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Diagnostic concordance between mobile interfaces and conventional workstations for emergency imaging assessment

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ABSTRACT

Introduction: Mobile devices and software are now available with sufficient computing power, speed and complexity to allow for real-time interpretation of radiology exams. In this paper, we perform a multivariable user study that investigates concordance of image-based diagnoses provided using mobile devices on the one hand and conventional workstations on the other hand.

Methods: We performed a between-subjects task-analysis using CT, MRI and radiography datasets. Moreover, we investigated the adequacy of the screen size, image quality, usability and the availability of the tools necessary for the analysis. Radiologists, members of several teams, participated in the experiment under real work conditions. A total of 64 studies with 93 main diagnoses were analyzed.

Results: Our results showed that 56 cases were classified with complete concordance (87.69%), 5 cases with almost complete concordance (7.69%) and 1 case (1.56%) with partial concordance. Only 2 studies presented discordance between the reports (3.07%). The main reason to explain the cause of those disagreements was the lack of multiplanar reconstruction tool in the mobile viewer. Screen size and image quality had no direct impact on the mobile diagnosis process.

Conclusion: We concluded that for images from emergency modalities, a mobile interface provides accurate interpretation and swift response, which could benefit patients' healthcare.

1. Introduction

In image-based diagnosis processes, radiologists interact with a dedicated workstation with especially designed and calibrated video monitors to interpret image exams. Besides high-end hardware requirements, such workstations must be interconnected with often expensive picture archiving and communication system (PACS) and frequently depend on plug-ins installation.

Such conventional image analysis environments were developed for highly technical users trained in digital imaging, e.g. radiologists and medical physicists. This reality makes it difficult for other specialists, such as referring physicians (e.g. cardiologists, neurologists and surgeons) to access and understand the exams. Furthermore, for any specific radiology subspecialty, a specialist is often not available in clinics and hospitals to interpret the images as soon as they are provided. This problem is not solved by the recent widespread of teleradiology [1] as the schedule of professionals in teleradiology clinics is predetermined and patient data arrive randomly. Thus, a mobile viewer would allow immediate viewing by radiologists and other professionals without the need of being at a conventional workstation.

Let us understand mobile viewer as a hardware-software system that combines a pocket-size display, a wireless Internet connection and computing power to process and display digital images. Tablets and smartphones loaded with the appropriate application software are representative examples. Anywhere access through devices connected to the Internet is essential for patient care, particularly in emergency radiology. Mobile devices, wireless networks and software are now available with sufficient computing power, speed and complexity to allow for real-time interpretation of radiology studies [2,3]. Besides, the higher availability of data and tools provided by mobile technology implies in more study time for the present generation of radiology residents, with a net benefit in radiology education [4].

The inclusion of this new paradigm in medical image interpretation allows researchers to establish to which cases a mobile viewer can

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provide faster diagnosis, improved technical performance (accuracy of diagnosis) and ease of use compared with desktop image viewers [5,6]. For instance, instant mobile access by a remote expert of the subspecialty tends to provide more accurate diagnosis than workstation analysis by a general radiologist. In a previous study with patients with inconclusive diagnoses of appendicitis [7], the smartphone-based analysis by abdominal radiologists provided higher diagnostic confidence than the on-call workstation-based radiologists' preliminary reports.

A large variety of radiology-related smartphone applications are available with many potential benefits. Although, the lack of knowledge about how the use of smartphones impacts image interpretation still hinders the widespread use of DICOM viewing applications in the clinical practice. Further research into the accuracy of primary diagnosis using such applications is needed [8]. Another concern is the ergonomics of these applications for potential improvements in the development of radiology mobile apps [9].

Given this context, in this paper, we present a multivariable user study that investigates concordance of image-based diagnoses provided using mobile devices on the one hand and conventional workstations on the other hand. This study does not intend to be a systematic literature review. Its intention is not to be a clinical trial neither. Nevertheless, it brings a relevant contribution, as the data we used and the experimental conditions are those from a real clinic (unfiltered). A singular aspect of our experiments is that they were applied on a distinct DICOM viewer that uses a combination of client- and server-side procedures to optimize the image transfer and visualization.

Another noteworthy contribution is that our research covers typical modalities in on-call situations, especially including radiography exams, underexplored for mobile interpretation in previous works. We hypothesize that, for these modalities, the image analysis performed on a mobile device interface is not different from the image analysis made on conventional workstations. Moreover, we inquire a list of essential tools for mobile diagnosis, grouped by exam category and body part.

In the next section, we present a brief but thorough survey in medical image analysis with mobile devices. In Section 3, we describe in detail an experimental study with radiologists to analyze the concordance between the mobile and the workstation. The results obtained are presented in section 4 and are discussed throughout Section 5.

2. Related work

Previous studies have explored the use of mobile devices, such as tablets and smartphones, in medical images analysis. Most often, experiments occur with specific types of exams, e.g. computed tomography (CT) of the abdomen, on the same DICOM viewer (generally the OsiriX mobile [10]). A systematic review of the previous studies in the area is not the purpose of this paper. Such systematic literature review has yet to be made. In this section, we describe representative related works.

A complete analysis regarding the use of the iPad for mobile on-call radiology diagnosis was presented by John et al. [11]. They analyzed 79 CT and 9 magnetic resonance imaging (MRI) studies common in emergency situations, interpreted by one radiologist on a full-featured desktop workstation and viewed independently by three radiologists on the mobile OsiriX. The comparison was made on two scales: major findings, minor findings. Results showed 3.4% (9 of 264) of major discrepancies and 5.6% (15 of 264) of minor discrepancies. These results suggest that the emergency conditions commonly encountered in CT and MRI can be diagnosed using a portable DICOM viewer with good concordance in comparison to the workstation evaluation. However, the study is limited by the small number of participating radiologists (3). Another limitation is the comparison method, as they assume that the reports of the primary reporting radiologist were completely accurate. In our approach, the same radiologist prospectively reviews the studies on both platforms, avoiding this limitation.

Mc Laughlin et al. [12] studied emergency **brain CT** in preliminary interpretation. They compared the image quality and diagnostic performance between an Apple iPad and a 2-megapixel monochrome LCD. Any reported discrepancies were recorded using the American College of Radiology (ACR) RADPEER system. They analyzed one hundred emergency brain CT exams. The tablet allowed satisfactory identification of acute brain CT findings, but additional research will be required to examine the cause of discrepancies that occur when using tablet devices.

Bhatia et al. [13] demonstrated that mobile devices can display adequate resolution of CT and MRI sequences for diagnosing **acute central nervous system injuries** and other non-acute pathologies. Five radiologists were included in this research, and each independently interpreted specific exams on traditional high-resolution monitors (via eFilm software) as well as on an iPad mobile device (using Osirix software).

For musculoskeletal exams, De Maio et al. [14] analyzed the accuracy of mobile diagnostics related to **intra-articular knee pathology**. Fifty MRI studies of the knee followed by knee arthroscopy were prospectively evaluated. Two musculoskeletal radiologists independently reviewed each study using two different viewers: the OsiriX on an iPhone and eFilm conventional workstation. The authors concluded that an iPhone DICOM Viewer can be used and diagnosis results are similar to those obtained with a conventional radiology workstation. However, the mobile interface requires a significantly longer viewing time.

Park et al. [15] examined the potential of the iPad 2 as a teleradiology tool for evaluating brain CT scans with **subtle hemorrhage**. They selected 100 brain CT exams performed for head trauma or headache. Five emergency physicians reviewed these studies using the mobile device and the LCD monitor, scoring the probability of intracranial hemorrhage on each exam on a five-point scale. The results showed high sensitivities and specificities between the two different analyses.

An early and reliable diagnosis at any time is crucial for an adequate treatment strategy for **abdominopelvic hemorrhage**. Given this assumption, Schlechtweg et al. [16] investigated one hundred patients with a clinical suspicion of abdominopelvic hemorrhage. CT exams were retrospectively read by two radiologists on a dedicated display and on a tablet computer. The results showed that this type of exam can be diagnosed on a tablet computer with a high diagnostic accuracy allowing mobile on-call diagnoses.

Kim et al. [17] evaluated the feasibility of an iPhone-based system as a real-time remote CT reading tool for **suspected appendicitis** using a 3G network under suboptimal illumination. In total 120 abdominal CT scans were selected, 60 had no signs of appendicitis, whereas the remaining 60 had signs of appendicitis. Sixteen radiologists reviewed the images using the LCD monitor of a PACS workstation, as well as using a smartphone. They graded the probability of the presence of acute appendicitis using a five-point Likert scale. The overall sensitivity and specificity for the diagnosis of suspected appendicitis were not significantly different between displays. In another smaller abdominal CT study, Choudhri et al. [18] obtained similar results using the same mobile viewer. Twenty-five abdominal studies were interpreted on an iPhone by five radiologists. **Acute appendicitis** was correctly identified on 98% of interpretations, **appendicoliths** were correctly identified on 88% of interpretations and cases of **abscesses** were correctly identified by all readers. Another related study of the abdomen, investigated by Faggioni et al. [19] showed that the mobile diagnostic was comparable in accuracy for detection of **acute gastrointestinal bleeding** and can be significantly faster.

Park et al. [20] studied the performance of a smartphone for reading coronary CT angiography in patients with **acute chest pain** at the emergency department (ED). 107 patients with acute chest pain who underwent CCTA and coronary angiography (CAG) were included. The degree of stenosis at each coronary segment was scored on a 4-point