Flexible Image Evaluation:

iPad versus Secondary-class Monitors for Review of MR Spinal Emergency Cases, A Comparative Study

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Rationale and Objectives: Studies have highlighted the potential of handheld viewing devices for rapid diagnosis and increased smartphone usage among physicians and radiologists is known as is the clinical applicability of hand-held devices for computed tomography (CT) spinal injury cases. Magnetic resonance (MR), however, is the accepted gold standard for spinal imaging, providing visualization of both ligament and spinal cord pathology. This study investigated the diagnostic accuracy of the iPad, the most probable alternative display device outside the radiology environment and financially viable alternative, when reviewing emergency spinal MR images, in comparison with secondary-class LCD devices in the case of the interpretation of CT and MR imaging examinations.

Materials and Methods: In total 31 MR cases including both positives (n = 13) containing one of four possible presentations: spinal cord compression, cauda equine syndrome, spinal cord hemorrhage, or spinal cord edema and controls (n = 18) were reviewed. Ziltron iPad software facilitated the display of cases and the receiver operating characteristic (ROC) analysis. Thirteen American Board of Radiology board-certified radiologists reviewed all cases on both displays. Standardized viewing conditions were maintained.

Results: Dorfman-Berbaum-Metz multireader-multicase (DBM MRMC) analysis was performed including random readers/random cases, fixed readers/random cases and random readers/fixed cases. No differences of statistical significance ($P \leq .05$) could be found in terms of area under the curve, sensitivity and specificity between the iPad and secondary-class display.

Conclusion: The iPad performed with equal diagnostic accuracy when compared with the secondary-class LCD device after DBM MRMC analysis, demonstrating the iPad as an option to aid initial review of MR spinal emergency cases.

Key Words: Display devices; observer performance; receiver operating characteristic (ROC); magnetic resonance imaging: spine; spinal emergencies.

There has been much debate in recent years surrounding the application of handheld devices such as personal digital assistants (PDAs), smartphones, and more recently the Apple iPad, in health care. The potential applications for such devices and their utility in medicine is clear with studies in 2003 and 2005 suggesting that 46% of nonradiology attending physicians and trainees in one tertiary care academic medical center (1) and approximately 45% of randomly selected active and training radiologists who were members of the Radiological Society of North America were using PDAs (2). Aside from scheduling and calendar applications, the nonradiology physicians used their devices for accessing drug information programs, medical references, and medical calculators. In the 2005 study, only 24.6% of surveyed radiologists had a radiology application installed on their devices, whereas many remained skeptical about the potential utility for PDAs to be used to view entire imaging studies directly from a picture archiving and communication system (PACS) (1,2). The radiologists identified memory capacity, software availability, and screen resolution as the important factors influencing any decision to purchase a PDA. There is much anecdotal evidence to suggest that the usage rates amongst physicians and radiologists is much greater following ongoing developments in smartphone technology, along with the introduction of the iPhone and iPad (3–6). Since its launch in April 2010, the iPad itself has generated significant interest in terms of its role in medicine and its potential application for the display of radiological images.

Although these devices are used in modern medicine as outlined, the iPad with its larger display size and superior contrast ratio to other handheld devices warrants closer investigation in terms of its utility in radiology. Many of the other previously identified limitations of handheld devices such as user interface, inherently low resolution, poor connectivity, slow data transfer, available software, processor speed, memory, data security, and Digital Imaging and Communications in Medicine (DICOM) compatibility have now been overcome or have at least progressed (7–11). According to these studies, the consensus is that such handheld devices have the greatest

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potential in terms of accessing radiological images remote to the radiology department or indeed remote to the institution for initial review purposes and can be used to discern primary pathologies but should not be used to help prepare radiological reports. The application of such technology to primary diagnosis of emergency radiology examinations has been explored by several authors for a range of clinical scenarios and handheld technologies. Toomey at al have explored the use of PDAs and the iTouch for detection of orthopaedic fractures on radiographs and intracranial hemorrhage on computed tomography (CT) (10), Choudhri et al have undertaken some preliminary work exploring the utility of the iPhone for the review of abdominal CT for the evaluation of acute appendicitis (12), whereas Rosenberg explored the impact of reviewing CT brain examinations for the neurosurgical triage of patients (13).

With the growing demands on radiology services worldwide, there are many other clinical emergency scenarios that might benefit from the possibility that remote reviewing offers in terms of initial review. Spinal emergencies is an area that could benefit most in terms of examination prevalence and the need for rapid expert review and handheld devices may facilitate initial comment from an experienced neuroradiologist 24 hours a day to facilitate early intervention. Magnetic resonance (MR) examinations of possible indications for emergency MR imaging of the spine include spinal cord compression, cauda equina syndrome, spinal cord hemorrhage, or spinal cord edema. These pathologies, if suspected, may benefit from such rapid remote access and expert review by an experienced neuroradiologist and this has yet to be investigated.

There is already evidence to suggest that secondary-class displays, defined by the American Association of Physicists in Medicine as those used for purposes other than providing a primary diagnosis, may be a more financially viable option for early review and interpretation purposes in CT and MR imaging (14). In recent months the US Food and Drug Administration have issued clearance for the use of a specific software application (Mobile MIM, MIM Software Inc., Cleveland, Ohio) on the iPhone and iPad for viewing and diagnosis of CT, MR imaging, and nuclear medicine images where access to primary-class displays is an issue (15).

The aim of the current study was to explore the diagnostic accuracy of the iPad to a secondary-class display for the evaluation of emergency MR imaging examinations of the spine, for a range of clinical indications, using a receiver operating characteristic (ROC) methodology and through recruiting a panel of expert observers to review cases. To date few studies exploring the efficacy of handheld devices have used such a methodology.

MATERIALS AND METHODS

Overview

This study aimed to investigate the diagnostic accuracy of an iPad device for emergency magnetic resonance imaging of the spine in comparison to secondary-class LCD monitors. Secondary-class LCD monitors were studied as these are the type of display that may be used at locations remote to, or off-site from, the radiology department as well as being a more financially viable option for primary review and interpretation purposes in CT and MR imaging. Observers reviewed a total of 31 cases, each consisting of multiple sequences, on each display device and searched each case for the defined pathologies. The observers then used a 6-point scale to rate the images, a higher score representing greater confidence that a lesion was present and the lowest scores representing absence of a lesion. ROC analysis was used to test for statistical differences. Institutional approval was granted for the use of all images.

Equipment

The Apple iPad is a tablet computer developed primarily as a platform for accessing the web, emails, photos, and video along with a wide range of other applications. It was launched in April 2010 and features a 9.7-inch LED-backlit, multitouch (ability to recognize two or more points of contact simultaneously interacting with the display) touchscreen display with a 178° viewing angle (Apple Inc., Cupertino, CA). Two iPads with equal specifications were used in the study with luminance values of each within 5% of each other as measured using a calibrated Unfors Luxi photometer (Unfors Instruments, Billdal, Sweden). No provision was made to calibrate the iPads to DICOM gray-scale display function and color standards, but the displays were found to be consistent and adhering to the specifications in Table 1.

The secondary-class monitors used in the study were ViewSonic ViewPanel VP201m monitors (ViewSonic, Walnut, CA) with an NVIDIA GeForce 7100 graphics card (Nvidia, Santa Clara, CA). This is a widely available, commercial, off-the-shelf monitor used for nonprimary review. Monitors were calibrated to DICOM gray-scale display function and color standards using Verilum software (version 5.02) and luminance pod (Image Smiths Inc., Bethesda, MD) and a calibrated photometer (model 07-631; Nuclear Associates, Everett, WA) daily. The specifications are shown in Table 1.

Images

After a retrospective review of all emergency spinal MR imaging cases undertaken over a 2-month period in a major university hospital which is also a national spinal injury centre a total of 31 spinal MR imaging cases consisting of positive ($n = 13$) and control cases ($n = 18$) were identified for inclusion in the study. Positive cases contained one of four possible indications for emergency MR imaging of the spine (ie, spinal cord compression, cauda equina syndrome, spinal cord hemorrhage, or spinal cord edema). Control cases demonstrated none of the four pathologies. All cases contained multiple sequences and a range of dedicated cervical ($n = 5$) and lumbar ($n = 12$) spine cases along with 14 cases containing