnostic imaging approach for locating radiolucent foreign bodies.

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Appendix A-Literature Evidence Tables

Table A.1: Literature Evidence Tables

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Al-Zahrani, S., Kremli, M., Saadeddin, M., Ikram, A., Takroni, T., & Zeidan, H. (1995). Ultrasonography Detection of Radiolucent Foreign Bodies in Soft Tissue Compared to Computed Tomography Scan.	Comparative Study Level VI	To evaluate the use of US for the detection and localization of radiolucent FBs compared to X-ray and CT.	31 patients with wooden soft tissue FB X-ray, CT and US performed on all patients	X-ray: no FB detected CT: 14 FB US: FB in 18 patients Surgical Exploration: FB in 20 patients, 11 patients negative for FB	CT detected only 70% of FB, US detected 90% US detection accuracy not effected by infection, FB size and length of time to diagnosis US is appropriate imaging method for radiolucent soft tissue FBs
American College of Emergency Physicians. (1999). Clinical Policy for the Initial Approach to Patients Presenting with Penetrating Extremity Trauma.	Clinical Policy Expert Opinion Level VII	Clinical Policy for patients of all ages with penetrating extremity wounds.	None	None	US screening tool for radiolucent soft tissue FB. X-rays best for glass and metal FB. Paucity of evidence based data regarding the management of puncture wounds.
Ando, A., Hatori, M., Hagiwara, Y., Isefuku, S., & Itoi, E. (2009). Imaging Features of Foreign Body Granuloma in the Lower Extremities Mimicking a Soft	Case Reports Level VI	Report of lower extremity granulomas harboring FB.	Case report of 3 patients 9 year old with hx of puncture wound to foot by wood 2 years prior. 56 year old fell 4	(1) X-ray, CT and MRI revealed soft tissue mass. Surgical exploration detected 2 wooden FB. (2) CT revealed	Consider FB in patients with granulomas and history of skin penetrating trauma. US superior to CT and MRI in FB detection US less expensive and greater availability than CT or MRI

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Tissue Neoplasm.			years prior 3 year old with toothpick injury to RLE 1 wk prior.	mass to left thigh. MRI with contrast detected tile fragment. (3) X-ray negative, MRI target appearance, US hyperechoic focus, posterior acoustic shadowing, hypoechoic halo	
Aras, M.H., Miloglu, O., Barutcugil, C., Kantarci, M., Ozcan, E., & Harorli, A. (2010). Comparison of the sensitivity for detecting foreign bodies among conventional plain radiography, computed tomography, and ultrasonography.	Comparative Study Level VI	To compare the sensitivity of X-ray, ultrasound and CT in detecting foreign bodies.	In vitro study using sheep's head Observers aware of foreign bodies but not material composition.	X-ray detected stone, glass, and metal. No wood, graphite, acrylic, or plastic material was detected by X-ray. CT localized metal, glass, stone and graphite FB. On CT wood was not seen at all between bone and muscle. Ultrasound detected metal, glass, wood, stone, graphite, and plastic materials in muscle.	Radiopaque FB are detected by X-ray, CT and ultrasound Ultrasound visualization of radiolucent foreign bodies is better than CT Ultrasound better at exploring superficial FB than X-ray or CT. Limitations: type of study using sheep's head not human tissue. Air limits ultrasound visibility of FB and can mimic FB

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Arbona, N., Jedrzynski, M., Frankfather, R., Lo, A.E., Hetman, J., Mendicino, S.S., & Rockett, M.S. (1999). Is Glass Visible on Plain Radiographs? A Cadaver Study	Randomized Controlled Trial Level II	To determine the visibility of glass on X-ray.	30 nonleaded glass pieces randomly inserted into diabetic cadaver foot X-rays taken of cadaver foot then interpreted by 5 individuals	Sensitivity 90% overall for detection of glass	X-ray first line imaging modality for glass in foot. X-ray detection not affected by glass color or location Limitations: cadaver tissue, observers not blinded
Bierig, S.M. & Jones, A. (2009). Accuracy and Cost Comparison of Ultrasound Versus Alternative Imaging Modalities, Including CT, MRI, PET, and Angiography.	Literature Review Level V	US compared to MRI, CT , PET, and angiography based on diagnostic accuracy and cost effectiveness.	None	None	US provides rapid, accurate diagnosis and is cost effective compared to other imaging modalities.
Blankenship, R.B. & Baker, T. (2007). Imaging Modalities in Wounds and Superficial Skin Infections.	Expert Opinion Level VII	Discussion of the imaging modalities used in the detection of foreign bodies and skin infections.	None	None	US best for superficial soft tissue FB US can be used to detect, localize, and remove radiolucent and radiopaque FB. X-ray and CT poor sensitivity in detecting radiolucent FB CT and MRI expensive imaging modalities and lack availability. CT high dose of ionizing radiation and should be used after X-ray and US negative for FB.
Blankstein, A., Cohen, I., Heiman, Z., Salai, M., Heim,	Case Reports Level VI	The use of ultrasound for localization and removal of soft tissue	12 patients received X-ray and ultrasound	11 patients foreign body detected by ultrasound with 7	Ultrasound is a useful in conjunction with plain radiographs especially when foreign bodies are radiolucent

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
M., & Chechick, A. (2000). Localization, detection, and guided removal of soft tissue in the hands using sonography.		foreign bodies in the upper extremities.		containing wooden foreign bodies	such as wood or vegetative material. When ultrasound is used to assist in foreign body removal size, depth and local anatomical structures can be visualized.
Blankstein, A., Cohen, I., Heiman, Z., Salai, M., Diamant, L., Heim, M., & Chechick, A. (2001). Ultrasonography as a diagnostic modality and therapeutic adjuvant in the management of soft tissue foreign bodies in the lower extremities.	Case Series Level VI	To assess the use of ultrasound for diagnosis and treatment of retained soft tissue foreign bodies.	21 patients 19 patients with negative X-rays prior to ultrasound	In 19 of 21 patients foreign body detected with ultrasound. 7 foreign bodies were wood in the plantar surface of the foot	Ultrasound has advantage over X-ray for detecting radiolucent foreign bodies. Ultrasound makes exploration time shorter for provider and creates less tissue damage. Limitation: small group, no randomization, no control group
Blaivas, M., Lyon, M., Brannam, L., Duggal, S., & Sierzenski, P. (2004). Water Bath Evaluation Technique for Emergency Ultrasound of Painful Superficial Structures.	Case Reports Level VI	Seven case reports of the water bath technique used in conjunction with US for the examination and procedural guidance of painful superficial abscess I & D, laceration exploration and foreign body localization.	Extremities with superficial abscess, laceration or foreign body immersed in water or sterile saline bath allowing for conduction of ultrasound waves.	Greater accuracy for diagnosis and procedural performance. Increased patient comfort and cooperation with procedure.	Water bath avoids use of US gel and direct probe pressure on painful wounds allowing for decreased wound contamination and increased patient comfort during the procedure. Water bath technique can be performed under sterile conditions along with maintaining image quality. US superior to X-ray in localizing FB.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Bonatz, E., Robbin, M.L., & Weingold, M.A. (1998). Ultrasound for the Diagnosis of Retained Splinters in the Soft Tissue of the Hand.	Case Studies Level VI	To report the use of ultrasound to identify radiolucent FB material in the hand.	4 adult patients over 18 month period with negative x-rays for FB	All 4 patients had wooden splinters visualized by US	Advantages of US include: high sensitivity to all FB, low cost, examination is in real time, and no ionizing radiation. Limitations: US operator dependent, soft tissue air can create false + image and a large amount of air can obscure deep FB
Borgohain, B., Borgohain, N., Handique, A., & Gogoi, P.J. (2012). Case Report and Brief Review of Literature on Sonographic Detection of Accidentally Implanted Wooden Foreign Body causing Persistent Sinus.	Case Report Level VI	Report of patient presenting 9 months after initial injury with non-healing wound to right thigh.	Patient fell from tree injuring right thigh on branch. X-ray negative for FB	US detected 7-8cm FB in vastus lateralis muscle US used post-surgical exploration to ensure complete removal of FB	US should be considered as an useful screening tool when initial X-ray negative or FB suspected is radiolucent rather than ordering other expensive imaging modalities like CT or MRI.
Boyse, T.D., Fessell, D.P., Jacobson, J.A., Lin, J., van Holsbeeck, M.T., & Hayes, C.W. (2001). US of Soft-Tissue Foreign Bodies and Associated Complications with Surgical Correlation.	Case Reports Level VI	Report of US evaluation of soft tissue foreign bodies.	US detection of wood splinters, metal, and plastic with surgical correlation.	US echogenicity, shadowing, reverberation, hypoechoic rim, and soft tissue complications addressed.	US gives exact location of FB in relation to surrounding anatomical structures. US superior to CT in detection of superficial, non-radiopaque FBs Limitations: operator dependent; false positives occur with FB close to bone, surrounded by air, hematoma or scar tissue
Bradley, M. (2012).	Prospective Study	How to reduce pitfalls	350 patients	63 no foreign	Image guided removal of soft tissue

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Image-guided soft-tissue foreign body extraction-success and pitfalls.	Level IV	when using ultrasound guidance to remove foreign bodies in soft tissue.	Most with X-rays prior	bodies 252 removed and 8 with no attempt and foreign body left	foreign bodies is safe and successful. Anatomical relationship and location of the foreign bodies should be taken into account and proper referral initiated for this. Ultrasound less likely needed for superficial foreign bodies. Limitations: not randomized, no control group
Bray, P.W., Mahoney, J.L., & Campbell, J.P. (1995). Sensitivity and specificity of ultrasound in the diagnosis of foreign bodies in the hand.	Prospective Controlled Study Level II	With the use of cadaver hands to determine the sensitivity and specificity of ultrasound in the diagnosis of foreign body in soft tissue.	15 cadaver hands with 315 FB insertion sites randomized by computer program. Also random assignment of the FB material to the sites was conducted. The sites negative for FB were designated as controls. X-rays were taken of the hands. Examiners were blinded to the location of FB. Ultrasound examiners were blinded to the presence, absence and characteristics of FB.	Total of 166 FB inserted in the hands and 156 detected by ultrasound. Ultrasound sensitivity 94% and specificity 99%	Ultrasound sensitive and specific for FB in hand. Ultrasound relatively inexpensive If FB suspected radiopaque then X-ray should be done If FB radiolucent X-ray obtained first and if negative ultrasound should be done Limitations: cadaver study, ultrasound dependent on operator skill

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Bu, J., Overgaard, K.A. & Viegas, S.F. (2008). Distal Migration of a Foreign Body within the Long-Finger Flexor Tendon Sheath.	Case Report Level VI	Case report of 35 year old female patient with puncture wound by thorn to right palm resulting in migration of FB into finger flexor tendon sheath.	Initial X-ray negative 10 day recheck no change in symptoms except swollen right long finger. Palm puncture site surgically explored with no FB. 2mons later re-exploration of palmer site. Also decided to explore flexor tendon in finger.	After exploration of flexor tendon in finger, a fragment of thorn was removed and patient eventually regained FROM with no resulting complications.	US highly sensitive for plant material. Migration potential of FB should be considered based on proximity to tendons and characteristics of wound presentation.
Callegari, L., Leonardi, A., Bini, A., Sabato, C., Nicotera, P., Spano, E., Mariani, D., Genovese, E.A., & Fugazzola, C. (2009). Ultrasound-guided removal of foreign bodies: Personal experience.	Descriptive Study Level VI	To describe the technique for ultrasound guided foreign body removal.	62 patients All patients had both X-ray and ultrasound Foreign bodies removed under ultrasound guidance	X-rays detected stone, glass, and metal but not vegetation or plastic. 12 pts: 39 glass FB 35 pts: 35 metal FB 12 pts: 17 vegetative FB 2 pts: 2 plastic FB 1 pt: 2 stone FB Procedure time 15-	X-ray detects radiopaque foreign bodies 80% of the time and radiolucent foreign bodies 15% of the time. Ultrasound has a sensitivity of 90% and a specificity of 96% Ultrasound can detect foreign bodies as small as 1mm in size. Ultrasound limits bleeding since incision site is smaller and less damage to surrounding anatomical structures since they are visualized in real time. Suggests ultrasound use as first choice for removal of soft tissue foreign body.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
				30 minutes	Limitations: small sample size
Capellan, O. & Hollander, J.E. (2003). Management of Lacerations in the Emergency Department.	Expert Opinion Level VII	None	None	None	Direct visualization of FB in wound bed preferred but if not visualized or felt does not rule out the presence. Blind probing has the potential to damage underlying structures. Puncture wounds most difficult to clinically examine. Plantar puncture wounds are at great risk for infection and wound exploration methods for FB are controversial.
Chisholm, C.D., Wood, C.O., Chua, G., Cordell, W.H., & Nelson, D.R. (1997). Radiographic Detection of Gravel in Soft Tissue.	Randomized, Blinded Descriptive Study Level II	To investigate the detection of gravel using X-ray comparing radiologist and ER MD interpretations.	Gravel FB inserted randomly into 165 chicken legs Control group of 40 chicken legs X-rays completed in randomized groups of 10 Physicians blinded to each other's X-ray interpretation Statistical analysis performed	ER MD greater sensitivity (90.3%) and radiologists greater specificity (78.1%) accuracy of X-ray interpretation Detection rates decreased with gravel size smaller than 1mm Greatest accuracy in identifying salt and pepper gravel while least accuracy with crater rock.	Gravel of 1mm or greater detected by X-ray Limitations: chicken leg model, possible over-interpretation of X-ray by MDs, only A/P X-ray views performed

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Crankson, S. Oratis, P., & Mazaid, G.A. (2004). Ultrasound in the diagnosis and treatment of wooden foreign bodies in the foot.	Case Report Level VI	Case reports of 3 children using ultrasound for localization and removal of wooden toothpicks in the foot.	Case 1: 7 year old with toothpick puncture wound to plantar foot. Case 2: 4 year old stepped on object. Case 3: 5 year old stepped on object.	Case 1: Negative X-ray and initial wound probing in ER. Using ultrasound 2.1cm x 0.3 cm toothpick removed in OR. Case 2: X-ray negative. Ultrasound discovered 1.9cm x 0.5cm toothpick. Case 3: X-ray negative. Ultrasound revealed wooden FB 4 weeks later.	Ultrasound sensitive and accurate for locating wooden foreign bodies in soft tissue. Ultrasound also can be used during the removal process, decreasing dissection time. Limitations: type of study, small sample size
Crystal, C., Masneri, D.A., Hellums, J.S., Kaylor, D.W., Young, S.E., Miller, M.A., and Levsky, M.E. (2009). Bedside ultrasound for the detection of soft tissue foreign bodies: A cadaveric study.	Prospective Study Level II	To determine if ultrasound was sensitive and specific for soft tissue foreign bodies.	150 extremity sites on a cadaver. Foreign bodies randomized to sites. Those performing ultrasounds were blinded to number, type, and location of foreign body.	900 ultrasound examinations Ultrasound sensitivity 52.6%, specificity 47.2%, PPV 79.9% and NPV 20.0%.	Ultrasound should be used in conjunction with plain radiographs and physical exam. Limitations: cadaver tissue, deeper foreign body placement, very small foreign bodies
Davae, K.C., Sofka, C.M., DiCarlo, E., & Adler, R.S. (2003).	Retrospective Review Level IV	To present power doppler findings and hypoechoic US	12 patients included age range 14-82.	US located all FB in patients.	For negative X-rays but strong suspicion of retained FB, US recommended.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Value of Power Doppler Imaging and the Hypoechoic Halo in the Sonographic Detection of Foreign Bodies.		findings correlating with FB tissue findings.	Time to surgical excision was same day to 1 week. US images compared to pathologic evaluation of removed FB and tissues.	FB material: glass (2), wood (3), cactus spur (1), metal (1), rose thorn (1), fish spine (1), suture (1) 2 false positives: scar tissue and inclusion cyst 4 patients with X-ray prior to US revealed positive findings in 2 patients metal and glass	US most reliable method to detect radiolucent FB
Dean, A.J., Gronczewski, C.A., & Constantino, T.G. (2003). Technique for emergency medicine bedside ultrasound identification of a radiolucent foreign body.	Case Report Level VI	Description of the use of ultrasound for detecting radiolucent, superficial soft tissue foreign bodies.	Pt presents with soft tissue puncture wound after running across wooden floor.	Ultrasound identified a 4cm wooden splinter which was extracted at the bedside.	Ultrasound imaging allows for precise localization of radiolucent foreign bodies and under real time guidance, the provider can extract the FB. Ultrasound also allows for smaller incisions and minimizes dissection time. Limitations: type of study, air in wound or calcified bone can be misinterpreted as FB by ultrasound, ultrasound is operator dependent.
Dumarey, A., De Maeseneer, M., &	Case Report	Report of a patient undergoing CT and	37 year old patient with wooden FB to	Initial X-ray did not show FB.	Suggest US should be used after wound exploration to validate

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Ernst, C. (2004). Large Wooden Foreign Body in the Hand: Recognition of Occult Fragments with Ultrasound.	Level VI	US to localize and remove wooden FB splinters from hand.	hand obtained while working on wooden table. Patient removed wooden FB at home.	US performed identified all wooden fragments. CT images did not reveal smaller wooden splinters seen on US.	removal of all FB. US superior to other diagnostic modalities for identifying small FB.
Firth, G.B., Roy, A., & Moroz, P.J. (2011). Foreign Body Migration Along a Tendon Sheath in the Lower Extremity.	Case Report & Literature Review Level VI	Report on the migration of toothpick FB from heel puncture wound into the flexor halluces longus tendon sheath.	7 year old presented to ER with complaint of toothpick puncture wound to left heel.	X-ray negative for FB 48 hrs after injury US negative for FB 3 wks after injury bone scan no osteomyelitis, +diffuse hyperemia After ortho referral surgical exploration revealed wooden toothpick FB 10cm from initial puncture wound on heel	Consider migration of FB related to anatomical landmarks surrounding injury site. Since US did not detect wooden FB in 48 hrs suggests immediate migration from initial puncture wound. FB shape and orientation useful information when considering migration of FB from initial puncture wound.
Friedman, D.I., Forti, R.J., Wall, S.P., & Crain, E.F. (2005). The Utility of bedside ultrasound and patient perception in detecting soft tissue	Prospective Cohort Study Level IV	Investigation of bedside ultrasound for screening and detection of foreign bodies.	All children less than 18 years of age presenting to pediatric ED with suspected foreign body in wound first received ultrasound.	105 patients with 131 wounds meeting inclusion criteria. Foreign bodies in 12 wounds.	Bedside ultrasound was found to be more specific than X-ray. Highest sensitivity when bedside ultrasound and radiography were used in parallel.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
foreign bodies in children.			X-rays also performed with radiologist blinded to ultrasound results and patient complaint.	9 radiopaque foreign bodies: bedside ultrasound detected 6 and 8 detected by X-ray. The 3 radiolucent foreign bodies recovered were undetected by X-ray and bedside ultrasound detected 2 out of 3	Best results for localizing and detecting soft tissue foreign bodies may be conducting bedside ultrasound first and then ordering X-ray. Limitations: small sample size, bedside ultrasound interpretation and technique,
Gibbs, T.S. (2006). The use of Sonography in the Identification, Localization, and Removal of Soft Tissue Foreign Bodies.	Retrospective Study Level IV	To determine effect US has on removal of soft tissue FB.	20 patients, 10 females, 10 males	X-ray 17 of 20 patients revealed FB in 8 patients: 4 inorganic and 4 metal. US located all 8 inorganic FB, 4 metal FB	US allows for smaller incision site and less traumatic injury to surrounding tissues. Decreased time to removal versus X-ray. US allows for post-removal imaging. US low cost, widely available, and should be the imaging modality chosen for wooden FB. Limitations: US is operator dependent. Size and depth of FB.
Graham, D.D. (2002). Ultrasound in the emergency	Case Report Level VI	Case reports demonstrating the use of ultrasound for	4 case reports Case 1: non-healing	Case 1: No X-ray, ultrasound detected 1.6cm x 0.12 cm	X-rays unreliable for wooden FB CT and MRI useful for detecting

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
department: Detection of wooden foreign bodies in soft tissues.		removal of wooden soft tissue foreign bodies in the ED.	draining wound to plantar surface of left foot after stepping on a stick Case 2: Draining puncture wound to right heel after stepping on object Case 3: Puncture wound to base of left toe after stepping on a toothpick Case 4: Pain and swelling to medial left thigh after playing on a wooden fence.	wooden FB Case 2: X-ray negative for FB; ultrasound detected 2.0 cm x 0.4cm wooden foreign body Case 3: no X-ray; ultrasound detected 2.0cm x 0.2cm piece of toothpick Case 4: no X-ray; ultrasound revealed 1.7cm x 0.4cm wooden FB	wooden FB CT double the cost of ultrasound MRI often not available and double the cost of CT Bedside ultrasound is comfortable for the patient and sedation is often not needed. If pts present with complaint of FB and X-ray is negative, ultrasound should be used. Limitation: type of study, ultrasound operator dependent
Harcke, H.T., Levy, A.D., & Lonergan, G.J. (2002). The Sonographic Appearance and Detectability of Nonopaque and Semiopaque Materials of Military Origin.	In Vitro Blinded Study Level III	To demonstrate characteristic US appearance of semi-opaque and non-opaque military FB fragments in an in-vitro model.	60 FB fragments embedded into turkey breast models Sonographers blinded to number, size and position of FBs Criteria for FB assessment on US: visibility, surface echogenicity, acoustic shadowing	58 out of 60 FB detected by US Sensitivity 96.7% and Specificity 100%	US has potential for detecting non-opaque and semi-opaque soft tissue FB of military origin. Limitations: operator dependent; tissue air source of error
Harcke, H.T. & Rooks, V.J. (2012).	Case Reports	Report of 5 cases using US to locate	5 cases of military origin with US used	US detected all metallic FB and	US useful as adjunct to X-ray for location and guided removal of

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Sonographic Localization and Management of Metallic Fragments: A Report of Five Cases	Level VI	metallic FB in wounds.	as an adjunct to X-ray for localization of metallic FB in wounds.	was also used to guide removal of FB	metallic FB Limitations: US operator dependent, type of study, no follow up data
Harris, E.J. (2010). Retained Hawthorn Fragment in a Child's Foot Complicated by Infection: Diagnosis and Excision Aided by Localization with Ultrasound.	Case Study Level VI	Case report of delayed detection and treatment of retained foreign body in the foot.	10 year old female retained FB in foot undetected by 2 radiologists on 2 MRIs, X-rays negative Patient admitted to hospital and US performed 7 weeks after initial injury	US located 0.5cm linear FB In OR hawthorn fragment removed from peroneus brevis tendon sheath	X-rays not beneficial for radiolucent FB MRI can detect FB but very expensive test and children often have to be sedated in order to lie still for exam US used for identification of FB smaller than 0.5mm US inexpensive and can be repeated without ionizing radiation exposure. US has short imaging time and no sedation required.
Hill, R., Conron, R., Greissinger, P., & Heller, M. (1997). Ultrasound for the detection of foreign bodies in human tissue.	Prospective Randomized Study Level II	To determine the sensitivity and specificity of foreign body localization using ultrasound by relatively inexperienced providers.	53 FB (wood & plastic) inserted into cadaver legs randomly based on a computer program. 80 test sites created. Control puncture sites also created. Examiners were blinded.	44 out of 53 FB detected with ultrasound for a sensitivity of 83% Wood FB detected 25 out of 27 (sensitivity 93%); plastic FB detected 19 out of 26 (sensitivity 73%). 11 out of 27	Ultrasound possibly may be used to detect superficial FB in soft tissue. Limitations: cadaver study, provider skill level, transducer size

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
				controls were false positives None of the FB (wood & plastic) were visible on X-ray	
Hollander, J.E., Singer, A.J., Valentine, S.M., & Shofer, F.S. (2001). Risk Factors for Infection in Patients with Traumatic Lacerations.	Cross-Sectional Study Level IV	To determine characteristics of traumatic lacerations associated with increased risk of infection.	5,521 patients with lacerations from 1992-1996 enrolled Various injuries caused by blunt objects, sharp objects, non-sharp glass, wood, and bites were investigated.	194 patients with wound infections Characteristics of lacerations with infections included visible contamination, FB, long length, wider, deeper and jagged appearance. Patient characteristics for increased infection risk included old age and history of DM.	Reducing contamination and removal of FB by healthcare providers decreases infection risk. Recommend future evidence based studies to prevent infection in high risk patients with traumatic lacerations.
Hung, Y.T., Hung, L.K., Griffith, J.F., Wong, C.H., & Ho, P.C. (2004). Ultrasound for the Detection of Vegetative Foreign Body in hand: A Case Report.	Case Report Level VI	Report of puncture wound to thumb with bamboo.	Initial X-ray and US negative Patient admitted and remained with swelling after IV antibiotics	US at 1wk after IV antibiotics positive for 2 FB At outpatient follow up 5 days later another US performed revealed additional FB	Non-healing wound, persistent pain, and draining wound should raise suspicion for retained FB. Wood and vegetative FB have potential to splinter and cause infection if retained in soft tissue. US reliable for detection of radiolucent FB.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
					Limitations: false positives, time consuming, operator dependent
Imoisili, M.A., Bonwit, A.M., & Bulas, D.I. (2004). Toothpick Puncture Injuries of the Foot in Children.	Case Series Level VI	Report of 5 children with toothpick FB in foot.	Review of medical records. X-ray negative for toothpick FB in all 5 cases thus early removal delayed	Delayed removal resulted in cellulitis and osteomyelitis (3 cases)	Blind probing during clinical exam can miss FB fragments X-ray poor for detecting nonradiopaque FB
Ipaktchi, K., DeMars, A., Park, J., Ciarallo, C., Livermore, M., & Banegas, R. (2013). Retained Palmar Foreign Body Presenting as a Late Hand Infection: Proposed Diagnostic Algorithim to Detect Radiolucent Objects	Case Report Level VI	Case presentation of two patients with wooden splinters in hand.	Both cases had negative plain film X-rays.	Authors created a diagnostic algorithm. Using their pathway on the case #2 pt with negative X-ray they found a 2.7mm wooden splinter with ultrasound.	Diagnostic Algorithm for radiolucent FB in hand. Recommend use of ultrasound for radiolucent FB due to no ionizing radiation and decreased cost.
Jacobson, J.A., Powell, A., Craig, J.G., Bouffard, J.A., & van Holsbeeck, M.T. (1998). Wooden foreign bodies in soft tissue: Detection at ultrasound.	Randomized Controlled Trial In vitro study Level II	Evaluate the effectiveness of ultrasound to detect wooden foreign bodies.	20 wooden toothpicks randomly inserted in cadaver soft tissue Ultrasound examiners were blinded to location of soft tissue foreign bodies	2.5 mm long foreign bodies: sensitivity 86.7%, specificity 96.7% 5.0 mm long foreign bodies: sensitivity 93.3%, specificity 96.7%, accuracy 92.3%, PPV 98.0%, NPV 83% 6 false negative	Ultrasound should be used when X-ray negative and a high clinical index of suspicion remains for foreign body. Ultrasound is relatively inexpensive and allows for imaging of vascular structures adjacent to the foreign body. Limitations: cadaver skin

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
				results and 1 false positive result	
Joint Commission on Accreditation of Healthcare Organizations. (2011). Radiation Risks of Diagnostic Imaging.	Expert Opinion Level VII	Recommendations to eliminate unnecessary radiation exposure.	None	None	US or MRI should be ordered instead of CT, X-ray, etc. when similar diagnostic results would be achieved to avoid unnecessary radiation exposure.
Kaiser, C.W., Slowick, T., Spurling, K.P., & Friedman, S. (1997). Retained Foreign Bodies.	Retrospective Study Level IV	To determine the occurrence and outcomes of retained FB in patients post treatment at an urgent care facility.	Review of closed medical malpractice claims	54 claims with 32 patients having retained FBs Glass most common FB (53%) X-rays performed on 6 of 17 (35%) patients with retained glass FB at initial visit 81% of patients with complaint of possible FB did not receive an initial wound exploration on clinical exam	Not performing X-ray on suspected glass foreign bodies particularly in hand wounds is dangerous practice. US should be next imaging modality if X-ray negative for glass FB CT should be performed if US negative or deep FB suspected
Konez, O., Nazinitsky, K.J., Goyal, M., Kellermeyer, S.A., Hissong, S.L., & Ciavererlla, D.P. (1999). Retrospective	Retrospective Study Level IV	Analysis of the cost-effectiveness of procedural guidance using ultrasound and CT.	2971 patients in 4 year period Ultrasound guidance used in 2782 procedures and 117 CT guided procedures	When compared to other community hospitals, ultrasound guided procedures saved Medicare patients approximately	Ultrasound saves physician time and hospital equipment costs compared to CT. Ultrasound is a safer procedure than CT due to the lack of ionizing radiation.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
cost analysis of ultrasound versus computed tomography-guided nonvascular invasive radiologic procedures at a community based hospital: A 4-Year experience.				$20,331	Ultrasound is portable and can be used at the bedside allowing for communication with the patient throughout the procedure.
Lee, G.P.C., Chung, K.L., & Kam, C.W. (2008). Ultrasound Guided Foreign Body Removal.	Case Study Level VI	Presentation of a case study of an adult patient examined at 3 different emergency departments for penetrating leg injury.	40 year old male with penetrating leg injury from wooden FB.	FB undetected during physical exam and wound exploration at 2 visits. 3rd visit US used and revealed wooden FB after negative X-ray.	US has ability to make correct diagnosis during the patient's initial presentation avoiding possible hospital admission and unnecessary tissue trauma from blind exploration. Limitations: US is operator dependent, tissue inflammatory changes can distort FB image
Leung, A., Patton, A., Navoy, J., & Cummings, R.J. (1998). Intraoperative Sonography-Guided Removal of Radiolucent Foreign Bodies.	Case Report Level VI	Report of preoperative and intraoperative use of US to detect wooden FB.	11yr old boy with splinter fragments to left thigh from sliding down wooden bannister Pt seen at ER same day of accident with few fragments of wood removed from wound. Returned following day due to continued pain.	X-ray negative for FB US detected wooden FB and was used intraoperatively to guide removal under real time imaging.	US for radiolucent FB beneficial preoperative and intraoperative. US guided removal of radiolucent FB intraoperative reduces OR time. Precise localization of radiolucent FB by US allows for reduced tissue trauma and wound healing time.
Levine, M.R., Gorman, S.M., Young, C.F. &	Retrospective Case Series	To describe the characteristics of patients, wounds and	Retrospective Case Series of patients presenting with	X-ray sensitivity for glass was 75.5%, metal	Physical exam and X-ray both should be performed to rule out FB.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Courtney, M. (2008). Clinical characteristics and management of wound foreign bodies in the ED.	Level VI	foreign bodies along with the management and patient discharge.	wound FB over a 2 year period in 2 separate emergency departments. A majority of the FB materials included wood (168), metal (134), and glass or ceramic (134) located in the upper extremities (58.2%) and lower extremities (36.3%).	98.6%, and wood 7.4%. Thus wooden FB were missed in 93% of cases and glass was missed in 25% of cases.	Ultrasound is a more sensitive imaging study for wooden FB. Approximately 90% of the FB identified in the ED were removed in the ED without surgical consultation. Limitations: type of study, ICD 9 codes may not have been representative of all wounds with FB
Levine, W.N. & Leslie, B.M. (1993). The use of ultrasonography to detect a radiolucent foreign body in the hand: A case report.	Case Report Level VI	Case report of ultrasound use to guide removal of a radiolucent FB.	Patient reports pain and swelling to right forearm. Relates he had a sterile glass pipette from the biochemistry lab strike him in the arm approximately 3 months ago.	Ultrasound revealed a 6mm piece of glass embedded in tendon.	Ultrasound is cost effective versus CT or MRI and is less time consuming. Recommend to study the extremity in multiple orientations while using ultrasound probe for scanning. Limitations: type of study, only one case report
Levsky, M.E., McArthur, T. & Abell, B.A. (2007). A Procedure for Soft Tissue Foreign Body Removal under Real Time Ultrasound Guidance.	Case Study Level VI	The report of ultrasound guided localization and removal of needle FB in toe.	16 year old female with complaint of stepping on needle which broke into 2 pieces leaving one piece embedded in right great toe X-ray positive for FB	FB visualized and removed under real time US guidance US revealed FB migrated from initial puncture wound site.	US allows for more precise localization and removal of FB

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Levy, A.D. & Harcke, H.T. (2003). Handheld Ultrasound Device for Detection of Non-Opaque and Semi-Opaque Foreign Bodies in Soft Tissues.	In Vitro Blinded Study Level III	To investigate the use of portable ultrasonography in the detection of soft tissue foreign bodies.	22 FBs divided among 2 turkey breasts FB material: plastic, fabric, rubber, wood, leather and plant fiber Sonographers blinded to number, dimensions and locations of FBs US Image Criteria: visibility, surface echogenicity, acoustic shadowing	All 22 FBs located with portable US 100% detectability rate US measurements of FBs differed from actual measurements	US may be employed for the detection of semi-opaque and non-opaque FB material not identified by X-ray. Limitations: turkey muscle did not allow for deep implanted FB, experienced sonographers with previous experience in using US on in vitro models
Lyon, M., Brannam, L., Johnson, D., Blaivas, M., & Duggal, S. (2004). Detection of soft tissue foreign bodies in the presence of soft tissue gas.	Prospective Randomized Study Level II	A determination of the effect soft tissue gas has on localizing foreign bodies using real time ultrasound.	Metal, glass and bone randomly inserted in turkey breasts. 10ml of air randomly injected around half of foreign bodies Investigators had knowledge of foreign body and air injection Those performing ultrasound unaware of location of foreign body or presence or absence of air	Sensitivity in locating foreign body 100% (48 out of 48) no effect by air/soft tissue gas	Ultrasound has advantage over X-ray for identifying both radiolucent and radiopaque foreign bodies. Ultrasound accurately predicts size, location, 3D structure, local anatomical structures and depth in real time. Soft tissue intramuscular gas has the potential to limit identification of type of foreign body due to the distortion of some of the usual characteristic signals emitted by certain objects such as glass. Limitations: turkey breast, small

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
			injection.		study group
Manson, W.C., Ryan, J. G., Ladner, H., & Gupta, S. (2011). Comparison of metallic foreign body removal between dynamic ultrasound and static radiography in a pigs' feet model.	Single-blinded, randomized, crossover study Level II	To determine if bedside ultrasound removal of soft tissue foreign bodies improves cosmetic outcome.	14 emergency medicine residents received Pins randomly embedded in pigs feet Residents used X-ray of pigs' feet and bedside ultrasound. Reviewers of cosmetic appearance post removal of pins blinded to imaging modality and resident identity.	14 residents removed 28 foreign bodies Ultrasound no different from X-ray for removal of metallic foreign body. .	Routine use of X-ray to locate foreign bodies is not indicated. Ultrasound favored for time. Additional studies needed regarding removal of foreign bodies under ultrasound guidance. Limitations: metallic foreign bodies, participants lacked ultrasound proficiency, cosmetics examined immediately after removal and no sutures could be placed in pigs' feet.
Manthey, D.E., Storrow, A.B., Milbourn, J.M., & Wagner, B.J. (1996). Ultrasound versus radiography in the detection of soft tissue foreign bodies.	Randomized, blinded descriptive study Level II	To determine the effectiveness of ultrasound and X-ray in identifying foreign bodies in soft tissue puncture wounds.	120 chicken thighs Types of FB: metal, wood, plastic, cactus spine, gravel and glass	Radiopaque objects detected 98% of time on X-ray	Limitations: FB too small to locate with ultrasound
McDevitt, J. & Gillespie, M. (2008). Managing Acute Puncture Wounds	Literature Review Level V	Literature review to guide the assessment and management of plantar puncture wounds.	None	None	US 95% sensitivity compared to MRI and CT for FB detection in foot trauma US useful for detecting nerve or tendon injuries and soft tissue

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
					abscess.
McGuinness, A., Snaith, B., Wilson, J., & Wolstenhulme, S. (2011). A Cohort Study to Evaluate Emergency Medicine Ultrasound by Non-Sonographers in Clinical Practice.	Cohort Study/ Prospective Non-Randomized Study Level IV	After EM providers attended 2 day US course, a questionnaire to determine clinical governance and US service provided was distributed.	Electronic questionnaire sent to 160 EM practitioners that had attended a 2 day emergency medicine ultrasound course	59 of 160 returned responses, 22 undelivered 51 of 59 (86%) responded that the 2 day training was adequate 73% using ultrasound in their practice	Debate continues on what constitutes adequate US training preparation. Wider national surveys recommended to capture best practices of US training guidelines and clinical governance.
Mizel, M.S., Steinmetz, N.D., & Trepman, E. (1994). Detection of Wooden Foreign Bodies in Muscle Tissue: Experimental Comparison of Computed Tomography, Magnetic Resonance Imaging, and Ultrasonography.	Experimental Comparative Study In Vitro Study Level IV	To compare the sensitivity of CT, MRI and US in the detection of wooden FB in muscle tissue.	Various sizes of wooden splinters first immersed in saline for either 3 days or 5 months then inserted into porcine shoulder both distant and near bone. US, CT and MRI conducted.	US and MRI more sensitive than CT for wooden splinters distant from bone regardless of length of saline soaking time for splinters. US sensitivity poor for splinters embedded close to bone. MRI best for small splinters close to bone.	US or MRI better than CT for identifying wooden splinters in muscle. Clinical application compared to foot since FB may be embedded in skin close to bone. Limitations: in vitro study lacks skin, blood flow, cellular metabolism and edema that could affect imaging. Study was not blinded and no control group
Mohammadi, A., Ghasemi-Rad, M., & Khodabakhsh, M. (2011). Non-opaque	Experimental Study Level IV	To evaluate the effectiveness of US at detecting radiolucent FB.	47 patients with soft tissue FB All patients with	US detected FB in 45 of 47 patients	US should be used in patients with suspected FB and negative X-ray

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Soft Tissue Foreign Body: Sonographic Findings			negative X-rays		
National Guideline Clearinghouse. (2010). ACR Appropriateness Criteria Acute Trauma to the Foot	Evidence Based Guideline Level I	Guideline	None	None	X-ray initial imaging modality US for radiolucent FB When X-ray negative US should be used as next imaging study
Ng, S.Y., Songra, A.K., & Bradley, P.F. (2003). A New Approach Using Intraoperative Ultrasound Imaging for the Localization and Removal of Multiple Foreign Bodies in the Neck	Case Report Level VI	A report of the use of US to guide surgical removal of FB.	28 year old patient with a 15cm laceration wound to chin and neck from grinder accident	US performed prior to surgical exploration, during surgical exploration and at the conclusion of surgery to ensure complete FB removal. FB smaller than 1mm detected.	US used to identify, locate and successfully remove FB during surgical exploration. Surrounding anatomical structures and vascular evaluation by doppler mode US imaging. US allows for real time imaging and post FB removal imaging. US minimizes operation time compared to blind probing exploration.
Nicks, B.A., Ayello, E.A., Woo, K., Nitzki-George, D., & Sibbald, R.G. (2010). Acute Wound Management: Revisiting the Approach to Assessment, Irrigation, and Closure Considerations	Literature Review Level V	Current evidence for wound management reviewed.	None	None	Best practices for wound management. Wound management is based on individual wound characteristics and location.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Nienaber, A., Harvey, M., & Cave, G. (2010). Accuracy of Bedside Ultrasound for the Detection of Soft Tissue Foreign Bodies by Emergency Doctors	Controlled Study Level III	To investigate the accuracy of emergency MDs in detecting soft tissue FB using US.	6 EM physicians and 14 EM trainees with various levels of US experience from novice to expert. All participants received 20 min training session. Using porcine belly FB of glass, sewing needle, splinter, plastic, and gravel were randomly inserted into incision sites.	400 US exams completed by 20 individuals EM physician: 96.7% sensitivity, 70% specificity, 76.3% PPV, 95.5% NPV Trainees: 85.7% sensitivity, 82.9% specificity, 83.3% PPV, 85.3% NPV	Newer trainees detected soft tissue FB with comparable accuracy to ER MD with extensive US experience Limitations: porcine tissue
Oikarinen, K.S., Nieminen, T.M., Makarainen, H., & Pyhtinen, J. (1993). Visibility of foreign bodies in soft tissue in plain radiographs, computed tomography, magnetic resonance imaging, and ultrasound.	Comparative Study Level VI	A comparison of X-ray, CT, MRI, and ultrasound in detecting various FB materials in cow tongue (simulates orofacial soft tissues).	Various FB materials embedded in cow tongue	Wood not visualized on any X-ray and fragments of wood were not detected on CT or MRI but ultrasound examination of wood showed size clearly. Best sensitivity and specificity results were with ultrasound which showed size and form of wood, composite,	Plain radiograph recommended as best method for identifying FB except wood. MRI visualizes soft tissues best but is very expensive and often unavailable. If FB not detected on X-ray then ultrasound or CT is indicated. Limitations: use of cow tongue and not human tissue

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
				amalgam, and glass.	
Orlinsky, M. & Bright, A.A. (2006). The Utility of Routine X-rays in all Glass-Caused Wounds.	Prospective Study Level IV	To determine if certain patients with glass-caused wounds benefit from X-ray.	Patients presenting with glass caused wounds over 2 yr period to level I trauma center ED. All patients underwent X-ray Providers blinded to X-rays results until clinical exam completed	167 patients with a total of 264 wounds X-ray beneficial in 12 of 264 wounds	X-ray beneficial in deeper glass caused wounds but not in superficial wounds that may be adequately explored during clinical examination.
Orlinsky, M., Knittel, P., Feit, T., Chan, L., & Mandavia, D. (2000). The Comparative accuracy of radiolucent foreign body detection using ultrasonography.	Prospective Study Level IV	Evaluate the use of ultrasound for locating radiolucent foreign bodies.	104 chicken thighs total Toothpicks inserted for FB Control group no FB Group randomized into 52 chicken thighs for 2 ultrasound machines	Accuracy rate 82% for ultrasound detecting radiolucent foreign bodies	Ultrasound accurately detects radiolucent (wood) FB. Limitations: chicken thighs used not human tissue, only 1 day of experiment
Ozsarac, M., Demircan, A., & Sener, S. (2011). Glass Foreign Body in Soft Tissue: Possibility of High Morbidity due to Delayed Migration.	Case Study Level VI	Report of migration of glass FB in lower back 12 years after initial injury.	Initial injury was fall onto glass door that shattered. X-rays not completed during initial injury. 2cm laceration repaired at initial	X-rays detected FB and plastic surgeon attempted removal which was unsuccessful. Under fluoroscopy ortho surgeon	Wound characteristics of retained FB include: mechanism of injury, location, material composition and shape of object. Inspection, palpation and exploration of the wound alone are insufficient to rule out FB.

Brief Citation	**Research Design/Level of Evidence**	**Purpose of the Study**	**Methods**	**Results**	**Recommendations Limitations**
			visit to ER. Months later soft tissue lump noticed at right scalpula border. 12 yrs later lump moved and now localized pain and soft tissue lump at T10 noted on clinical exam.	extracted glass FB	US has demonstrated efficacy in the detection and removal of FB regardless of infection, size, and time from injury decreasing multiple removal attempts and eliminating further tissue or structural injury.
Pattamapaspong, N., Srisuwan, T., Sivasomboon, C., Nasuto, M., Suwannahoy, P., Settakorn, J., Kraisarin, J., & Guglielmi, G. (2012). Accuracy of Radiography, Computed Tomography, and Magnetic Resonance Imaging in Diagnosing Foreign Bodies in the Foot.	Controlled Study Level III	To explore the accuracy of FB detection among X-ray, CT and MRI.	16 cadaver feet with a total of 160 FB various FBs composed of glass, porcelain, wood and plastic randomly inserted then frozen for 5-7 days X-ray, MRI and CT performed on thawed specimens Interpreting radiologists were blinded to FB location but knew the number of FB	X-ray detected 46 of 160 FB (29%), CT detected 101 (63%), and MRI detected 92 (58%) X-ray did not detect radiolucent dry wood, fresh wood or plastic X-ray did not detect 15 glass FB or 3 porcelain FB CT significant over MRI for detecting glass and fresh wood	CT and MRI high specificity (98-100%) but low sensitivity (29-63%) in the detection of FB in the foot. X-ray remains initial imaging modality recommended for FB even though may not detect all FB CT recommended for chronic retained or fluid/water soaked wood.
Paziana, K., Fields, M., Rotte, M., Au, A., & Ku, B. (2012).	Case Report Level VI	Report the use of ultrasound for identification of FB	2 adult patients with negative X-rays with complaints of FB.	US detected non-radiopaque FB and was used for	US allows for visualization of radiolucent FB along with nearby anatomical structures.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Soft Tissue Foreign Body Removal Technique using Portable Ultrasonography.		particularly in patients with negative X-rays.		guided removal of FB in both patients.	US allows for post removal images to ensure complete removal of FB.
Peterson, J.J., Bancroft, L.W., & Kransdorf, M.J. (2002). Wooden Foreign Bodies: Imaging Appearance.	Retrospective Review/Comparative Assessment Level IV	To identify imaging characteristics of wooden FB.	Retrospective review of 12 patients 7 females and 5 males, ages 10-65 All patients had X-ray. Other imaging: 9 US, 8 MRI, 3 CT, 1CT arthrography	No FB on X-rays FB visualized on MRI, CT and US	Wooden FB can be difficult to locate on MRI if they are small and no abscess or fluid collection exists. US best imaging modality for wooden FB but is often not used due to nonspecific patient complaints.
Pfaff, J.A. & Moore, G.P. (2007). Reducing Risk in Emergency Department Wound Management.	Expert Opinion Level VII	Overview of litigation surrounding wound management.	None	None	Wound management controversial with few evidence based guidelines exist. Failure to diagnose FB in wound common reason for malpractice.
Read, J.W., Conolly, W.B., Lanzetta, M., Spielman, S., Snodgrass, D., & Korber, J.S. (1996). Diagnostic Ultrasound of the Hand and Wrist.	Retrospective Chart Review Level IV	To assess the role of ultrasound and its efficacy in a variety of surgical conditions of the hand and wrist.	98 ultrasound examinations reviewed X-rays completed on all patients prior to US exam	18 patients with suspected FB US identified and located 9 FB in 12 cases proven in OR. US excluded FB in 5 cases. X-ray identified only 3 FB	US indicated when X-ray negative for FB Limitations: US operator dependent, US can have false positive results.
Rockett, M.S., Gentile, S.C., Gudas,	Retrospective Review	To demonstrate the use of ultrasound in	20 patients from 1986 to 1994	X-rays detected no FB in the 20	Ultrasound has the advantage over X-ray for providing length, width,

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
C.J., Brage, M.E., & Zygmunt, K.H. (1995). The Use of ultrasonography for the detection of retained wooden foreign bodies in the foot.	Level IV	localizing foreign bodies in the foot during acute, subacute and chronic phases.	X-rays completed on all patients prior to ultrasound	patients 10 patients with FB identified by ultrasound (all FB were wood)	depth and orientation of the FB. Ultrasound does not expose patient to ionizing radiation. Limitations: small sample size, study type
Roobottom, C.A. & Weston, M.J. (1994). The Detection of Foreign Bodies in Soft Tissue- Comparison of Conventional and Digital Radiography.	Comparative Study Level VI	To compare conventional and digital radiography in the detection of plastic and wood FBs.	Wood and plastic FBs inserted into porcine model 6 plastic FB types 7 wood FB types X-rays completed at initial insertion of FBs and at 14 and 24 hour post insertion	3 types of plastic invisible. Plastic visibility unchanged with time. Visibility of wood declined over time becoming invisible at 24 hours Fresh wood and thorns invisible on initial X-ray	Digital radiography demonstrates some improvement in FB visibility over conventional radiography but some plastics and wood remain invisible. US can be employed in certain instances with radiolucent material not visible on X-ray.
Royall, N.A., Farrin, E., Bahner, D.P., & Stawicki, S. P. (2011). Ultrasound-Assisted Musculoskeletal Procedures: A Practical Overview of Current Literature.	Literature Review Level V	Summary of the literature surrounding common musculoskeletal US procedures.	None	None	Evidence supports use of US to localize FB and identify nearby anatomical structures during the removal process. US allows real time 3D imaging of FB allowing for quick removal planning.
Rubin, G., Chezar, A., Raz, R., & Rozen, N. (2010). Nail	Retrospective Cohort Study	A description of patient characteristics and treatment	96 adult patients with nail puncture wounds through rubber soled	X-ray depicted 1 metal FB	US recommended for patients with nail puncture through rubber soled shoes.

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Puncture Wound Through a Rubber Soled Shoe: A Retrospective Study of 96 Adult Patients.	Level IV	strategies from a chart review of patients presenting with nail puncture wounds to the foot through rubber soled shoes.	shoes Outcome comparisons of surgery vs no surgery, DM vs no DM Independent t tests or Mann-Whitney test, Fisher's exact test	US revealed 9 FB in 22 patients	
Saboo, S.S., Saboo, S.H., Soni, S.S., & Adhane, V. (2009). High-resolution sonography is effective in detection of soft tissue foreign bodies.	Case Series Level VI	To examine the use and effectiveness of ultrasound in locating soft tissue foreign bodies in humans.	123 patients from 1999-2008 referred for ultrasound. 12 patients did not report for follow up thus 104 patients yielded data	Out of 104 cases, 91 had FB Ultrasound detected FB in 86 of 91 cases with FB Ultrasound for FB: Sensitivity 94.5% and specificity 53.8%; PPV 93.4% and NPV 58.3% with accuracy of 89%.	Ultrasound highly sensitive tool to aid in assessment for soft tissue foreign body. Limitations: type of study, when using ultrasound, calcifications, scar tissue, or air can create false positive results for FB in soft tissue
Salati, S.A. & Rather, A. (2010). Missed Foreign Bodies in the Hand: An Experience from a Center in Kashmir.	Retrospective Study Level IV	Review of patient cases reporting missed FB in hand.	61 cases of missed FB in hand from June 2003-May2009	18 patients with routine X-ray had missed FB Wooden splinters most common FB	US recommended as imaging modality for FB in hand. US suggested for accurate location of FB during surgical exploration yielding smaller incision sites.
Schlager, D., Lazzareschi, G., Whitten, D., &	Prospective Study Level IV	To determine the frequency, accuracy and type of US	ED MD received orientation and equipment	167 US studies over 1 year period	Real time US beneficial to locate and remove FB

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Sanders, A.B. (1994). A Prospective Study of Ultrasonography in the ED by Emergency Physicians.		studies performed over a 1 year period by ED physicians in a community hospital.	instructions and spent 4 mornings with US tech performing examinations. 3 US exams were mandatory proctored by radiologist and minimum of 6 negative studies were required to be submitted for evaluation	14 US studies labeled miscellaneous with 1 FB detection Other categories of US studies were performed by not relating to FB	7.5mHz transducer best for localization and removal of FB. Several questions recommended for further studies: does patient satisfaction increase with US use? Are procedures such as FB removal facilitated by US use? Does bedside US testing decrease patient cost and time?
Shepherd, M., Lee, J., & McGahon, M.C. (2007). Diagnostic Modalities for the Detection of Soft Tissue Foreign Bodies.	Literature Review Level V	Literature review of imaging modalities for soft tissue foreign bodies.	None	None	To detect soft tissue foreign bodies composed of metal, glass, or gravel, two view X-ray recommended. US recommended for vegetative material, splinters, thorns, and animal spines. FB undetected by X-ray but high index of suspicion then US or CT recommended. X-ray and US both recommended for plastic FB.
Shiels, W.E. (2007). Soft Tissue Foreign Bodies: Sonographic Diagnosis and Therapeutic Management.	Expert Opinion Level VII	Management of soft tissue foreign bodies to include localization and ultrasound guided removal of FB in muscle, tendon, and intra-articular spaces.	Based on author's 15 years of clinical experience with US guided localization and removal of over 400 FB in various locations.	US detection, FB characteristics, removal techniques, pitfalls, and outcomes described.	US beneficial for localization and removal of soft tissue FB. US safe and minimally invasive for FB localization and removal with no provider or patient exposure to ionizing radiation.

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					US allows for less painful and faster FB removal with smaller incision sites.
Shrestha, D., Sharma, U.K., Mohammad, R., & Dhoju, D. (2009). The Role of ultrasonography in detection and localization of radiolucent foreign body in soft tissues of extremities.	Retrospective Study Level IV	The use of ultrasound to detect radiolucent foreign bodies in soft tissue of the extremities.	23 patients presenting for radiolucent foreign body in the extremities received both ultrasound and plain radiographs (X-rays)	19 patients had radiolucent foreign body discovered by ultrasound No radiolucent foreign bodies were detected by plain radiographs (X-rays)	Ultrasound use for localization of foreign bodies allows for smaller incisions for removal and minimizes provider time. Limitations: all foreign bodies were wood. Study lacks randomization.
Sidharthan, S. & Mbako, A.N. (2010). Pitfalls in Diagnosis and Problems in Extraction of Retained Wooden Foreign Bodies in the Foot.	Case Report Level VI	The report of retained wooden FB in the foot after an initial surgical exploration with ultrasound used to locate and remove the retained FB.	Pt initially presented with 2wk history of wooden FB puncture to plantar right foot.	First provider ordered x-ray with negative results and wound was dressed and pt sent home with oral antibiotics. Return visit 2wks later wound with abscess and draining. I & D performed with removal of two wood pieces 2cm in length. 4wks later pt returns with discharge and scattered fragments of wood in wound. US now used to	Compared to CT and MRI, US is superior for detecting small wooden FB. X-ray with only 15% accuracy of detecting wooden FB Since wood has potential to splinter and US is beneficial for post extraction imaging.

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				assist in removing multiple splinters. Post op ultrasound performed to confirm complete extraction of FB.	
Singer, A.J. & Dagum, A.B. (2008). Current Management of Acute Cutaneous Wounds.	Expert Opinion Level VII	Recommendations based on randomized trials; small observational trials; or expert opinion	None	None	US or CT should be used for the detection of radiolucent FB. X-ray recommended for radiopaque FB To prevent missed FB in wounds recommend meticulous wound exploration and imaging as needed.
Soubeyrand, M., Biau, D., Jomaah, N., Pradel, C., Dumontier, C., & Nourissat, G. (2008). Penetrating Volar Injuries of the Hand: Diagnostic Accuracy of US in Depicting Soft-Tissue Lesions.	Prospective Study Level IV	To investigate the effectiveness of US at locating tendon, nerve and arterial injuries caused by penetrating lacerations.	Comparison of US examination by radiologist results to surgical exploration results 30 injuries in 26 patients Patients and surgeons blinded to US results	US detected all 17 tendon injuries, 14 of 16 arterial injuries, and 12 of 16 nerve injuries. FB found in 2 injuries. US depicted FB prior to wound closure.	US effective in detecting tendon and arterial injuries but poorly detected nerve injuries. US may save money related to hospitalization and unnecessary hand surgery
Soudack, M., Nachtigal, A., & Galtini, D. (2003). Clinically Unsuspected Foreign Bodies.	Case Series Level VI	To demonstrate the usefulness of ultrasound in patients presenting with soft tissue masses for FB identification.	288 patients with soft tissue masses evaluated No patients specifically complained of possible retained FB.	6 patients with 8 lesions: positive US for FB All underwent subsequent imaging (MRI, CT, bone and labeled	Positive sonographic findings for FB correlated with a positive clinical history for FB eliminates the need for further imaging studies. US should be first line imaging modality for superficial soft tissue masses regardless of complaint.

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				RBC scintigraphy) 3 patients had surgical exploration with FB in 2 patients	
Steele, M.T., Tran, L.V., Watson, W.A., & Muelleman, R.L. (1998). Retained Glass Foreign Bodies in Wounds: Predictive Value of Wound Characteristics, Patient Perception, and Wound Exploration.	Prospective Study Level IV	To determine characteristics useful in identifying high risk of glass FB retained in wounds.	164 pts with 185 total wounds Lacerations 87% wounds, Puncture wounds 13%	Retained glass in 28 wounds	Limitations: X-ray does not detect glass fragments smaller than 2mm in size and CT has not been shown to be better.
Teng, M. & Doniger, S.J. (2012). Subungal Wooden Splinter Visualized with Bedside Sonography.	Case Study Level VI	Case of pre and post imaging with US for visualization and removal of wooden subungal splinter.	10 year old presents with subungal wooden splinter	US used to identify, measure and aid in post removal imaging to verify complete removal of FB.	US can confirm FB presence regardless of opacity of material composition. Limitations: sonographer skill, scar tissue, calcified tissue, sesamoid bones can create false positive results
Tuncali, D., Yavuz, N., Terzioglu, A., & Aslan, G. (2005). The Rate of Upper-Extremity Deep-Structure Injuries through Small	Prospective Study Level IV	An investigation of tendon, nerve and artery injuries in the hand and forearm resulting from small penetrating lacerations.	226 patients with small penetrating lacerations caused by glass and knife Patients underwent next day and one	134 of 226 (59.3%) had at least one deep structure injury 124 of 134 (92.5%) had at least 1	Missed deep structural injuries can result from inadequate examination of small penetrating lacerations. Combination injuries to deep structures often include nerve, tendon, and arterial injury.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Penetrating Lacerations.			week follow up	tendon, 25 of 134 (18.7%) had at least 1 nerve, 20 of 134 (14.9%) had at least 1 artery 20 patients had combination injuries	Extensor tendon lacerations are common deep structural injuries.
Tuncer, S., Ozcelik, I.B., Mersa, B., Kabakas, F. & Ozkan, T. (2011). Evaluation of Patients Undergoing Removal of Glass Fragments from Injured Hands: A Retrospective Study.	Retrospective Study Level IV	To describe the management and removal of glass FB from the hand.	26 patients On clinical examination 12 patients had one or more glass FBs X-ray on 24 patients positive for FB	Under surgical exploration 46 glass FB removed	Minor small lacerations can be overlooked and have the potential to harbor FB or underlying structural damage. A negative physical examination alone with glass injuries to the hand does not rule out FB or underlying structural damage. Sensitivity for X-ray detection of glass FB decreases as the size of the FB is less than 2mm. The authors do not recommend blind probing of wounds in the hand. Limitations: retrospective study, routine X-ray not completed initially on all patients.
Turkcuer, I., Atilla, R., Topacoglu, H., Yanturali, S., Kiyan, S., Kabakci, N., Bozkurt, S., & Cevik,	Randomized, blinded, descriptive in vitro study Level II	The purpose of this study was to compare radiography and ultrasound in the detection of soft	40 chicken thighs with radiolucent foreign bodies (wood and rubber) embedded and 40	No wooden foreign bodies were detected on X-rays. 2 rubber foreign	If the foreign body is less than 2cm deep and radiolucent, ultrasound may be a better choice over plain radiography.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
A.A. (2006). Do we really need plain and soft-tissue radiographies to detect radiolucent foreign bodies in the ED?		tissue foreign bodies.	chicken thighs as control group with no foreign bodies embedded	bodies were detected on X-rays. 17 of 20 wood foreign bodies (85%) were detected by ultrasound and 19 of 20 rubber foreign bodies (95%) were detected by ultrasound	
Turner, J., Wilde, C.H., Hughes, K.C., Meilstrup, J.W., & Manders, E.K. (1997). Ultrasound-Guided Retrieval of Small Foreign Objects in Subcutaneous Tissue.	Comparative Study Level VI	To determine the ease of locating various FBs in chicken breast using US.	Chicken breast model with various FB materials inserted. X-ray and US imaging completed for comparison.	Wood most visible using US and metal less visible. On X-ray metal most visible with wood, plastic and glass more difficult to visualize.	Wood most easily identified by US with thin metal poorly identified. US has potential for use in identifying and locating radiolucent FB.
Vargas, B., Wildhaber, B. & La Scala, G. (2011). Late Migration of a Foreign Body in the Foot 5 Years after Initial Trauma.	Case Study Level VI	Case report of 11 year old with plantar granuloma.	Case Report	Initial injury was 5 years ago from stepping on glass and was repeatedly treated as lesion or plantar wart. US located FB and patient underwent surgery for removal.	US to identify FB is indicated for lacerations with unexplained or recurring soft tissue infection or repetitive episodes of inflammation or granuloma presentation or a delay in wound healing.
Wang, R. & Frazee, B.W. (2011). Visual	Case Report	Case report of the removal of a splinter	US used to identify and locate	US successfully located wooden FB	US useful for identification and localization of radiolucent FB.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Stimulus: Splinter Localization with Ultrasound.	Level VI	from right middle finger using ultrasound to visualize and locate.	radiolucent wooden FB in finger.	in right middle finger and was extracted intact.	
Wedmore, I.S. (2005). Wound Care: Modern Evidence in the Treatment of Man's Age-Old Injuries.	Literature Review Level V	Literature Review conducted	None	None	Increased risk for infection in traumatic wounds related to history of DM, old age, laceration width, wound contamination and foreign body. Routine X-ray of glass contaminated wounds recommended US successful at locating radiolucent FB (wood, plastic, vegetative material)
Weinberger, L.N., Chen, E.H., & Mills, A.M. (2008). Is Screening Radiography Necessary to Detect Retained Foreign Bodies in Adequately Explored Superficial Glass-Caused Wounds?	Literature Review Level V	A determination for the need for X-rays in superficial glass caused wounds.	None	None	3 prospective studies Superficial wounds not clearly defined 0.6%-4.3% wounds detailed in literature had retained glass FB on X-ray after clinical exploration Careful consideration should be given to patients with FB sensation, head or foot wounds, and MVC or puncture wounds.
Wu, T.S., Roque, P.J., Green, J., Drachman, D., Khor, K.N., Rosenberg, M., & Simpson, C. (2012). Bedside	Prospective Study Level IV	To explore the accuracy for the use of bedside US to detect tendon injuries.	34 patients US results compared to wound exploration in ED, wound exploration in OR or	US accurate in diagnosing tendon injury in 97% of patients 33 of 34 cases (Sensitivity 100%, Specificity	US can be used at bedside for assistance with physical examination decreasing time to diagnosis and discharge. US beneficial for wound exploration

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Ultrasound Evaluation of Tendon Injuries.			MRI results. US performed by ER MDs after 2 hr training session	95%) Physical exam detected 29 of 34 tendon injuries (86% of patients) (Sensitivity 100%, Specificity 76%)	locating FB for removal and minimizing tissue damage from otherwise blind probing attempts. Limitations: small sample size, nonrandomized, US operator dependent
Wyn, T., Jones, J., McNinch, D., & Heacox, R. (1995). Bedside Fluoroscopy for the Detection of Foreign Bodies.	Prospective, Randomized Masked Study Level II	To determine the detection of FB in meat cubes using portable fluoroscopy.	FB of glass, metal, wood, graphite, plastic and gravel randomly inserted into beef cubes. 4 cubes were controls with no FB. Total of 100 beef cubes ER MD blinded to FB type, location and controls.	300 observations Fluoroscopy detected 117 of 180 FB: sensitivity 65% All glass, metal and gravel were detected.	Beside fluoroscopy unable to detect wood or plastic FB.
Yen, K. & Gorelick, M.H. (2002). Ultrasound Applications for the Pediatric Emergency Department: A Review of the Current Literature.	Literature Review Level V	Review of the literature regarding US principles and its applications in the emergency department.	None	None	US beneficial for FB in superficial soft tissue when X-ray not appropriate.
Young, A.S., Shiels, W.E., Murakami, J.W., Coley, B.D., & Hogan, M.J. (2010). Self-Embedding Behavior: Radiologic Management of Self-Inserted Soft Tissue	Retrospective Study Level IV	Report on the clinical effectiveness of using imaged guided FB removal for patients with self-embedding behavior.	Database of 600 patients with 11 patients selected that had either US guided or Fluoroscopy removal of FB.	76 FB inserted into soft tissue arm, neck, ankle, foot and hand of 11 patients. Material of FB: metal, plastic,	US used to identify radiolucent FB. Image guided removal of FB less invasive and yields less scarring.

Brief Citation	Research Design/Level of Evidence	Purpose of the Study	Methods	Results	Recommendations Limitations
Foreign Bodies.				graphite, glass, wood, crayon, stone. 68 FB removed with US guided removal used for 43 FB, Fluoroscopy for 15 FB and combination of both for 10FB	
Zehtabchi, S., Tan, A., Yadav, K., Badawy, A., & Lucchesi, M. (2012). The Impact of Wound Age on the Infection Rate of Simple Lacerations Repaired in the Emergency Department.	Literature Review Level V	Address the research question regarding increased infection risk with primary closure of wounds outside of the "golden period"	Literature review of prospective observational study or randomized controlled trials	None	Correlation between wound location and increased risk of infection. Further research needed wound location and wound age. Limitations: No standardized cutoff parameters for "golden period" exists