RESEARCH ARTICLE

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Using Smartphone to Evaluate Cranial Computed Tomography Videos: An Inter-Observer Study

ABSTRACT

Objective: Many clinicians receive Cranial Computed Tomography (CCT) images or videos by their smartphone. The aim of this study was to evaluate the reliability of the CCT videos that are shared through smartphone in the diagnosis.

Methods: The CCT videos that were sent via WhatsApp were examined in 9 sections: soft tissue, bone structure, parenchyma, ventricle, vascular structures, middle ear, orbits, sinuses and the extra axial space.

Results: The CCT videos were analyzed in 9 sections; there was a perfect agreement among specialists in one of these sections, good agreement in 6 and poor agreement in 2. When compared with the gold standard, it was shown that 5 out of 9 sections could be an alternative to the gold standard.

Conclusions: It may be thought that evaluation of the CCT videos can be obtained with messenger applications such as WhatsApp, which is a cheap, fast and common application. But this study shows that diagnostic images and videos shared through the smartphone by a messenger application can not be an alternative to standard evaluations.

Keywords: WhatsApp, Multidedector Computed Tomography, Video Recording, Smartphone.

Kranial Bilgisayarlı Tomografi Videolarını Değerlendirmek İçin Akıllı Telefon Kullanma: Gözlemciler Arası Çalışma

ÖZET

Amaç: Birçok klinisyen akıllı telefonlarından Beyin Bilgisayarlı Tomografi (BBT) görüntüleri veya videoları ile hasta değerlendirmektedir. Bu çalışmanın amacı, akıllı telefon aracılığıyla paylaşılan BBT videolarının tanıda güvenilirliğini değerlendirmektir.

Gereç ve Yöntem: WhatsApp üzerinden gönderilen BBT videoları 9 bölgeye ayrılarak değerlendirildi: yumuşak doku, kemik yapısı, parankim, ventrikül, damar yapıları, orta kulak, orbita, sinüsler ve ekstra aksiyel alan.

Bulgular: BBT videoları 9 bölümde incelendi; bu bölümlerden birinde uzmanlar arasında mükemmel uyum, 6'sında iyi uyum, 2'sinde zayıf uyum vardı. Altın standart ile karşılaştırıldığında, 9 bölümden 5'inin altın standardına alternatif olabileceği gösterildi.

Sonuç: BBT videolarının değerlendirilmesinin ucuz, hızlı ve yaygın bir uygulama olan WhatsApp gibi mesajlaşma uygulamaları ile sağlanabileceği düşünülebilir. Ancak bu çalışma, bir messenger uygulaması tarafından akıllı telefon üzerinden paylaşılan tanısal görüntü ve videoların standart değerlendirmelere alternatif olamayacağını göstermektedir.

Anahtar Kelimeler: Whatsapp, Çok Kesitli Bilgisayarlı Tomografi, Video Kayıt, Akıllı Telefon.

INTRODUCTION

The use of cranial computed tomography (CCT) has become an important tool in the emergency department (ED), especially in the management of patients with head trauma. The CCT has become the first-choice imaging method in patients with head trauma due to the facts that it provides rapid evaluation, has a low number of contraindications, has high sensitivity and it is easily accessible in our country (1). However, the diagnostic support of clinics such as the emergency medicine, radiology, neurology and neurosurgery are sometimes needed in the evaluation of the CCT images obtained in the ED. This support, both within the hospital itself and among hospitals that are not integrated with each other, is often provided by social media applications such as WhatsApp via smartphones. Evaluating CCT videos on a smartphone is a confusing ethical and technical problem for physicians. Medical assessments via WhatsApp have often been the subject of articles (2-4). The aim of this study was to evaluate the reliability of the CCT videos that are shared via WhatsApp application in the diagnosis.

MATERIAL AND METHODS

The study was initiated with the approval of the Local Ethics Committee. Using the appropriate random sampling method, the CCT scans of the first 111 patients who had presented to the ED starting from the first day of January 2020, which were performed with the appropriate imaging technique, were included in the study. Thirteen radiologists/radiology residents were interviewed for the study. Five radiologists/radiology residents who agreed to participate in the study were quizzed with 20 the CCTs that had not been included in the study and chosen through the hospital's Picture Archiving and Communication System (PACS), the success rate of 2 of which had exceeded 90% were included in the study.

Process

First Step: 111 the CCT scans were first evaluated by two radiologists (one with 20 years and the other with 4 years of experience) on a medical monitor (Totoku brand, 3MP 21.3-inch medical monitor) on a desktop computer. The scans were interpreted in a low-light quiet environment in the radiology evaluation room and the pathologic findings were recorded. These results made with the consensus among the radiologists have been accepted as the gold standard.

Second Step: The CCT scans were recorded on videos with an iPhone 7 plus smart (12 MP camera) phone. The video recording was carried out at a distance of 30 cm in an artificially lit environment without daylight, without using flash and direct light on the computer screen. Each video was short (≤30 seconds), included 90-110 sections (half containing parenchyma, half containing bone window).

Third Step: The smartphone of the participants were tested and calibrated by a multicolor video. These videos (with MP4 extension; with a mean picture frame seconds of 28.98; resolution 480p: 854x480 and about 4.6-5.8 mb) were sent to two different participants via WhatsApp application (one radiologist with 20 years of experience, the other 3.5-year radiology resident) and they were asked to evaluate the videos. The evaluation process was carried out in a closed and illuminated environment without daylight, without direct exposure of light to the phone screen. One radiologist (Mobile1) evaluated the videos with a Samsung Galaxy S6 Edge (5.1 Inch Super AMOLED screen, 1440x2560 (QHD) Pixel resolution), and the other (Mobile2) with an iPhone 6 (4.7-inch IPS 750 x 1334 pixels 326 ppi), and these evaluations were written in the pre-prepared forms. The CCT videos were examined in 9 sections: soft tissue, bone structure, parenchyma, ventricle, vascular structures, middle ear, orbita, sinuses and the extra axial space. If any finding (whether acute, chronic or pathological) were seen or not seen in the relevant sections, it was indicated by the signs "x finding" and "normal". The evaluations made were analyzed as follows:

Statistical Analysis: The agreement between the two participants was examined with the kappa coefficient. The interpretation of agreement accordingly was as follows; a kappa value higher than 0.76: perfect agreement, a kappa value between 0.40-0.75: substantial beyond chance, between 0.00-0.39: poor beyond chance and values lower than zero: no agreement (5). Sensitivity, Specificity, PPV, NPV and Accuracy measurements, as well as the ROC analysis and AUC (areas under the curve) were compared in measuring the adequacy of the diagnoses. As descriptive statistics mean±standard deviation was given for the numerical variables and number and % values were given for the categorical variables. The SPSS Windows version 21.0 package program was used for the statistical analysis and a p value of <0.05 was considered statistically significant.

RESULTS

The mean age of the patients was 52.30±23.47 and 58.6% (n= 65) of the patients were male. The most common complaint on admission was determined to be trauma (40.6%) (Table 1).

Table 1. Descriptive statistics of the patients

Age (mean±sd)	52.30±23.47
Male/Female (%)	65 (58.6) / 46 (41.4)
Reason for presentation (%)	45 (40.6%) traumas 28 (25.2%) neurological deficits 19 (17.1%) dizziness 12 (10.8 %) headaches 7 (6.3%) other

Considering the answers given by the two radiologists while interpreting the CCT videos, the highest success rate was seen in the extra-axial space (Mobile1 & 2: 98.2%), and the lowest success rate was seen in the ventricule analysis (Mobile1: 80.2% & Mobile2: 59.5%) (Table 2).

Table 2. Findings detected on CCTs and the answers of the participants

Evaluated region	*Monitored findings (Gold Standard)*	*Mobile 1*	*Mobile 2*
Soft tissue n (%)	Normal findings 104 (93.7%) Subcutaneous hematoma 2 (1.8%) Soft tissue swelling 5 (4.5%)	Correct answer 98 (72.1%) • Normal 93 (67.6%) • Finding 5 (4.5%) False positive 11 (9.9%) False negative 2 (1.8%)	True answer 96 (86.5%) • Normal 95 (85.6%) • Finding 1(0.9%) False positive 7 (6.3%) False negative 8 (7.2%)
Bone n (%)	Normal findings 104(93.7%) Fracture 5 (1.8%) Craniotomy area 2 (4.5%)	True answer 93 (83.8%) • Normal 88(79.3%) • Finding 5(4.5%) False positive 16 (14.4%) False negative 2 (1.8%)	True answer 98 (88.3%) • Normal 94 (84.7%) • Finding 4 (3.6%) False positive 10 (9%) False negative 3 (2.7%)
Parenchyma n (%)	Normal findings 70(63.1%) Ischemic sequelae 17 (15.3%) Acute/subacute ischemia 7 (6.3%) Hypodense lesion 3 (2.7%) Encephalomalacia 5 (4.5%) Surgical sequelae 1 (0.9%) Atrophy findings 8 (72%)	True answer 88 (79.3%) • Normal 60(54.1%) • Finding 28(25.2%) False positive 15 (13.5%) False negative 8 (7.2%)	True answer 94 (84.7%) • Normal 59(53.2%) • Finding 35(31.5%) False positive 11 (9.9%) False negative 6 (5.4%)
Ventricule n (%)	Normal findings 99 (89.2%) Ventricular enlargement 12 (10.8%)	True answer 89 (80.2%) • Normal 82 (73.9%) • Finding 7 (6.3%) False positive 17 (15.3%) False negative 5 (4.5%)	True answer 66 (59.5%) • Normal 55 (49.6%) • Finding 11 (9.9%) False positive 44 (39.6%) False negative 1 (0.9%)
Vascular n (%)	Normal Findings 102 (91.9%) Calcification 8 (7.2%) Spontaneous Subarachnoid hemorrhage 1 (0.9%)	True answer 99 (89.2%) • Normal 98 (88.3%) • Finding 1 (0.9 %) False positive 4 (3.6%) False negative 8 (7.2 %)	True answer 93 (83.6%) • Normal 88 (79.3%) • Finding 5 (4.5%) False positive 14 (12.6%) False negative 4 (3.6%)
Middle ear n (%)	Normal Findings 110 (99.1%) Effusion 1 (0.9%)	True answer 105 (94.6%) • Normal 105 (94.6%) • Finding 0 (0%) False positive 5 (4.5%) False negative 1 (0.9%)	True answer 106 (95.5%) • Normal 106 (95.5%) • Finding 0 (0%) False positive 4 (3.6%) False negative 1 (0.9%)
Sinus n (%)	Normal Findings 83 (74.9%) Cyst 2 (1.8%) Mucosal thickening 14 (12.6%) Polyp 3 (2.7%) Septal deviation 9 (8.1%)	True answer 91 (82%) • Normal 78 (70.2%) • Finding 13 (11.8%) False positive 5 (4.5%) False negative 15 (13.5%)	True answer 83 (74.8%) • Normal 71(64%) • Finding 12(10.2%) False positive 12 (10.8%) False negative 16 (14.4%)
Orbit n(%)	Normal Findings 111 (100%)	True answer 103 (92.8%) • Normal 103(92.8%) • Finding 0(%) False positive 8 (7.2%) False negative 0 (%)	True answer 108 (97.3%) • Normal 108 (97.3%) • Finding 0(%) False positive 3 (2.7%) False negative 0 (%)
Extra-axial space n (%)	Normal Findings 109 (89.2%) Hemorrhage 1 (9.9%) Menengioma 1 (0.9%)	True answer 109 (98.2%) • Normal 107(96.4%) • Finding 2 (1.8%) False positive 2 (1.8%) False negative 0 (%)	True answer 109 (98.2%) • Normal 107(96.4%) • Finding 2(1.8%) False positive 2 (1.8%) False negative 0 (%)

When the agreement between the two radiologists was examined, perfect agreement was determined for the extra-axial space (Kappa: 1.0; p = 0.001) and a substantial agreement beyond chance (Kappa: 0.40-0.75; p = 0.001) was determined in the evaluation of soft tissue, bone, parenchyma, middle ear, sinuses and the orbita.

In the evaluation of ventricular and vascular structures, a poor agreement was determined between the two participants (Kappa <0.39; p = 0.001) (Table 3).

Table 3. Concordance analysis between the two participants

		Kappa value	P value
Soft tissue	*Mobile 1* / *Mobile 2*	0.723	**0.001**
Bone	*Mobile 1* / *Mobile 2*	0.697	**0.001**
Parenchyma	*Mobile 1* / *Mobile 2*	0.733	**0.001**
Ventricle	*Mobile 1* / *Mobile 2*	0.330	**0.001**
Vascular	*Mobile 1* / *Mobile 2*	0.282	**0.001**
Middle ear	*Mobile 1* / *Mobile 2*	0.421	**0.001**
Sinuses	*Mobile 1* / *Mobile 2*	0.591	**0.001**
Orbit	*Mobile 1* / *Mobile 2*	0.527	**0.001**
Extra-axial space	*Mobile 1* / *Mobile 2*	1.0	**0.001**

Kappa value >0.76 excellent concordance. 0.40-0.75 good concordance. 0.00-0.39 poor concordance (1). Significant p >0.05

A statistically significant agreement was determined between the soft tissue evaluations made by the two specialists on the phone (Kappa=0.723 p=0.001). Similarly, in the bone, parenchyma, ventricle, vascular structures, sinuses, middle ear, orbita and the extra-axial space evaluations, a statistically significant agreement was achieved between the diagnoses made by the two specialists on the phone. The highest level of agreement of the two specialists (Kappa=1) was observed in the extra-axial space assessment, whereas the lowest level of agreement (Kappa=0.282) was determined in the vascular assessment.

Comparing the two radiologists with the gold standard according to Sensitivity, Specificity, PPV, NPV and Accuracy and the AUC values, soft tissue, bone, parenchyma, ventricle and orbital evaluations made through WhatsApp application were found to be sufficiently consistent to be an alternative to the evaluations made on the standard computer screen ($p<0.05$). In the evaluation of the vascular structures, only the evaluations of Mobile 2 participants were consistent, which may be an alternative to the gold standard (Sensitivity: 0.56; Specificity: 0.86). While the evaluations of two radiologists could not be an alternative to the gold standard in the evaluation of sinus structures, orbital and extra-axial structure evaluations could not be evaluated (Table 4).

Table 4. Comparison of the two participants with the gold standard

		Sensitivity	**Specificity**	**PPV**	**NPV**	**Accuracy**	**AUC**	**p**
Soft tissue	*Mobile 1*	0.71	0.89	0.31	0.98	0.88	0.80	**0.007**
	Mobile 2	0.57	0.91	0.31	0.97	0.89	0.74	**0.032**
Bone	*Mobile 1*	0.71	0.85	0.24	0.98	0.84	0.78	**0.013**
	Mobile 2	0.57	0.90	0.29	0.97	0.88	0.73	**0.036**
Parenchyma	*Mobile 1*	0.68	0.86	0.74	0.82	0.79	0.77	**0.001**
	Mobile 2	0.85	0.84	0.76	0.91	0.85	0.85	**0.001**
Ventricle	*Mobile 1*	0.58	0.83	0.29	0.94	0.80	0.71	**0.020**
	Mobile 2	0.92	0.56	0.20	0.98	0.59	0.74	**0.008**
Vascular	*Mobile 1*	0.11	0.96	0.20	0.92	0.89	0.54	0.721
	Mobile 2	0.56	0.86	0.26	0.96	0.84	0.71	**0.038**
Middle ear	*Mobile 1*	0.46	0.94	0.72	0.84	0.82	0.70	**0.001**
	Mobile 2	0.43	0.86	0.50	0.82	0.75	0.64	**0.025**
Sinuses	*Mobile 1*	0.00	0.95	0.00	0.99	0.95	0.47	0.938
	Mobile 2	0.00	0.96	0.00	0.99	0.95	0.48	0.950
Orbit	*Mobile 1*	0.00	0.93	0.00	1.00	0.93	*NC*	
	Mobile 2	0.00	0.97	0.00	1.00	0.97	*NC*	
Extra-axial space	*Mobile 1*	0.00	0.89	0.00	1.00	0.89	*NC*	
	Mobile 2	0.00	0.89	0.00	1.00	0.89	*NC*	

PPV:Positive predictive value. NPV: Negative predictive value. AUC: Area under the curve. NC: Non-calculated. Significant p >0.05

DISCUSSION

There are contradictory results in studies evaluating the photographs of direct radiographies to be sent to the participants vie WhatsApp and similar applications. The decrease in the image quality according to the quality of both the program and the phone used by the participants is an issue to be discussed (3). While these evaluations have been

found to be reliable in some studies, contrary results have been found in some other studies (3,6,7). Evaluation requests made by sharing images (photo or video) with such applications can be requested, especially when there is a need for support from physicians working in hospitals that are not integrated with each other, or in cases where the hospital's PACS system does not have a mobile version. There are also suggestions that sharing tomography videos with the healthcare team in the hospital would enable rapid decision making and rapid treatment planning (8). Radiologists, with whom many images are shared, including the CCT images and videos taken in the emergency or other wards, often evaluate these images and express their opinions. However, how accurate and reliable is the evaluation of these videos sent via WhatsApp? This study was created to discuss this situation.

The consultation process has begun to be standardized in many institutions by sharing radiographs, ECG, skin lesion, laboratory results and sometimes tomography images via WhatsApp. In a survey study conducted with 87 oral medicine and radiology specialists, 95.40% of the specialists were found to evaluate the images consulted with their smart phones with WhatsApp application (9). In the study of Gülaçtı et al., it was found that radiograph sharing was utilized mostly by orthopedic surgeons (2). When the remote consultations with text messages, photos, videos and voice messages sent to the oral medicine and radiology experts via WhatsApp are examined, the evaluations have been shown to give accurate results with a high percentage of 82% (10). As seen from these examples, WhatsApp application can be an alternative to many expensive applications used for telemedicine due to its advantages such as being cheap, accessible and globally used for consultation purposes (11).

The contribution of the application to the consultations has been widely discussed in the literature (2,10,12). Handelman et al. had the PA chest radiographs sent on the WhatsApp app interpreted by 12 interns, and their interpretations were then compared with the comments of radiologists who interpreted the radiographs on the computer screen. In this study, no significant difference was found between the two groups (3). Another study that we would like to mention is the inter-observer study of Şener et al. with urologists, because it has a similar concept, although it did not include radiological imaging. In the study, it was shown that the sensitivity and specificity of spot urine sample photographs sent via WhatsApp were high in determining the presence and severity of hematuria (13). In the intra-observer study made by Stahl et al. with thoracolumbar CT videos sent to orthopedic surgeons via WhatsApp, it was shown to have a very good agreement with fracture, calcification, follow-up of treatment, neural canal penetration and evaluation of the Denis classification (14). In another study carried out by Stahl et al. by sending the X-ray images taken due to orthopedic traumas in children via WhatsApp application, they found an almost perfect agreement between WhatsApp reviews and the standard computer screen reviews (15).

Issues such as the change of image quality during transfer, the fact that the images are not evaluated by a user on a standard phone (not every user uses the same phone), the amount of light in the indoor and outdoor environment may affect the evaluation and which images can be effectively evaluated this way, are still not clarified. In our study that the CCT videos were analyzed in 9 sections, there was a perfect agreement among specialists in only one of these section, good agreement in 6 and poor agreement in 2. When compared with the gold standard, it was shown that 5 out of 9 sections could be an alternative to the gold standard. However, sensitivity (11-92%) and specificity (56-97%) vary according to the section and user. In addition, although the correction rate is high in the comments made by the participants (59.5-98.2%), false positivity (1.8-39.6%) and false negativity (0-14.4%) also show serious variation. When we consider CCT as a whole, it is not appropriate to use this method in almost all of the sections we determined because of low sensitivity. Therefore, using smartphone and messenger applications could not be alternative to evaluate of the CCT.

The CCT is one of the most frequently used examination techniques in emergency departments. Low cost, ease of accessibility and being a method that provides fast results are among the reasons for this method being preferred (1). Trauma-related injuries are among the most common reasons for presentation to ED. In our study, 40.6% of the patients who had undergone CCT had presented to the ED due to trauma. In the study of Yıldız et al., 42.9% of the patients who had undergone CCT had similarly presented with trauma (1). In another study conducted in our country, 46.8% of patients who had undergone CCT had a traumatic etiology (16) Due to the high mortality of intracranial injuries caused by severe head trauma (10-40%), we think that the CCT will continue its popularity in the emergency departments as it is an effective method in the early diagnosis of lesions associated with trauma (1,17).

Although the numbers of the CCT scans are gradually increasing due to its rapid and inexpensive nature, the detected intracranial pathology rates are quite low. Positive CCT findings were observed in 159 (4.1%) of 3866 patients in the study of Osmond et al, 24 of whom (0.6%) had undergone neurosurgical operations (18). Yıldız et al. retrospectively examined the CCT images of 1700 patients, and 1427 (83.94%) of these patients did not have any acute pathology in

their CCT images (1). In 42 (37.8%) of 111 CCT videos included in our study, no pathology was observed in any area. Acute pathology was observed in 14 (12.6%) cases (skull fracture in 5 (4.5%) cases, acute/subacute ischemia in 7 (6.3%) cases, subarachnoid hemorrhage in 1 (0.9%) case and extra-axial bleeding in 1 (0.9%) case)). The high levels of normal CCT scans may be attributed to the increased defensive medicine approaches due to different reasons (such as severity, malpractice, pressure by the patient and their relatives', insufficient follow-up area).

CONCLUSION

It may be thought that evaluation of the CCT videos can be obtained with messenger applications such as WhatsApp, which is a cheap, fast and common application. But this study shows that diagnostic images and videos shared through the smartphone by a messenger application can not be an alternative to standard evaluations. It is more appropriate to use FDA-approved Digital Imaging and Communications in Medicine (DICOM) viewers applications rather than using social media applications (19-21). However, it is recommended to use these applications in emergency situations rather than primary diagnostic evaluation and to repeat the evaluation on the standard monitor as soon as possible (22,23).

Ethics Declarations

Declaration of Conflicting Interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Informed Consent: The informed consent was obtained from each participants.

Ethical Approval: Ethics committee approval was obtained from Düzce University (Date:16/03/2020, Decision no: 2020/51).

Human Rights: Authors declare that human rights were respected according to the Declaration of Helsinki.

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