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COMPARISON OF SONOGRAPHIC AND RADIOGRAPHIC FINDINGS AMONG CHILDREN WITH SUSPECTED FOREARM FRACTURES AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET KENYA
Naima Mbarak, Department of Radiology & Imaging Moi University, School of Medicine, P.O. Box 4606 - 30100, Eldoret, Kenya, Joseph Abuya, Department of Radiology & Imaging Moi University, School of Medicine, P.O. Box 4606 - 30100, Eldoret, Kenya, Loice Sitienei, Department of Radiology & Imaging Moi University, School of Medicine, P.O. Box 4606 - 30100, Eldoret, Kenya, Jack Odunga, Department of Reproductive Health Moi University, School of Medicine, P.O. Box 4606 - 30100, Eldoret, Kenya

Corresponding Author: Naima Mbarak, Department of Radiology & Imaging Moi University, School of Medicine, P.O. Box 4606 - 30100, Eldoret, Kenya, email naima.mbarak@gmail.com

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

N. Mbarak, J. Abuya, L. Sitienei, and J. Odunga

ABSTRACT

Background: **Forearm fractures 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. Ultrasonography, on the other hand, is radiation free, portable and a quick tool to use.**
Objectives: **To describe and compare the sonographic and radiographic findings among children with suspected forearm fractures in Moi Teaching and Referral Hospital (MTRH).**
Design: **Cross-sectional study design from April 2021 to March 2022.**
Setting: **MTRH.**
Participants: **373 participants aged less than 18 years with suspected forearm fractures following trauma.**
Interventions: **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.**
Outcome measures: **Continuous variables were summarized using mean and categorical variables were summarized in frequencies and percentages. Sensitivity and specificity were used for comparison.**
Results: **On x-ray, fractures present were 60.2% with both the radius and ulna bones fractured at 56.0%. The right distal radius was the commonest fracture site at 43.8%. On ultrasonography, fractures diagnosed were 59.2% with both the radius and ulna bones fractured at 57.8%. The right distal radius was the most fractured at 44.6%.**

The sensitivity and specificity were 92.83% and 92% respectively at 95% confidence interval.
***Conclusion*: Ultrasonography can be used in the diagnosis of forearm fractures due to its high sensitivity and specificity.**

INTRODUCTION

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% (1). In sub–Saharan Africa, forearms are the most fractured with 37% of cases (2). Worldwide, childhood forearm fractures are the commonest type of injuries brought to the emergency department (3).

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 (4). It is 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 (5). This predisposes patients to avoidable exposure to radiation and wasting of resources.

The paediatric bone has a good reflective acoustic property therefore ultrasound (US) imaging of the cortex is better, enabling visualization and identification of fractures about 1 mm in size (6)

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 (7). US are simple to use, readily available in all levels of healthcare, and more convenient in the diagnosis of fractures.

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 (8). 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 and the burden of sending patients for radiographs decrease.

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 (9).

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 (10). Paediatric age group also have an overtime increased risk to accumulative radiation dose (11). This has led to increased attention to forearm injuries since they are the most common injuries present in the emergency room.

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 (11). 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 (12). 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 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 (4). 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 locate the exact fracture site, and appropriate management given.

In the emergency department, point of care ultrasound (POCUS) is done in the assessment of fractures because it is quick, easy to do and with minimal pain. It has the capability to access different planes during examination rather than the pre-determined views of x-rays (13).

US is a good modality for examining forearm fractures because the soft tissue is thin and the distance from the transducer to the bone is shorter thus ensuring very high image quality. Due to high spatial resolution of US, soft tissues interposed between fracture fragments can be seen prior to surgery (14).

Use of POCUS has demonstrated that it can be used as an alternative in diagnosis of fractures and a much more accuracy if done by a qualified sonologist (13).

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 (4).

US is very specific in diagnosis of fractures which are very small up to about 1mm due to increased bone reflective acoustic properties (6). This enables better visualization of the bony cortex.

METHODOLOGY

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 MTRH's accident and emergency department and Shoe for Africa Children's Hospital and sent to the radiology and imaging department for x-ray.

Study site

The study was conducted at the Radiology and Imaging Department at the MTRH, Eldoret (x-ray unit), and x-ray unit at the Shoe for Africa.

Study population

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

Eligibility criteria

3.141. 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.

3.142. Exclusion criteria

Patients with open fractures

Pathological fractures such as rickets, osteogenesis imperfecta.

Arrival at the emergency department with prior diagnosis of fractures or x-rays done elsewhere.

Hemodynamic instability.

Polytrauma patients.

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 (5), found the proportion of those with forearm fractures among children with suspected fractures to be 50.0% and (15) 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.

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 MTRH's 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.

Study procedure

Paediatric patients with clinical features suggesting 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.

Data collection

Data was collected between for a period of 1 year from April 2021 to March 2022. Entry was done in a 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.

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.

Data analysis and presentation

Data was imported into STATA 16 where data cleaning, coding and analysis was done.

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.

Ethical considerations

Ethical approval for the study was sought from the Institutional Research and Ethics Committee (IREC), Moi University/Moi Teaching and Referral Hospital. 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 were 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.

RESULTS

Socio-demographic characteristics

Majority of the participants were male 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%). Differed kinds of fall attributed to the highest mechanism of injury.

Table 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

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 2
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

Table 3
X ray 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 3 above shows the descriptive distribution of cortical disruption on various sites.

Table 4
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

Table 5 above 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 6
Ultrasound cortical disruption

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 7
Concordance levels between X-Ray and ultrasound tests

		X-ray		**Total**
		Yes	**No**	
Ultrasound	Yes	210	12	222
	No	17	138	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.

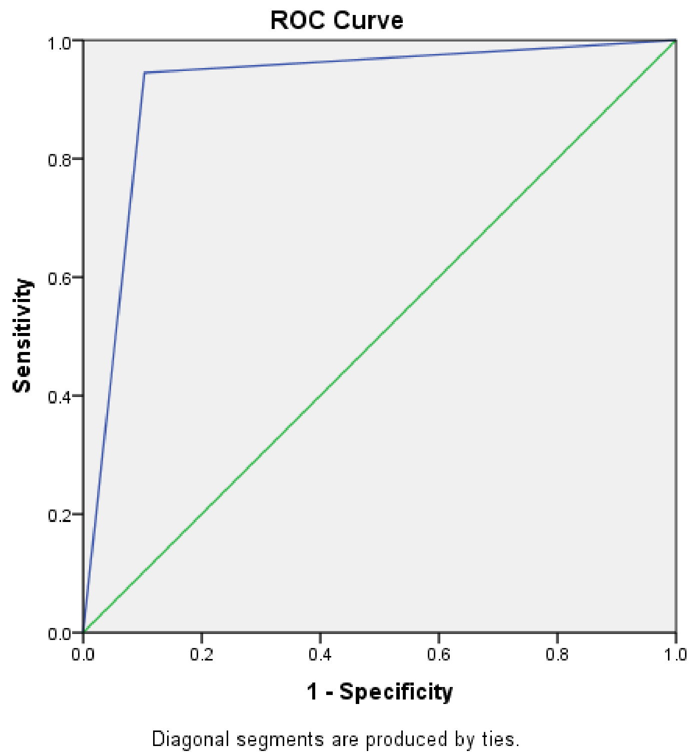
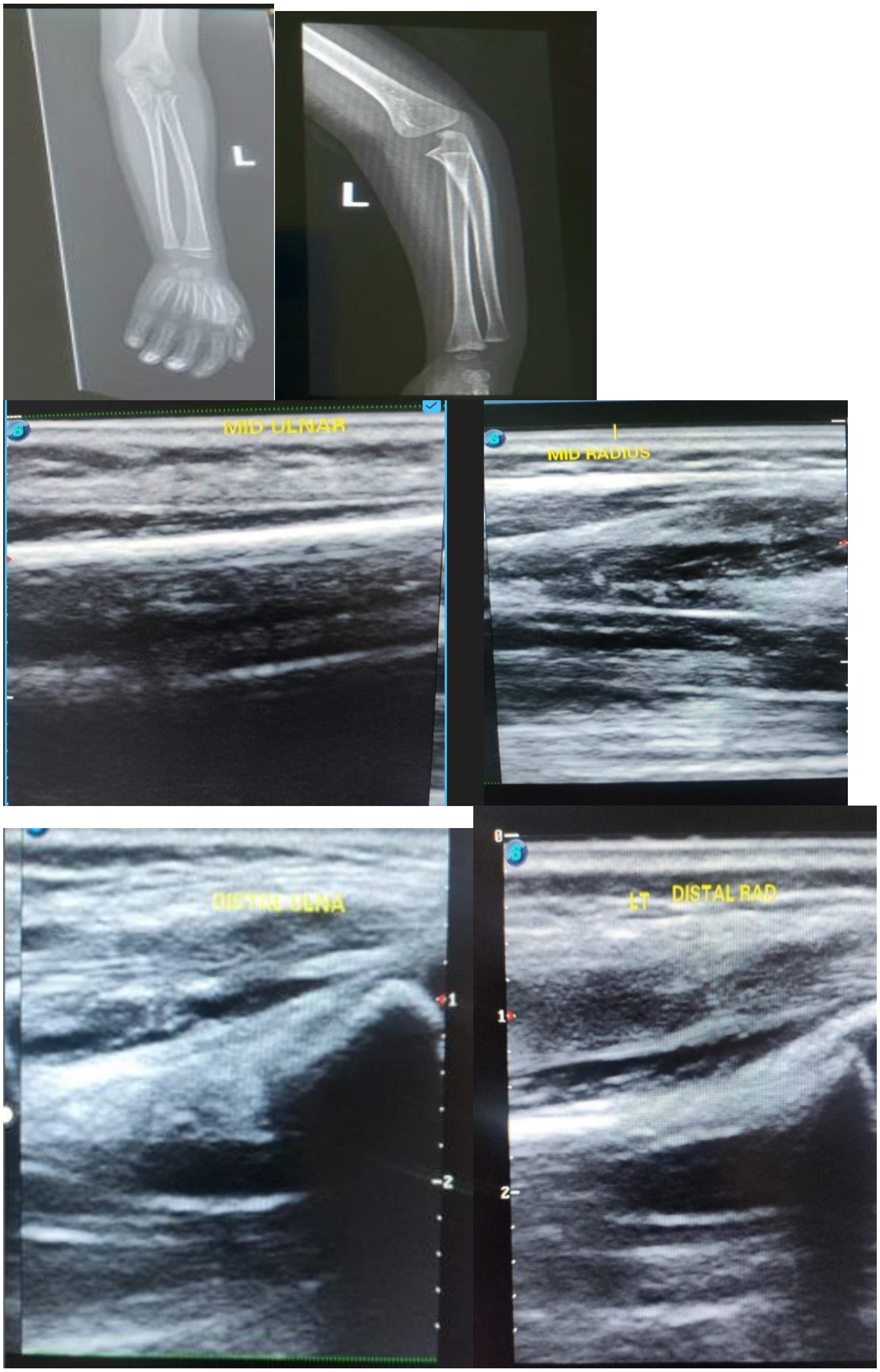


Table 8

Sensitivity and specificity

Sensitivity	92.5%
Specificity	92%
Positive likelihood ratio	11.5625
Negative likelihood ratio	0.08152
Accuracy	92.25%

SAMPLE IMAGES



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

SAMPLE IMAGE 2: *7-year-old boy with history of a fall. Images on the top are X-rays of the left forearm demonstrating 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: *16-year-old girl with history of a fall while cleaning the house, images on 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*

Comparison of 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 on US at 59.2% (223). The patients that were missed on US were because 1 of them had salter Harris 1 fracture with no displacement, the other had a torus fracture and 1 was a greenstick fracture on the medial aspect of the bone which was missed. The other one had distal radius torus fracture which was near the Physis-metaphysis.

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 (15). 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 (16).

Our study found a high level of agreement between X-Ray and ultrasound examination. These sentiments were also echoed by a study done by Caroselli (13)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.

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 as that of x-rays.

US has a high sensitivity and specificity in the diagnosis of paediatric forearm fractures. This study therefore stresses the need to use ultrasound examination as an alternative to radiography in diagnosing fractures in paediatric patients.

Study limitations

Considering that 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.

Recommendations

Increase awareness to clinicians about the utilization of ultrasound among pediatric patients as a cost-effective modality and as a way of reducing radiation exposure to paediatric patients.

Use of US in the diagnosis torus fractures is highly recommended since they are better visualized than on x-rays.

In case of doubt/equivocal diagnosis on US, use of x-rays is recommended

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