RESEARCH ARTICLE

Interobserver Variability of Radiographic Assessment Using a Mobile Messaging Application as a Teleconsultation Tool

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Abstract

Background: To examine whether interobserver reliability, decision-making, and confidence in decision-making in the treatment of distal radius fractures changes if radiographs are viewed on a messenger application on a mobile phone compared to a standard DICOM viewer.

Methods: Radiographs of distal radius fractures were presented to surgeons on either a smart phone using a mobile messenger application or a laptop using a DICOM viewer application. Twenty observers participated: 10 (50%) were randomly assigned to the DICOM viewer group and 10 (50%) to the mobile messenger group. Each observer was asked to evaluate the cases and (1) classify the fracture type according to the AO classification, (2) recommend operative or conservative treatment and (3) rate their confidence about this decision.

Results: There was no significant difference in interobserver reliability for AO classification and recommendation for surgery for distal radius fractures in both groups. The percentage of recommendation for surgery was significantly higher in the messenger application group compared to the DICOM viewer group (89% versus 78%, *P=0.019*) and the confidence for treatment decision was significantly higher in the mobile messenger group compared to the DICOM viewer group (8.9 versus 7.9, *P=0.026*).

Conclusion: Messenger applications on mobile phones could facilitate remote decision-making for patients with distal radius fractures, but should be used with caution.

Keywords: Decision-making, Distal radius, Interobserver agreement, Messaging application, Teleconsultation

Introduction

The use of smartphones in daily practice is greater than 85% among health care providers in the USA (1). Smartphone applications offer possibilities for improvements in medical care by improving access to medical information and communication between health care providers (2).

Mobile messenger applications are a subclass of mobile applications that are commonly used in health care. Messaging services allow users to exchange multimedia data such as text messages and images. The use of mobile messenger applications as a communication platform helps to relay clinical data in surgical practice (3). For example, these applications make it possible to relay images for communication when orthopedic surgeons are on call, which can greatly improve the confidence of remote clinical decision-making by orthopedic surgeons (4).

Mobile teleradiology is an upcoming phenomenon in numerous fields of medicine (5-9). When compared to plain films viewed on a light box or display monitors for common radiological tasks, handheld devices seem to be promising for diagnostic purposes (10, 11). Multiple recent studies show that physicians often teleconsult each other for assessment of radiographic images by using their smartphone camera to take and send pictures of radiographs through messaging applications (12-15). In orthopedic surgery, this form of teleconsultation has been studied for the classification of tibial plateau fractures (13). Radiographic picture messaging does however not offer scaling, windowing or leveling options

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that are present when using a standard Digital Imaging and Communications in Medicine (DICOM) viewer. It is unclear if this form of radiographic picture messaging influences interobserver reliability, decision-making, and confidence in decision-making in orthopedic care in comparison to a standard DICOM viewer platform.

In this study, we examine whether interobserver reliability, decision-making, and confidence in decision-making in the treatment of distal radius fractures changes if radiographs are viewed on a messenger application on a mobile phone compared to a standard DICOM viewer. We tested the null hypotheses that there is no difference in 1) interobserver agreement for the Arbeitsgemeinschaft für Osteosynthesefragen (AO) fracture classification for the distal radius, 2) recommendation for operative treatment, 3) interobserver agreement regarding recommendation for surgery, and 4) confidence in treatment decision-making between observers using a DICOM viewer on a high-resolution screen compared to those using a messenger application on a mobile phone.

Materials and Methods

Study design

Our Institutional Review Board approved the study. A series of radiographs of distal radius fractures were presented to individual observers on either a smart phone using a mobile messenger application or a high-resolution screen laptop using a DICOM viewer application. The observers were randomized in a 1:1 ratio through permuted block randomization to each group. The permuted block design is a commonly used approach in which the number of assignments to the groups satisfies a specified allocation (1:1 in our study) in a specific 'block' of participants or observers (16). We have used a fixed-size block of 2 observers and a computer random number generator to assure balance of the groups.

Observers

Fully trained surgeons, clinical fellows, and residents, were invited to participate in this study. A total of 20 observers participated: 10 (50%) were assigned to the DICOM viewer group and 10 (50%) to the mobile messenger group. Demographic data for the surgeons was acquired including age, gender, geography, position, specialty, years of experience, supervisory role and work status [Table 1].

The mobile messenger group consisted of more fully trained surgeons with more experience (i.e., years in practice) compared to the DICOM viewer group. Most respondents were male (95%), from the United States (65%) and hand and wrist surgeon (65%). With the exception of the age variable, the two groups of observers were statistically similar and all observers completed the evaluation [Table 1].

Table 1. Observer Characteristics

	All Observers (n=20)	DICOM Viewer (n=10)	Mobile Messenger (n=10)	*P-value*
Age, mean (SD), y	42 (12)	36 (6.5)	48 (13)	0.03
Sex, n(%)				0.99
Men	19 (95)	10 (100)	9 (90)	
Women	1 (5.0)	0.0 (0.0)	1 (10)	
Geography, n(%)				0.99
USA	13 (65)	7 (70)	6 (60)	
Canada	1 (5.0)	0 (0.0)	1 (10)	
Europe	3 (15)	2 (20)	1 (10)	
Asia	2 (10)	1 (10)	1 (10)	
Other	1 (5.0)	0 (0.0)	1 (10)	
Position, n(%)				0.23
Surgeon	12(60)	4 (40)	8 (80)	
Fellow	3 (15)	2 (20)	1 (10)	
Resident	5 (25)	4 (40)	1 (10)	
Specialty, n(%)				0.12
General Orthopaedic Surgery	4 (20)	4 (40)	0 (0.0)	
Orthopaedic Traumatology	3 (15)	1 (10)	2 (20)	
Hand and Wrist Surgery	13 (65)	5 (50)	8 (80)	
Years in practice, n(%)				0.057
0-5	9 (45)	6 (60)	3 (30)	
6-10	4 (20)	3 (30)	1 (10)	

Continuous of Table 1.				
11-20	2 (10)	1 (10)	1 (10)	
21-30	5 (25)	0 (0.0)	5 (50)	
Supervisor, n(%)				0.30
Yes	15 (75)	6 (60)	9 (90)	
No	5 (25)	4 (40)	1 (10)	
Workstatus, n(%)				0.99
Fulltime	18 (90)	9 (90)	9 (90)	
Parttime	2 (10)	1 (10)	1 (10)	

Subjects

The cases for this study were acquired from a research database. Ten fractures with adequate anteroposterior and lateral digital radiographs were selected by consensus of two of the authors in order to represent a spectrum of distal radius fracture types according to the AO classification. All radiographs were pre-reduction radiographs that were not obscured by splinting or cast material.

The sample of subjects with distal radius fractures consisted of 2 (20%) men and 8 (80%) women, with a mean age of 70 years (range, 51-87 years). The left side was affected in 7 (70%) patients and fall on an outstretched arm was the mechanism of injury in 9 (90%) patients [Table 2]. As the sample size in interobserver reliability studies require an appropriate balance between the number of observers evaluating each subject and the number of subjects (17, 18), it was decided to limit the number of radiographs in order to decrease participant burden and increase the number of observers rating each subject.

Radiographic images

The radiographs were obtained and anonymized with proprietary software (AquariusNet Thin Client, TeraRecon, San Mateo, USA) in DICOM format. The DICOM images of the radiographs were then photographed with an iPhone 6 (Apple, Cupertino, USA) with a 4.7-inch retina display with a 1334 by 750 resolution at 326 pixels per inch and an 8-megapixel camera. The operating system on the iPhone was iOs version 8.3. The reason we used an iPhone is because in clinical practice, the iPhone appears to provide the highest proportion of images that are evaluated as 'good' by clinicians (19). All radiographs were photographed in Joint Photographic Experts Group (JPEG) format. The photographs were taken at a distance of approximately 20 centimeters and the images were then send to a fellow researcher through WhatsApp Messenger version 2.12.2 on a case by case basis via WiFi technology. The DICOM files were grouped per case and loaded in OsiriX DICOM viewer (Pixmeo, Bernex, Switzerland) on a 13-inch Apple MacBook Pro Retina (Apple, Cupertino, USA) with a 2560 by 1600 resolution at 227 pixels per inch.

Table 2. Subject Characteristics

Case	Age (years)	Gender	Side	Mechanism of injury
1	82	Female	Left	Mechanical fall
2	51	Female	Right	Mechanical fall
3	87	Female	Left	Mechanical fall
4	83	Female	Left	Mechanical fall
5	75	Male	Left	Mechanical fall
6	54	Female	Left	Hit with a stick
7	66	Male	Left	Mechanical fall
8	68	Female	Right	Mechanical fall
9	63	Female	Right	Mechanical fall
10	67	Female	Left	Mechanical fall

Radiographic evaluation

After obtaining observer characteristics, each observer was asked to evaluate the cases on either the smartphone or the high resolution screen laptop and answer the following 3 questions for each set of radiographs: (1) "What is the fracture type according to the AO classification?", (2) "Would you recommend operative treatment for this fracture?", (3) "How confident are you about this decision? (0 being not confident, 10 being most confident)".

A copy of the AO classification was available for reference. During the assessment, the participants assigned to the mobile messenger group were asked to open the messenger application and select the option 'view all media' in a conversation named 'DRF study'. There, an overview of all radiographs belonging to the 10 cases was presented consecutively [Figure 1]. Observers were then given instructions on how to use the application. The participants assigned to the DICOM viewer group were asked to open the DICOM viewer application, where an overview of the 10 cases was presented. They were then given instructions on how to use the application. In comparison to the mobile messenger group, the users of the DICOM viewer group had the advantage of adjusting the contract window level of the radiographs. This was not possible in the mobile messenger group.

Statistical analysis

A post-hoc power analysis, based on the method as described by Guitton and Ring, showed that 20 observers yielded 62% power with α=0.05 to detect a clinical

Figure 1. Overview of the radiographs in the messenger application on the smartphone.

significant difference of 0.20, according to the guidelines proposed by Landis and Koch, in Kappa value between the mobile messenger group and DICOM viewer group (20, 21).

Surgeon characteristics were summarized with frequencies and percentages for categorical variables and with the means and standard deviations for continuous variables. The Wilcoxon rank-sum test was used for continuous variables and the Fisher exact test for categorical variables to assess for differences between the groups.

Interobserver reliability was determined with use of the multirater kappa measure as described by Siegel and Castellan, which is a frequently used measure of chance-corrected agreement between multiple observers (22). The calculated kappa values were interpreted according to the guidelines of Landis and Koch and compared using the two-sample z-test (21).

The two-sample test for proportions was used to determine the difference in proportion of agreement and percentage of recommendation for surgery, and the independent t-test was used to assess the difference in confidence in treatment decision between the respective groups. *P-values* less than 0.05 were considered significant.

Results

The interobserver reliability for AO classification of distal radius fractures was fair (κ=0.34) in the DICOM viewer group and moderate (κ=0.43) in the mobile messenger group, although this difference was not significant (*P=0.32*).

The percentage of recommendation for surgery was significantly higher in observers that determined treatment recommendation using a messenger application on a mobile phone compared to observers that used a DICOM viewer (89% versus 78%, *P=0.019*) and there was no difference in interobserver reliability for recommendation for surgery between the respective groups (κ=0.53 and κ=0.60, *P=0.83*). The confidence for this treatment decision was also significantly higher in observers that used a messenger application on a mobile phone compared to observers that used a DICOM viewer (8.9 versus 7.9, *P=0.026*) [Table 3].

Table 3. Interobserver agreement for AO classification and recommendation for surgery for distal radius fractures, recommendation for operative treatment and confidence in treatment decision

	DICOM viewer		WhatsApp viewer		*P-value*
	(n=10)	(95% CI)	(n=10)	(95% CI)	
AO classification					
Proportion of Agreement*	0.73	(0.64 – 0.82)	0.79	(0.71 – 0.87)	0.32
Kappa (SE)	0.34 (0.055)	(0.23 - 0.45)	0.43 (0.069)	(0.29 - 0.57)	0.32
Category	Fair		Moderate		
Recommendation for surgery					
% recommendation for surgery	78	(71 - 85)	89	(83 - 95)	0.019
Proportion of Agreement*	0.86	(0.79 – 0.93)	0.95	(0.91 – 0.99)	0.030
Kappa (SE)	0.60 (0.14)	(0.33 - 0.87)	0.53 (0.25)	(0.04 - 1.02)	0.83
Category	Moderate		Moderate		
Confidence treatment decision, mean (SD)	7.9 (0.92)	(7.2 - 8.5)	8.9 (1.0)	(8.2 - 9.6)	0.026

* Proportion of agreement: the proportion of observers agreeing with the most provided answer

Table 4. Interobserver agreement for AO classification and recommendation for surgery for distal radius fractures, recommendation for operative treatment and confidence in treatment decision

	DICOM viewer		WhatsApp viewer		*P-value*
	(n=10)	(95% CI)	(n=10)	(95% CI)	
AO classification					
Proportion of Agreement*	73	(61 - 85)	79	(72 - 86)	0.35
Kappa (SE)	0.34 (0.055)	(0.23 - 0.45)	0.43 (0.069)	(0.29 - 0.57)	0.32
Category	Fair		Moderate		
Recommendation for surgery					
% recommendation for surgery	78		89		0.036
Proportion of Agreement*	86	(79 - 93)	95	(90 - 100)	0.029
Kappa (SE)	0.60 (0.14)	(0.33 - 0.87)	0.53 (0.25)	(0.04 - 1.02)	0.83
Category	Moderate		Moderate		
Confidence treatment decision, mean (SD)	7.9 (1.6)		8.9 (1.5)		< 0.001

* Proportion of agreement: the proportion of observers agreeing with the most provided answer

Discussion

Mobile messenger applications improve the communication between healthcare professionals and might be useful as a way to review medical information remotely (23-25). The inclusion of images of radiographs in on-call communication, for example, seems to increase confidence for understanding and management of orthopedic trauma patients (4). In this study, we assessed the effect of the most popular mobile messenger application on interobserver reliability, decision-making, and confidence in decision-making for treatment of distal radius fractures based on radiographs when compared to a standard DICOM viewer. We found that the interobserver agreement for distal radius fracture classification and recommendation for surgery ranged from moderate to fair and was not significantly different between observers that used a mobile messenger application compared to surgeons that used a DICOM viewer. In addition, our results showed the use of messenger application on a mobile phone might have an effect on recommendation for surgery and confidence for this treatment decision as both rates were significantly higher in the mobile messenger group compared to the DICOM viewer group.

Our study should be interpreted in light of its strengths and limitations. This study included a large number of observers, which allowed randomization and comparison to a control group (i.e. DICOM viewer group). On the other hand, the number of participants appeared to be too small to generate balanced groups through randomization. More specifically, the observers in the mobile messenger group were significantly older than the DICOM observers. Since we applied a non-adaptive fixed randomization, this could not be avoided as it was subject to chance. However, it is not clear that an uneven distribution of age had an influence on our response variables. Prior studies note that the correlation between a surgeon's experience and a surgeon's consistency in classification of distal radius fractures on radiographs appears to be poor (26). Additionally, a recent study assessing the influence of surgeon and radiographic factors on distal radius fracture treatment showed that surgeon experience only accounts for 1% of the variation in treatment recommendation, while the radiographs explained 49% of the variation (27). The observation that surgeon experience explains such a small part of the variation emphasizes that the difference in age between the groups may have had little influence on our results. Furthermore, the results of our study might only be extrapolated to teleconsultation on an iPhone, because the iPhone appears to provide the highest proportion of image quality that is evaluated as 'good' by clinicians (19). Another limitation of our study is that the observers had no patient-specific information (e.g., comorbidities and age) on which to base their recommendation for surgery.

In this study, the interobserver agreement of the AO classification for distal radius fractures was the same for observers that evaluated radiographs based on a messenger application on a mobile phone compared to a standard DICOM viewer. This is in line with the findings of Giordano et al. which demonstrated substantial inter- and intraobserver agreement for the classification of tibial plateau fractures based on radiographic images presented via WhatsApp Messenger (13). Blaivas et al. reported substantial interobserver agreement for pathology and structure detection when assessing ultrasound image transmission via low-resolution camera phones in the Emergency Department setting (28).

We found that the confidence for treatment decision was higher using a messenger application on a mobile phone compared to a DICOM viewer. Confidence in diagnosis of emergency ENT radiological investigations using mobile phones versus an x-ray box were comparable (25).

The difference in treatment recommendation and confidence for this treatment decision illustrates that, although the use of a messenger application on a mobile

phone seems potentially useful, it should be approached with caution. The fact that the assessment modality influences the clinical reasoning of surgeons could imply that this type of teleconsultation could result in unnecessary surgeries when decisions are made using this remote technology. Furthermore, the recent acquisition of the world's most popular messenger application by Facebook raises concerns about the privacy management of this messenger application (29). Even though this messenger application uses end-to-end encryption, recent tests show that the implementation of this encryption is not properly executed in all devices (30). Therefore, the security of the data that is processed through this mobile messenger application cannot be guaranteed.

In conclusion, despite the fact that messenger applications on mobile phones are often used as a teleconsultation tool in clinical practice, they should be used with caution. In order to minimize unnecessary surgery due to the use of these applications for remote decision-making purposes, future research should focus on optimizing messenger applications for remote clinical decision making in order to minimize interobserver variability when compared to more advanced viewer platforms such as DICOM viewers. Furthermore, future research should focus on the data privacy of transmitting medical information through publicly accessible communication applications and explore ways to ensure both adequate information sharing and data privacy.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Conflict of Interest Disclosure

Each author certifies that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Statement of Informed Consent

Informed consent was obtained from all subjects, and all identifying details have been omitted from publication.

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