COMPARISON OF SONOGRAPHIC AND RADIOGRAPHIC FINDINGS AMONG CHILDREN WITH SUSPECTED FOREARM FRACTURES AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET KENYA.

BY

MBARAK NAIMA AHMED SALIM

THESIS PRESENTED IN PARTIAL FULFILLMENT OF THE AWARD OF THE DEGREE OF MASTER OF MEDICINE IN RADIOLOGY AND IMAGING AT MOI UNIVERSITY.

DECLARATION

I declare that this thesis is my original work written in partial fulfillment for the award of a Master of Medicine in Radiology and Imaging and has not been submitted to any other university or organization.

SM/PGR/03/19- MS/RAD/4275/20

Mbarak Naima Ahmed Salim

Registrar in Radiology and Imaging, Moi University

Signature: ………………………………….. Date: ………………………………

Declaration by supervisors

This thesis has been submitted with our approval as the university supervisors.

DR. JOSEPH ABUYA

Senior Lecturer, Moi University

Signature: ………………………………….. Date: ………………………………

DR. LOICE SITIENEI

Lecturer, Moi University

Signature: ………………………………….. Date: ………………………………

DEDICATION

I dedicate this work to the Almighty God. To my family for their motivation and steady support. To all the radiology registrars and friends for their daily words of encouragement.

To you all, I am truly grateful.

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ABBREVIATIONS

AP	Antero-posterior
IREC	Institutional Research and Ethics Committee
LT	Left
NAI	Non-Accidental Injuries
KNH	Kenyatta National Hospital
MES	Managed Equipment Services
MTRH	Moi Teaching and Referral Hospital
MUSOM	Moi University School of Medicine
POCUS	Point of Care Ultrasonography
RT	Right
US	Ultrasonography
WHO	World Health Organization

OPERATIONAL DEFINITION OF TERMS

Child: Any person under the age of 18 (UNCRC, 2009).

Diaphysis : The shaft of a long bone, resulting from periosteal, membranous ossification of the original endochondral model; a stable structure where periosteal osteoblasts produce new layers of bone during growth increasing its thickness (Sinikumpu, 2013).

Epiphysis: A cartilaginous structure (chondro-epiphysis) at the end of each long bone that goes through chondro-osseous transformation at a time characteristic for each bone (Sinikumpu, 2013).

Fracture: A discontinuity in a bone or cartilage as a result of increased mechanical forces which is beyond bones ability to withstand them.

Greenstick fracture: Disruption of the periosteum and cortex on the convex side of angulation and deformation of the cortex on the concave side (Zimmermann et al., 2004)

Metaphysis: The part of a long bone between the growth line and the diaphysis, showing active bone turnover by osteoblasts and osteoclasts and being in response to converting newly created mineralized cartilage to true bone tissue (Sinikumpu, 2013).

Non-union: Is a process of scar formation in which the rate of endosteal and periosteal osteogenesis is zero or low, being outweighed by bone resorption. As an end point non-union is evidenced by cessation of periosteal and endosteal new bone formation (Marsh, 1998).

Physis: Located between the metaphysis and epiphysis as a radiolucent line in skeletally immature patients. It contains zones of mesenchymal cells in various maturation stages.

Plastic deformations: A type of fracture that occurs as a result of micro-fractures that occur both in tensile and compressive forms typical in paediatric population (Sinikumpu, 2013).

Torus fractures: Buckle fracture of the cortex on the compression side of an axially loaded side (Zimmermann et al., 2004)

Sensitivity: It is the ability of a test (Ultrasound) to correctly classify an individual as diseased (fractured) as compared with the goal standard (x-ray)

Specificity: The ability of a test to correctly classify an individual as disease free (no fracture)

Suspected fracture: Patients with swollen, painful and deformed limb in the background of trauma.

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ABSTRACT

Background: Forearm fractures are the commonest injuries in children and account for about 36.4% of all paediatric injuries. Plain radiography is the gold standard in the diagnosis of fractures. However, ionising radiation is harmful in children and have up to ten times increased risk of morbidity, making their highly dividing cells susceptible to its undesirable effects. About 50% of the suspected forearm fractures sent for x-ray, are found to be normal. Ultrasonography is radiation free, portable and a quick tool to use. This makes it a safe tool to use hence a larger area can be imaged to know where the exact fracture site is, especially for younger children since they cannot express themselves well. Various studies have shown that ultrasonography is capable of accurate diagnosis and can be done in resource poor setups.

Objectives: To describe and compare the sonographic and radiographic findings among children with suspected forearm fractures in Moi Teaching and Referral Hospital (MTRH).

Methods: This was a descriptive cross-sectional study conducted at the MTRH from April 2021 to March 2022. Consecutive sampling method was used to enrol 373 participants aged less than 18 years with suspected forearm fractures following trauma. Ethical approval was sought. Data collection tool was used using structured questionnaires. Appropriate analgesia was administered in the Emergency Department to all patients with suspected forearm fractures before sending them for imaging. Adequate ultrasound gel was used to reduce firm contact of the transducer with the patient's skin and decrease pressure on the site that has been injured. Forearm ultrasound was done prior to radiography using SonoScape ultrasound machine with a linear array transducer 7.5 MHZ to 12 MHZ. Forearm radiograph was done as per the MTRH protocol. Continuous variables were summarized using mean and categorical variables were summarized in frequencies and percentages. Sensitivity and specificity were used for comparison.

Results: Age of participants ranged from 0 to 17 years with a mean age of 9 years. The males accounted for 65.1%. On x-ray, fractures present were 60.2% with both the radius and ulna bones fractured at 56.0%, the radius bone alone was at 39.6% and ulna bone alone was at 4.4%. Distal third of the radius was the commonest fracture site with 39.2% on the left and 43.8% on the right. On ultrasonography, fractures diagnosed were 59.2% with both the radius and ulna bones fractured at 57.8%, radius alone was at 37.7% and ulna alone was at 4.5%. The distal radius was the most fractured at 38% on the left and 44.6% on the right. Positive and negative likelihood ratios were 11.56 and 0.08 respectively. The sensitivity and specificity of diagnosis of forearm fractures using ultrasound was 92.83% and 92% respectively at 95% confidence interval. There was a strong agreement between x-ray and ultrasonography with $k=0.845$ at $P< 0.0001$ which is considered as almost perfect agreement.

Conclusion: Both radius and ulna bones are the commonest fractured bones with the right distal radius as the most common fractured site on both x-rays and ultrasonography. Ultrasonography can be used in place of plain x-rays in the diagnosis of forearm fractures due to its high sensitivity and specificity.

Recommendation: It is recommended to clinicians and radiologists to use U/S instead of radiography in the diagnosis of suspected paediatric forearm fractures.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Trauma is the major cause of injury and disability in paediatric patients and young adults (Akinmade, 2018). It is the major cause of loss of lives and is incapacitating as reported by the WHO (Mock C, Lormand JD, Goosen J, Joshipura M, 2005)

A study done in KNH in 2016, where pattern of long bones fractures in paediatric patients was assessed, revealed that males had most fractures at 59% with ratio of male to female at 1.4:1. Most fractures occurred at home and its environment and were at 56% with falls from a height of less than 1 meter being the majority. Fractures of the radius were at 23% and ulna at 11% of all the long bone fractures. Most fractures of the radioulnar occurred at the diaphysis at 55% followed by distal metaphysis at 23% and distal epiphysis at 23% (Mwangi et al, 2017).

In a study done in South Africa by Strydom et al, the forearm is the most fractured part of the body making up to about 36.4% of all fractures (Strydom et al., 2020). Korup et al from Denmark demonstrated that fractures of the distal forearm are the commonest in children for both gender and they make up about 74% of all upper limb injuries in childhood. (Korup et al., 2022).

Fractures of the forearm occur more commonly as a result of fall within the home and fractures which occur as a result of sports is the second commonest. Amongst them, 75 to 84% are distal third ,15 to 18 % middle third and 1 to 7 % are at the proximal third (Rodríguez-merchán, 2005)

Using radiographs to investigate trauma is necessary to diagnose fractures nonetheless, ionizing radiation can be dangerous to the growing bones of the child (Ekþioðlu et al., 2003).

When comparing with radiographs, Weinberg et al demonstrated that US has a high sensitivity in diagnosis of fractures. (Weinberg et al., 2010).

Ultrasonography, according to Moritz et al, gives similar results to x-rays in the diagnosis of fractures (J. D. Moritz et al, 2008). The use of US in paediatric patients before having a radiograph done is recommended because paediatric patients do not have specific clinical findings of fracture following trauma.

Plain radiographs are taken as the gold standard in the diagnosis of forearm fractures in both the AP and lateral views (Ackermann et al., 2010)

1.1.1 Embryology of the forearm

The limbs begin developing by late fourth week where a group of mesenchymal cells are activated in the somatic lateral mesoderm. a thick band of ectoderm develop from the limb buds called the apical ectodermal ridge. By day 24, the upper limb bud is seen. Because of early development of cranial half of the embryo, the upper limb bud appears abnormally low on the trunk of the embryo. The development of both the upper and lower limbs are similar in the early stages. These upper limb buds arise opposite the lower cervical segments. The ectoderm thickens at the apex of each limb bud to form an apical ectodermal ridge.

Mesenchymal tissue by the end of the sixth week condenses the hand plates to form digital rays these outline the digits' patterns. Cellular aggregation of mesenchymal models of the bones begins as the limbs elongate. By the fifth week chondrification canters develop. The whole limb becomes cartilaginous by the end of the sixth week. In the seventh week long bones osteogenesis begins. In all long bones, ossification centres of the long bones appear (Moore, 2019).

The mesenchyme of the limb buds forms the bones of the limbs and develop from endochondral ossification. It starts in the eighth week in utero as ectoderm within the mesenchyme which develops into bones, connective tissue and blood vessels. Myotomes of somites develop the muscles. The forelimb buds which give rise to arm, forearm and hand develop earlier. The preaxial bone of the forearm is the radius(Inderbir Singh's, 2018).

Formation of the synovial joints starts in the ninth week which occurs simultaneously with muscles and nerves functional differentiation (Moore, 2019).

1.1.2 Anatomy of the forearm

The forearm is located between the elbow and the wrist and is made up of two bones both parallel to each other; the radius and the ulna. It has two joints the distal radio-ulna joint and proximal radio-ulna joint. Above is the proximal radio-ulna joint that is stabilized by elbow joint's capsule and the annular ligaments while the distal radio-ulna joint is stabilized by wrist capsule, ligaments of the radio-ulna and triangular fibrocartilage complex. In between the radius and ulna shaft is the interosseous membrane to give it an axial stability between the two bones. Developmentally, in the human embryo the upper extremity begins to be seen by the fourth week of life with fingers seen in the sixth week of life and muscle the seventh week. Ossification of radius and ulna begins in the eighth week in utero. Development and ossification continue after birth. The forearm has different parts; the physis which is the growth plate new bone formation occurs via enchondrial ossification. The distal radial epiphysis becomes visible at about one year of age and they become the secondary ossification centres. Radial styloid may have a different ossification centre. The proximal radial epiphysis starts forming at the age of 4-7 years. 75% of the radius grows distally (Sinikumpu, 2013).

The distal radio-ulna joint is a synovial pivot type of joint with its articular surfaces comprising of the ulna head and the ulna notch of the radius and proximal part of the triangular cartilage. The distal radioulnar is separated from the radiocarpal joint by the triangular cartilage (Stephanie Ryan, Stephen J. Eustace, 2011) .

1.1.1.1 Radius

The radius situated on the lateral aspect and is shorter compared to the ulna. It is cylindrical at its upper third and the middle third has a triangular shape from its metaphysis to diaphysis. It is rectangular with flattened surface on the dorsal and volar aspects. It bows laterally and that starts distally to the bicipital tuberosity, which is usually the attachment of biceps tendon, and has an apex midshaft (Herman & Marshall, 2006).

The head of the radius proximally is covered by a cartilage. The shaft of the radius widens in diameter from the proximal to distal aspect and is smallest at the neck of the radius distally. The wrist joint forms on the distal side of the radius (Sinikumpu, 2013).

1. 2 Ulna

The ulna is triangular proximally and becomes cylindrical mid-shaft and at the distal side. It more straight compared to the radius. Its proximal apophysis ossifies at the age of about 10 years. Rotation of the forearm takes place when the radius rotates around the ulna usually assisted by the bow at the radius and interosseous membrane (Herman & Marshall, 2006).

The ulna adds to the forearm’s stability. It has a proximal end that is hooked shaped, the olecranon, which forms the uniaxial hinge joint with the humerus. The diameter of the ulna becomes smaller as it goes distally and does not form part of the wrist joint (Sinikumpu, 2013).

The interosseous membrane connects the radius and ulnar.(Stephanie Ryan, Stephen J. Eustace, 2011).

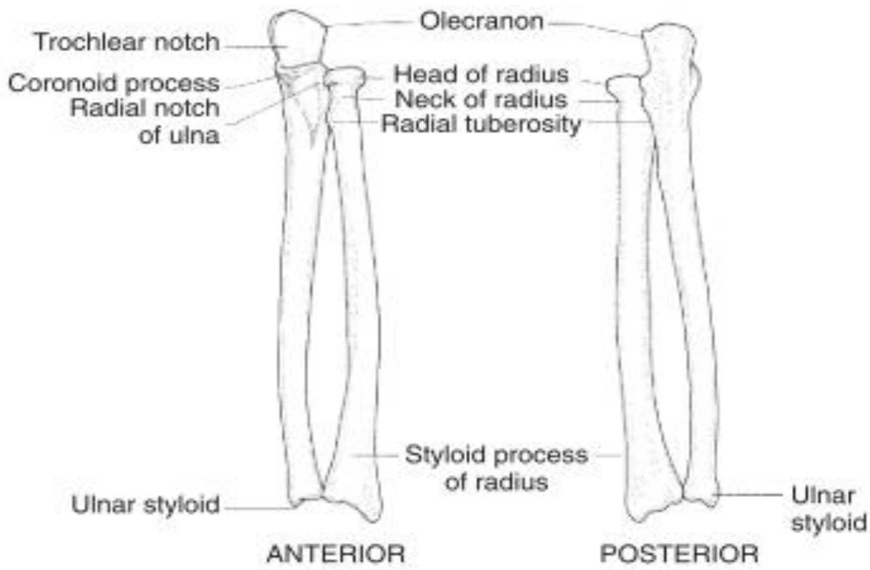


Figure 1: Diagrammatic representation of the radius and ulnar(Stephanie Ryan, Stephen J. Eustace, 2011).

1.1.2.3 Maturation of the forearm skeleton:

1.2.1.3.1 Radius

During the eighth week in utero, the primary ossification centre appears in the radius. At the age of 1 year and 5 years the secondary ossification centres appear distally and proximally respectively. These centres fuse with the distal at the age of 20 years and the proximal at the age of 17 years (Stephanie Ryan, Stephen J. Eustace, 2011).

1.2.2.3.2 Ulna

Ossification of the radius takes place at the age of eight weeks in utero. Distal ulna and olecranon's secondary ossification centres appear by the age of 5 years and 10 years respectively. Ossification of these centres is at the age of 20 years for the distal ulna and 17 years for the proximal ulna(Stephanie Ryan, Stephen J. Eustace, 2011).

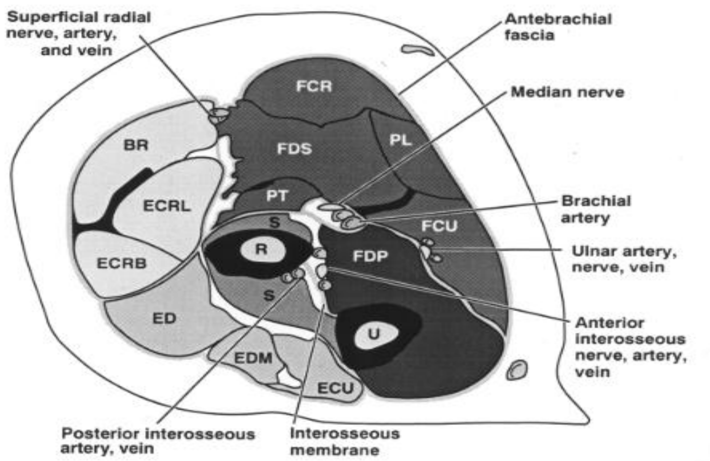
1.2.2.4 Muscle compartments of the forearm

The compartments of forearm muscles are formed by the antebrachial fascia which is a continuation of the brachial fascia. This covers the muscles individually thus providing its attachment to the radius, ulna or the interosseous membrane. It divides the muscles of forearm into mobile wad (radial group muscle), volar and dorsal compartments. There may be communication between different compartments seen.

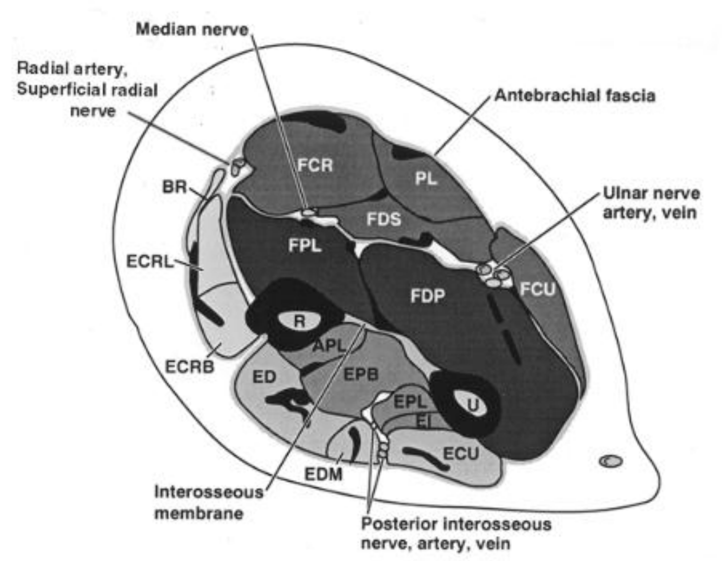
The radial group compartment constitutes of the extensor carpi radialis brevi and extensor carpi radialis longus muscles which enables the extension and abduction of the hand and brachioradialis muscle causes flexion of the forearm. At proximal part of this compartment lies the radial nerve and its two main branches whereas the radial artery is situated between this compartment and the volar compartment. No major neurovascular components found in this compartment with only the radial nerve and artery. The radial artery lies between this mobile wad and volar compartments. The volar compartment comprises of the muscles of flexion and pronation it is divided into deep and superficial group by a transverse septum. The flexor digitorum profundus and flexor pollicis longus are used in flexion of phalanges and pronator quadratus used in pronation form the deep group. Whereas the flexor carpi radialis and flexor digitorum superficialis used in flexion of the wrist and hand and the pronator teres used in pronation of the forearm and in elbow flexion form the superficial group. In this compartment lies the median nerve and its branch, the anterior interosseous nerve and the deep branch of radial nerve. It has the major vessels of the forearm.

The dorsal compartment is also divided into deep and superficial group of muscles. The supinator, abductor pollicis longus and extensor indicis form the deep compartment. Superficial compartment consists of extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, and the anconeus muscle form the superficial group. This compartment is innervated by the interosseous nerve a branch of radial nerve and supplied by posterior interosseous artery (Boles et al., 2000).

Fig 2



A



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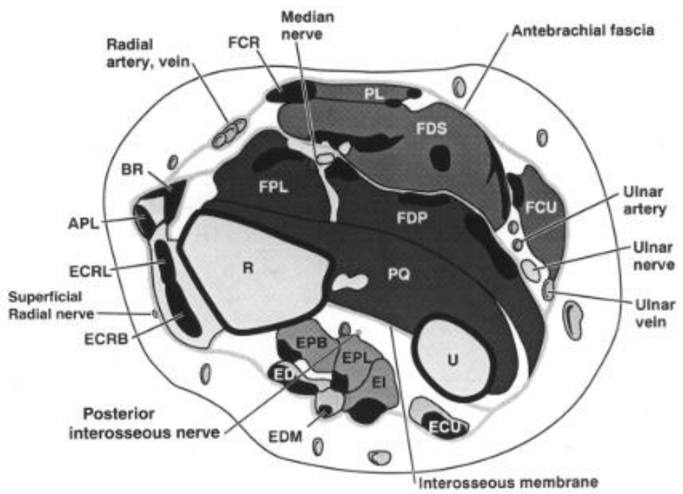


C

Figure 2: Forearm compartments. ECRB = extensor carpi radialis brevis, ECRL = extensor carpi radialis longus, BR = brachioradialis, FCU = flexor carpi ulnaris, PL = palmaris longus, FCR = flexor carpi radialis, FDS = flexor digitorum superficialis, ED = extensor digitorum, EDM = extensor digiti minimi, ECU = extensor carpi ulnaris, FDP = flexor digitorum profundus, FPL = flexor pollicis longus, PT = pronator teres, S = supinator, APL = abductor pollicis longus, EPB = extensor pollicis brevis, EPL = extensor pollicis longus, EI = extensor indices, R = radius, U = ulna.

Image A: Drawing of proximal forearm. **Image B:** Drawing of mid forearm compartments. **Image C:** Drawing of distal forearm at junction of radial diaphysis and metaphysis. **Images adopted from Boles et al** (Boles et al., 2000).

1.2.2.5 Blood supply of the forearm

The blood supply to the forearm is from the brachial artery which is a continuation of the axillary artery at the teres major's lower border. The brachial artery divides into radial and ulna artery at the level of the head of ulna or it can branch a bit higher. On the lateral side of the forearm up to the level of the wrist passes the radial artery. Bigger and deeper is the ulna artery which form the common interosseous artery. The common interosseous artery splits into anterior and posterior interosseous arteries. The posterior interosseous membrane passes above the membrane to supply the muscles of the back of the forearm.

The venous drainage of the forearm is formed by the deep and superficial veins. The superficial veins are formed by three veins that run along the forearm which are as a result of the small veins of the hand uniting. These are namely the cephalic vein and basilic vein from the back and basilic vein from the back and median vein from the front. On the radial side of the posterior aspect of the hand lies the cephalic vein which ascends to the elbow. On the medial side lies the basilic vein. Along the volar side of the forearm passes the median vein which at the level of the elbow it either joins the basilic or cephalic vein. The deep veins are usually paired and follow the arteries (Stephanie Ryan, Stephen J. Eustace, 2011).

1.3 Paediatric anatomy of the forearm on ultrasound:

MSK US is acceptable in children and does not necessitate the use of sedation or anaesthesia. US of the skin and subcutaneous tissues looks like that of adults. There is a connective tissue septum separating hypoechoic fat lobules. Below it is a thicken hyperechoic band that is as a result of the union of both superficial and deep fascia that separate hypoechoic fat lobules from muscle fascicles which are also hypoechoic making them appear feather like. Majority of the skeletal muscles join the bone via a tendon, forming a muscle tendon bone complex. In children, this complex is different because it joins on a bone that is not completely ossified or is just cartilaginous. As opposed to adults, the muscles, tendons and ligaments have a much higher tensile strength compared to the apophysis making it a regular site of trauma. As the children grow older, the bones mature making avulsion injuries uncommon and follow adult pattern of injuries. On US matured bone and its attachment to soft tissue or muscle is highly reflective unlike immature cartilage which is hypoechoic and may be incorrectly taken as fluid. In this group, joints contain great amounts of cartilage as well as the epiphysis (Chambers et al., 2018).

The 3 compartments are divided by the antebrachial fascia of the radius, the ulna and interosseous membrane. These compartments are namely the volar (anterior), dorsal (posterior) and mobile wad (radial group).

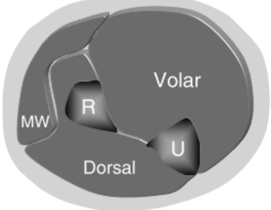


Figure 3: A. transverse diagrammatic representation of muscles of the forearm with different muscle compartments Mobile wad (MW), Volar(flexor) and Dorsal (extensor) compartments. R(radius) U(ulna) (Bianchi & Martinoli, 2007).

Individual muscles of the volar compartment are best identified by the distal tendons, nerves and vessels which are used as the landmarks during US with the probe in transverse plane. The flexor and pronator muscles are found in this compartment. Transverse septum divides them further into superficial and deep layers. Flexor polis longus, flexor digitorum profundus and pronator quadratus form the deep layer. The pronator teres, palmaris longus flexor carpi radialis and flexor carpi ulnaris form the superficial muscles of the anterior compartment.

The posterior compartment is divided into to two layers the deep and superficial. Examination of the posterior compartment on US should begin at the wrist where the individual tendons are easily identified. Supinator, the extensor pollicis brevis, the abductor pollicis longus, the extensor pollicis longus and the extensor indicis proprius form the muscles of the deep layer. The abductor pollicis longus, extensor digitorum communis, the extensor digiti minimi and the extensor carpi ulnaris make up the superficial layer. The interosseous membrane which appears hyper echoic divides the anterior and posterior compartments.

The US technique of the radial compartment is similar to that of posterior compartment. The muscles include the extensor carpi radialis brevis , the extensor carpi radialis longus and brachioradialis (Bianchi & Martinoli, 2007)

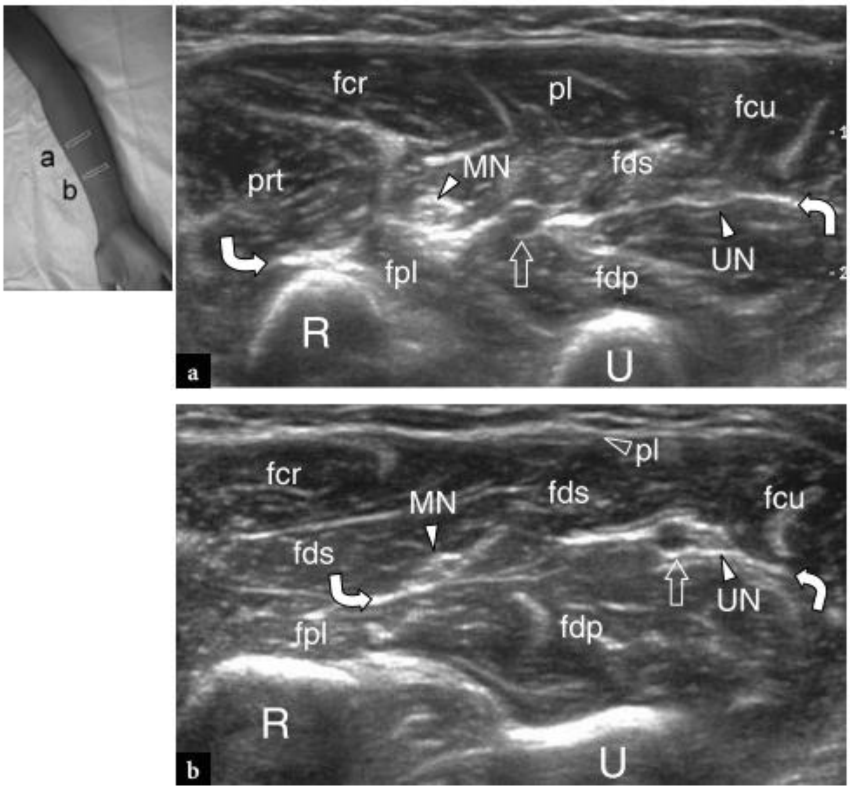


Figure 4: Transverse images adopted from Bianchi & Martinoli et al, showing the volar compartments of the forearm using 12-15MHz US a - distal to the sublimis bridge and b, more caudally, at the middle third of the forearm demonstrate the relationships of the deep muscles. the flexor pollicis longus (fpl) and the flexor digitorum profundus (fdp) – with the superficial muscles – the pronator teres (prt), the flexor carpi radialis (fcr), the flexor digitorum superficialis (fds), the flexor carpi ulnaris (fcu) and the palmaris longus (pl) – of the volar forearm. The two layers of muscles are separated by a transverse hyperechoic cleavage plane (curved arrows) representing an extension of the antebrachial fascia within which the median nerve (MN), the ulnar nerve (UN) and the ulnar artery (straight arrow) are found. From proximal (a) to distal (b), observe the muscle belly of the palmaris longus which continues in a thin superficial tendon. R, radius; U, ulna. The photograph at the right of the figure indicates probe positioning (Bianchi & Martinoli, 2007).

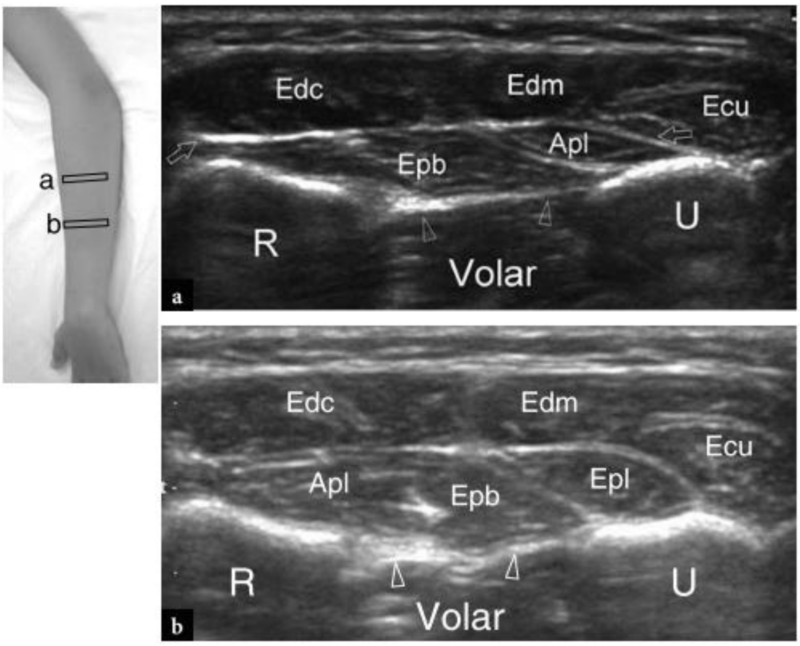


Figure 5: Dorsal compartment of the forearm as adopted by Bianchi & Martinoli et al: a Proximal and b distal transverse 12–5 MHz US images obtained at the middle third of the forearm reveal the two layers of extensor muscles located over the posterior aspect of the interosseous membrane (arrowheads) and seperated by a transverse hyperechoic septum (arrows). From lateral to medial, the superficial layer of muscles includes the extensor digitorum communis (Edc), the extensor digiti minimi(Edm) and the extensor carpi ulnaris (Ecu), whereas the deep layer houses the abductor pollicis longus (Apl), the extensor pollicis brevis (Epb) and the extensor pollicis longus (Epl). R, radius; U, ulna. The photograph at the upper right of the figure indicates probe positioning(Bianchi & Martinoli, 2007).

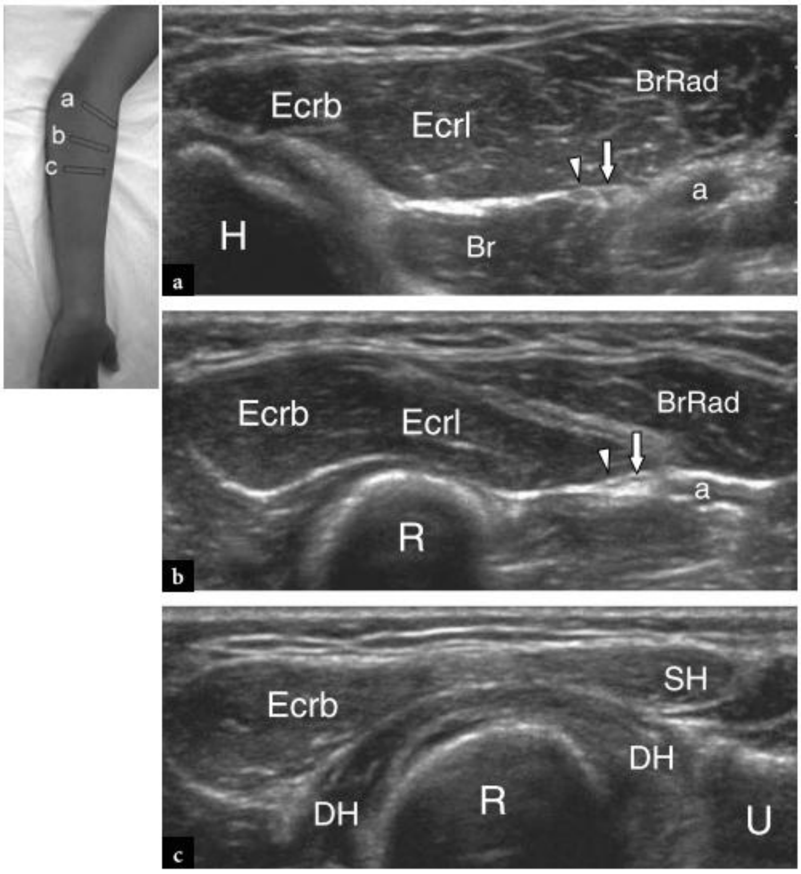


Figure 6: a–c. Mobile wad as adopted by Bianchi & Martinoli et al compartment of the forearm. a–c Series of transverse 12–5 MHz US images obtained at the elbow and the proximal forearm from a proximal to c distal reveal the bulk of muscles of the mobile wad, consisting of the brachioradialis (BrRad), the extensor carpi radialis longus (Ecrl) and the extensor carpi radialis brevis (Ecrb). The relationships of these muscles with the posterior interosseous nerve (arrowhead), the superficial sensory branch of the radial nerve (arrow), the radial artery (a) and the superficial (SH) and deep (DH) heads of the supinator muscle are shown. Br, brachialis; H, humerus; R, radius; U, ulna. The photograph at the upper right of the figure indicates probe positioning (Bianchi & Martinoli, 2007).

The cortex of the bone is seen as an echogenic line (Snelling, 2020). Ultrasound beam’s total reflection causes the cortex of the bone to be echogenic. The plate and cartilage of epiphyseal plate appear anechoic to hypoechoic and the core of the epiphysis appears hyperechoic (Eckert et al., 2012).

High acoustic impedance mismatch causes the soft tissue and cortical bone interface to be echogenic. Posterior acoustic shadowing and reverberation artifacts are seen at the echogenic line of the bony cortex. In immature bone of paediatric patients the growth plate may present similar to a fracture and thus their anatomical locations may help distinguish the two (Bianchi & Martinoli, 2007).

1.4 Aetiology and mechanism of forearm fractures

Throughout childhood, the type and distribution of fractures varies. This differs from that of adults at large due to the difference in the anatomy and physiology of the children's developing skeleton. The elasticity of the bones is increased and the cartilage is in higher amounts especially around the growth plate than that of adults. Therefore, compressive, tensile or shearing stresses occur when force is applied to a paediatric bone. This causes deformity to the bone and increases with increased force. The bone may sometimes get back to normal when the stress is removed, it can also result in microscopic fractures what is called plastic deformity where the bone can be normal on radiographs but may show some periosteal healing when the imaged on a later date. With further increase in stress fractures can occur. Compressive stresses are better tolerated in cortical bones than tensile or shearing forces (Grainger & Allison et al, 2013)

Most childhood causes of forearm fractures are as a result of a fall which accounts to about 83% of cases, those caused by RTA are about 16%. the falls mostly occur in younger children whereas RTA mostly occurred in children older than 12 years(Alrashedan et al., 2018).

Paediatric fractures are commonly caused by a simple fall that is below height of a bed and this causes fractures of the upper limbs of which distal radius makes 50% of them in majority of cases. About 20% of all fractures are caused by blunt trauma. This occurs in children who are older and also occurring majorly in the upper limbs. Fractures from other causes such as assaults such as those which are as a result of non-accidental injuries are rare (Rennie et al., 2007).

The fall, which as described above, that is the most common cause of forearm fractures in children and adolescents is because of a fall from ground level making about 44% of all fractures requiring admission. The RTAs come second but mainly result in lower limb fractures which occur in school going children as they walk to school. High index of suspicion health care workers should to rule out non accidental injuries which make about 1% to 707% in children presenting with injuries to the musculoskeletal system (Strydom et al., 2020).

Grabala et al studied the Polish population and found out that the commonest cause of fracture was falling from a height of less than 1 metre at 39%and those caused by road traffic accidents seldomly occur at 3% (Grabala, 2015).

However, Onyemaechi et al studied all paediatric injuries in Nigeria from the age of 2 days to 17 years and found that injury from RTA is the commonest cause. Falls were second on the list and the least mechanism of injury was from gunshots. Most of the falls in pre-schoolers were falls while playing while falls from heights and stairs make 33.3% and 6.1% respectively (Onyemaechi et al., 2020)

According to Rodriguez- merchan, fracture of the forearms occur more commonly as a result of fall within the home and those as a result of sports as the second commonest(Rodríguez-merchán, 2005).

As described by Herman & Marshall et al, fractures of the forearm occur mainly as a result of indirect forces most commonly; a fall on an outstretched arm such as fall from equipment at the playground, bicycles and trees. Road traffic accidents and non-accidental injuries such as child abuse are not so common (Herman & Marshall, 2006).

Chaar-alvarez also stated that the major cause of forearm fractures is a fall on an outstretched hand (Chaar-alvarez et al., 2011).

Forearm fractures children occur when they fall, they outstretch their upper limbs as a way of protecting themselves. There is first pronation of the hand with the thenar taking the first hit on the ground. Supination of the pronated forearm takes place rapidly and the greatest impact will be absorbed by the radius thus getting fractured before the ulna. As a result, there is usually malalignment rotational malformation of the fracture. In most scenarios, shaft fractures have both bones fractured (Sinikumpu, 2013).

The commonest cause of paediatric forearm fractures is a fall where the children between the ages of 0-4 years the fall was from a furniture. Children older that is those between the ages of 5-9 years commonest was still a fall but the fall was from monkey bars for children older than 10 years the most common cause of fractures was trauma as a result of organised sporting activities (Ryan et al., 2010).

1.5 Site of forearm fractures

Grabala et al found out that the commonest site of the fracture was the distal radius fracture which accounted for 43% of all fractures and the least common site was isolated ulna fracture at 3%.(Grabala, 2015).

Paediatric fractures are most common in the distal third of the forearm, including the metaphyseal and the junction between metaphysis and diaphysis, with about 48% of them. The distal third of the shafts of the forearm are the second most common site of fractures having about 34%. The middle third and proximal third of the forearms shafts have about 16% and 1.6% respectively (Alrashedan et al., 2018).

According to Hubner et al, in his study done in Germany, the most fractured site in paediatric age group is the distal part of the forearm (Hübner et al., 2000).

75% of forearm fractures occur at the distal part of the forearm (Chaar-alvarez et al., 2011).

Herman & Marshall described the forearm fractures that about 75% of them occur on the distal third, occurrence at the middle third is 15% and proximal third is 5%. In the paediatric age group, the younger ones have fractures mainly at the middle third while the older ones have the fractures occurring distally. Fractures of the radius occur higher than those of the ulna in many children and adolescents. The complete and transverse or short oblique types are the main fracture patterns. In younger children plastic deformation and greenstick type of fracture tend to happen more frequently (Herman & Marshall, 2006)

Fractures of the metaphysis of the forearm make up 20% of childhood fractures as reported by Katzer et al, fractures of the distal forearm for those aged 0 to 4 years have an incidence of 2234 in 100000 persons and 3506 in 100000 persons for those aged 15 to 19 years (Katzer et al., 2016).

The site of forearm fractures is the same across all paediatric age groups as reported by Alrashedan et al (Alrashedan et al., 2018).

1.6 Classification and types of forearm fractures

Fractures in children depending on the amount of stress yielded can be classified as complete or incomplete, simple or comminuted fractures, closed or open/compound fractures. When the discontinuity of the bone is complete then it is termed as a complete fracture. When part of the bone cortex is intact then it is an incomplete fracture. If there is a single fracture line then they are termed as simple fractures which with respect to the long axis of the bone can be termed as transverse, oblique or spiral. Presence of several fracture lines, fragments or segments is termed as comminuted fracture. Closed fractures are those when bone is not exposed to the surrounding through the skin while open fractures are those that are exposed through the skin.

In children the forearm fractures can occur in isolation or together with the radius being more common isolated bone that is fractured. These fractures can be associated with adjacent joint dislocation mainly the wrist or the elbow joint. It is therefore important when imaging to include both joints so as not to miss the dislocations. Injuries to the meta-diaphysis of the distal forearm results mainly in incomplete buckle fractures with falling on an outstretched hand being the mechanism of injury. Such injuries occur in young adolescents and preteens the boys having a peak between 12-14 years and the girls having a peak between 10-12 years of age. This could be due to growth spurt and meta-diaphyseal weakness during that age (Grainger & Allison et al, 2013).

The specific types of forearm fractures in children include torus or buckle/cortical fractures, greenstick fractures and the epiphyseal-metaphyseal fractures which are also known as Salter-Harris fractures. Fractures of the midshaft, transverse, spiral, oblique and comminuted types of fractures may also be found in children but are not specific to children.

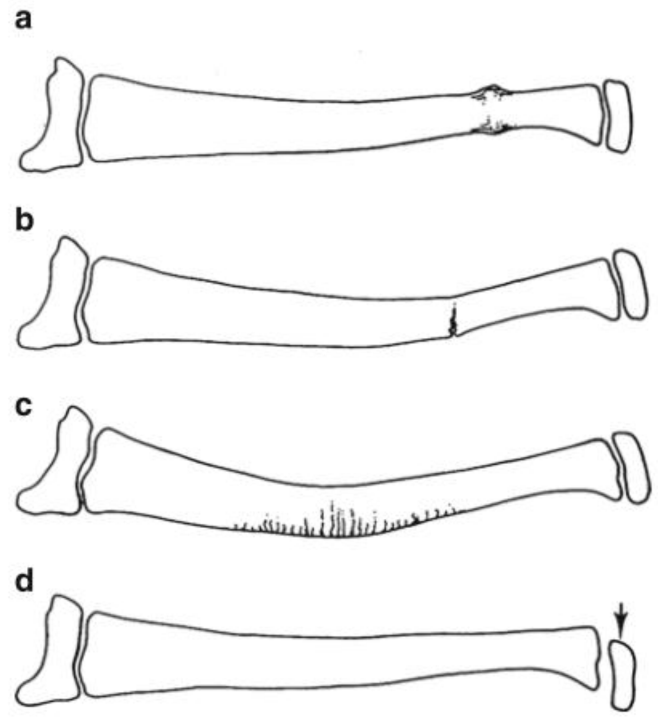


Figure 7: Fractures that are specific in children. (a) Typical buckle fracture. (b) Greenstick fracture. (c) Plastic bowing fracture. (d) Salter–Harris epiphyseal metaphyseal fracture with a displaced epiphysis (arrow).(Swischuk & Jadhav, 2014).

Simple axial loading results in buckle or torus fractures that present with the cortex of the bone buckling, kinking or notching. This type of fracture most commonly occurs in the metaphysis of the long bones. Buckle/torus fractures are of two types; type I and type II. Type I buckle fracture causes buckling or bulging of the cortex outward.

This is due to direct axial load transmitted down the length of the bone with an abrupt deceleration. As a result, the metaphysis impacts and crumbs or buckles. This causes compression of the trabeculae and bulging of the cortex outwards through the metaphysis.

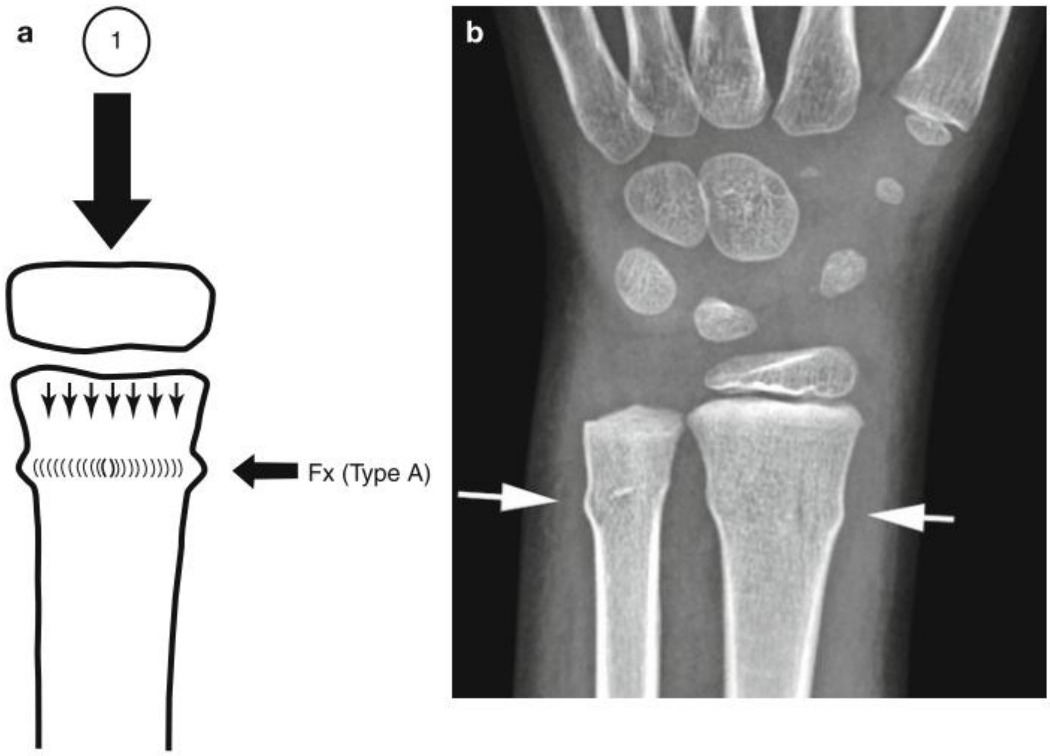


Figure 7: Buckle fracture type (I) Axial loading forces (1) are exerted down the length of any given bone. The result is a cortical buckle fracture (fx). (b) Typical type I buckle fractures of the radius and ulna (arrows).(Swischuk & Jadhav, 2014)

Type II buckle fractures are seen as sub-epiphyseal metaphyseal cortex buckling that is unilaterally angled. This angled buckle fracture is as a result of the axial loading being shifted off the centre hence the cortex is buckled on one side or another in an angled form. This type continues as a Salter- Harris II fracture. (Swischuk & Jadhav, 2014).

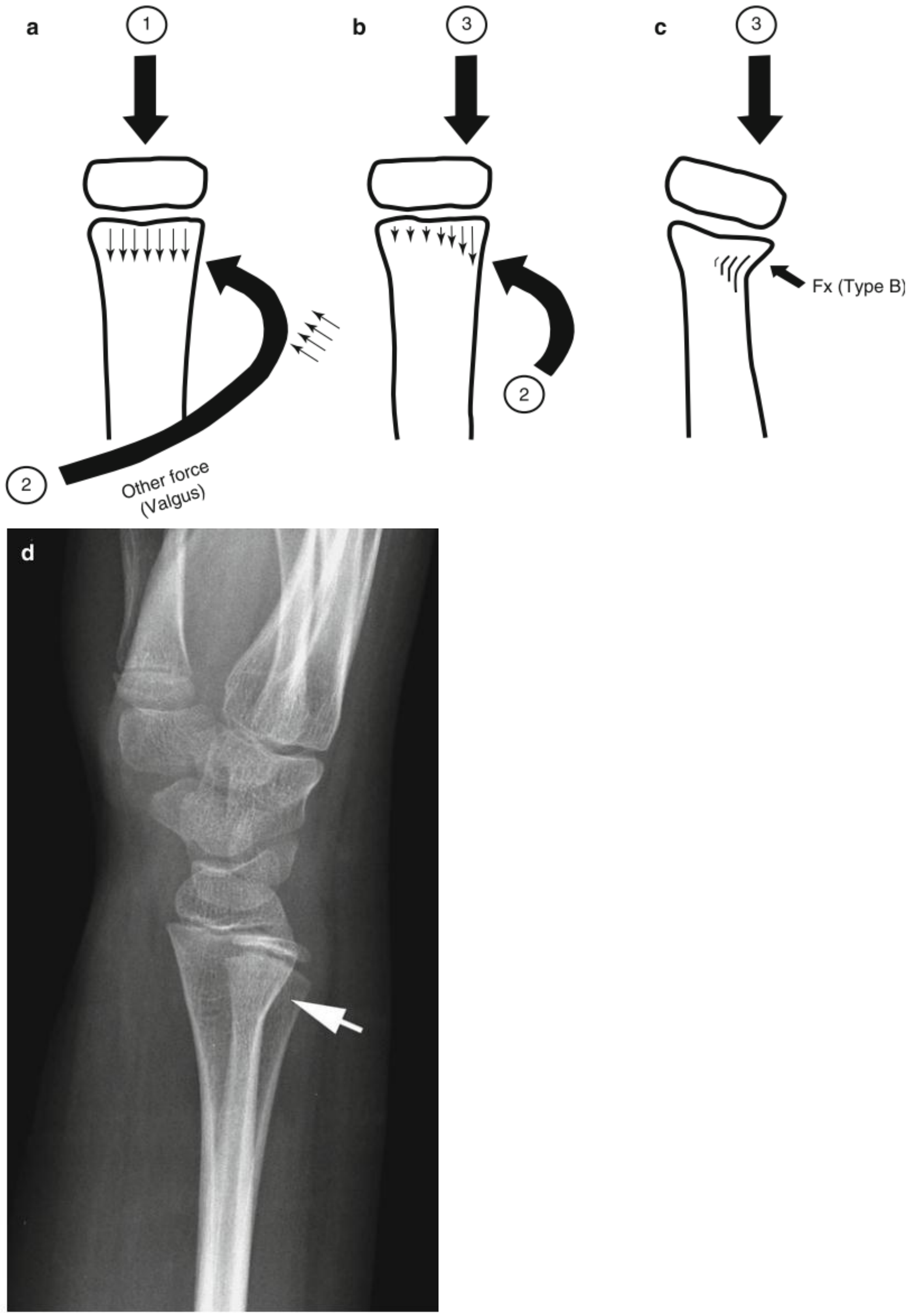


Figure 8: Buckle fracture type II. (a) Axial loading forces (1) are exerted down the length of the bone. However, other forces such as valgus also are at play. (b) This results in shifting of the axial load axis (3) and compression of the underlying metaphysis (2). (c) The same laterally placed axial loading forces (3) eventually

result in an angled buckle fracture (fx). (d) Typical angled buckle fracture of the distal radius (arrow). Compare with the smooth cortex over the anterior aspect of the radius.(Swischuk & Jadhav, 2014).

As a result of axial loading on the long axis of the long bones greenstick and plastic deformity or bowing types of fractures occur. Paediatric bones are soft hence result in bowing most of the times before the fracturing occurs when the forces are exceeded. This fracturing in most cases results in a greenstick type of fracture.

Epiphyseal-metaphyseal fractures occur almost exclusively in children since the epiphyseal-metaphyseal junction is weak and when the forces which cause shearing or twisting are applied at the long bone ends then a fracture would occur at that junction (Swischuk & Jadhav, 2014).

These fractures can be classified as described by Rodriguez-merchan, on the basis of site and fracture type. According to fracture site: they can be distal third, midshaft, or proximal growth plate. There are special fracture patterns among them are the fracture dislocations such as the Monteggia and Galeazzi fractures and a combinations of fractures humerus fractures and forearm or floating elbow. On the basis of fracture type as described above: plastic deformation or bending of the bone not involving a fracture, buckle, torus or compression fractures, greenstick fractures and complete fractures (Rodríguez-merchán, 2005).

Fractures classified on the basis of the fracture site can be proximal, mid shaft and distal for both the radius and ulna bones. For the proximal radius, the radial head fractures are the most common. This fracture type occurs as a result of axial loading which causes impaction of the radial head and most of the time a valgus force accompanies it. This causes a Salter- Harris type II fracture. Fragmented and displaced radial head fractures are easy to detect. The subtle, angled corner buckle fractures are difficult to detect however changes in the soft tissues and fat pad increases suspicious for them. Having comparative views thus helps in the diagnosis of such fractures.

Dislocation of the head of the radius can also occur though rare. They usually occur together with fractures of the ulna which are termed as Monteggia fractures. The head of the radius may dislocate without a fracture from the disruption of the annular ligament which is not a true dislocation. It usually results from incomplete tearing of the annular ligament resulting in subluxation of the radial head. A portion of the ligament is entrapped into the joint resulting in sudden severe pain in children from lifting or pulling the child on one arm. Xray is most of the times normal in this case though sometimes changes in the fat pad may be seen.

For the proximal ulna there maybe variable types of fractures owing to the fact that the ulna is fixed into the olecranon unlike the radius bone. Some of the proximal ulna fractures include: transverse fractures, longitudinal fractures, spiral fractures, hairline fractures and avulsion fractures.

Proximal ulna transverse fractures rarely occur alone. They are commonly combined with fracture of the radius. Longitudinal fracture of the proximal ulna is usually linear and mainly hairline type of fracture. They are caused by shearing and twisting forces when the elbow is rotated since the ulna is fixed to the olecranon. Hairline fractures occur from forces applied on the posterior broad surface. Lateral view radiographs are used to be able to see these hairline fractures.

Avulsion fractures of the proximal ulna which usually involves the olecranon process may occur. They often happen when there are dislocation injuries of the elbow as a result of forceful contraction of brachialis muscle resulting in avulsion of the olecranon process. This can easily be missed because it is often a small fragment although its location enables easier identification. The olecranon apophysis or a portion of it make also avulse but this is usually uncommon. This type of avulsion mainly occurs when the triceps muscles contract forcefully since the triceps muscles are inserted distally its avulsion is rare. Direct blow to the back of the elbow may cause avulsion injuries.

The midshaft of the forearm may have the following fractures; transverse, spiral, oblique, green stick fractures and plastic or bowing deformity. Buckling fractures are rare in the midshaft because the strong cortex in this region. The commonest fractures of the midshaft are greenstick fractures and plastic deformity fractures. Plastic bowing fractures are usually missed since they are subtle hence the need of doing comparative views to diagnose them. For isolated ulna fractures, a Monteggia fracture complex always needs to be ruled out by checking on the head of the radius for any dislocations. This can be assessed by drawing a line on the shaft of the radius which must cross the radial capitellum on both AP and lateral view radiographs which if it does not then diagnosis of radial head dislocation is made. The vascular grooves on both sides of the bones may be confused for a fracture.

Fractures of the distal radius and ulna are commonly transverse or oblique and are easy to detect. Other fractures of the distal radius and ulna include torus or buckling fractures, Salter Harris fractures (Swischuk & Jadhav, 2014).

Based on x-ray findings fractures can be categorized as complete or incomplete fractures. For the incomplete fractures they can be greenstick fractures, torus fractures also plastic deformations. Plastic deformations are persistent malformation without loss of bone continuity. Fractures of the metaphysis with swelling of the cortex are termed as torus fractures while greenstick are those that have one side of the bone intact (Fatih Ekþioðlu et al., 2003).

Zimmermann et al summarized fractures into four categories; torus fracture, greenstick fractures, complete fracture and Physeal fractures. Physeal fractures can be classified according to Salter/Harris classification into types I to IV. Salter/Harris type I involves growth plate separation without a fragment of metaphysis attached to the part of the epiphysis displaced. Type II growth plate is separation of growth plate with a fragment of metaphysis attached. Salter/Harris type III the joint space of the epiphysis is fractured and growth plate separated. Salter/Harris type IV involves fractured joint space, physis and comes out through the metaphysis (Zimmermann et al., 2004).

As described by Iles et al, fractures involving the distal radius can be classified based on their location, amount of displacement, angulation and rotation, whether they are at the physeal or metaphyseal region. Fractures involving the metaphysis can either be torus fractures or bi-cortical. They can be plastic deformation where they are as a result of the bone bending but the force causing the bend is not exceeding the bone strength to cause a fracture. Greenstick fractures occur when only part of the cortex is disrupted and this occurs when it is between a plastic deformity and fractures which are complete. Complete fractures involve disruption of the whole cortex (Iles et al., 2019).

1.7 Diagnosis of forearm fractures

1.7.1 Clinical diagnosis of forearm fractures:

Children and adolescents' clinical evaluation of fractures is usually very difficult. A thorough evaluation of the whole upper limb is usually mandatory to be able to diagnose any dislocation associated with the forearm fractures. In children and adolescents, the clinical presentation of fractures of the forearm is swollen, painful and deformed limb in the background of trauma. Those with complete and displaced fractures will have specific point tenderness and bony crepitus. Children usually get plastic deformities, torus fractures, minimally displaced complete fractures and greenstick fractures these cannot be easily picked clinically. Moreover, children have a thick periosteum which will result in difficulty in assessing fragment mobility. Discomfort with use of the upper limb and non-weight bearing of the affected limb may be the only presentation in the young children who unable to communicate. The children may also present with minimal swelling and limited range of motion. The limb may appear deformed and swollen within the compartments. Signs of injury such as abrasions, lacerations and signs of NAI maybe be seen. Pulses are palpated and capillary refill done to assess for perfusion of the forearm. The motor and sensory function tests are done to assess for any injury to the median, ulnar and radial nerves. Examination of the whole upper limb from the shoulder to the phalanges is necessary in order not to miss out on any other associated injuries related to the forearm fracture and to detect any joint dislocations present (Herman & Marshall, 2006).

Clinically, forearm fractures can be diagnosed by the presence of limb deformity, pain, limb getting swollen and ecchymosis (Galletebeitia et al., 2017).

1.7.2 Diagnosis of forearm fractures using plain radiographs

In paediatric patients with suspected forearm fractures, emergency physicians cannot make accurate diagnosis of fractures nor the exact location of injury from physical examination alone as this is greatly influenced by the patient's state of mind and also other injuries. In this case x-rays have been used to as the initial modality to make the diagnosis (Barata et al., 2012).

CT and MRI are considered superior in giving adequate information regarding fractures, but they are not cost effective or time efficient, therefore plain radiography is normally used as the standard of imaging modality for fractures in many facilities. Usually, in postero-anterior and lateral views are done an additional oblique view done (Porrino, 2014).

Diagnosis of fractures on radiography is done by checking on fracture lines, displacement and angulation in the radiograph(Akinmade, 2018).

X-rays are usually done using 2 main views AP and lateral views with inclusion of both the proximal and distal joints (Galletebeitia et al., 2017).

A good AP and lateral views of the forearm should be at right angles to each other and must have the ability to see the radius and ulna at full length with inclusion of both the elbow joint and the wrist joint (Clark, 2016).

Proper positioning is ideal in getting good AP and lateral views for the diagnosis of forearm fractures. For the AP projection, the patient should be seated with the affected limb next to the x-ray table. Abduction of the arm and full extension of the elbow joint with supination of the affected forearm. Elbow joint and the shoulder should be at the same level. The radial and ulnar styloid processes together with the medial epicondyles are adjusted in a way that they are equidistant to the image receptor (Clark, 2016).

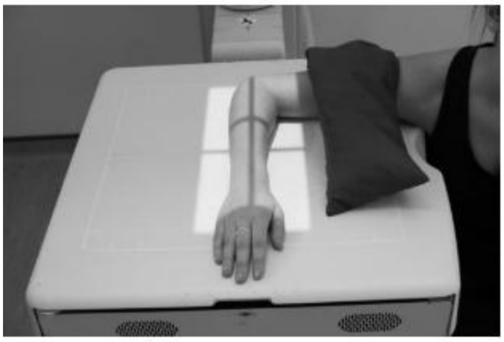


Figure 9 : Positioning of AP projection radiograph image adopted from Clark's positioning in Radiography (Clark, 2016).

Demonstration of both elbow and wrist joint in their true lateral position is needed for a good lateral radiograph. It entails flexion of the elbow to 90 degrees from the AP projection. 90 degrees internal rotation of the humerus is done so as to have the medial side of the hand, wrist, forearm and arm touching the x-ray table (Clark, 2016)

Figure 10: positioning of lateral projection radiograph adopted from Clarks positioning in Radiography (Clark, 2016).

1.7.3 Diagnosis of forearm fractures using ultrasound

X-rays are used by emergency physicians in the diagnosis of fractures. However, this takes more time, uses more resources in terms of sedation in patients requiring pre-procedure sedation, transferring patients to radiology department and also different views may be needed for accurate diagnosis which may be painful during that process and exposing the patients to ionizing radiation. Due to the above US has been used in the diagnosis of fractures of the forearm and other long bones. US is usually fast, cheap, and not invasive. On US a bright and echogenic line with posterior shadowing represents the cortex of the long bones. In the setting of trauma any discontinuity or gap in the echogenic line is a fracture (Barata et al., 2012).

Continuous hyperechoic bright line normally represents the bone cortex. It also demonstrates posterior acoustic shadowing and reverberation artifacts. Except for pathologies which cause thinning of the bone cortex, the deeper structures of the bone such as the internal architecture of the cortex, the underlying trabecular and endosteum cannot be visualized on US. In immature skeletal, the growth plates may resemble a fracture of the bone surface, it can be distinguished from a fracture through the knowledge of its anatomic location. In acute fractures, US is usually not the initial imaging modality of choice. It is normally used where x-rays could not detect the fractures, but the patient still has persistent pain. However, they are helpful in the diagnosis of nondisplaced fractures which could not be diagnosed on x-rays (Bianchi & Martinoli, 2007).

According to Williamson et al, US can be equally used as radiography in diagnosis of single forearm fractures that do not have complications (Williamson et al., 2000).

Using US technology for medical imaging started much later even though its discovery was earlier than x-rays. US uses tissue echogenicity to visualize different structures in the body. When a bone is normal and unfractured, the cortex of the bone appears as a continuous dense white line. This is due to complete sound waves reflection from the bone. When there is a gap in what was supposed to be continuous line, it represents a fracture (Chachan et al., 2015).

Fractures on US are diagnosed on the basis of cortical disruption or irregularity (Weinberg et al., 2010).

A study done in Turkey in 2003, described ultrasound findings in fractures can be seen as disruptions of the cortical bone, para-osseous hematomas, bending signs and reverberating echoes. According to this study, for patients with complete fractures, all the above-described ultrasound findings were seen except for bending. In plastic deformations, all patients had the finding of subperiosteal hematoma and bending visualized, interruptions of the cortex and reverberation of echoes occurred in about 50% of them. As for torus fractures, 100% of them had subperiosteal hematoma and interruption of the cortex whereas 14.3% had reverberations. Greenstick fractures had all US findings as described. (Fatih Ekþioðlu et al., 2003).

Weinberg et al described fractures as per US as disruption of the bony cortex when imaging on the long axis. While on the short axis imaging(transverse plane) there will be skipping or discontinuity effect (Weinberg et al., 2010).

According to Ackermann et al, US diagnosis of fracture is made when there is a cortical gap, a kink, formation of torus or presence of displacement (Ackermann et al., 2010).

Sometimes paediatric patients present with pain in the forearm but the parent/ caregiver is unable to know of any history of trauma or if it was NAI and when it occurred therefore use of ultrasonography may enable early differentiation of acute fractures and a healing/ old fractures. As described by Nicholson et al, healing and evolution of fracture healing can be detected on US as early as 2-6 weeks following trauma. This is seen as presence of hyperechoic signal bridging ends of a fracture on US which represents signs of healing (Nicholson et al., 2019).

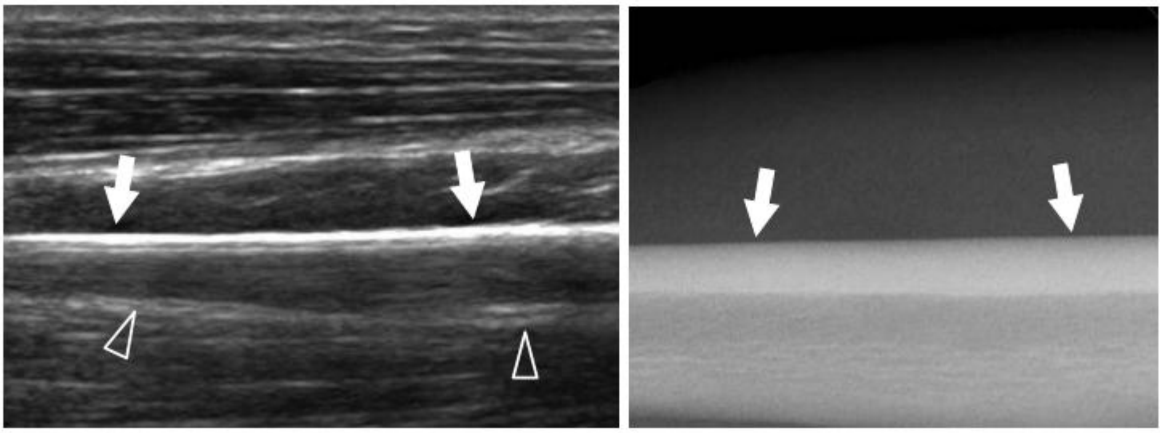


Fig 9: A Fig 9: B

Figure 11: A and B demonstrates appearance of a normal bone diaphysis on ultrasonography fig 9A and on radiography fig 9B. the arrows demonstrate continuous straight hyperechoic lines with associated reverberation artifacts pointed by the arrow heads (Bianchi & Martinoli, 2007).

1.8 Statement of the problem

Paediatric forearm fractures are very common in Kenya, with the radius accounting for about 23% of all upper limb fractures and the ulna accounting for 11% (Mwangi et al, 2017). In sub–Saharan Africa, forearms are the most fractured with 37% of cases (Ndoumbe et al, 2017). Worldwide, childhood forearm fractures are the commonest type of injuries brought to the emergency department (Wellsh & Kuzma, 2016). They make the burden of childhood injuries brought to the emergency department.

Fractures involving the long bones are the most common type of injuries due to trauma and amount to 3.5% to 3.9% of the emergency department visits in United

States. These fractures usually have a high risk of bleeding and neurovascular injury or even death (Barata et al., 2012). It is therefore important to identify and treat them early to avoid fatal outcomes such as limb loss or even death.

Despite this, most patients in general sent for x-rays with suspected distal radius fractures about 50% of the radiographs come out normal. (Bentohami et al., 2011). This therefore predisposes patients to avoidable exposure to radiation and wasting of resources.

Radiographs have about ten times increased risk of morbidity in children than in adults since x-rays subject patients to ionizing radiation that is evident to be carcinogenic and teratogenic mainly in paediatric age group making their highly dividing cells susceptible to such undesirable effects (Ackermann et al., 2010).

The paediatric bone has a good reflective acoustic property therefore US imaging of the cortex is better enabling visualization and identification of fractures about 1 mm in size (Akinmade, 2018)

Paediatric patients do not have a straightforward clinical presentation of fractures (J. D. Moritz et al, 2008). It is therefore recommended to have an US done as the first imaging modality in fractures to know the exact fracture site.

About three quatres of the world population do not have access to x-ray services. Unlike US which is recommended by WHO to be available in all levels of health facilities (Weinberg et al., 2010). US are simple to use and readily available in all levels of healthcare, it is easier to use and more convenient in making the diagnosis of fractures.

1.9 Justification

The main imaging modality in the diagnosis of forearm fractures is by anteroposterior (AP) and lateral radiographs. Radiographs have about ten times increased risk of morbidity in children than in adults. US can be used as a safer modality for diagnosis and adequate measurement of the fracture deformity (Ackermann et al., 2010). Due to the increased rates of paediatric forearm fractures, US can be safely used for diagnosis therefore decreasing the cost of radiography, speed of diagnosis can increase especially when done bedside and the burden of sending patients for radiographs decreased.

Increased use of radiographs predisposes patients to ionizing radiation and its unwanted effects which is much higher in children because their body parts are still developing making them susceptible to the unwanted effects of radiation (Mulvihill et al., 2017).

Paediatric patients have an increased risk of carcinogenesis on exposure to radiation even at lower doses because the radiosensitivity of their body tissues is about 10 times that of adults (Donnelly, 2005). Paediatric age group also have an over time increased risk to accumulative radiation dose (Hamer et al., 2016). This has led to increased attention to forearm injuries since they are the most common injuries presenting in the emergency room.

AP and lt radiographs have a radiation dose of about 0.02gray (Gy), although this dose is low, repeated exposures may lead to cumulative radiation owing to the fact that at least a minimum of two to three x-rays are needed from the time of fracture diagnosis to healing (Bochang et al., 2008).

Use of ultrasound enables us to get more information about musculoskeletal system and is easier to learn on how to perform it. In addition to that US has an increased level of precision in identification of forearm fractures (Hamer et al., 2016). Therefore, US can be used as a dependable tool and a replacement for radiography with an upper hand being free from radiation.

Utilization of ultrasound in the diagnosis of forearm fractures has been done by many emergency care givers especially in remote setups or in areas that setting up a radiography unit will need a lot of hassle (Christopher et al, 2015). Ultrasounds are portable, quick tool to use and can adequately help in decision making.

In paediatric patients with suspected forearm fractures, emergency physicians can neither make accurate diagnosis of fractures nor know the exact location of fracture from physical examination alone as this is greatly influenced by the patient's state of mind and also other injuries. Since x-rays have always been used as the modality of choice, in view of the above, the paediatric patient ends up having a larger area exposed to radiation. (Barata et al., 2012). US is radiation free and because the patients can stay with the caregiver during the examination, is more comfortable to the patient. A larger area can be imaged using US to know where the exact fracture site is, and appropriate management given.

In the emergency department Point of care ultrasound (POCUS) done in the assessment of fractures because it is quick easy to do and with minimal pain. It can also be used in the diagnosis of fractures due to its capability to access different planes during examination rather than pre-determined views of x-rays (Caroselli et al., 2021).

US is a good modality for examining fractures of the forearm because the soft tissue is thin and the distance from the transducer to the bone is shorter thus ensuring very high image quality. Upon US imaging, use of the six planes method enables proper visualization of the bone in all planes therefore signs of indirect fractures including hematoma, periosteum detachment, muscle oedema, tendon and function of the joint maybe visualized. Due to high spatial resolution of US soft tissues interposed between fracture fragments can be seen prior to surgery (Herren et al., 2015).

Use of POCUS has demonstrated that it can be used as a possible alternative in diagnosis of fractures and a much more accuracy if done by a qualified sonologist (Caroselli et al., 2021).

Plain x-ray uses a lot of time and resources and is potentially invasive especially if used in patients who need procedural sedation or repeat images for accurate diagnosis. In addition to that, the exposure to radiation from x-rays may disturb normal development of cells and in the long run cause cancer (Barata et al., 2012).

Patients are usually taken for x-rays to diagnose fractures, probably a check x-ray following reduction and maybe another x-ray to check on healing process. This results in multiple small dose radiation exposures. US is better at diagnosis of forearm fractures with precision and causes no exposure to radiation. It can also be used to confirm adequate reduction. It therefore can be used as a replacement for radiography.

US is very specific in diagnosis of fractures which are very small up to about 1mm due to increased bone reflective acoustic properties (Akinmade, 2018). This enables better visualization of the bony cortex.

The aim of this study is to show that ultrasound can be used as an alternative to radiographs in children with suspected forearm fractures.

1.10 Research questions

What is the comparison of sonographic and radiographic findings among children with suspected forearm fractures in MTRH.

1.11 Research objective

1.11.1 Broad Objectives

To describe and compare sonographic and radiographic findings among children with suspected forearm fractures.

1.11.2 Specific objectives

1. To describe the sonographic findings among children with suspected forearm fractures in MTRH.
2. To describe radiographic findings among children with suspected forearm fractures in MTRH.
3. To compare the radiographic and sonographic findings among children with suspected forearm fractures in MTRH.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Epidemiology

In Kenya, a study done in KNH in 2016 by Eric et al, showed that 53% of all paediatric long bone fractures were fractures of the upper limb with 23% of them being fractures of the radius bone and 11% fractures of the ulna bone (Mwangi, 2017).

Forearm fractures in South Africa are about 36.4% of all fractures and is the most fractured part of the body as studied by Strydom et al (Strydom et al., 2020). A study done in Cameroon by Ndoumbe et al, showed that males have increased incidence of fractures than females with majority occurring between the age of six and eleven years with a higher preference on the non-dominant hand (Ndoumbe et al., 2017).

In school going children, trauma to the MSK make about 30% of hospital visits and by the age of 16 years about 25-50 % will get a fracture(Naveen Poonai et al, 2016).

A study done on the Polish population by Grabala, revealed that forearm fractures account to 38% of the fractures with the incidence in boys more than that of girls (boys having 66% and girls 34%) (Grabala, 2015) .

In the United States, fractures of the long bones are regarded as the most common injuries due to trauma and make up to 3.5% to 3.9% of the emergency department visits (Barata et al., 2012).

In patients with forearm fractures about 80% were boys and majority were more than 12 years old, the fractures in females are mostly in those less than 12 years(Alrashedan et al., 2018).

The world report on child injury prevention by WHO reveals that trauma in childhood is one of the main causes of mortality and morbidity worldwide with those which are accidental making 90% of them. It also revealed that most deaths in developing countries were due to infectious diseases in the past and that they are now reduced. However, death due to trauma is still the leading cause of death in these countries (Peden M, 2008).

Worldwide, childhood forearm fractures are the commonest type of injuries brought to the emergency department (Wellsh & Kuzma, 2016).

Khosla et al reported that the incidence of forearm fractures particularly the distal forearm has significantly been increasing and this is probably either due to change in physical activity or poor bone health because of low calcium or both. He also reported that over a period of time the rate of fractures of the distal forearm have an increase of about 60% in girls and 35% in boys (Khosla et al., 2003).

Forearm fractures occur at about 45% of all paediatric fractures and about 62% of all fractures of the upper limb as reported by Rodriguez-merchan, and these fractures happen in about 81% of children above the age of 5 years with a peak incidence of 12 to 14 years in males and 10- 12 years in females. Among them 75 to 84% are distal third, 15 to 18 % middle third and 1 to 7 % are at the proximal third (Rodríguez-merchán, 2005).

Each year about 25% of children are injured with an incidence of 20.2 fractures in 1000 patients per year below the age of 16 years and 82.2% of the fractures occurred in the upper limb (Rennie et al., 2007).

Fractures of the distal radius are common during pubertal age and often occur in boys than girls, this is probably because of decreased mineralization during this period and increased sporting activities in the boys (Porrino, 2014).

According to Malviya, for every 100 children 1 has a forearm fracture. One third of long bone fractures in paediatric age group being fractures of the diaphysis they have a peak age of 12- 14 years (Malviya et al., 2007).

Forearm fractures occur in boys more commonly than in girls with the non-dominant arm mostly injured. In boys it has two peaks at the age of 9 years and 14 years. The girls have a peak at 9 years of age. Majority of the injuries occur as isolated injuries (Herman & Marshall, 2006).

Fractures in children, as studied in Scotland, has two peaks with the first peak between the ages of 6-7 years and another between the ages of 13-14 years with the incidence of in girls just slightly below that of boys for the ages of 12 years and below but those older than 12 years the incidence is much higher in boys (Rennie et al., 2007).

According to Alrashedan et al, who studied the population of Saudi Arabia and found out that 80.82% of fractures of the forearm occurred in boys and 19.18% were girls. The most common mechanism of injury was a fall at 83.96% while those from road traffic accident were 16.04%. Fractures of the distal forearm are the commonest type of forearm fractures at 48.11% distal third of the shaft 34.28%, middle third of shaft were 16.04% and proximal third of the shaft were 1.57%. Injuries as a result of being hit directly accounted for 14.4% of distal forearm fractures, distal third fractures of the shaft of the forearm was 17.4% midshaft was 17.6% and upper third of the forearm was 20% (Alrashedan et al., 2018).

2.2 X-ray findings of forearm fractures

Presence of bone shortening on radiography following trauma, indicates a possibility of a fracture in either of the bones which radius is the commonest (Porrino, 2014).

Fractures on x-rays are seen as fracture lines on the bone either complete or partial. Displacement and angulation of the bones may also be present (Akinmade, 2018).

On x-ray fractures taken on an AP and lateral views can be classified as complete or incomplete fractures. Complete is when both bone cortices are disrupted. Incomplete fractures on the other hand include plastic deformity where the continuity of the bone is maintained but there is permanent deformation of the morphology, torus fractures which are fractures of the metaphysis which cause bulging of the cortex as a result of trabecular compression due to axial loading force on the long axis of the bone and greenstick fractures where the cortex of the bone and the periosteum break usually on the convex sided. Greenstick fractures usually occur in the mid-diaphyseal region of the forearm (Fatih Ekþioðlu et al., 2003).

2.3 US findings of forearm fractures

In the setting of trauma, a gap seen in the highly echogenic cortex of the bone is regarded as a fracture on US. If a fracture displacement is suspected, the bone fragments that are separated can be seen as echogenic areas, will demonstrate a gap in between them this can be used to measure the amount and degree of displacement. Soft tissue injuries, tears and joint effusions can also be easily diagnosed on US and may be accompanied by the fracture (Barata et al., 2012).

Fractures appear as a defect in the continuity of the hyperechoic line of the cortex with a subperiosteal hematoma. It detects nerve impingement or soft tissue interposition between the fracture lines that may interfere with fracture healing (Bianchi & Martinoli, 2007).

Changes on the soft tissues of the forearm, presence of collections which are usually hematomas, abnormalities seen on the periosteum together with break in the discontinuity of the cortex signify a fracture on US (Akinmade, 2018).

Presence of cortical interruptions, lesions in the periosteum, haematomas, and changes in the soft tissues demonstrate the presence of fractures on US (Hübner et al., 2000).

On US fractures are seen as disruption of the cortex, bending of the cortex without break in its continuity, elevation of the periosteum if a subperiosteal haematoma is present and reverberating artifacts from increase in the echogenicity of the medulla (Fatih Ekþioðlu et al., 2003).

2.4 Comparison of plain radiographs to ultrasound findings in forearm fractures

A study done in Netherlands by Epema et al, where he investigated 100 children and 64 of them were diagnosed with fractures using x-rays which was used as the gold standard, diagnosis of distal forearm fractures by US in 92% of them with a sensitivity of 95% and specificity of 86% all the above values were at 95% confidence interval.at the same confidence interval PPV, NPV, PLR and NLR was 92%,91%, 6.86 and 0.05 (Epema et al., 2019).

In a prospective study done by Akinmade, where he did a study on long bone fractures and studied 62 individuals. 52 fractures were diagnosed on plain x-rays and the prevalence was calculated as 83.9%. Upon US examinations, 50 fractures were correctly diagnosed. The sensitivity of 96.2% and specificity of 83.3% was found.

The positive predictive value was 100% and negative predictive value was 83.3% (Akinmade, 2019).

A study done by Galletebeitia et al, where the use of US in diagnosis of distal forearm fractures was investigated, 115 children with suspected fractures were studied. 57 of them had a diagnosis of fracture using the standard radiography and fractured bones were 72. US was done on the patients and diagnosis of 73 bones with fractures made. There were 5 false negatives and 5 false positives when compared to radiographs. Therefore, the sensitivity of POCUS compared to radiography was 94.4% at 95% confidence interval and specificity of 96.8% at 95% confidence interval. The positive and negative likelihood ratios were 0.06 and 29.84 at 95% confidence interval respectively (Galletebeitia et al., 2017).

According to meta-analysis done by Hamer et al, fractures of the distal forearm are detectable on US having a high sensitivity of 97% and specificity of 95% both at 95% confidence interval when x-rays were used as gold standard. The use of US has a Likelihood Ratio (LR) of +20 and -0.03 therefore a good modality to rule in or rule out fractures of the distal forearm in paediatric age group. He also found out the 6-view method of performing US has a sensitivity of 98% and specificity of 98 % at 95% confidence interval. There is and increased sensitivity LR of the radius compared to the ulna (Hamer et al., 2016).

In a study done Rowlands et al, where they studied 419 patients 214 of them were diagnosed with a fracture and 185 had no fracture on plain radiographs, amongst those US made a correct diagnosis of fractures in 214 of the patients giving it a sensitivity of 91.5% and 162 of the patients US made a diagnosis of no fractures giving a specificity of 87.6%.kappa agreement of 0.792 was made($p<0.001$) (Rowlands et al., 2016).

A study done by Poonai et al in 2016 where 165 patients with suspected non-angulated distal radius fractures had a POCUS done, amongst them 76 had a diagnosis of fracture. Compared to x-ray which was used as the standard of diagnosis, sensitivity of POCUS was 94.7% at 95 % confidence interval and specificity was 93.5% at 95% confidence interval and POCUS was also associated with less pain (Naveen Poonai et al, 2016).

Christopher et al, in 2015 did a study in a battalion aid centre, where he examined 44 patients with acute fractures via ultrasound and found that 12 had abnormal ultrasound findings and 32 were regarded as normal on ultrasound, the patients with abnormal findings on US had radiographs done and 10 of them had acute fractures. The patients who had negative for fractures on US were reviewed after 72hours and 4 of them still complained of pain which warranted them do radiography on them that came out as normal. This gives it a specificity of 94% and sensitivity of 100% (Christopher et al, 2015).

Barata et al studied 53 patients with long bones fractures where 30 (56.6%) of them were males. Multiple examinations were needed in 42 patients. He therefore did a total of 98 US. Of those, 69(70.4%) of them were bones from the upper extremity and from these the forearm was the majority. Radiography identified 43 fractures 41(95.3%) of them were seen on US. There were 55 negative readings on US which 47 were assessed and 8 false positive ultrasound results found. He got a sensitivity of 95.3% and a specificity of 85.5% at 95% CI(Barata et al., 2012).

Chaar-alvarez et al studied 103 patients with suspected non angulated fracture of distal forearm, plain x-rays were used as the gold standard in diagnosis of fractures. Diagnosis of distal forearm fractures was made in 46 of them using plain x-rays. US was done on them and at 95% confidence interval, they had an accuracy of 94%. Sensitivity of 96% and specificity of 93%. Basing on the prevalence of distal forearm fractures at the time of study, positive predictive value was at 92% and negative predictive value of 96% (Chaar-alvarez et al., 2011)

Weinberg et al in 2010, Studied children and young adults less than 25 years of age and studied all long bones and non-long bones. He enrolled 212 patients and got 43 false positive and false negative results where 37 of them were involving ends of bones and growth plates accounted for 12 of them. The diagnosis of radius fractures on US had a sensitivity and specificity of 71& and 81% at 95% CI respectively while that of ulna had a sensitivity and specificity of 50% and 95% at 95% CI respectively(Weinberg et al., 2010).

Ackermann et al did a study on 77 fractures 72 of them (94%) were correctly diagnosed via US. Diagnosis by use of US had a sensitivity of 64% and specificity of 99% with the radiograph taken as the gold standard for diagnosing forearm fractures (Ackermann et al., 2010).

In a study done by Patel et al, where he studied 33 patients and 66 bones, fractures were diagnosed in 59.1% of all bones studied. Both US and plain radiographs agreed on presence fracture diagnosis in 95.5% of them. Bedside US diagnosis had a sensitivity of 97% and specificity of 93% at 95% confidence interval (Patel et al., 2009).

A study done by Moritz et al, where he made a conclusion that in diagnosing fractures US can be comparable to radiographs; he studied 726 body parts, 308 of them had fracture 266 were diagnosed on US and plain radiography, 20 of them were diagnosed only on US and 21 only on radiographs. US had a sensitivity of 92.9% and 93.2% was sensitivity using plain radiographs, in terms of specificity, US had 99.5% and radiographs 99.8%(J. D. Moritz et al, 2008).

In study done by Chen et al, where he studied 68 patients with suspected forearm fractures. patients had US done first and plain x-rays done thereafter. Among them 65 fractures were diagnosed in 48 patients on radiographs. US was able to correctly identify fractures the type and fracture site in 63 of the fractures among 46 patients at 95% confidence interval, sensitivity of US in detection of fractures was 97% and specificity of 100% (Chen et al., 2007).

As described in Germany by Hubner et al, where he examined 85 fractures of the distal radius, 59 of fractures seen on plain radiographs 58 were identified via US giving it a sensitivity of 98.3% and of the 18 that were identified as not having fractures 8 of them were false positives the specificity being 69.3%. Fractures of the ulna was rightly diagnosed via US in 88.8% of them (Hübner et al., 2000).

According to Williamson et al, where he studied children with suspected non-displaced non articular and isolated fractures were studied. 26 patients were studied, the girls were 10 and boys were 16, out of those 16 had a diagnosis of fractures on US and upon doing x-rays of the same they all confirmed the fractures. Whereas the 10 had normal US findings and also confirmed to be normal on x-rays. Making it have a sensitivity and specificity of 100% (Williamson et al., 2000).

In a study done by Eckert et al, where 67 patients were studied. Diagnosis of fractures was made using plain radiography in 42 patients with 52 metaphyseal fractures of the forearm. 31 of them had isolated radial fractures, 10 had fractures of both radius and ulna and 1 had fractured ulna alone. US was then used and 52 fractures were also diagnosed and all patients without fractures were rightly diagnosed. The isolated radius fractures were all seen on US. 1 radius fracture seen on US was not diagnosed on x-rays. For both radius and ulna fractures US diagnosed 9. US diagnosed the isolated ulna fracture. 2 fractures of the ulna were not seen on US and 2 fractures of ulna seen on US were not seen on x-rays. Sensitivity, specificity, positive predictive value and negative predictive values were calculated and results were 96.1%,97%,94.3% and 97.9% respectively (Eckert et al., 2012)

2.5 Complications of forearm fractures

Fractures of the long bones including the forearm have serious complications. Such complications include increased risk of bleeding and neurovascular injury. It is therefore necessary to diagnose the fractures early to avoid serious complications such as loss of limb and death (Barata et al., 2012).

According to Rodriguez-merchan, complications include compartment syndrome, malunion, non-union, refracture, neurovascular injuries, muscle or tendon entrapment, reflex sympathetic dystrophy and infections (Rodríguez-merchán, 2005).

As described by Marshburn et al, fractured long bones may result to substantial bleeding and injury to the neurovascular system leading to increased morbidity (Marshburn et al., 2001).

Complications of fractures can be as follows; malunion where there will be decreased range of motion resulting from length discrepancy, mal-angulation and malrotation.

There may be delayed union or non-union which is quite uncommon in children. Re-fracture mostly occurs about 4-6 months after cast removal and mainly occurs in diaphyseal fractures. Compartment syndrome happens usually after multiple closed reduction manipulation attempts. Neurovascular damage in children it is uncommon since they have good vascular healing compared to adults. Cross-union and overgrowth of bone resulting in impaired rotation and limb discrepancies which may need excision (Sinikumpu, 2013).

Fracture remodelling and healing with excess angulation is not predictable therefore checking the alignment of fractures through radiography does not guarantee rotation and function of the limb. Corrective osteotomy is usually done 1 year after fracture healing in case of malunion. Refractures occur in about 5% of cases and treatment is usually by open reduction and internal fixation. Synostosis of the radius and ulna are rare but may occur in high energy trauma. Re-synostosis after surgical manipulation may also occur. Intermedullary nail complications may occur such as migration of the hardware, irritation of the skin, infection and injury to the nerves. Loss of reduction following removal of the implant and delayed union may also occur (Herman & Marshall, 2006)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Study design

The study was conducted as a hospital based descriptive cross-sectional study that was conducted for a period of 12 months on all patients with suspected forearm fractures that came to the accident and emergency department and Shoe for Africa Children's Hospital who were sent to the radiology and imaging department for plain radiographs.

3.2 Study site

The study was conducted at the Radiology and Imaging Department at the Moi teaching and Referral Hospital, Eldoret, which included the x-ray unit at the Accident and Emergency department and the x-ray unit at the Shoe for Africa.

The hospital is a level 6 hospital located in Eldoret town, Uasin Gishu County which is 310 kilometres Northwest of Nairobi, the capital city of Kenya. The hospital is a teaching and referral hospital and serves as a teaching hospital for Moi University School of Medicine, Nursing, Public Health, and Dentistry. Other institutions that use this hospital for teaching purpose include University of East Africa, Baraton. School of Nursing and Kenya Medical Training Centre (KMTC) Eldoret. MTRH is also a training centre for medical, clinical, and nursing officer interns. It serves as the main referral hospital for the Western part of Kenya and North Rift region and has a catchment population of approximately 13 million people. Apart from Radiology and imaging, the facility has several other departments including Internal Medicine, Surgery, Paediatrics, Obstetrics and Gynaecology, Psychiatry, Orthopaedic surgery, and others.

Paediatric patients are treated and managed in the Shoe for Africa Hospital which is part of Moi Teaching and Referral hospital. It is the only public kids' hospital serving the entire region of East and Central Africa. It has different paediatric sub specialities including paediatric cardiology, paediatric Nephrology, Paediatric Oncology, Paediatric Gastroenterology, Paediatric Neurology and Neonatology. It has its own dedicated x-ray department.

3.3 Study population

All children below the age of 18 years old, presenting at the Radiology and Imaging department and Shoe for Africa with localized tenderness and swelling over the forearm due to trauma.

3.4 Study period

This study was conducted for a period of 12 months between the month of April 2021 and March 2022.

3.5 Eligibility criteria

3.5.1 Inclusion criteria

All children with suspected forearm fractures seen at the accidents and emergency department and Shoe for Africa Children's Hospital and sent to radiology department for forearm x-ray.

3.5.2 Exclusion criteria

1. Patients with open fractures
2. Pathological fractures such as rickets, osteogenesis imperfecta.
3. Arrival at the emergency department with prior diagnosis of fractures or x-rays done elsewhere.
4. Hemodynamic instability.
5. Polytrauma patients.

3.6 Sample size

The main aim of the study was to evaluate the diagnostics accuracy of ultrasound in diagnosing forearm fractures using forearm x-ray findings as the gold standard. A study done by (Bentohami et al., 2011), found the proportion of those with forearm fractures among children with suspected fractures to be 50.0% and (Epema et al., 2019) found a sensitivity of 95.0% and specificity of 86%. Assuming the same values in our settings the sample size will be estimated using Buderer's 1996 formula

$$n \geq \frac{Z^2{}_{1-\alpha/2}(S_P)(1-S_P)}{L^2 \times prevalence)}$$

S_P = the anticipated specificity taken as 86%

Proportion of forearms fractures among those with suspected fractures= 50.0%

1-α = size of the critical region (confidence level)

$Z^2{}_{\alpha/2}$ = standard normal deviation corresponding to the critical region α = 1.96

L^2 = absolute precision desired on either side (5%)

Substituting for the above figures the minimum sample size required was 373.

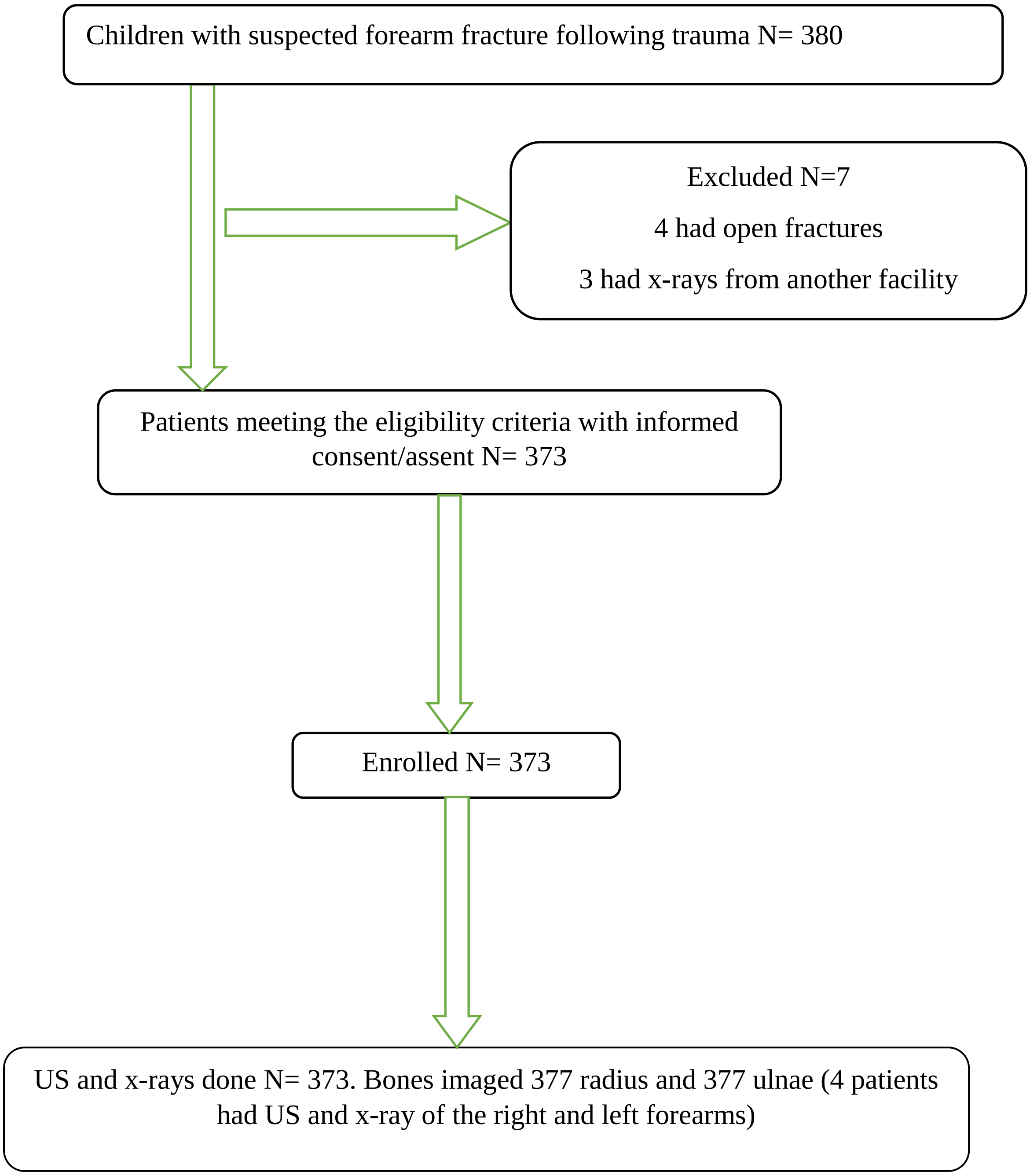
3.7 Sampling technique

According to the radiology department data, a total of 392 patients with suspected forearm fracture presented for forearm x-rays in the year 2020. Therefore, consecutive sampling technique was used to recruit patients from the Accidents and Emergency department and Shoe for Africa Children's Hospital after clinical evaluation by the clinicians with suspected forearm fracture. All clinicians in the Accident and Emergency department and Shoe for Africa Children's Hospital were sensitized about the study and to consider patients with suspected forearm fracture to be subsequently subjected to x-ray of the forearm and US scan of the forearm.

3.8 Study procedure

Paediatric patients with clinical features suggestive of forearm fractures, after being examined by the clinicians and appropriate analgesics given, were recruited into the study. Consent was obtained from their parents/guardians while those aged 7 years and above provided assent in addition to the consent from their parents/guardians. Consent for US was taken after request for radiography has been done by the clinician examining the patient. The recruited patients had forearm ultrasound at the department of radiology and imaging followed by the forearm radiograph. Forearm US was performed by the principal investigator and the US findings were then confirmed by a consultant radiologist on duty who were both blinded of the x-ray findings. The final diagnosis of forearm fracture was confirmed by two independent consultant radiologists at the department. In cases where two radiologists did not agree a 3rd radiologist read the images.

3.9 Enrolment flow chart



3.10 Analysis done.

3.10.1 Forearm ultrasound protocol:

All paediatric patients with suspected forearm fractures sent for x-ray by the primary clinician had a waiver from the hospital to get a complementary ultrasound done**.** Appropriate analgesia was administered to all patients with suspected forearm fractures in the accident and emergency department and shoe for Africa children's hospital by the attending clinician prior to sending them for imaging.

Patients were examined either seated or supine at the position of comfort on the examination couch in the presence or the parent/guardian. A paper towel was used to protect their clothes. Prewarmed gel was applied. The forearm US was done using SonoScape ultrasound machine ST-180 model with a linear array transducer 7.5 MHZ to 12 MHZ. The normal limb was examined first to ensure that the patient is comfortable, doesn't decline the study and for comparison. Adequate US gel or a water bath technique was used to reduce firm contact of the transducer with the patient's skin and decrease pressure on the site that has been injured. Each bone was scanned separately to ascertain the presence and the site of fracture. Six views method of scanning was used where both the radius and ulna were examined in the dorsal, lateral, and volar region from the proximal to the distal aspect of the forearm. the US transducer is placed longitudinally with the probe marker facing the direction closest to the joint. US findings of fractures can be seen as disruptions of the cortical bone, para-osseous hematomas, bending signs and reverberating echoes.

The above protocols were borrowed from studies done by ((Fatih Ekþioðlu et al., 2003),(Weinberg et al., 2010),(Blaivas et al., 2004),(Hamer et al., 2016)), (Galletebeitia et al., 2017).

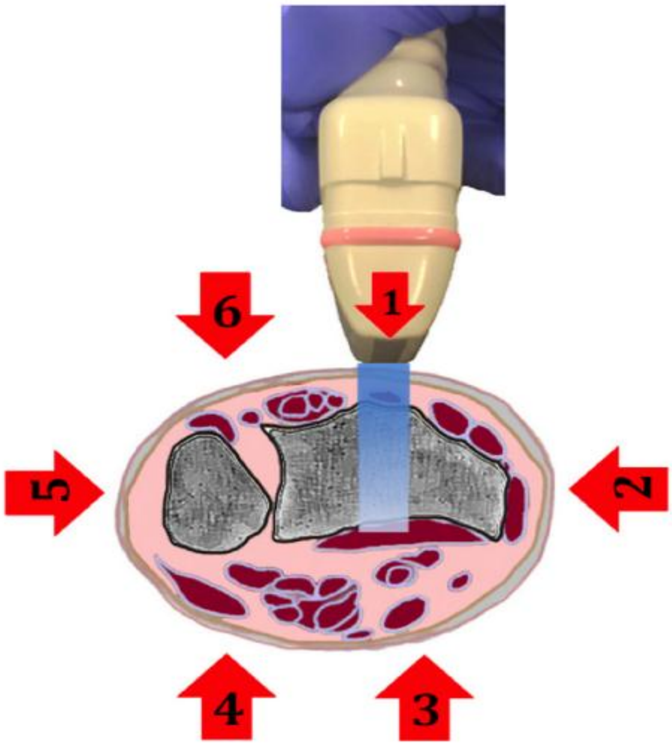


Figure 12: six views method of scanning the forearm. 1; Dorso-radial. 2; Radial. 3; Palmar-radial. 4; Palmar-ulnar. 5; Ulnar. 6: Dorso-ulnar (Herren et al., 2015)

3.10.2 Forearm radiograph interpretation

AP and lateral projection of the radiograph was done to all patients according to the MTRH protocol. This included visualization of both the elbow and the wrist joint to rule out any joint dislocations or other associated fractures.

Forearm radiographs characterised as normal or fractured, the bone fractured, the site of fracture, displacement and type of fracture recorded.

3.11 Data collection

Data was collected between for a period of 1 year from April 2021 to March 2022. Entry was done in the questionnaire and later transferred to a computer database using double entry to ensure accuracy. All patients' details were kept confidential, and data was only available to the investigator and the supervisors via password access.

Patients had a copy of the results and had the autonomy over who else could view their results. Serial numbers have used to protect patients' identity. At the end of each day data collection forms were verified for completeness and coded.

3.12 Quality controls

All forearm ultrasound and forearm x-rays were done in MTRH ultrasound and x-ray rooms using an internal standardized protocol. Forearm radiographs were done by radiographers while forearm US done by the principal investigator and her assistant. The images were reviewed by the principal investigator and two senior consultant radiologists. The results were recorded after an agreement of the final diagnosis.

3.13 Data analysis and presentation

Data was imported into STATA 16 where data cleaning, coding and analysis was done. Data on age will be summarized as median and corresponding interquartile range while data on gender was summarized in frequencies and percentages.

To answer objective one and two data on forearm x-ray and forearm US findings they were tabulated as frequencies and corresponding percentages. For objective three, composite variables were created to come up with diagnosis of forearm fracture for both US of the forearm and plain radiography. Sensitivity, specificity, positive predictive value, and negative predictive values was calculated taking plain radiography as the standard modality for imaging forearm fractures. All statistics was performed at 95% level of confidence. The results of this study were presented in form of tables, figures, radiological images, and prose format.

3.14 Ethical considerations

Ethical approval for the study was sought from the Institutional Research and Ethics Committee (IREC), Moi University/Moi Teaching and Referral Hospital. NACOSTI approval was sought to conduct this study. Permission to carry out the study was sought from IREC and the MTRH management. A waiver was sought from the hospital to allow for the ultrasound to be done as a complementary study. All patients/guardians were informed about the study and the procedures involved in the study and the possible benefits and harm. Consent was sought from the parents/guardians of the children and assent from children above 7 years. All patients received medical attention as necessary regardless of their willingness/unwillingness to participate in the study. No incentives or inducements was used to convince patients to participate in the study. Patients were allowed to withdraw from the study at any point. The findings were conveyed to the clinicians in standard report attached to the patient's images.

Confidentiality was maintained throughout the study. The data collection forms neither contained the names of the patients nor their personal identification numbers. Data collecting material was kept in a locked cabinet during the study period. The data was entered into a password protected computer and using codes in place of individual names.

No major risks occurred from participating in this study apart from the time consumed during the study participation.

The results from this study will be disseminated to the department of radiology and imaging, Moi University School of Medicine. It will also be published in the journals of radiology, presented in meetings, conferences and seminars.

CHAPTER FOUR: RESULTS

4.1: Socio-demographic characteristics

Table 4.1 below shows the demographic characteristics.

Majority of the study participants were males 243 (65.1%) the mean age was 9.72 with a standard deviation of 5.01. The most popular site where the accident took place was at home 252 (67.6%) followed by school 114 (30.6%). Fall attributed to the highest mechanism of injury.

Table 4.1: Socio-Demographic characteristics

Variable	N 373	Frequency (n)	Percent (%)
Gender			
Female		130	34.9
Male		243	65.1
Age in Years	373		
Mean 9.72			
SD 5.01			
Accident site	373		
At church		1	.3
At home		252	67.6
At school		114	30.6
Road accident		6	1.6
Mechanism of injury			
A fall while playing		358	96.0
Hit by a blunt object		6	1.6
Road Accident		9	2.4

4.2 Forearm ultrasound findings

Table 4.3.1 below shows that ultrasound test results revealed 223 (59.1%) fractures among the suspected fractures with majority of them being radius. On the radius the most common site of fracture was right distal 1/3 at 95 (44.6%) while in the Ulna it was the right distal 1/3 at 58 (41.7%).

Table 4.2.1: Forearm ultrasound findings

Variable	Frequency (n)	Percent (%)
Fracture present on Ultrasound		
No	154	40.9
Yes	223	59.1
Bones involved		
Radius	84	37.7
Ulna	10	4.5
Both	129	57.8
Site of fracture		
Radius	**213**	
LT DISTAL 1/3	81	38
LT MIDSHAFT	18	8.5
LT PROXIMAL 1/3	0	0
RT DISTAL 1/3	95	44.6
RT MIDSHAFT	18	8.5
RT PROXIMAL 1/3	1	0.5
Ulna	**139**	
LT DISTAL 1/3	53	38.1
LT MIDSHAFT	14	10.1
LT PROXIMAL 1/3	1	0.7
RT DISTAL 1/3	58	41.7
RT MIDSHAFT	13	9.4
RT PROXIMAL 1/3	0	0

Features indicating a fracture on ultrasound: cortical disruption and cortical bulge

Table 4.2.2 below shows the descriptive distribution of cortical disruption on various sites

Table 4.2.2 :Cortical disruption on ultrasound

Variable		Frequency (n)	Percent (%)
Cortical disruption Present			
Complete			
Radius	212		
No		7	3.3
Yes		205	96.7
Ulna	143		
No		2	1.4
Yes		141	98.6
Partial			
Radius			
No	212	211	99.5
Yes		1	0.5
Ulna	143		
No		143	100

Table 4.2.3 below shows the descriptive distribution of cortical bulge on various sites as seen on ultrasound.

Table 4.3.3 :Ultrasound cortical bulge

Variable		Frequency (n)	Percent (%)
Cortical Bulge Present			
Radius	212		
No		196	92.4
Yes		16	7.6
Ulna	143		
No		137	95.8
Yes		6	4.2

4.3 Forearm X-ray findings

X ray investigations showed fractures present in 227 (60.2%) patients with majority of them being radius. On the radius the most common site of fracture was right distal 1/3 95 (43.8%) while in the Ulna it was the left distal 54 (39.4%).

Table 4.3.1 shows presence or absence of a fracture as seen on x-ray and the site of the fracture.

Table 4.3.1: Forearm X ray findings

Variable	Frequency (n)	Percent (%)
Fracture present on x-ray		
No	150	39.8
Yes	227	60.2
Bones Involved		
Radius	90	39.6
Ulna	10	4.4
Both	127	56.0
Site of fracture		
Radius	**217**	
LT DISTAL 1/3	85	39.2
LT MIDSHAFT	17	7.8
LT PROXIMAL	0	0
RT DISTAL 1/3	95	43.8
RT MIDSHAFT	19	8.6
RT PROXIMAL 1/3	1	0.5
Ulna	**137**	
LT DISTAL 1/3	54	39.4
LT MIDSHAFT	15	10.9
LT PROXIMAL 1/3	2	1.5
RT DISTAL 1/3	50	36.5
RT MIDSHAFT	15	10.9
RT PROXIMAL 1/3	1	0.7

Features indicating a fracture on x-ray: cortical bulge and cortical disruption

Table 4.3.2 below shows the descriptive distribution of cortical disruption on various sites.

Table 4.3.2: Cortical disruption

Variable		Frequency (n)	Percent (%)
Cortical disruption Present			
Complete			
Radius	216		
No		34	15.7
Yes		182	84.3
Ulna	142		
No		22	67.8
Yes		120	31.9
Partial			
Radius	216		
No		191	88.4
Yes		25	11.6
Ulna	142		
No		122	85.9
Yes		20	14.1

Table 4.3.3: X ray cortical bulge

Table 4.3.3 below shows the descriptive distribution of cortical bulge on various sites.

Variable		Frequency (n)	Percent (%)
Cortical Bulge Present			
Radius	216		
No		163	75.5
Yes		53	24.5
Ulna	142		
No		130	91.5
Yes		12	8.5

Table 4.4 below is a 2 x2 table showing true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN). The number of true positives where x-ray and ultrasound detected fractures were 210 and true negatives where x-ray and ultrasound detected normal bones were 138. The false positives where ultrasound detected a fracture and it was not present were 12 and where ultrasound did not detect a fracture and it was present false negatives was 17

Table 4.4 :Concordance levels between X-Ray and ultrasound tests

		X-ray		Total
		Yes	No	
Ultrasound	Yes	210(TP)	12(FP)	222
	No	17(FN)	138(TN)	155
Total		227	150	377

Cohen Kappa test was run to determine if there was agreement between x ray and Ultrasound examination. There was a strong agreement between the two tests k= .845 P< 0.0001 which is considered as almost perfect agreement.

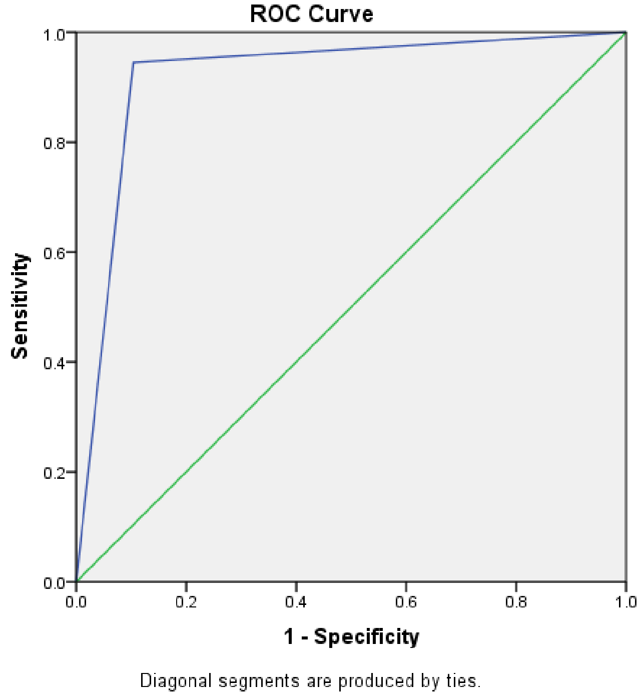


Table 4.5 below indicates the sensitivity, specificity, positive likelihood ratios, negative likelihood ratios and accuracy level of the ultrasound based on the findings of table 4.4 above

Table 4.5: Sensitivity and specificity

Sensitivity	**92.5%**
Specificity	92%
Positive likelihood ratio	11.5625
Negative likelihood ratio	0.08152
Accuracy	92.31%

SAMPLE IMAGES

SAMPLE IMAGE 1: 2-year-old girl with history of a fall while playing at home, both the x-ray and us are normal

SAMPLE IMAGE 2: a 7-year-old boy with history of a fall while playing in school. Images at the top are Xray of the left forearm demonstrates a fracture of the left midshaft radius and ulna. Images at the bottom are ultrasound images of the same patient demonstrating left midshaft radius and ulna fractures.

SAMPLE IMAGE 3: a 16-year-old girl with history of a fall while cleaning the house, images at the top are x-ray images showing bowing of the right radius and ulna indicating plastic deformity. Images at the bottom are ultrasound images of the same patient showing fractures of the right distal third radius and ulna

SAMPLE IMAGE 4: images of a 9-year-old boy with history of a fall while playing at home. Images on the top are x-ray images demonstrating left distal third radius and ulna fractures. Images at the bottom demonstrate left distal third radius and ulna fractures

CHAPTER FIVE

5.0 Discussion

5.1 Introduction

In paediatric patients and young adults, the major cause of injury and disability is trauma which results in loss of lives and renders them incapacitated. In Kenya and the rest of the world forearm fractures are the commonest of the long bone fractures. Distal radius is the is the site mostly affected. Plain x-ray using the standard AP and lateral view is the gold standard for diagnosis of fractures. Due to the unwanted effects of radiation in children US has been used in the diagnosis of forearm fractures since the paediatric bone has good reflective acoustic properties. It is always difficult to diagnose a fracture and know the exact location of fractures in children because their state of mind is usually affected by emotions and also other injuries. This can lead to a large area exposed to x-rays in order to localize the exact fracture location. In this case US can be used to localized and diagnose fractures in children. Use of US is easily acceptable by children because the can be scanned while their parents/guardian is with them so easier to make them relax and scan in different planes unlike x-rays. In most studies done previously, demonstrate that US done easily be used to diagnose fractures. It has a sensitivity and specificity ranging between 64- 98% and 83-100% respectively.

5.2 Demographics

In this study, boys are the most injured with suspected forearm fractures. They have a frequency of 243 (65.1%) while the girls were 130 (34.9%). This could be because boys engaged in more physical activity and also that they have high risk behaviours than girls (Valerio et al., 2010). This study concurs with the study done in Poland where Grabala et al found that of the forearm fractures the boys had 66% of them while the girls had 34% of them. Though Grabala studied paediatric forearm fractures for a longer duration of 4 years and his sample size was larger we are able to get similar results as our own study because the age bracket is the same 0-18 years and he only studied the forearm (Grabala, 2015). These results are almost similar to the study done in KNH by Mwangi et al which revealed that males were the most fractured with 59%. Though Mwangi studied all paediatric long bone fractures in KNH for a period of 3 months and his sample size was lower (Mwangi, 2017). This study also concurs with Ndoumbe et al in Cameroon where he demonstrated increased incidence of fractures in boys than girls (Ndoumbe et al., 2017). It is also in agreement with Mamoowala et al who found that the male to female ratio of distal forearm fractures was 64% to 36% (Mamoowala et al., 2019). This study also concurs with a study done by Erik et al where he studied the epidemiology of fractures in Sweden over a period from 1993- 2007 and found that fractures in boys accounted for 61%. Though Erik accounted for all fractures affecting children less than 19 years but still found the distal forearm as the most fractured part (Hedström et al., 2010). This study is almost similar to Valerio et al in Italy where he studied paediatric fractures for a period of six months and got that boys were 68.3% while girls were 31.7% though in his study, he studied all paediatric fractures in children less than 14 years (Valerio et al., 2010). This study is almost in agreement with Rennie et al which showed that boys had 61.4% of fractures (Rennie et al., 2007).

In this study, children with suspected forearm fractures are very common and mostly occurred after a fall which were 358 (96%), road traffic accidents were 9 (2.4%) and being hit by a blunt object were 6 (1.6%). The fall while playing was not be quantified further in terms of the height but it is assumed that it is a fall at the ground level due to the fact if it was on a higher ground the guardian/parent would have described it and got documented and also the patient would have sustained other fractures apart from the forearm. Also falls from ground level were described as the commonest cause of forearm injuries as described by Rennie et al (Rennie et al., 2007). This study also agrees with Ryan et al he found out that fall related injuries caused 83% of forearm fractures and he categorised the fall further by age but an overall increase in childhood fractures is as a result of increase in childhood participation in sports-related activities this can be at home or in school (Ryan et al., 2010).These findings are approximately similar to with Al Rashedan et al where he found that forearm fractures as a result of falls were about 83% but fractures as a result of RTA differed from what we found. He found those caused by RTA were 16% while in this study they were 1.2%. This could be because his sample size was slightly lower than ours and he did his study in those with the diagnosis of confirmed forearm fractures also, his study site is from a more developed country (Alrashedan et al., 2018). The 6 patients who had suspected forearm fractures due to being hit by a blunt object, 3 of them were hit by a football while playing in school, the other 3 slide from the ground and hit a wall. None of them was as a result of NAI though high index of suspicion is still necessary to pick these in children. These findings are also similar to a study done by Strydom et al in South Africa which found that falls from ground level are the commonest followed by RTA (Strydom et al., 2020). This study differed with the study by Grabala et al which found that fractures caused by fall from height were 39 % while concured with those from RTA which were about 3%. This could be because he studied a larger population and for a longer duration of time (Grabala, 2015).

In this research, we found that distal forearm fractures predominantly affect paediatric age groups, within school going age with mean age of 9 years in affected patients, this was approximately similar to the findings reported by(Mathison & Agrawal, 2010).

Most suspected paediatric forearm fractures occurred at home 67.6% this study is in agreement with Mwangi et al where he reported most paediatric injuries occurred at home or its surroundings at 56%. This is due to the fact that children are mostly taken care of by untrained nannies or elder siblings in developing countries since both parents go to work (Mwangi, 2017).

OBJECTIVE 1: To describe the sonographic findings among children with suspected forearm fractures in MTRH

From this study, of the suspected forearm fractures 223 (59.2%) have a diagnosis of fractures on ultrasound while 154(40.8%) had no fractures on ultrasound. This contrasts Fatih et al in Turkey where he was able to diagnose patients with clinical features of fractures to be 100% on U/S (Fatih Ekþioðlu et al., 2003). Explanation is that he included patients in his study who had a clinical diagnosis of fractures and have had an x-ray diagnosis of the same.

Fractures of both the radius and ulna are the commonest at 57.8%, while radius alone was at 37.7% and ulna alone was at 4.5%.

The missed diagnosis of fractures on US were: distal radius torus fracture which was near the Physis-metaphysis, Salter Harris 1 fracture of the radius, proximal ulna fracture and greenstick fracture of midshaft radius. These findings were in agreement with Galletebeitia et al where he had false negatives on salter Harris fractures and fractures near the growth plate (Galletebeitia et al., 2017).

From this study, both distal radius and ulna of the right and left forearm were the commonest fracture site detected on ultrasound with the left having 38% and the right having 44.6% and the left ulna having 38.1% and right distal ulna having 41.7%. This compares well with Hubner et al where he scanned all suspected paediatric long bones fractures (224 bones) and found about majority of the (85) had suspected distal radius fracture (Hübner et al., 2000).

Cortical disruption was better detected in this study with the complete disruptions at 205(96.7%) on the radius and 141 (98.6%) on the ulna and partial disruptions at 1(0.3%) on the radius and none on the ulna. In patients with plastic deformities on x-ray no cortical disruption was present, US was able to detect them as having a cortical disruption. This contrasts Galletebeitia et al, in Spain who got majority of fractures were incomplete fractures of the radius at 61.1% while complete cortical disruption was at 9.7% on the radius and 4.2% on the ulna metaphysis (Galletebeitia et al., 2017). Explanation is that his sample size was smaller, he studied 115 patients and studied patients younger than 15 years of which majority had either green stick fractures or plastic deformity fractures.

OBJECTIVE 2: To describe radiographic findings among children with suspected forearm fractures in MTRH.

From this study, of the suspected forearm fractures who had plain radiographs done, 227 (60.2%) of them had a fracture diagnosis while 150 (39.8%) did not. This is in agreement with Bentohami et al who reported that despite plain radiographs being the modality of choice in the diagnosis of fractures about 50% come out normal (Bentohami et al., 2011). This predisposes patients to unnecessary radiation exposure and wasting resources

From this study Both the left and the right forearms are almost equally fractured with the right at 78% and the left at 76%. This contrasts Ndoumbe et al in Cameroon who reported that the non-dominant hand, that is the left hand, is the most injured at 61%

(Ndoumbe et al., 2017). Ndoumbe et al studied all paediatric fractures and had a lower sample size of 145.

This study further divided the bones into distal third, midshaft and proximal third. The distal and proximal third included both the epiphysis and the junction between metaphysis and diaphysis both proximally and distally while the midshaft included only the diaphysis.

From the above findings it is evident that both radius and ulna are the most fractured at 56.0% is the most fractured bone this concurs with that of Wellsh et al where he found that the commonest forearm fracture was that of both bones at 83% (Wellsh & Kuzma, 2016).

Distal third radius is the commonest fracture site at 21.4% on the left and 23.9% on the right this could be because of reduced bone density and cortical mineralisation in the distal forearm (Khosla et al., 2003). Distal forearm fractures also occur around the age of puberty due to low bone mineralization during this period (Porrino, 2014). This also could be because of increased sporting activities both in school and at home. This study is in agreement with Herman et al who reported that fractures of the distal third of the forearm are the commonest followed by the middle third while the proximal third has the lowest fractures (Herman & Marshall, 2006). This study is in agreement with Alrashedan et al where he found that fractures of the distal forearm are the most prevalent at 48.11% followed by the distal third of the shaft of forearm at 34.28%(Alrashedan et al., 2018).

In this study both the left and the right forearms are almost equally fractured with the right at 78% and the left at 76%. This contrasted Ndoumbe et al and Herman et al who reported that the non-dominant hand is the most injured at 61% (Ndoumbe et al., 2017),(Herman & Marshall, 2006).

Other findings such as cortical disruption and cortical bulge help in the diagnosis of fractures as either complete or incomplete, cortical bulge mostly demonstrates the presence of a torus fracture. On x-ray, cortical disruption was diagnosed as complete in 182 (84.3%) on the radius and 120 (31.9%) on the ulna. Partial disruption which could mean either plastic deformity or greenstick fractures were seen on the radius in 25(11.6%) and on the ulna in 20(14.1%) of cases. This contrasts Zimmermann et al, in Austria who found that majority of the fractures were incomplete fractures at 57% (Zimmermann et al., 2004), Explanation is that he did a retrospective study with a follow up range of 10 years and studied only the distal forearm.

OBJECTIVE 3: To compare the radiographic and sonographic findings among children with suspected forearm fractures in MTRH.

Forearm x-ray identified almost similar numbers of fractures on x-ray 60.2% (227) as that of the US of 59.2% (223). This compared well with Galletebeitia et al in Spain where he was able to diagnose 62.6% (72) fractures on x-ray and US detected 63.5% (73) fractures (Galletebeitia et al., 2017).

The patients that were missed on US (false negatives) were in the distal radius torus fractures which were near the Physis-metaphysis, Salter Harris type 1 fractures of the radius, proximal ulna fracture and greenstick fracture of midshaft radius. This compared well with Galletebeitia et al in Spain had false negatives on salter Harris fractures and fractures near the growth plate (Galletebeitia et al., 2017).

In this study a few cases (12) had a false positive result in that fracture was only detected on ultrasound with a normal x-ray despite clinical features of fracture being present. This could probably be due to the fact that ultrasound has good reflective acoustic properties and can detected very small fractures of up to about 1mm (Akinmade, 2018).

In this study the sensitivity and specificity were at 92.83% and 92% at 95% confidence interval respectively. The positive likelihood ratio of 11.603 and a negative likelihood ratio of 0.07799 with an accuracy of 92.25%. This agrees with Epema et al where he got a diagnostic accuracy of 92% at 95% CI and a sensitivity of 95% and specificity of 86% at 95% CI. His PLR and NLR was 6.86 and 0.05 at 95% CI respectively (Epema et al., 2019). This study also agrees with Galletebeitia et al where he got a sensitivity of 94.4% and a specificity of 96.8% with a PLR of 0.06 and a NLR of 29.84 all at 95% CI (Galletebeitia et al., 2017). It also agrees with Barata et al where he got a sensitivity of 95.3% and a specificity of 95.3% at 95% confidence interval though his sample size was smaller of 53 and had included all paediatric long bone fractures(Barata et al., 2012). This study also compares well with Hubner et al where he got a sensitivity of 98.3%. his sensitivity was slightly higher than what we got this is probably because he scanned only the distal radius and his sample size for the patients with forearm fractures was lower at 85(Hübner et al., 2000). This study also agrees with Hamer et al a high sensitivity of 97% and specificity of 95% both at 95% confidence interval. He also found out that the use of US has a Likelihood Ratio (LR) of +20 and -0.03 therefore a good modality to rule in or rule out fractures of the distal forearm in paediatric age group(Hamer et al., 2016).

Our study found out a high level of agreement between X-Ray and ultrasound examination. These sentiments were also echoed by a study done by Caroselli (Caroselli et al., 2021)which found a sensitivity of 91.67% and a sensitivity of 88.89% with high skilled centers which is a similar centre to where this present study was done. A Cohen Kappa of 0.81 which shows a high agreement level which our study found out similar results.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Suspected forearm fractures following trauma sent for radiography in MTRH is very common and only about 60% of them have the diagnosis of fractures on x-ray.

US gives similar findings in the diagnosis of forearm fractures.

Complete fractures are the commonest fracture type diagnosed on both the radius and ulna bones with the distal forearm as the most common fractured site on both ultrasonography and radiography.

Ultrasonography has a high sensitivity and specificity in the detection of fractures of the forearm in paediatric patients.

6.2 Study limitations

This study was conducted in a level 6 tertiary Referral facility where most clinicians are highly trained, the results may not be a true representation of ultrasound findings done in the other health facilities.

Salter Harris type 1 fractures and fractures near the physis of the forearm are not well diagnosed on US and may be missed. In such cases x-rays may be used for proper diagnosis.

6.3 Recommendations

It is recommended to clinicians and radiologists to use U/S instead of radiography in the diagnosis of suspected paediatric forearm fractures.

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APPENDICES

Appendix I: Consent

English Version

Investigator: My name is Dr Naima Ahmed Mbarak Salim. I am a qualified doctor, registered by the Kenya Medical Practitioners and Dentists Board. I am currently pursuing a Master's degree in Radiology and Imaging at Moi University. I would like to recruit you into my research which is to study the comparison of radiographic and sonographic findings among children with suspected forearm fractures at Moi teaching and referral hospital in Eldoret.

Purpose: this study will aim to describe and compare radiographic and sonographic findings among children with suspected of forearm fractures at MTRH

Procedure: children presenting with suspected forearm fracture following trauma referred for forearm ultrasound and forearm x-ray will be recruited for the study after the consent has been obtained. They will be interviewed by using a structured questionnaire and the forearm ultrasound will be performed. Data will be collected on data collection forms. Data collecting material will be kept in a locked cabinet in the office of the principal investigator during the study period.

Benefits: There will be no direct benefits of participating in this study. Study subjects will be accorded same quality of management as non-study subjects

Risks: There are no anticipated risks to the participants attributable to this study.

Confidentiality: All information obtained in this study will be treated with utmost confidentiality and shall not be divulged to any unauthorized person

Rights to Refuse: Participation in this study is voluntary, prospective participants have freedom to decline enrolment or withdraw at any point during the study. This study has been approved by the Institutional Research and Ethics Committee (IREC) of Moi University/Moi Teaching and Referral Hospital.

Sign or make a mark if you agree to take part in the study

Parent/Guardian: ……………… Investigator: …………………... Date:

Swahili Consent Form

Mtafiti: Jina langu ni Dkr Naima Ahmed Mbarak Salim. Mimi ni daktari aliyehitimu na kusajiliwa na bodi ya Kenya ya Madaktari na Madaktari wa meno.Kwa sasa natafuta shahada ya uzamili katika Radiologia na Imaging katika Chuo Kikuu cha Moi.Ningependa kusajili mtoto wako katika utafiti wangu ambao ni wa kujifunza usawa wa matokeo ya ultrasonograf ya kigasha katika watoto wanaofika katika MTRH wakiwa na wanadhaniwa wamevunjika kigasha.

Kusudi: Utafiti huu utachunguza usawa wa matokeo ya ultrasonograf na xray ya kigasha katika watoto walio dhaniwa wamevunjika kigasha.

Utaratibu: Watoto,wazazi na/au walezi wao wataelimishwa kuhusu kuvunjika kwa kigasha. Watoto watatayarishwa kwa ajili ya utafiti wa ultrasonograf na xray ya kifua baada ya idhini kupatikana. Watashughulikiwa kwa kutumia dodoso la muundo na ultrasonograf itafanyika. Data zitakusanywa kwenye fomu za ukusanyaji data. Hifadhi zitakazotumika katika ukusanyaji wa data zitawekwa katika kabati iliyofungwa na mpelelezi mkuu katika kipindi cha utafiti.

Faida: Hakutakuwa na faida ya moja kwa moja ya kushiriki katika utafiti huu. Wanaofanyiwa utafiti watakuwa na haki na kupewa matibabu sawa na wale ambao hawatahusishwa na utafiti huu.

Hatari: Hakuna hatari inayotarajiwa kwa washiriki inayotokana na utafiti huu.

Usiri: Habari zote zitakazopatikana katika utafiti huu zitawekwa kwa usiri mkubwa na wala hazitatolewa kwa mtu yeyote asiyehusika na utafiti.

Haki za Kuepuka: Kushiriki katika utafiti huu ni kwa hiari yako, kuna uhuru wa kukataa kusajiliwa au kutoka wakati wowote. Utafiti huu umepitishwa na Utafiti wa

Taasisi na Kamati ya Maadili (IREC) ya Chuo Kikuu cha kufundishia Moi na Hospitali ya Rufaa.

Tia sahihi au kufanya alama kama unakubali kushiriki katika utafiti

Mgonjwa: ....Mpelelezi: .... Tarehe: ....

Appendix II: Assent Form

English version

Information

This informed assent form is for above 12 years of age who have suspected forearm fracture and are scheduled for forearm ultrasound and radiograph of the forearm.

What is medical research?

Medical research is when doctors collect information to get new knowledge about disease or illness. This helps doctors find better ways of treating diseases and helping children or people who are sick.

What is this research study about?

A study will be conducted on children below 14 years of age with suspicion of forearm fractures where the participant's forearm ultrasound findings will be compared to forearm x-ray findings. This information will influence the consideration of forearm ultrasound use as an alternative to forearm x-ray in the diagnosis of paediatric forearm fractures. This will be of help for children by avoiding radiation exposure.

Who is doing this research?

My name is Dr Naima Ahmed Mbarak Salim and I'm a medical doctor. I'm currently studying for my second degree (Masters in Medicine) in Radiology & Imaging at Moi University.

What will happen to me in this study?

I will invite you to be part of this study. If you agree to participate in this study, your x-rays and ultrasounds will be reviewed, and forearm fracture findings recorded. You will then be followed up and treatment initiated.

There are no risks or benefits of participating in this study and you will be given the same medical care as the children who are not in the study. You can choose whether you would like to participate in the study. I have discussed this with your parent(s)/ guardian(s) and they know we are asking for your permission to be part of the study. In case you refuse to be part of the study you will not be forced to even if your parents agreed for you to participate.

In case of any questions, feel free to ask, I will be happy to assist.

Certificate of assent

Do you understand this research study and are willing to take part in it?

Yes: ……………...   No: …………………...

Has the researcher answered all your questions?

Yes: ……………...   No: …………………...

Do you understand that you can pull out of the study at any time?

Yes: ………………   No: …………………

I agree to take part in the study.

OR

I do not wish to take part in the study, and I have not signed the assent below. ___________

Only if child assents:

Name of child ___________________

Child's thumb print: [ ]

Date: ________________

Kiswahili version

Fomu hii ya idhini ni ya watoto walio umri juu ya miaka 18 ambao wameonekana na daktari na kudhania kigasha kimevunjika.

Utafiti wa matibabu ni nini?

Utafiti wa matibabu ni wakati madaktari wanapopata taarifa ili kupata ujuzi mpya kuhusu magonjwa. Hii husaidia madaktari kupata njia bora za kutibu magonjwa na kusaidia watoto au watu ambao ni wagonjwa.

Utafiti huu unahusu nini?

Utafiti huu unahusisha watoto walio dhaniwa kuvunjika kwa kigasha. Katika utafiti huu, kuvunjika kwa kigasha kwenye x-ray utafananishwa na katitaka ultrasound ya kigasha ili kuamua kama ultrasound ya kigasha inaeza tumika kwa niaba ya xray. Hii itakuwa ya manufaa kwa watoto kwa kuwa hakutakuwa na radiations kutokana na ultrasound.

Nani anafanya utafiti huu?

Jina langu ni Dkt. Naima Ahmed Mbarak Salim na mimi ni daktari aliyehitimu. Kwa sasa ninajifunza kwa shahada yangu ya pili (Masters in Medicine) katika Radiologia & Imaging katika Chuo Kikuu cha Moi.

Nini kitatokea kwangu katika utafiti huu?

Nitakualika kushiriki katika utafiti huu. Iwapo utakubali, matokeo yako ya x-ray na ultrasound yataangaliwa na kurekodiwa. Baada ya huu utafiti matibabu yataanzishwa katika ward ya watoto.

Hakuna hatari au faida za kushiriki katika utafiti huu na utapewa huduma sawa ya matibabu kama watoto ambao hawatashiriki kwenye utafiti. Unaweza kuchagua kama ungependa kushiriki katika utafiti huu. Nimezungumza na mzazi na/au mlezi wako na anajua tunaomba ruhusa yako kushiriki katika utafiti. Ikiwa unakataa kuwa sehemu ya utafiti huwezi kulazimishwa hata kama wazazi wako walikubali kushiriki.

Ikiwa kuna maswali yoyote, jisikie huru kuuliza, nitafurahia kusaidia.

Hati ya kukubali

Je unaelewa utafiti huu na uko tayari kushiriki?

Ndio: .... La: ....

Je, mtafiti alijibu maswali yako yote?

Ndio: .... La: ....

Je unaelewa kwamba unaweza kuondoka kwa utafiti huu wakati wowote?

Ndio: ……………. La: ………………

Nakubali kushiriki katika utafiti huu

AU

Sitaki kushiriki katika utafiti huu na sijasaini idhini hii __________________

Ikiwa tu mtoto ataidhinisha:

Jina la mtoto: ……………………………...

Alama ya idle cha mottos:

Tarah: ………………………

Appendix III: Data Collection Form

Instructions

1. All sections to be ticked or filled accordingly.

2. Writings should be clear and legible.

3. To be filled in by the principal investigator or assistant once the patient's parent or guardian has given consent for their child to be involved in the study and both consent and assent obtained children above the age of 12 years.

IP/OP No: ……………………………….

Serial No: ………………………………...

Date: ……………………………………...

PART 1: DEMOGRAPHIC DATA

1. Patient initials …………………………
2. DOB/ Age ………………………......
3. Gender ………………………………
4. Residence ……………………………...
5. Contact No: ……………………………...
6. Site where the injury occurred……………………….
7. Mechanism of injury ……………………………….
8. Duration of imaging from the time of injury ………………………………

PART 2:

SECTION A: RADIOGRAPHIC FINDINGS

Forearm X-ray findings:

Site of the fracture: Radius……………………….

Ulnar …………………………..

Both ……………………………….

Distance from the joint: Wrist joint…………………………..

Elbow joint………………………….

Bones involved…………………………………………………………..

Cortical disruption: Present ☐ complete ☐ partial ☐

Others ☐ specify……………………

Absent ☐

Cortical bulge: Present ☐

Absent ☐

Others: ……………………………………………………..

Fracture displacement: Anterior ☐

Posterior ☐

Others ☐

SECTION B: SONOGRAPHIC FINDINGS

Forearm ultrasound findings

Site of the fracture: Radius……………………….

Ulnar …………………………..

Both ……………………………….

Distance from the joint: Wrist joint…………………………..

Elbow joint………………………….

Bones involved…………………………………………………………..

Cortical disruption: Present ☐ complete ☐ partial ☐

Others ☐ specify…………………….

Absent ☐

Cortical bulge: Present ☐

Absent ☐

Others: ………………………………………………………..

Fracture displacement: Anterior ☐

Posterior ☐

Others ☐

SECTION C: OTHER FINDINGS:

RADIOGRAPHIC:

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………..…………………

SONOGRAPHIC:

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………….

APPENDIX IV: Time Plan

ACTIVITY	START	END
PROPOSAL CONCEPT DEVELOPMENT	February 2020	March 2020
PROPOSAL WRITING	April 2020	November 2020
IREC APPROVAL	March 2021	April 2021
DATA COLLECTION	September 2021	August 2022
DATA ANALYSIS	September 2022	October 2022
THESIS WRITING	November 2022	January 2023

ITEM	QUANTITY	UNIT PRICE(KSHS)	TOTAL(KSHS)
Laptop Computer	1	50,000	50,000
Printing and photocopying	-	12,000	12,000
Stationery	-	5,000	5,000
Storage Devices	50	20	1,000
Statistical Consultation	-	15,000	15,000
Research Assistant	1	50,000	50,000
Internet services and communication	-	10,000	10,000
Publication	-	50,000	50,000
Ultrasound services	373	2,000	746,000
Fare for followup	50	300	15,000
GRAND TOTAL	-	-	954,100

APPENDIX V: Estimated Project Budget

ITEM	QUANTITY	UNIT PRICE(KSHS)	TOTAL(KSHS)
Laptop Computer	1	50,000	50,000
Printing and photocopying	-	12,000	12,000
Stationery	-	5,000	5,000
Storage Devices	50	20	1,000
Statistical Consultation	-	15,000	15,000
Research Assistant	1	50,000	50,000
Internet services and communication	-	10,000	10,000
Publication	-	50,000	50,000
Ultrasound services	373	2,000	746,000
Fare for follow up	50	300	15,000
GRAND TOTAL	-	-	954,100

Appendix VI: IREC Approval

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471//2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET
Tel: 33471/2/3

25th March, 2021

Reference: IREC/2021/44
Approval Number: 0003833
Dr. Naima A. M. Salim,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA

Dear Dr. Mbarak,

COMPARISON OF SONOGRAPHIC AND RADIOGRAPHIC FINDINGS AMONG CHILDREN WITH SUSPECTED FOREARM FRACTURES AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET

This is to inform you that ***MTRH/MU-IREC*** has reviewed and approved your above research proposal. Your application approval number is ***FAN: 0003833.*** The approval period is **25th March, *2021 – 24th March, 2022.***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***MTRH/MU-IREC***.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***MTRH/MU-IREC*** within 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***MTRH/MU-IREC*** within 72 hours.
v. Clearance for export of biological specimens must be obtained from ***MTRH/MU-IREC*** for each batch of shipment.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***MTRH/MU-IREC.***

Prior to commencing your study; you will be required to obtain a research license from the National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and other relevant clearances. Further, a written approval from the CEO-MTRH is mandatory for studies to be undertaken within the jurisdiction of Moi Teaching & Referral Hospital (MTRH), which includes 22 Counties in the Western half of Kenya.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
25 MAR 2021
APPROVED
P. O. Box 4606 - 30100 ELDORET

Sincerely,

PROF.E.O.WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD

Appendix VII:Nacosti Approval

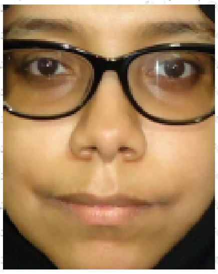
REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 697368

Date of Issue: 20/April/2021

RESEARCH LICENSE



This is to Certify that Dr.. Naima Ahmed Salim Mbarak of Moi University, has been licensed to conduct research in Uasin-Gishu on the topic: COMPARISON OF SONOGRAPHIC AND RADIOGRAPHIC FINDINGS AMONG CHILDREN WITH SUSPECTED FOREARM FRACTURES AT MOI TEACHING AND REFFERAL HOSPITAL, ELDORET KENYA for the period ending : 20/April/2022.

License No: **NACOSTI/P/21/10004**

697368

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearence from relevant Government Agencies
5. The License does not give authority to tranfer research materials
6. NACOSTI may monitor and evaluate the licensed research project
7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one year of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

National Commission for Science, Technology and Innovation
off Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100 Nairobi, KENYA
Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077
Mobile: 0713 788 787 / 0735 404 245
E-mail: dg@nacosti.go.ke / registry@nacosti.go.ke
Website: www.nacosti.go.ke

Appendix VIII: Hospital Approval

An ISO 9001:2015 Certified Hospital

MOI TEACHING AND REFERRAL HOSPITAL

Telephone :(+254)053-2033471/2/3/4
Mobile: 722-201277/0722-209795/0734-600461/0734-683361
Fax: 053-2061749
Email: ceo@mtrh.go.ke/directorsofficemtrh@gmail.com

Nandi Road
P.O. Box 3 – 30100
ELDORET, KENYA

Ref: ELD/MTRH/R&P/10/2/V.2/2010

26th March, 2021

Dr. Naima A. M. Salim,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET – KENYA.

COMPARISON OF SONOGRAPHIC AND RADIOGRAPHIC FINDINGS AMONG CHILDREN WITH SUSPECTED FOREARM FRACTURES AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET

In order to conduct research within the jurisdiction of Moi Teaching and Referral Hospital (MTRH) this includes 22 counties in the Western half of Kenya. You are required to strictly adhere to the regulations stated below in order to safeguard the safety and well-being of staff and patients seen at MTRH involved research studies.

1. The study shall be under Moi Teaching and Referral Hospital regulation.
2. A copy of MU/MTRH-IREC approval shall be provided.
3. Studies dealing with collection, storage and transportation of Human Biological Material (HBM) will not be allowed to export the HBM outside the jurisdiction of **MTRH.**
4. For those tests which are unavailable locally the PI is tasked to ensure sourcing of equipment and subsequent training of staff to build their capacity.
5. No data collection will be allowed without an approved consent form(s) to participants to sign.
6. Take note that **data** collected must be treated with due confidentiality and anonymity.

Permission to conduct research shall only be provided once all the requirements stated above have been met.

MOI TEACHING AND REFERRAL HOSPITAL
26 MAR 2021
SIGN.......................................
P. O. Box 3 - 30100, ELDORET

26/03/2021

DR. WILSON K. ARUASA, *EBS*
CHIEF EXECUTIVE OFFICER
MOI TEACHING AND REFERRAL HOSPITAL

c.c. - Senior Director, Clinical Services
- Director of Nursing Services
- HOD, HRISM

All correspondence should be addressed to the Chief Executive Officer
Visit our Website: www.mtrh.go.ke
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