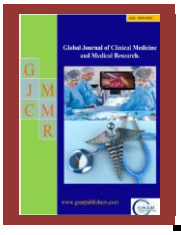


Global Journal of Clinical Medicine and Medical Research [GJCMMR]
ISSN: 2583-987X (Online)
Abbreviated key title: Glob.J.Clinic.Medici.Medica.Res.
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjcmmr-home/

Reliability of ultrasound scan compared to computed tomographic scan in the diagnosis of maxillary sinusitis: A cross-sectional analytical study

By

Shamaki AMB[1], Jega MA[2], Adamu A[3], Saleh MK[4], Danbatta AH[4], Sule MB[1], Shirama YB[5], Danyaro RM[2].

[1]Department of Radiology, Usmanu Danfodiyo University, Sokoto. Nigeria.
[2]Radiology Department, Federal Teaching Hospital Birnin Kebbi, Nigeria.
[3]Department of Otorhinolaryngology, Federal University of Health Sciences, Azare, Nigeria.
[4]Department of Radiology, Bayero University, Kano, Nigeria
[5]Department of Radiology, Abubakar Tafawa Balewa University Teaching Hospital Bauchi, Nigeria.

Article History

Received: 25/07/2026
Accepted: 01/08/2026
Published: 03/08/2026

Vol – 4 Issue – 8

PP: -05-12

Abstract

Introduction: *Sinusitis is an inflammation of paranasal sinus mucosa caused by a viral, bacterial or fungal infection, with the maxillary sinus being the most commonly involved paranasal sinus. Computed Tomography (CT) scan may be the ideal method of diagnosis of maxillary sinusitis, but in Nigeria and other less developed countries, CT scan is not readily available and is expensive. Ultrasonography is rapid, cheap, convenient, non-invasive and readily available. However, the reliability of ultrasonography is required to be evaluated in the diagnosis of maxillary sinusitis.*

Aim: *was to evaluate the reliability, sensitivity, specificity, positive and negative predictive values of ultrasound scan compared with CT scan in the diagnosis of maxillary sinusitis.*

Materials and Methods: *A cross-sectional analytical study of randomly selected patients with a clinical diagnosis of rhinosinusitis. Informed consent was obtained. All eligible patients had maxillary sinus ultrasound and CT scans performed. The findings were recorded, and the data was analysed. The Cohen's kappa reliability test was conducted, and the sensitivity, specificity, positive and negative predictive values were calculated.*

Results*: There were 100 participants comprised of 53 (53.0%) males and 47 (47.0%) females, within the age range of 13 – 69 years. Of 200 sinuses studied, ultrasound and CT scans showed 39% and 45% abnormal findings, respectively. A comparison between ultrasound scan and CT scan (as a gold standard) showed that the ultrasound scan had sensitivity, specificity and positive and negative predictive values of 82.7%, 65.6%, 74.6%, and 75.6%, respectively. A Cohen's kappa reliability test showed a moderate agreement between ultrasound and CT scans with $k = 0.489$ and $p < 0.001$.*

Conclusion: *This study showed that sinus ultrasound is reliable with moderate kappa agreement and good sensitivity, specificity, positive and negative predictive values when compared with CT scan. Therefore, ultrasound can be considered as a first-line imaging modality in the diagnosis of maxillary sinusitis.*

Keywords: *CT scan, Maxillary sinusitis, Predictive values, Reliability, Rhinosinusitis, Sensitivity, Specificity, Ultrasound scan.*

INTRODUCTION

Paranasal sinuses are air-filled cavities in the human facial bones that play very vital roles, which include humidifying and warming inspired air, controlling pressure within the nasal cavity, reducing the weight of the skull and helping in the resonance ability of the nasal cavity [1]. The paranasal sinuses are a frequent site of inflammation. Recently, the term "rhinosinusitis" has been preferred in place of "sinusitis," mainly because rhinitis and sinusitis often coexist [2]. Rhinosinusitis is an inflammatory condition of the nose and paranasal sinus mucosal lining. It is a broad umbrella term covering multiple disease entities, including acute rhinosinusitis and chronic rhinosinusitis [3,4]. Rhinosinusitis is a significant health challenge, with its rising prevalence corresponding with the increasing frequency of allergic rhinosinusitis worldwide [5]. It constitutes 78% of the rhinologic cases attending an otolaryngology clinic in West Africa. Its burden on the quality of life of the affected individual is significant, and the disease poses management

*Corresponding Author: **Adamu A**

challenges to the physicians [6]. In Sokoto, Northwestern Nigeria, the prevalence of rhinosinusitis was reported to be 11.7%, with 1.4% having acute and 7.3% chronic rhinosinusitis [7]. A similar prevalence of 7.92% was reported in Ilorin, Northcentral Nigeria. In the above two studies, the maxillary sinus was the most commonly affected by rhinosinusitis [8]. The maxillary sinus was identified as the most involved paranasal sinus by the disease; hence, the role of maxillary sinus ultrasound in rhinosinusitis is very important and should be considered while investigating the disease [6].

Many investigative modalities have been used in the evaluation of the nose, nasopharyngeal and paranasal sinus diseases, such as CT scan [6], Magnetic Resonant Imaging (MRI) [9], plain radiograph [10], flexible endoscopy [11], fibre-optic endoscopy [12], and antral washout [13]. However, currently CT scan is considered to be the gold standard for not only the diagnosis but also planning for endoscopic sinus, endoscopic trans-sphenoid, and endoscopic septal surgeries [14-16]. However, CT scan is still not routinely used in the diagnosis of rhinosinusitis in Nigeria. This is because the preference for a specific imaging modality depends largely on the availability, radiation dose exposure and the cost of the procedure [1,6]. CT scan has a sensitivity of 92% and a specificity of 94% in the diagnosis of rhinosinusitis [17]. Moreover, the imaging modality is not readily available in many centres and hospitals in Nigeria, and the cost of the procedure might be a problem for many patients, which usually paying out of pocket. Consequently, plain radiography is still in use in our environment for the diagnosis of this disease. Unfortunately, plain radiography lacks reliability, especially in inexperienced hands [6,7].

Ultrasound is one of the methods proposed by researchers nowadays as an effective method to investigate the facial as well as paranasal sinus disease conditions like rhinosinusitis [18].This method, unlike a CT scan, does not involve exposure to radiation, and it is cost-effective. Moreover, it is a safe and non-invasive method, and it is easily accepted by patients. Other advantages of ultrasound are its availability and its use in various clinical settings. Limited research has reported the role of ultrasound scan in the evaluation of nose and paranasal sinus diseases. Furthermore, there is not enough information on the efficiency of ultrasound scan in the diagnosis of paranasal sinusitis compared to conventional methods, such as plain radiograph and CT scan [18]. Ultrasound can also be suitable for individuals for whom radiation exposure may be undesirable, such as children, pregnant women and unconscious patients. However, there is no adequate evidence on the efficiency of the ultrasound method in the diagnosis of paranasal sinusitis compared to a CT scan. There is also paucity of literature regarding the accuracy of ultrasonography when compared to other imaging modalities in the diagnosis of maxillary sinusitis in our environment. Hopefully, this research would go a long way in easing the diagnostic challenge encountered by radiologists, ENT surgeons and general physicians in the diagnosis of maxillary sinusitis. Thus, the purpose of this study was to evaluate the reliability, sensitivity, specificity, positive and negative predictive values of ultrasound scan compared with CT scan in the diagnosis of maxillary sinusitis.

MATERIALS AND METHODS

Study Area: This study was carried out at Aminu Kano Teaching Hospital (AKTH), a tertiary health facility located in Kano, Northwestern Nigeria, latitude 11^0 15^l and longitude 8^0 29^1. The hospital serves the population of about nineteen (19) million people, mainly from the states of Kano, Jigawa and Katsina, based on the 2006 population census.

Study Design: This was a hospital-based cross-sectional analytical study.

Study Population: All patients with a clinical diagnosis of rhinosinusitis presented to the Otorhinolaryngology/Radiology departments of the hospital during the study period of January 2020 to March 2021.

Inclusion Criteria: Patients with a clinical diagnosis of rhinosinusitis aged 13 years and above that satisfy the inclusion criteria and consented to participate in the study. We used 13 years because the maxillary sinus growth pattern reaches adult size at about 12 years of age [19]. Studies have also shown that maxillary sinusitis affects up to 40% of school children aged 13 – 14 years in Nigeria [19].

Exclusion Criteria: We excluded patients with a previous history of nose or paranasal sinus surgery, facial trauma, head and neck congenital malformations, patients with jaw masses, and patients less than 13 years of age.

Sample Size Estimation: Sample size was calculated using the following formula:

$N = Z^2P(1-P)/D^2$. Where: N = the minimum sample size required

Z = Standard normal deviate (constant of 1.96 corresponding to 5% significant level)

D = Degree of accuracy desired (0.05)

P = the proportion of maxillary sinusitis (6.89%) obtained from a previous study in Nigeria [7].

Substituting the values, N= (3.8416 x 0.068 x 0.9311)/0.0025 = 98.5643 = 99.

Using the design effect for a finite population less than 10,000, nf = n/(1+n/N) [20].

Where: nf = desired sample size when study population is less than 10,000

n = desired sample size when study population is greater than 10,000

N = estimate of the finite population

Substituting for the value, nf = 99/(1 + 99/108) = 90.098 = 90

To cater for attrition, 10% of the calculated minimum sample was added.

The final sample size was 100 participants.

Sampling Technique: Simple random sampling technique was used.

*Corresponding Author: **Adamu A**

Ethical Consideration: Ethical approval was obtained from the Research Ethics Committee of Aminu Kano Teaching Hospital with reference number NHREC/21/08/2008/AKTH/EC/2760 dated 24th December, 2019. Informed consent was also obtained from the patients, parents or guardians of the patients, as the case may be. The study was conducted according to the Helsinki declaration of 1964 (revised edition). We declare that no Artificial Intelligence (AI) was used to write, draft or edit this article. This declaration is made according to the recent (2024) GAIT guideline [20].

Technique of Maxillary Sinus Ultrasound Scan: Ultrasound was performed for patients on the same day, but before acquiring paranasal sinuses CT images. The procedure was explained to the patient and informed consent obtained. An ultrasound imaging machine (Sonoscape Ultrasound System, SSI 8000, Shenzhen, China), equipped with a curvilinear probe with a frequency of 3.0 - 5 MHz was used. Patients were placed in a sitting position, slightly flexing the head forward, and ultrasound gel was applied to the area to be scanned. The probe was placed transversely on the anterior wall of the maxillary sinus in the vicinity of the nose and below the inferior wall of the orbit, and the maxillary sinus was scanned slowly in the craniocaudal direction. The first observed layer was the skin and subcutaneous tissue, and then, a continuous linear echogenic layer, which was the anterior wall of the sinus (First Echo). Since a normal sinus contains air, its ultrasound view due to sound reflections was seen as parallel echogenic lines (A-Line Artifact), and has a view similar to a normal lung. Sinusitis can cause inflammation of the mucosa and accumulation of fluid within the sinus. The accumulation of fluid within the sinus causes the creation of a hypoechoic or anechoic triangular area within the sinus, which is called a sinugram. When all posterior, external, and internal walls of the maxillary sinus are clearly visible, the sinugram is called complete, and if a part of them is specified, the sinugram is called incomplete. A complete sinusogram was considered as collection in the sinus, and an incomplete sinusogram was considered mucosal thickening. Back Wall Echo (BWE) is a clear hyperechoic line formed by the posterior wall of the sinus, and its appearance indicates pathology in the sinus. When the distance of the BWE line from the anterior wall of the sinus (First Echo) was more than 20 mm, it was considered as complete sinus collection, and when it was less than 20mm it was considered as mucosal thickening. The ultrasound results were classified as mucosal thickening (MT), complete sinusogram (CS), and normal [18]. After the ultrasound scan, the gel applied on the patient was cleaned, and findings documented on the data collection form.

Technique of CT scan of the Paranasal Sinuses: On the same day as the maxillary sinus ultrasound, a paranasal sinus CT scan was done. The procedure was explained to the patient, and informed consent was obtained. A 4-slice multi-detector spiral CT-scanner (GE/bright Speed, 2335179-2, 172297HM4, Beijing, China) was used to performed a Non-contrast paranasal sinus CT scan. The patient was positioned in supine, and the scanning field extended from the base of the skull to the vertex. Standard-dose sinus CT was performed by using 100-120 kV (peak), 200-300 mA, 0.4-second rotation time, 0.531 pitch, and 2.5 mm section collimation; images were generated by using filtered back-projection. The acquired images were transferred to an Advantage Workstation (Version 4.2; GE Health Care), where they were reformatted at 2.5-mm increments in the sagittal and coronal planes and viewed in both bone window (window width = 2500, window level = 480) and soft tissue window (window width =350, window level = 90). The CT findings were graded according to the Lund-Mackay grading system that graded each paranasal sinus separately as Grade 0: Normal, Grade 1: Partial opacification, and Grade 2: Complete opacification [3,6]. CT scan findings were documented on the data collection form.

Statistical analyses: The data generated was analysed with the Statistical Products and Service Solution (SPSS) version 22.0 for Windows (IBM Inc., Chicago, Illinois, USA). Data was explored to identify missing values. Data filtering and cleaning were performed before data analysis began. Quantitative variables were summarized using mean and standard deviation, and categorical variables were summarised using frequencies and percentages. The sensitivity, specificity, positive and negative predictive values of ultrasound (compared with CT scan as the gold standard) in the diagnosis of maxillary sinusitis were calculated using formulas obtained from a two-by-two contingency table. Measurement of the reliability of ultrasonography compared with CT scan was done using Cohen's kappa analysis. Kappa values were interpreted as follows [22]: < 0.00 = no agreement, 0.01 – 0.20 = slight agreement, 0.21 – 0.40 = fair agreement, 0.41 – 0.60 = moderate agreement, 0.61 – 0.80 = substantial agreement, and 0.81 – 1.0 = almost perfect agreement. The results obtained were presented in prose, tables, and charts. Level of statistical significance was set at $p < 0.05$.

RESULTS

There were 100 participants comprising 53 males (53.0%) and 47 females (47.0%). The age of the male subjects ranged from 13 – 69 years with a mean age of 32.8±10.4 years, while the female patients' age ranged from 14 – 68 years with a mean age of 30.9±9.4. The modal age group among the study subjects was 31 – 40 years. Table/Fig. 1 showed age group distribution based on the gender of the participants.

A total of 200 sinuses were studied for both ultrasound and CT scans. Ultrasound scan showed a total of 122 (61%) normal and 78 (39%) abnormal findings. All the ultrasound scan findings showed a statistically significant difference between the right and the left side with $p < 0.001$ [Table/Fig-2]. A sample of an ultrasound scan of the maxillary sinus of one of the patients showing a complete sinusogram of the left maxillary sinus and a normal right maxillary sinus containing air [Table/Fig- 3].

On CT scan, a total of 110 (55%) normal and 90 (45%) abnormal findings. A statistically significant relationship was

*Corresponding Author: **Adamu A**

found between the right and the left side on the normal and mucosal thickening parameters, but a complete sinusogram showed no statistically significant relationship [Table/Fig- 4]. A sample of a coronal CT scan of the paranasal sinuses of one of the patients showing complete opacification of the left maxillary sinus and a normal right maxillary sinus. [Table/Fig- 5].

Comparison between the ultrasound scan and the CT scan (as a gold standard) showed that the ultrasound scan had a sensitivity of 82.7% and a specificity of 65.6%. The study also showed that the ultrasound scan had a positive predictive value of 74.6% and a negative predictive value of 75.6% [Table/Fig- 6]. A Cohen's kappa reliability test found a moderate agreement between ultrasound and CT scan with $k = 0.489$ and $p < 0.001$ [Table/Fig- 7].

DISCUSSION

Rhinosinusitis is a spectrum of inflammatory and infectious diseases concurrently affecting the mucosae of the nose and paranasal sinuses [23]. The maxillary sinus is most commonly involved in the disease process of rhinosinusitis [24]. Ultrasound is one of the methods proposed by researchers nowadays as an effective method to investigate the facial as well as paranasal sinus medical conditions like rhinosinusitis [18]. This study is set out to compare the sonographic and computed tomographic findings in patients with a clinical diagnosis of rhinosinusitis.

In this research, 200 sinuses were studied with ultrasound scans, with 61% normal scan and 39% abnormal ultrasound findings. This is comparable to what was reported by Fufezan et al. [26] in Romania, where they found 59.7% normal sinus ultrasound scan and 40.29% abnormal sinus scan. However, Varonen et al. [26] in Finland, reported 50% normal and 50% abnormal ultrasound sinus scans. The slight disparity could be due to the fact that they used an A-mode ultrasound scan and compared it with plain radiography as the gold standard while in this study a B-mode ultrasound scan was used and compared with a CT scan as the gold standard. The most frequent abnormal finding in this study was mucosal thickening seen in 27.5% of sinuses on ultrasound and partial opacification on CT seen in 39.5% of sinuses. This is in agreement with the findings of Mustafa et al. [27] in Iran, who reported 30.95% on ultrasound and 14.66% on CT. In contrast to this study, Zarei et al. [18] reported 25% complete sinusogram on ultrasound and complete and 28% opacification on CT scan. The disparities may be due to the fact that the study was conducted only on patients with a clinical diagnosis of acute rhinosinusitis. This study was conducted on subjects with clinical diagnosis of both acute and chronic rhinosinusitis.

In this study, the sensitivity, specificity, positive and negative predictive values of ultrasound compared to CT scan were 82.7%, 65.6%, 74.6%, and 75.6% respectively, and moderate agreement with Cohen's kappa (k) of 0.489 was found. Abdalla et al. [28] in Sudan reported a similar sensitivity of 76.6%, but with a slightly higher specificity of 92.2%. Similarly, Mustafa et al. [27] also reported a similar sensitivity of 81.1% but with a higher specificity of 100%. Furthermore, Ghasemi et al. [29] in their study, showed a sensitivity of 73% and moderate agreement using kappa statistics of $k = 0.545$. But with higher specificity of 100%, a positive predictive value of 100% and a lower negative predictive value of 50.95%. In variance with the findings of this study, Mori et al. [30] in Japan reported higher sensitivity, specificity, positive and negative predictive values of 92.6%, 100%, 100%, and 81.8%, respectively. Additionally, Jorge et al. [31] in Uruguay also reported slightly higher sensitivity, specificity, positive and negative predictive values of 91%, 92.5%, 86%, and 95%, respectively. Although the above-mentioned studies had some similarities compared to this study, slightly higher values in most of the indices (sensitivity, specificity, positive and negative predictive values) were reported. These differences could be attributed to the lower sample sizes of 42 participants enrolled by Mustafa et al. [27], 50 subjects used by Abdallah et al. [28], 60 patients recruited by Ghasemi et al. [29], 18 studied by Mori et al. [30], and 50 enrolled by Jorge et al. [31].

Furthermore, higher indices were also recorded by Fufezan et al. [25] in Romania, with 94.9% sensitivity, 98.4% specificity and kappa statistics agreement of $k = 0.835$. Similarly, Hilbert et al. [32] in France reported much higher indices in their study with a sensitivity of 100%, a specificity of 96.7%, a positive predictive value of 98.6%, a negative predictive value of 100%, and almost perfect agreement of $k = 0.93$ using Cohen's kappa statistics. These differences could be attributed to the nature of their study that defined radiologic maxillary sinusitis as complete opacification of the sinus or as the presence of an air-fluid level only, while mucosal thickening was categorised as the absence of radiologic findings.

Validity of Ultrasonography in the diagnosis of acute maxillary sinusitis was studied by Puhakka et al.[33] in Finland, who reported 56% and 13% as sensitivity and false-positive rate of sinus ultrasound compared with plain radiograph. The agreement between ultrasonography and plain radiograph was 80% with Cohen's kappa coefficient of $k = 0.44$. In the same study ultrasonography was found to have a sensitivity of 64% and specificity of 95% compared with MRI. The discrepancies could be due to the fact that ultrasound and plain radiograph were performed on all patients, but MRI was performed only on 40 randomly selected patients. Alaskaree et al. [34] in Iraq compared ultrasound versus plain radiograph and diagnostic antral washout in the diagnosis of maxillary sinus diseases. The sensitivity of the ultrasonography and plain radiograph were 92.5% and 90.5%, respectively. The specificity of the ultrasonography and the plain radiograph were 55% and 41%, respectively. The slightly lower specificity recorded in their study could be due to their choice of diagnostic antral washout as the gold standard, which may only diagnose fluid collection in the sinus.

The strength of this study lies in the comparison of these two diagnostic methods among randomly selected patients with no bias. Overall this study demonstrated a good sensitivity, positive and negative predictive values of ultrasound scan in

*Corresponding Author: **Adamu A**

the diagnosis of maxillary sinusitis in our environment. Therefore, a sinus ultrasound scan is relatively accurate in the diagnosis of maxillary sinusitis in our environment.

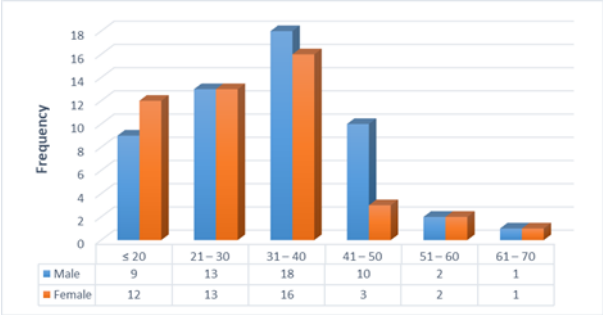
Limitations

We acknowledged the inability to compare the sinus ultrasound scan with MRI findings, as it has better soft tissue delineation than a CT scan. The use of sinus ultrasonography, like all ultrasonographic examinations, is highly examiner-dependent. Therefore, the findings must always correlate with the clinical status of the patient, endoscopic as well as other laboratory investigations to arrive at an accurate diagnosis.

CONCLUSION

This study showed that sinus ultrasound is reliable with moderate kappa agreement and good sensitivity, specificity, positive and negative predictive values when compared with CT scan. Therefore, ultrasound should be considered as a first-line imaging modality in the diagnosis of maxillary sinusitis, especially in pregnant women, children, unconscious patients and low-resource centres, considering its availability, lack of ionising radiation and easy to operate even in a clinic setting.

TABLES AND FIGURES



Table/Fig- 1: Showing the age group distribution based on gender of the participants

Table/Fig- 2: Ultrasound scan findings among the participants

Variables	Ultrasound findings		Total (%)	p-value
	Right	Left		
Normal	64 (52.5)	58 (47.5)	122 (100)	< 0.001*
Mucosal Thickening	29 (52.7)	26 (47.3)	55 (100)	< 0.001*
Complete Sinusogram	7 (30.4)	16 (69.6)	23 (100)	< 0.001*
Total (%)			**200 (100)**	

*Statistically significant

Table/Fig- 3: Ultrasound scan of the maxillary sinus showing complete sinusogram of the left and normal right side.

Table/Fig- 4: CT Scan findings among the participants

Variables	CT findings		Total (%)	p-value
	Right	Left		
Normal	58 (52.7)	52 (47.3)	110 (100)	< 0.001*

*Corresponding Author: **Adamu A**

Partial Opacification	38 (48.7)	40 (51.3)	78 (100)	< 0.001*
Complete Opacification	5 (41.7)	7 (58.3)	12 (100)	0.38
Total (%)			**200 (100)**	

*Statistically significant

Table/Fig- 5: Coronal CT scan of the paranasal sinuses showing complete opacification of the left maxillary sinus and normal right maxillary sinus.

Table/Fig- 6: Predictive analysis, Sensitivity and Specificity of ultrasound scan (USS) against CT scan findings

Test results		CT findings		Total
		Positive	Negative	
USS findings	Positive	TP = 91	FP = 31	122
	Negative	FN = 19	TN = 59	78
	Total	110	90	200

TP = True Positive, FP = False Positive, FN = False Negative, TN = True Negative

Sensitivity = TP/(TP+FN) = 91/(91+19) = 91/110 = 82.7%

Specificity = TN/(TN+FP) = 59/(59+31) = 59/90 = 65.6%

Positive Predictive Value = TP/(TP+FP) = 91/(91+31) = 91/122 = 74.6%

Negative Predictive Value = TN/(TN+FN) = 59/(59+19) = 59/78 = 75.6%

*Corresponding Author: **Adamu A**

Table/Fig- 7: Kappa analysis of ultrasound scan (USS) against CT scan findings

			CT findings		Total
			Normal	**Abnormal** (Partial /Complete Opacity)	
USS findings	**Normal**	**Frequency**	**91**	**31**	**122**
		% within USS	74.6%	25.4%	100.0%
		% within CT	82.7%	34.4%	61.0%
	Abnormal (Mucosal Thickening/ Complete Sinusogram)	**Frequency**	**19**	**59**	**78**
		% within USS	24.4%	75.6%	100.0%
		% within CT	17.3%	65.6%	39.0%
Total		**Frequency**	**110**	**90**	**200**
		% within USS	55.0%	45.0%	100.0%
		% within CT	100.0%	100.0%	100.0%

Measure of Agreement, Kappa (K) = 0.489, p-value <0.001

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*Corresponding Author: **Adamu A**