Implementation of Pediatric Shoulder Ultrasound at the University of Virginia Medical Center

Amy Dela Cruz

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The Implementation of

of Pediatric Shoulder

Ultrasound at the

University of Virginia Medical Center

A Research Paper Presented to the Graduate Faculty of the Department of

STEM Education and Professional Studies

Old Dominion University

In Partial Fulfillment of the Requirement for the Degree of Master of

Science in Occupational and Technical Studies

Amy Dela Cruz

July, 2010
This research paper was prepared by Amy Dela Cruz under the direction of Dr. John M. Ritz in OTED 636, Problems in Occupational and Technical Education. It was submitted to the Graduate Program Director as partial fulfillment of the requirements for the Master of Science in Occupational and Technical Studies.

Approved by: ______________________________   ____________

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Graduate Program Director

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Old Dominion University
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Amy Dela Cruz
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Chapter I

Introduction

The uses for ultrasound have exponentially grown over the last ten years. Because of advances in technology, imaging babies and gallstones are no longer the cornerstone to this modality. One of the more recent uses for ultrasound is the evaluation of musculoskeletal anatomy, which includes bone, muscle, ligaments, and tendons. Traditionally, the musculoskeletal anatomy has been evaluated by X-ray and MRI.

The general ultrasound division at the University of Virginia Medical Center services many pediatric physicians to include orthopedic surgeons to the primary care physician. This division is the primary source for pediatric general ultrasound imaging due to the fact that the two imaging facilities associated with the medical center do not perform pediatric ultrasound.

Musculoskeletal (MSK) ultrasound within this division at UVA Medical Center has been limited to primarily the evaluation of hip dysplasia, but with great success and reliable results. Shoulder anatomy is very similar to that of hip anatomy, both being ball and socket joints. Pediatric shoulder ultrasound has been slower to be developed and utilized, with most physicians relying on x-ray and MRI for evaluation of this anatomy. If the sonographers could be trained to proficiently evaluate pediatric shoulder anatomy, in many cases physicians could begin their diagnostic process with a non ionizing, low cost ultrasound and possibly by pass MRI studies altogether.
The goal of this study was to implement pediatric shoulder protocols at the University of Virginia Medical Center general ultrasound division. With this implementation pediatric orthopedists would have an alternative to radioactive studies in the evaluation of pediatric patients with shoulder anomalies and infections.

Statement of the Problem

The goal of this study was to implement pediatric shoulder protocols in the general ultrasound division at the University of Virginia Medical Center.

Research Goals

To guide this study the following research questions were established:

RQ1 Was it possible to effectively visualize the anatomy of the pediatric shoulder with ultrasound?

RQ2 Was ultrasound effective in determining dysplasia and/or subluxation of the pediatric shoulder based on predetermined measurements and protocols?

RQ3 Was ultrasound of the pediatric shoulder anatomy effective in evaluating patients with possible brachial plexus injury?

RQ4 Was it possible to formulate ultrasound protocols for the evaluation of pediatric shoulder anatomy?

Background and Significance

Musculoskeletal ultrasound has been a developing modality for many years, but only in the past few years has gained the reputation for accurate and reliable diagnosis. As recent as 2007, one of the major governing bodies of ultrasound, the American
Institute of Ultrasound in Medicine (AIUM), published guidelines for MSK scanning and guided biopsies. The variable that has put MSK ultrasound imaging in the forefront is the advance in technology that has taken place just within the last five years. Ultrasound resolution and techniques such as tissue harmonics have helped decrease the number of MRI studies to evaluate the same areas of anatomy (Moore & Pinzon, 2009).

Dysplasia of ball and socket joints is a pathology that many babies are born with whether through traumatic birth, breech presentation in utero, or a congenital anomaly. Hip dysplasia has been diagnosed and followed up by sonography for years (Grissom & Harcke, 2001). Shoulder anatomy evaluation has been limited thus far, especially in the United States, but holds the potential to be just as effective as pediatric hip ultrasound.

Multiple reasons exist for using ultrasound to evaluate shoulder anatomy of infants and children, and with the research and data from this study ultrasound can be confirmed as a screening tool and diagnostic imaging modality for pediatric shoulder anatomy. The pediatric patient is most amenable to ultrasound. These patients are smaller with bones that are not completely calcified and still made of cartilage, making penetration easier, lending to optimal visualization. No radiation is used in ultrasound versus x-ray and CT, which is especially important for children. Recent research shows the culmination of radiation over years can increase the risk of many cancers. Most pediatric patients need to be sedated to have a CT or MRI, adding to the risk of the exam. Parents can stay with their children during the ultrasound exam, reducing stress for both the child and parent. Cost of the exam is crucial in these times of health care
reform and high priced exams. The ultrasound examination is a fraction of the cost of MRI (Keller, 2005).

Patients come from many states to receive treatment at the pediatric orthopedic department at the University of Virginia Medical Center. This clinic is nationally known for treating pediatric diseases and anomalies. Implementing pediatric shoulder protocols in the general ultrasound division at the University of Virginia could be extremely beneficial to both the pediatric patient and physicians treating these patients. The doctors could have an alternative to expensive and time consuming tests and the patient could have the ease of a timely ultrasound without the exposure to radiation and sedation medication.

Limitations

The following were limitations during the course of the study:

1. Findings and protocols will be limited to what can be visualized by ultrasound.
2. Information will be gathered from only one facility, limiting the number of patients that will be examined.
3. Exams are limited exclusively to pediatric patients in the age range of 1 to 12 months.
4. Procedure can only be performed on patients who are cooperative.
Assumptions

The following are a list of assumptions made about the research study:

1. All sonographers are capable of performing quality shoulder ultrasound exams.
2. Pediatric shoulder anatomy will be visualized and evaluated by ultrasound.
3. Protocols will be able to be formulated based on the gathered information from sonograms performed on pediatric shoulder anatomy.
4. Degree of subluxation will be determined from calculated measurements formulated by data gathered from sonograms performed on pediatric shoulder anatomy.
5. Pediatric shoulder protocols will be effective in helping to diagnosis and follow up patients with a possible diagnosis of brachial plexus palsy.
6. Shoulder ultrasound exams that are not ordered specifically by the physician must have written consent by the parent or guardian.
7. All sonographers will follow written protocols.
8. Physicians will utilize ultrasound as a viable option to scanning the pediatric shoulder anatomy.
Procedures

Previous to involvement of the entire ultrasound department, two steps were taken to prepare for the study. First, the Institutional Review Board was petitioned to obtain a consent form to scan patients who would be asked to participate in gathering data on the ultrasound of pediatric shoulder anatomy. Secondly, patients were scanned to obtain information on anatomy, positioning, and proper ultrasound angles and techniques. Data from the ultrasounds were assessed on first the ability to visualize the anatomy. Secondly, it was determined if appropriate positions were able to be obtained during the scanning. Lastly, the measurability of the angle between the scapula and humeral head was assessed. Based on the data gathered the next step was to formulate pediatric shoulder protocols and approval by the pediatric radiologist was obtained. Items included in the protocols were basic shoulder anatomy, scanning planes, anatomical positioning, and images obtained in each plane and position. Physicians were notified that the ultrasound division would begin to evaluate pediatric shoulder anatomy if they needed to refer a patient for that type of study.

Patients coming to the department for other exams were asked to consent to a fifteen to twenty minute scan of the shoulder anatomy. Because of the limited number of this population the permission was granted to perform shoulder ultrasounds on consented infants in the newborn nursery. The pediatric radiologist was called to be present and assist in the exam if needed. As information was gathered the protocols were adjusted accordingly. All infants scanned had normal shoulder anatomy. The
research period did not allow enough time to test the new pediatric shoulder protocols on abnormal shoulder anatomy or patients with suspected Erb’s Palsy.

Definition of Terms

The following are a list of terms and definitions relevant to the study:

1. Abscess – collection of pus in a body cavity usually as a result of an infection
2. Anomaly – anything that is abnormal
3. Brachial Plexus – series of nerves in the shoulder and arm
4. Congenital – something one is born with
5. Diagnostic – able to identify a problem
6. Hyperemia – excess of blood
7. Hypothermia – low body temperature
8. Magnetic Resonance Imaging (MRI) – an imaging modality that uses electromagnetic radiation to visualize anatomy
9. Musculoskeletal (MSK) – study of bones, tendon, and ligaments
10. Osteotomy – incision of the bone
11. Subluxation – partial dislocation
12. Ultrasound – an imaging modality that uses sound waves to produce images of anatomy
Overview of Chapters

Chapter I has given a brief explanation and history of musculoskeletal ultrasound with an emphasis on the benefits of pediatric musculoskeletal ultrasound. The goal of this study was to formulate and implement pediatric shoulder protocols in the general ultrasound division at the University of Virginia Medical Center. Data were gathered from a population of pediatric patients consenting for a shoulder sonogram and a protocol was developed. Pediatric patients could benefit from an expansion of this modality because of factors such as no radiation or sedation, low cost, and comfortability of exam. The high number of pediatric patients at the University of Virginia Medical Center could be serviced greatly by an implementation of ultrasound pediatric shoulder protocols.

Chapter II, Review of the Literature, supported the need for pediatric shoulder protocols through research and literature already established on the subject. Topics included were the advances in musculoskeletal ultrasound and methods of visualization and evaluation of shoulder anatomy. Pediatric diseases and anomalies that can affect shoulder anatomy were discussed and how ultrasound can be used for diagnosis and follow up care. Chapter III will describe the methods and procedures that were followed to obtain the data about pediatric shoulder anatomy, implementation of the protocols, and assessing the data. Chapter IV will review the findings of the data gathered and the use of this data in developing protocols. Chapter V will summarize the findings of the
study. Conclusions were formulated from the gathered data, and recommendations for any further research that may enhance this study were given.
Chapter II

Review of Literature

Ultrasound is the use of sound waves transmitted into the body to produce images of anatomy. Ultrasound is mostly used to visualize soft tissue and internal organs because the sound waves can penetrate this type of structure. Historically, ultrasound has not been widely used to diagnosis conditions of the bones due to the fact that sound waves cannot penetrate the calcification of a bony structure. When this is the case, no sound waves are transmitted back to the machine for the production of a diagnostic image (Kremkau, 1998). For this reason, ultrasound imaging of the musculoskeletal system, bones, ligaments and tendons, has been limited until recent years.

Advancements in Musculoskeletal Ultrasound

The movement of musculoskeletal ultrasound has come about through several different reasons. One of those is the advancement of ultrasound technologies to include higher resolution transducers. Recent years have led to improvements in the linear transducers and higher megahertz probes. The increased resolution generated by a higher megahertz transducer is optimal in evaluating the joint capsule for fluid collections and abscesses because the depth of this anatomy is not as great as that of internal organs. Also enabling improved musculoskeletal imaging are advances in beam steering. Superior imaging is achieved by producing a picture from many different angles versus a single angle. Tissue harmonic imaging is another advancement in technology that improves scanning of the musculoskeletal system. Tissue harmonics
uses all the sound waves and the corresponding harmonics to produce an image. Essentially, this adds more quality information to the image, thus producing an image with more diagnostic details (Klauser & Peetron, 2009).

Benefits of Ultrasound

Health care trends are also causing ultrasound to be a leading diagnostic tool. Recent research is promoting a concern in the accumulation of radiation over a person’s lifetime. Increased risks of some cancers have been linked to excessive radioactive imaging. For obvious reasons the pediatric physicians are becoming more aware of this danger and the long term affect on their patients. Alternate sources of diagnosis have been investigated and one of those is ultrasound because of the lack of radiation in this type of study. Another health care trend is cost cutting. A number of hospitals are seeing the impact of decreased health dollars. Lower cost exams, like ultrasound, may be a sound financial alternative to CT and MRI, which can cost thousands of dollars more than a sonogram.

New techniques for scanning pediatric patients have brought about an increased usage of ultrasound in the evaluation of bony structures. Joint evaluations are especially successful in pediatric patients. Infants lack ossification in their bones, which means more cartilage exists in these bony joints then actual calcified bone. The cartilaginous tissue is amenable to ultrasound because of the ability of the sound waves to still penetrate this type of structure. Also being of a benefit, is the fact that the anatomy of the pediatric patient is small, helping with penetration and extending the field of view possible on the ultrasound image (Keller, 2005).
Ultrasound offers other benefits to the pediatric patient. One of the most important reasons for doing an ultrasound versus a CT or MRI is the lack of radiation. Ultrasound uses sound waves to produce the image. These sound waves have proven to not be harmful to the body. The majority of pediatric patients must be sedated to have a CT or MRI because of the need for them to be still during the exam. Risks are always associated with the use of any drugs. Having a sick child is stressful for any parent. Staying with their child during the ultrasound can help to relieve some of the stress and place the parent and child in a comfortable atmosphere. Ultrasound is also a dynamic imaging modality. The ability to move the anatomical part during visualization is crucial to the diagnosis of joint abnormalities such as dysplasia and subluxation (Ezaki & Zang, 2008).

Ultrasound Joint Evaluation

The ultrasound evaluation of pediatric ball and socket joints, in particular the hip joint, has been well respected for years. Infants presenting with breech presentation at birth have a significant risk of having hip dysplasia. This condition causes the head of the femur to not sit correctly in the acetabulum, either positioning at a shallow angle or being completely dislocated. When diagnosed early, the infant can be placed in a harness to stabilize the hip joint. A good prognosis usually comes with this treatment.

The shoulder is a ball and socket joint similar to the hip. The humeral head sets in the glenoid which is at the end of the scapula. This is comparable to the head of the femur sitting in the acetabulum creating the hip joint. The humeral head should align with the scapula, seen as a bright echogenic line leading up to the head. If subluxation
occurs part of the humeral head will appear posterior to the line of the scapula and the posterior margin or lip of the glenoid will be rounded. Total dislocation can be recognized when the entire humeral head is posterior to the scapula. This type of evaluation can be accomplished through scanning the posterior aspect of the shoulder. Internal and external rotation during scanning will evaluate if the humeral head stays in contact with the glenoid and is properly aligned during movement (Ezaki & Zhang, 2008).

**Ultrasound Techniques for Shoulder Joint Evaluation**

Grissom and Harcke (2001) studied both anterior, posterior, and coronal scanning angles to obtain diagnostic images of the pediatric shoulder. Static and dynamic images were taken, totaling seven angles in all. Their studies have shown that the transverse views both anterior and posterior are advantageous for alignment of the humeral head. The anterior view shows the humeral head sitting on top of the glenoid when normal. The posterior view shows the alignment of the scapula with the humeral head. Internal and external rotations were shown to be beneficial in the transverse posterior position. The longitudinal view directly over the shoulder at the edge of the arm was best when visualizing fractures of the humerus. Grissom and Harcke (2001) advised using the coronal approach for evaluation of the soft tissue for fluid collections or infection.

Subluxation may not always be black and white, with slight dysplasia being missed by just a casual viewing of the images. Measurement of the alignment of the joint is what will be crucial for proper diagnosis. To add a component of validity to the
pediatric shoulder ultrasound for subluxation or dislocation, Browne et al. (2007) developed a procedure of measuring the angle of the head of the humerus in relation to the scapula. This alpha angle is “...formed by the intersection of a line along the posterior scapular margin and a line tangent to the humeral head passing through the posterior osseous lip of the glenoid” (Browne et al., 2007, p. 1711). For the shoulder joint to be sitting correctly in the glenoid this angle should be ≤ 30 degrees. Another measurement of validity is an angle to measure the posterior displacement of the humeral head. “This measurement is calculated by taking the distance from the posterior scapular line to the posterior margin of the head, divided by the greatest diameter of the humeral head and multiplying by 100” (Browne et al., 2007, p. 1711). The midline of the humeral head should line up with the scapula, so ≤ 50 would indicate the humeral head is sitting correctly in the glenoid. Carter et al. (2004) did not incorporate a specific measurement for the amount of the humeral head below the scapula. In their research they visually estimated if the center of the humeral head was lined up with the scapula.

When Browne et al. (2007) studied their data they concluded that the measurement of the alpha angle between the margin of the scapula and the lip of the glenoid to be the most reliable. When reading physicians were knowledgeable about the anatomy and the measuring of the angle the results were easily reproduced with consistency by multiple physicians reading the ultrasound. Of course, the physicians were also relying on sonographers to be consistent with their imaging and protocols. MRI and CT will always be superior in evaluating tendons, ligaments, and the invasion of
tumors in the shoulder. Discussion at the end of the study revealed the benefit of ultrasound as a screening tool in the diagnosis of subluxation or dislocation of the humeral head and abnormalities of the glenoid in patients less than a year old (Browne et al., 2007).

Joint Effusions and Ultrasound

Tissues around the shoulder joint can also be visualized with ultrasound. Joint effusions are particularly amenable to ultrasound evaluation in both adult and pediatric patients. A joint effusion is an abnormal amount of fluid around the joint. In pediatric patients this is most likely due to an infectious process, unlike adults who can get joint effusions from arthritis.

Sources of infections are many and can be difficult to diagnosis. The infant will often present with a flaccid limb. In children an infection is many times a product of osteomyelitis, which is an infection of the bone. The infection can be contained to one area or spread throughout the body. Osteomyelitis can be asymptomatic except for pain at the site which becomes a problematic diagnosis with a patient who is not yet old enough to speak. Even though osteomyelitis is an infection of the bone it can spread to the surrounding soft tissue. When a limb is affected symptoms may include tenderness, swelling, and limited movement. Fever can be a symptom but is unreliable. “At least 15% to 25% of newborns with sepsis present with hypothermia rather than a fever because of thermoregulatory dysfunction” (Sankar et al., 2009, p. 114).

Radiographic studies are the usual first line of imaging, but ultrasound has proven to be helpful in the evaluation of the affected areas of soft tissue. Fluid collections or
abscesses may form around the bone (King & Johnson, 2009). If the infection has progressed far enough ultrasound may see “...peritoneal elevation of the infected bone and deep soft tissue inflammation” (Keller, 2005, p. 1172). Also as an aid to the diagnosis, is hyperemia shown at the site of the infection by color doppler. Infection will increase the blood flow to the area which is shown by increased color perfusion when color doppler is applied to the area. When assessing areas with color or power doppler, one must be certain to apply appropriate technical settings to ensure an optimal Doppler image. Some of the factors that will affect the diagnostic quality of this image are scale setting, small color box, pulse repetition frequency settings, and appropriate wall filters (Klauser & Peetrons, 2009). The benefit of ultrasound can extend beyond just visualizing the area. The fluid can be drained through the use of ultrasound guided needle aspiration (Keller, 2005). For soft tissue evaluation Grissom and Harcke (2001) recommended the coronal view, which is from the top of the shoulder.

Erb’s Palsy and Ultrasound Evaluation

Pediatric shoulder joint abnormalities often come with trauma during birth. If excessive pulling on the neck and shoulders are applied during birth a brachial plexus injury can occur. Initially the infant will present with a weak or flaccid arm. This type of injury produces impairment of the nerves which in turn leads to muscular imbalance in the shoulder anatomy. The weak muscles do not support the shoulder joint and in turn the joint will not form properly. “Glenoid dysplasia and posterior shoulder subluxation with resultant shoulder stiffness is a well-recognized complication in infants with neonatal brachial plexus palsy” (Carter et al., 2004, p. 788).
Symptoms of brachial plexus palsy, otherwise known as Erb’s Palsy, are varied and change over time. Initially, the infant will appear to have abnormal or even lazy movement of the affected side. A clicking sound might be heard with internal and external rotation. Asymmetric arm folds may be noticed right away or within the first few weeks of life. Over the course of the first few months the upper arm segment of the affected side will become shorter than the contra lateral normal side. With this comes the inability to easily externally rotate the shoulder. A dislocated shoulder can cause a palpable prominence of the subcutaneous tissue over the posterior shoulder (Carter et al., 2004).

When brachial plexus palsy is suspected the baby will be followed up in about three months because this is the normal recovery period. Some infants will recover on their own with no need of intervention (Jaramillo et al., 1998). Early intervention is especially important for the pediatric patient because deformities can occur much quicker than in adults. Before the use of MRI and CT, radiographs were the first imaging test ordered to diagnosis dislocation of the shoulder joint. The x rays were often non diagnostic in showing slight dislocation of the humeral head, mostly because of the lack of ossification in the bones. This factor works as an advantage to ultrasound (Hughes et al., 1998). Ossification can be delayed in children with dysplasia making ultrasound effective for even older children who normally would not be evaluated as well with ultrasound (Grissom & Harcke, 2001). Research by Carter et al. (2004) references studies that indicate a possibly higher incidence of shoulder dislocation or subluxation in brachial plexus palsy patients than some doctors have suspected. Kocher and Sarwark
(2004) studied 84 children diagnosed with Erb’s Palsy, with 61% of them having some shoulder pathology. The tendency in the research shows that many cases have gone undiagnosed and the patient is left with arm and shoulder disabilities. Some of the error here came with the non diagnostic quality of x rays for this type of abnormality (Carter et al., 2004).

Surgical intervention is often suggested for patients with brachial plexus palsy. Tendon transfers and osteotomy are possible to increase stability of the glenohumeral joint. In surgical cases, an MRI may be necessary to evaluate the articular cartilage around the shoulder joint. Jaramillo et al. (1998) describe the glenocapular angle measured on MRI images as the standard for subluxation and dislocation of the shoulder joint. This angle is the same as the one explained by Browne et al. (2007) used in the ultrasound examination.

Summary

The Review of Literature presented an overview of the uses of ultrasound in the evaluation of pediatric shoulder anatomy. Technology advancements and benefits of ultrasound were discussed. Previous research of proper ultrasound techniques for shoulder anatomy and how these techniques could be applied to pediatric patients were reviewed. Anomalies and pathologies that could affect the pediatric shoulder were described along with benefits of diagnosing and following up these patients through the use of ultrasound.
Chapter III, Methods and Procedures, will be presented next. The information in Chapter III will describe the methods by which data were gathered and analyzed. Procedures for analyzing the data to formulate and implement protocols will follow.
Chapter III

Methods and Procedures

This chapter describes the methods and procedures used to perform this research study. The data were collected from forty pediatric patients coming for an ultrasound at the University of Virginia Medical Center. This chapter will give a more detailed explanation of data collection and will include the following sections: population, instrument design, methods of data collection, statistical analysis, and summary.

Population

The population for this study was pediatric patients one year old or less coming to have an ultrasound examination in the general ultrasound division at the University of Virginia Medical Center. Because of the limited number of this population, permission was granted in the later stages of the research to perform shoulder ultrasounds on consented infants in the newborn nursery. Eligibility was dependent on the guardian or parent signing a consent form and the cooperation of the infant. None of the patients were suspected to have shoulder anomalies because of the need to set standard normal protocols. The number of patients needed for this study was determined by information gathered and repetition of normal anatomy to in order to justify standard protocols.

Instrument Design

The ultrasound examination was the instrument used to collect data. Several scanning techniques were employed to visualize the shoulder anatomy. The first
scanning technique was performed with the patient in the supine position with the ultrasound transducer in a transverse position over the area of the shoulder. The second scanning technique was also with the patient in a supine position with the ultrasound transducer over the same anatomical area but in a longitudinal plane. The patient was then put into the prone position for the third scanning technique while the shoulder anatomy was scanned in a transverse plane. The fourth scanning technique for data collection was also with the patient in the prone position but with the transducer in a longitudinal position. In each of these positions dynamic scanning took place with the arm being either abducted or adducted or internally or externally rotated. A coronal scanning technique was also employed with the patient in the supine position.

Methods of Data Collection

The previously described ultrasound examination was performed on nine pediatric patients of less than one year of age. A sonographer and pediatric radiologist were present and participating in each exam. Pertinent shoulder anatomy for each scanning technique was defined. Each scanning technique was performed to determine how well shoulder anatomy was visualized. Information was also gathered to determine which view would be useful in diagnosing the degree of subluxation of the shoulder joint.

Statistical Analysis

During the course of the research images were consistently reviewed to determine which patient positions and scanning techniques would provide diagnostic images of the shoulder anatomy. Shoulder images that could be used to measure
degrees of subluxation were also defined. These measurements were applied to the images post processing and tested for reliability.

Summary

Chapter III described the methods and procedures by which the data for this research study were collected. Nine pediatric patients at the University of Virginia Medical Center were given an ultrasound examination of their shoulder anatomy to determine the scanning techniques that would be most useful to produce diagnostic quality images. Chapter IV will describe the findings of this study.
CHAPTER IV

Findings

The goal of this study was to implement pediatric shoulder protocols in the general ultrasound department at the University of Virginia Medical Center. This chapter will describe the data gathered throughout the research process. The data were used to determine the best possible scanning techniques to utilize when visualizing and evaluating shoulder anatomy of the pediatric patient of less than one year of age.

Response Rate

Rate of participants was determined by the number of pediatric patients less than one year of age having other ultrasound exams. This number was variable and unpredictable. Another factor in response rate versus actual patients scanned was that several of the babies were unable to cooperate, or scanning time was limited due to level of cooperation. These factors are inherent in pediatric research. Because of population numbers being so low and lack of cooperation, the researcher requested a change in protocol to include healthy babies born in the newborn nursery. This request was granted late in the research process. In total nine patients were scanned that were cooperative and from which information was gained during the exam.

Visualization of Anatomy

The first research question posed by this study was to determine if ultrasound could effectively visualize pediatric shoulder anatomy. Five scanning techniques were tested. The first scanning technique was with the patient supine and the transducer in a
transverse orientation directly over the shoulder. This anterior transverse scanning technique produced an image that displayed the humeral head sitting anterior to the glenoid (Figure 4.1). The second scanning technique was with the patient supine and the transducer in a sagittal orientation aligned with the humeral head and humeral shaft. This anterior sagittal scanning technique produced an image that displayed the humeral head and the line of the humeral shaft (Figure 4.2). The third scanning technique was with the patient prone or in a lateral decubitus position and the transducer in a transverse plane aligned with the scapular margin and humeral head. This posterior transverse scanning technique produced an image that displayed the humeral head at the end of the scapular margin cupped medially by the glenoid (Figure 4.3). The fourth scanning technique was with the patient in a prone or lateral decubitus position and the transducer oriented sagittally with the humeral head. This posterior sagittal scanning technique produced an image that displayed the humeral head sitting anterior to glenoid (Figure 4.4). The fifth and final scanning position was with the patient in a right lateral decubitus (RLD) or a left lateral decubitus position (LLD) and the transducer in a coronal plane from the superior aspect of the shoulder aligned with the scapular margin and humeral head. This scanning position was found to result in non visualization of the shoulder anatomy.

In all patients shoulder anatomy could be visualized in some form in the first four scanning planes. The fifth scanning plane, which most closely correlated with views taken by a CT scan described by Jaramillo et al (1998), showed no shoulder anatomy.
Levels of ossification varied depending on age. Resolution also varied depending on the size of the infant. Both of these factors did affect the clarity of visualization.

**Determining and Measuring Degree of Dysplasia**

The second question posed by this research was whether or not ultrasound could be effective in evaluating dysplasia of the pediatric shoulder joint. Images and data were gathered to produce a protocol image on which a measurement of subluxation could be determined. One scanning position was determined to produce images with reliable measurements for subluxation. The transverse image with the patient prone or in a lateral decubitus position produced an image of the humeral head sitting in the humeral socket at the end of the scapular margin. An angle was formed between a parallel line drawn along the margin of the scapula and a line drawn along the slope of the glenoid. The average of the measured angles was determined to be 108.17 and the standard deviation of these measurements was 4.9.

**Evaluating Patients with Brachial Plexus Palsy (Erb’s Palsy)**

The third question posed by this research was the effectiveness of ultrasound in evaluating patients with Erb’s Palsy. Because of the rarity of this abnormality and the time frame of this research no patients with possible Erb’s Palsy were referred to the ultrasound department, and thus the researcher was not able to answer the third question posed by the research.

**Formulating Pediatric Protocols**

The fourth question posed by this research was whether or not the data were valid and reliable enough to formulate pediatric shoulder protocols that could be
implemented in the general ultrasound department at the University of Virginia Medical Center. Because of the consistency of anatomical visualization of the tested scan planes and positions the data proved three of the five scanning positions could be used to visualize and evaluate general shoulder anatomy. These techniques were used to develop a pediatric shoulder protocol for the general ultrasound department at the University of Virginia Medical Center (Appendix A).

Summary

Chapter IV presented the data collected during the course of this research study. The population of the study was pediatric patients less than a year old. Nine infants were scanned that fit into this population. This chapter described the scanning planes used to collect the data and results that were obtained through the use of these specific scanning techniques. This chapter also detailed each question posed by the researcher and how the data were used to answer each of these research questions.
Figure 4.1 Scanning technique
1. Transverse anterior view of shoulder. Humeral head (H) sits anterior to glenoid (G).

Figure 4.2 Scanning technique
2. Anterior sagittal view of the humeral head (H) and length of humeral shaft (HS).

Figure 4.3 Scanning technique
3. Posterior transverse view of the humeral head (HH) sitting at the end of the scapula (S). Humeral head cupped medially by glenoid (G).
Figure 4.4 Scanning technique 4. Posterior sagittal view of humeral head (HH) anterior to glenoid (G).

Figure 4.5 Scanning technique to measure degree of subluxation. Angle formed between scapular margin and lip of glenoid.
Chapter V

Summary, Conclusions, and Recommendations

This chapter will present a summary of the research study. Through the data gathered conclusions were made. Finally, recommendations for further research based on the data gathered will be presented.

Summary

The problem of this study was to determine if it was possible to develop and implement ultrasound protocols for pediatric shoulder anatomy in the general ultrasound department at the University of Virginia Medical Center. In order to conduct this research four questions were presented:

RQ1 Was it possible to effectively visualize the anatomy of the pediatric shoulder with ultrasound?

RQ2 Was ultrasound effective in determining dysplasia and/or subluxation of the pediatric shoulder based on predetermined measurements and protocols?

RQ3 Was ultrasound of the pediatric shoulder anatomy effective in evaluating patients with possible brachial plexus injury?

RQ4 Was it possible to formulate ultrasound protocols for the evaluation of pediatric shoulder anatomy?

The problem for this study arose for several reasons. Ultrasound has not been utilized in the area of musculoskeletal abnormalities until recent years. With the improved technology of modern ultrasound machines, visualization of joints, tendons,
ligaments and bony structures has become possible. Ultrasound of pediatric anatomy is of special importance because of the radiation exposure with other imaging modalities and possible sedation to perform some tests such as MRI and CT. The researcher chose to gather data for the purpose of developing ultrasound protocols for pediatric shoulder anatomy and to aid in the diagnosis of shoulder joint dysplasia and patients with possible Erb’s Palsy.

The research for this study was limited by several factors. The number of patients scanned was limited to those of less than one year of age coming to the general ultrasound department for other types of ultrasounds. Within the time frame of the research the number of this population was low. A request was granted at the end of the research period to scan healthy infants in the newborn nursery. Scanning was dependent on consent from the parents or legal guardians. Another limiting factor in this pediatric research was the cooperation of the patient. In a substantial number of patients, scanning was limited and sometimes not possible because of the level of cooperation of the infant. Because of the low incidence of Erb’s Palsy, no patients with a probable abnormality were scanned during the time of research.

The instrument used to gather data was the ultrasound machine. Five scanning techniques were formulated to test the effectiveness of ultrasound when visualizing the shoulder anatomy. Data were collected from each of the five scanning techniques. Specific anatomy was described for each scanning technique and angle measurements were formulated to calculate the degree of subluxation of the shoulder joint. These angles could be calculated post examination on saved images in the radiology PACS.
system. Once the measurements for subluxation were determined they were tested for validity and reliability on 6 of the research patients. Results were consistent on 100 percent of the test patients.

Conclusions

Research Question 1 was to determine the effectiveness of ultrasound to visualize pediatric shoulder anatomy. Five scanning techniques and positions were formulated to determine which, if any, could be used to examine shoulder anatomy. These scanning techniques were derived from research done by Grissom and Harcke (2001). The first scanning technique was with the patient in the supine position with the transducer in a transverse position placed over the shoulder area. The anatomy consistently seen with this technique was the humeral head with the glenoid positioned posteriorly. The anatomy in this position most closely parallels that seen in the transverse view of the hip when scanned by ultrasound. Rotation of the humeral ball within the socket with abduction and adduction could be seen and evaluated with this position. The second scanning technique was with the patient in the supine position with the transducer in a sagittal plane over the ball and socket of the shoulder joint and the humeral shaft. In this technique a full view of the humeral head was consistently visualized with the humeral shaft extending laterally. Because the ball of the humeral head and the humeral shaft was consistently seen with this scanning technique, this view could be used to detect fractures in the humeral shaft. The third scanning technique positioned the patient prone or in a lateral decubitus position with the transducer in a transverse plane over the shoulder joint and along the line of the
scapula. The anatomy consistently seen with this scanning technique was the humeral head at the end of the scapular margin. An angle formed by the junction of the scapular line with the lip of the glenoid proved to be a reliable measurement of the seating of the humeral head. Angles were measured in six patients with the mean angle measurement being 108.17 and the standard deviation was 4.9. This scanning technique was also valuable in visualizing rotation of the humeral head in the socket. With manipulation of the limb through abduction and adduction the humeral head could be evaluated for displacement out of the socket. The fourth scanning technique was also with the patient in the prone or lateral decubitus position with the transducer angled sagittally over the shoulder joint. Even though anatomy was well visualized through this scanning technique the researcher concluded that this view added no diagnostic information to the scan. The fifth and final scanning technique was with the patient in the right lateral decubitus or left lateral decubitus position and the transducer was placed in a coronal scanning plane coming from the superior aspect of the shoulder joint along the scapular margin. This scanning technique found to not be effective in visualizing shoulder anatomy. This scanning technique was chosen based upon CT images gathered by Jaramillo et al (1998) to help correlate the scanning plane of CT to ultrasound. The failure of this scanning technique was thought to be because of the placement of the transducer directly over an area of bony structure with no soft tissue to propagate the sounds waves.

Research Question 2 was if ultrasound could be effective in calculating degrees of subluxation of the shoulder joint. Initial scanning techniques from the posterior
aspect of the shoulder were based upon those researched by Ezaki and Zhang (2008) and Browne et al. (2007). The researcher also took into account the positions, techniques and anatomy used when measuring the dysplasia of the pediatric hip joint (Keller, 2005). A specific scanning technique was found to be useful in measuring degrees of subluxation. An angle of measurement was formulated from the third scanning technique. The manipulation of these angles was done in the PACS system during post processing. A line was drawn parallel to the line of the scapula and another line drawn along the edge of the glenoid to form an angle with the scapular margin. The mean of these angle measurements in six patients was 108.17 and the standard deviation was 4.9.

The Research Question 3 was posed to determine if ultrasound was effective in evaluating patients with possible Erb’s Palsy. Statistically Erb’s Palsy is a rare abnormality occurring in approximately 1 in 1,000 births (Pearl, 2009). The first part of the research was used to determine correct scanning angles and techniques to evaluate the shoulder. Only after these were developed could the researcher scan patients with possible Erb’s Palsy. During the time period of this research no Erb’s Palsy patients were referred to the ultrasound department. Because of this limitation, Research Question 3 could not be answered. Erb’s Palsy may be a rare anomaly, but with studies like the one done by Pearl (2009) a basis for this type of research is provided. In Pearl’s study, 20 of the 74 children diagnosed with Erb’s Palsy required surgery and about half had some kind of shoulder abnormality. These children will face multiple cat scans and MRI’s in a short period of time. If ultrasound can be used as a screening tool and/or a
means of follow up for these patients other types of radioactive and sedation studies could be decreased. The researcher felt that a good basis of scanning techniques had been formulated to effectively evaluate Erb’s Palsy patients in the future.

The Research Question 4 stated was to determine if ultrasound pediatric shoulder protocols could be formulated from the research. Even with the limited population of this study the researcher and pediatric radiologist felt confident of knowledge gained about normal anatomy of the pediatric shoulder. Not much variation exists among musculoskeletal normal anatomy, so with the reproduction of just a few normal scans a baseline had been set for protocols. The data gathered on the appropriate scanning techniques to visualize shoulder anatomy and measure degrees of dysplasia were used to develop pediatric ultrasound protocols to be used in the general ultrasound department at the University of Virginia Medical Center. The protocols consisted of three of the views previously discussed with angle measurements made from the posterior transverse images calculated on the radiology PACS system in the post processing stage.

Recommendations

Through the findings and conclusions gathered from this study the researcher presents several recommendations.

The first recommendation based upon this research is to spread an awareness of this type of exam. Pediatric physicians should be made aware of the capabilities of the general ultrasound department in evaluating pediatric shoulders. As patients come to the clinics with shoulder abnormalities, possible Erb’s Palsy, joint effusions or even
fractures, the physicians can consider ultrasound as a screening tool and option of evaluation for these patients.

The emergency room would be another department that could utilize this ultrasound service. Pediatric patients coming to the emergency room with shoulder abnormalities and trauma can possibly be referred to ultrasound for evaluation and diagnosis. The emergency room treats many dislocation injuries. Further research would be warranted to consider the effectiveness of ultrasound in evaluating the realignment of shoulder joints, which is normally done through x-ray.

The second recommendation is based upon the population for this type of research. The population of children less than one year of age having general ultrasound exams is extremely limiting. This factor cannot be changed and this is the only population that can be tested for this research. Due to these factors more time is needed to obtain a larger sample from a variety of ages under twelve months old. A year or more would be needed to collect a larger sample size from varying ages. Based upon the population and acting as a limiting factor to the research is cooperation of the patient. Infants under one year of age are limited in the amount of time they will be still enough to perform an ultrasound. Because these infants had already had one ultrasound before the shoulder examination started, they often could not hold still long enough for the sonographer to perform the exam. In accordance with this limitation, many scans were only partially completed or not performed at all. A suggestion for some resolution to this limitation would be for the parents/guardians to be consented in the clinic with their doctor and come straight to the ultrasound department only for the
shoulder exam. With this arrangement the researcher could continue the procedure to verify the current findings and support the results based on a broader range of infants up to one year of age.

The third recommendation stems from the lack of Erb’s Palsy patients during the time of this research. The researcher suggests that future studies extend the knowledge gained from this study to perform ultrasound examinations on patients with Erb’s Palsy. A dialogue has begun with the pediatric orthopedic physicians for future referral of patients to the ultrasound department. If the research can continue, further data could be collected to establish guidelines for ultrasound examination of Erb’s Palsy patients.

To expand on the previous recommendation the researcher would further recommend correlation studies with patients who have had a definitive diagnosis of Erb’s Palsy. Once a patient has been officially diagnosed, an ultrasound could be performed to test the reliability and validity of the established ultrasound protocol images and measurements.

A fourth recommendation for further research is comparison studies with CT and MRI. Once an infant is diagnosed with Erb’s Palsy, follow up and recommendations are put into place. Depending on the severity of the case, surgery may be necessary. A CT or MRI is inevitable at this point in the care of the patient. Most likely more imaging studies will be needed after the surgery and as follow up. The researcher suggests further studies to compare the CT and MRI imaging and measurements of subluxation with those done by ultrasound. This type of research will take coordination between
the orthopedic surgeon and the ultrasound department. Follow up examinations could take place six to nine months after surgery.


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Appendix

Pediatric Shoulder Ultrasound Protocol

Image 1

Patient position: supine
Transducer orientation: transverse
Anatomy visualized: Humeral head anterior to glenoid
(Similar to transverse view of pediatric hip, with abduction and adduction can test whether or not the humeral head stays seated in the joint.)

Image 2

Patient position: supine
Transducer orientation: sagittal
Anatomy visualized: Humeral head and shaft of humerus
(Best view of the humeral shaft to be used for evaluation of fracture.)

Image 3

Patient position: prone or lateral decubitus
Transducer orientation: transverse
Anatomy visualized: Humeral head at the end of the scapula draped medially by the glenoid.
(This view is used to measure the degree of dysplasia. Can also use abduction and adduction to determine if humeral head stays in the humeral socket.)