Initial Experience with a Handheld Device Digital Imaging and Communications in Medicine Viewer: OsiriX Mobile on the iPhone

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Medical imaging is commonly used to diagnose many emergent conditions, as well as plan treatment. Digital images can be reviewed on almost any computing platform. Modern mobile phones and handheld devices are portable computing platforms with robust software programming interfaces, powerful processors, and high-resolution displays. OsiriX mobile, a new Digital Imaging and Communications in Medicine viewing program, is available for the iPhone/iPod touch platform. This raises the possibility of mobile review of diagnostic medical images to expedite diagnosis and treatment planning using a commercial off the shelf solution, facilitating communication among radiologists and referring clinicians.

KEY WORDS: Radiology, PACS, informatics, teleradiology, mobile phone, iPhone, PDA, medical images, health care, DICOM, smartphone

BACKGROUND

Medical imaging is critical for the diagnosis and management of many acute and chronic conditions. Dissemination of medical images was once limited to the speed at which one could transport a film jacket, only allowing a single physician to view the images at a time. Picture Archiving and Communication Systems (PACS), which store images in the Digital Imaging and Communications in Medicine (DICOM) format, combined with high-speed network connectivity now allows for timely dissemination of full-resolution medical images to any location with a computer and network connectivity. These locations may be within the same facility in which the images are acquired or in remote hospitals and even private residences.

There are published reports of mobile DICOM controllers, which can query PACS archives and retrieve JPEG or PNG images to mobile devices.¹⁻³ More recently, the OsiriX foundation (Geneva, Ch), responsible for the open-source PACS software OsiriX,⁴ has created a mobile

version of their software for the iPhone and iPod touch (Apple Inc, Cupertino, CA; Fig. 1), thus providing a commercial off the shelf (COTS) solution for viewing full-resolution DICOM images on mobile computing platforms.

The advantage of OsiriX mobile is that one can view and process DICOM images. In addition to zooming, panning, and rotation, OsiriX mobile allows traditional windowing and leveling, calibrated distance measurement, oval Region of Interest (ROI) measurements of area and density/signal intensity, and key image capture.⁵ These advantages are the result of using DICOM images as opposed to JPEG or PNG images. The advanced image processing capabilities raise the possibility of using this platform in a clinical setting for preliminary diagnosis and consultation in emergent situations. Initial investigations into the diagnostic capabilities of OsiriX mobile on the iPhone and iPod platforms^{6,7} support this hypothesis.

We describe the current features of OsiriX mobile on the iPhone platform and address technical issues that need further investigation to provide a pathway for successful clinical implementation of this technology.

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Fig. 1. Screen captures of sagittal CT reformat of the thoracolumbar junction (a) and an MIP reformat (b) and three-dimensional volume rendering (c) of a cerebral angiogram demonstrating an aneurysm of the anterior communicating artery.

METHODS

Software

The mobile version of the OsiriX software was first released on November 14, 2008, and is currently in version 1.1.2. The software is currently only available for the iPhone/iPod touch platform and is available only via download through the Apple/iTunes app store. No physical purchase option is available. A basic electronic users' manual is available for download in .pdf format.⁵

The current version of the software runs on version 3.0 and later of the iPhone system software and can run on all iPhone and iPod touch models produced to date (Table 1). While the iPhone system software v3.0 is available for free for all iPhones produced to date, iPod touch systems produced prior to the release of system software v3.0 require a paid upgrade. While the OsiriX software for Macintosh OS-X is open source

software, with the source and precompiled binaries available for download, the code for the OsiriX mobile software is proprietary.

Hardware

Three different iPhone models have been produced to date, with a new model released each summer since the initial release. The processor type and speed for the various iPhone and iPod touch models produced to date are listed in Table 1. A similar release schedule has taken place for the iPod touch lineup, with upgrades typically taking place in the autumn. Each release has had several versions with minor variations including different data storage capacities. The maximum read and write speed of the system storage and the maximum data throughput of the processor chipset are not publically available.

All iPhone and iPod touch models have had a 3.5-inch diagonal display with a resolution of

Table 1. Specification of Existing iPhone and iPod Touch Models

Device	RAM (MB)	Storage (GB)	Wi-Fi	Wireless	Processor	Processor speed (MHz)
iPhone	128	4, 8, 16	802.11 b/g	EDGE	Samsung ARM 11	412
iPhone 3G	128	8, 16	802.11 b/g	3G	Samsung ARM 11	412
iPhone 3GS	256	16, 32	802.11 b/g	3G	Samsung ARM Cortex A8	600
iPod touch (2007)	128	8, 16, 32	802.11 b/g	None	Samsung ARM	400
iPod touch (2008)	128	8, 16, 32	802.11 b/g	None	Samsung ARM	533
iPod touch (2009)	256	8, 32, 64	802.11 b/g	None	Samsung ARM	800

480×320 pixels, with published specifications of 163 pixels per inch yielding a pixel pitch of 0.156 mm and pixel area of 0.024 mm². All devices employ nonremovable solid-state storage. At the present time, there are no published specifications on the maximum brightness and contrast resolution of the display.

Network Access

All models of the iPhone and iPod touch have the ability to connect to Wi-Fi networks through the 802.11 b and g protocols. iPhone models can also connect to GSM wireless networks. Devices running system software v2.0 and later have via VPNs using the L2TP, PPTP, or Cisco IPsec VPN protocols.⁸ All iPhone and iPod touch models have Bluetooth wireless capabilities; however, data transfer via Bluetooth has not yet been implemented.

While maximum data transfer speeds are published, real-world performance can be limited by processor speed, available memory, VPN usage, Wi-Fi or wireless signal strength, and bandwidth availability related to other users on the network. Table 2 compares theoretical data transfer limits with real-world performance, as measured by a program dedicated to tracking iPhone bandwidth in various situations.⁹

Transfer of Images to the Mobile Device

Imaging data can be loaded into the OsiriX database by a query-retrieve protocol of the DICOM server, or by DICOM push to the mobile device. In the current version of the mobile OsiriX software, image transfer is not possible through GSM (EDGE or 3G) data networks. Background processing is not possible on the devices at the present time, due to limitations of the iPhone operating system. Thus, a user must begin running the OsiriX mobile program prior to data transfer. During transfer, other programs, including the telephone, cannot be used.

Table 2. iPhone Data Transfer Rates^{9, 10}

Data transfer method	Maximum data transfer rate (MBps)	"Real world" performance (k)
EDGE	1	0.162
GSM 3G	14	0.807
802.11 b/g	11/54	1.919 ^a

^aSeparate 802.11 b and g data are not available

To evaluate the speed of data transfer to a handheld device, computed tomography (CT) images from 20 studies of various body parts in our teaching file CT studies were transferred to the device, and the time required for the transfer was recorded.

DICOM Data

The OsiriX software for Macintosh OS-X stores image data in a folder system available from outside the program, including the OS-X finder and UNIX shell command line. As opposed to the OsiriX software for Macintosh OS-X, data transferred to the OsiriX mobile database can only be accessed, viewed, or deleted via the OsiriX mobile program. The data are backed up when the handheld device is synced with a computer.

OsiriX mobile can view black and white or color DICOM images from most imaging modalities, to include Digital Radiographic (DR), CT, magnetic resonance imaging, ultrasound, fluoroscopy, angiography, and nuclear medicine studies as well as Maximum Intensity Projection (MIP) images and volumetric renderings. The current version of the software will not display images larger than 1,024×1,024 pixels.

CT images are most commonly acquired at 512×512 pixels (0.25 megapixel), with 12 bits of data regarding the density in Hounsfield units. Accordingly, as each pixel is stored as 2 bits, a CT image represents approximately 0.5 megabytes of data. Sagittal and coronal reformats of data can have a larger matrix size. Most magnetic resonance, fluoroscopic, and ultrasound images have a similar image size. Angiographic images are commonly acquired at 1,024×1,024 pixels (1.0 megapixel), and thus, each image represents approximately 2 megabytes of data. DR images are typically larger than 1,024×1,024 pixels and are downsampled to accommodate the current maximum resolution. Monochrome images larger than this size are also downsampled for viewing. Color images larger than 1,024×1,024 pixels, such as fused positron emission tomography-CT images, cannot be displayed.

RESULTS

Accessing and Viewing of Images

To obtain new images via DICOM server query-retrieve, the handheld device needs to be

configured as a DICOM node. The simplest way is via a Wi-Fi network connection. After configuration information is entered and the device is declared as a DICOM node, images can be received from other DICOM workstations on the network. The query–retrieve function can search the DICOM server by the patient name, medical record number, birth date, imaging modality, or combinations of these parameters. As the mobile device is acting as a DICOM node, imaging data can be pushed from a DICOM server.

After images have been transferred to the device, a patient can be selected from the study database (Fig. 2a). Once a patient is selected, their imaging studies are listed in chronologic order, with individual sequences available for selection (Fig. 2b). After an image sequence is selected, the study is presented in the image viewer. The viewer has the ability to select preset window levels (Fig. 2c), or manual adjustment of the levels using the touch-screen. Zoom, rotate, and image panning functions are also available using the touch-screen.

Fig. 2. Screen captures of the study list where patients can be selected (a) and the patient browser where specific series can be selected (b). When using the viewing software, preset windows can be selected (c), and tools allow linear measurements (d) and oval ROI to measure area and signal density/intensity (e).

Tools can be selected for distance measurement (Fig. 2d), or oval ROI to measure area and signal density/intensity (Fig. 2e). A scroll-bar is present at the bottom of the viewing screen.

Data Transfer Times, Theoretical, and Real World

As previously stated, angiographic and DR data would typically represent 2 megabytes per image. CT, ultrasound, fluoroscopy, and magnetic resonance imaging datasets would typically represent 0.5 megabytes per image. By connecting a device to a 802.11-g Wi-Fi network, 20 CT studies that contained between 34 and 800 images were transferred to a handheld device, and the average time for transfer was approximately 0.6 s per CT image.

The number of images within a study depends on scanning protocols. Table 3 lists several commonly ordered imaging studies along with the typical number of images, average size of each study, estimated transfer times over wireless networks using maximum transfer speed, and the number of studies of each type, which could be stored in 1 gigabyte. The number of images per study is approximated based upon 5.0-mm axial images for most CT studies

and 1-mm axial images for CT angiography. Thin-section data and multiplanar reformats can result in a multifold increase in the size of a study.

Future Research

OsiriX mobile has not been approved by the United States Food and Drug Administration and accordingly cannot be marketed for clinical use. Therefore, the ability to obtain diagnostic information on the mobile platform needs further evaluation. Since the diagnostic properties of the mobile viewer have not been fully investigated, imaging studies viewed on a mobile device will need to be reviewed via conventional means, as soon as possible, to confirm the diagnosis. In addition to comparisons with the diagnostic capabilities of a PACS workstation, studies should also compare to that of JPEG screen captures, which is an alternate yet unproven method of transferring information that is currently being used.

Implementation of a mobile DICOM viewer into a clinical practice requires adherence to appropriate security and patient privacy measures. The iPhone/iPod touch can connect to wireless networks using encryption technology and has the

Table 3. Typical size of Commonly Performed Emergent Imaging Studies and the Expected Time in Seconds to Transfer the Images to a Handheld Device Using Wi-Fi (802.11 g), GSM-3G, and GSM-EDGE Networks at Maximum Theoretical Transfer Speed

	Images ^a	Size (MB)	Transfer time (second)		3g ^b	3g (rw) ^b	EDGE ^b	EDGE (rw) ^b	Studies/GB
			Wifi (g)	Wifi (rw)					
CT head	35	17.5	2.6	21.0	10.0	173.5	140.0	866.6	57.1
CT chest	50	25	3.7	30.0	14.3	247.9	200.0	1,238.0	40.0
CT abd/pelvis	85	42.5	6.3	51.0	24.3	421.4	340.0	2,104.6	23.5
CTA chest	200	100	14.8	120.0	57.1	991.5	800.0	4,952.0	10.0
CTA head	200	100	14.8	416.9	57.1	991.5	800.0	4,952.0	10.0
CTA abd/pelvis	250	125	18.5	521.1	71.4	1,239.4	1,000.0	6,190.0	8.0
CTA runoff	2,000	1,000	148.1	1,200.0	571.4	9,915.5	8,000.0	49,520.3	1.0
MR head	250	125	18.5	150.0	71.4	1,239.4	1,000.0	6,190.0	8.0
MR head/MRA (stroke protocol)	600	300	44.44	360.0	171.4	2,974.6	2,400	14,856.08	7.5
MR spine (cord compression)	400	200	29.6	240.0	114.3	1,983.1	1,600.0	9,904.1	5.0
DVT US	30	15	2.2	18.0	8.6	148.7	120.0	742.8	66.7
RUQ/GB US	30	15	2.2	18.0	8.6	148.7	120.0	742.8	66.7
cerebral angiogram	50	100	14.8	120.0	57.1	991.5	800.0	4,952.0	2.5
thoracic aortogram	30	60	8.9	72.0	34.3	594.9	480.0	2,971.2	1.5

"Real world" (RW) data transfer rates, as outlined in Table 2, are also listed. The RW rate for the Wi-Fi (Wi-Fi-RW) is based on the observed average transfer speed of 1.6 images per second for 512 × 512 images at 16 bits/pixel. The RW transfer rates for 3 g and EDGE networks are based on Table 2. The number of studies of a given type that can be stored in 1 gigabyte of storage is also listed.

^aEstimated number of images per study; the actual number can vary based upon institutional protocols

^bGSM (3G or EDGE) image transfer not currently possible with OsiriX mobile

CTA computed tomography angiography, MR magnetic resonance, MRA magnetic resonance angiography, DVT deep vein thrombosis, RUQ right upper quadrant

ability to connect via VPN. The impact of VPN usage on transfer time is unknown. With a fast Wi-Fi connection, many diagnostic studies can be transferred quickly (Table 3). Despite fast connections, other bottlenecks may limit transfer speed, including but not limited to the throughput of the mobile device CPU and memory.

While GSM transfer is slower than Wi-Fi, GSM coverage is much more widespread, and at times, this may be the best way to obtain data. The current version of OsiriX mobile only allows data transfer via Wi-Fi; however, it can be reasonably expected that future versions of the software or other mobile DICOM viewers would take advantage of the widespread coverage of cellular networks and VPN connections. As networks evolve to 4G or WiMax, transfer speeds may approach those of Wi-Fi networks.

At present, the device is unable to run processes in the background so the user would be unable to use their device as a telephone or for other purposes while receiving data. This is a limitation of the iPhone operating system; however, future updates may allow background transfer. As technology develops, it may eventually be possible for a push-notification to initiate a background transfer to the device, and the transfer could continue while the on-call physician receives a telephone call regarding the patient(s) whose scans are being sent.

Regardless, the potential roles for this technology need to be evaluated. In academic institutions, on-call radiology faculty could render immediate feedback to questions from resident physicians. Subspecialty consultation with radiology colleagues who have a specific expertise, but may not be on call, or may not have immediate access to a computer, would be facilitated. Once a diagnosis is made, consulting surgeons and interventional radiologists could have imaging studies immediately delivered to their handheld device allowing them to make preliminary decisions about treatment planning, patient transfers, subsequent diagnostic studies, as well as mobilization of support staff.

CONCLUSION

OsiriX mobile software on the iPhone represents an important step in the advancement of medical imaging. By providing a COTS solution to extending the reach of DICOM data to anywhere with an Internet connection, a more universal teleradiology solution has emerged. Rapid consultations via dissemination of digital imaging to computers, and now handheld devices, continues the evolution of the field of radiology and the implementation of technology into modern medical practice.

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