Successful Implementation of a PACS in Tanzania

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INTRODUCTION TO THE PROBLEM

Muhimbili Orthopaedic Institute (MOI) is a public, academic tertiary care referral center in Dar es Salaam, Tanzania, East Africa. MOI is the main referral center for orthopedic and neurosurgical patients in Tanzania. In July 2014, the Radiology Department at MOI consisted of two attending radiologists, 10 technologists, and three IT staff with imaging capabilities of radiography, fluoroscopy, and ultrasound. MOI is affiliated with and located on the same campus as Muhimbili National Hospital, the main national referral hospital, which had one four-slice CT scanner, one 1.5-T MRI scanner, four ultrasound units, and one analog radiography/fluoroscopy unit. MOI patients were often transported to Muhimbili National Hospital for cross-sectional imaging.

X-ray images acquired at MOI were first converted into the DICOM format by a computed radiography (CR) system. From the CR system, the DICOM data were sent to a laser printer for hard-copy films or a CD-ROM burner. Each hard-copy film cost approximately US $2.50, resulting in a total of over US $5,000 for an average of 2,000 radiology studies per month at MOI. Hard-copy film was a prohibitive recurrent expense for MOI, resulting in frequent film shortages and disruption of imaging services. CD-ROMs, which cost US $0.50 each, were considered as a cheaper alternative to hard-copy film. However, due to a lack of readily available DICOM viewers, CD-ROMs proved both inefficient and unpopular. In August 2012, a PACS implementation [1-3] was proposed to the MOI administration to both lower the cost and improve access to x-ray images.

WHAT WE DID TO ADDRESS THE PROBLEM

Our PACS implementation experience is described in four phases: planning, installation, expansion, and maintenance phases. The installation and expansion phases coincided with an academic sabbatical leave for the senior author (F.J.M.), who was a visiting professor at MOI from July 2014 to June 2015. The first author (J.W.S.) visited MOI in February 2016 on a global health elective during the maintenance phase.

Planning Phase

The planning phase lasting nearly 2 years, from August 2012 through July 2014, comprised of conducting a PACS needs and radiology workflow assessment at MOI and preparing and presenting a proposal and budget for a PACS implementation to the MOI administration. The PACS needs assessment required an initial inventory of the infrastructure at MOI. The radiology department workflow was also carefully examined to understand how to improve efficiency. After these assessments, a proposal and budget spanning a 3-year period for the installation and hardware configuration of a PACS was presented to the MOI administration. Our planning phase mirrored the RAD-AID PACS readiness assessment utilized by the RAD-AID International outreach informatics program to determine the readiness of a site for the successful deployment of radiology resources [2,4].

In July 2014, MOI had in place most of the basic infrastructure required for a PACS implementation, namely a local area network internet throughout the institution, reliable electricity with a backup generator, and, most importantly, a CR system capable of converting x-ray images into DICOM data. The immediate goal of the PACS installation phase was to replace the inefficient and unpopular CD-ROMs.

Installation Phase

The installation phase was a 3-month-long proof-of-concept phase needed to ensure compatibility of the proposed PACS with the pre-existing workflow. ClearCanvas ImageServer 2.0 SP1 and ClearCanvas ImageViewer 2.0 (Toronto, Canada) were robust open-source PACS software selected for installation on the test server and workstations, respectively.
Two clinical work areas (radiologists’ office and emergency room) and the conference room were designated for the initial PACS installation. The test server and initial server configuration expertise were critical components of the installation phase and were fortunately secured gratis from a private IT company in Tanzania. Significant effort was spent troubleshooting local network connections between the test server and the three initial viewing workstations. Online open-source support forums were extensively consulted, and a US-based volunteer provided additional IT support remotely. Normalizing the patient medical record number entries also required considerable effort, as there was no image library tradition or Radiology Information System at MOI. To retrieve an x-ray image from PACS requires exact name spelling or a medical record number; however, such exact patient identification entries were not strictly enforced by the prevailing handwritten medical records. For example, medical record number “BOO123456” would retrieve a different patient compared with medical record number “B00123456.” The MOI medical record number convention was therefore simplified to “B123456” and was preferable to actual patient names for retrieving x-ray images from PACS.

At MOI, the patients were traditionally responsible for storage of their hard-copy films, as most hospitals in Tanzania do not maintain a radiology image library. Before the PACS server, the CR system provided the intermediate storage of x-ray images before printing on hard-copy films. At times of acute hard-copy film shortage, x-ray images on the CR system were periodically deleted to provide storage for newly acquired x-ray images. By contrast, the PACS server automatically stored and recorded the daily image case-load. The initial test server was actually a desktop computer configured with a server operating system and the PACS software. The test server was therefore checked each morning to make sure that the storage limit (128 GB) was not exceeded.

Expansion Phase

The expansion phase spanned 6 months and consisted of expanding both the server memory and storage capacity and the number of PACS workstations. Several donated workstations and additional workstations purchased by the MOI administration were configured with the PACS software and placed in the radiologists’ office, operating room, clinical offices, and inpatient wards. The test server was replaced by another server with more memory (16 GB) and storage capacity (2.0 TB), compared with 4 GB and 128 GB, respectively. The increased memory capacity was required to support the additional 12 workstations allowing simultaneous access to x-ray images from the server and to accommodate the increasing number of stored x-ray images. The image storage function enabled by PACS presented a new institutional responsibility for MOI. Frequent backups of the imaging data on the server were manually done using an external hard drive. MOI IT personnel were also trained
during the expansion phase to perform workstation configurations and server maintenance tasks and to train clinical staff.

**Maintenance Phase**

MOI has continued to independently maintain and slowly expand the described PACS implementation for more than a year after the initial installation. The shift away from hard-copy film to PACS at MOI has ironically also introduced a significant operational risk, namely the total dependence on the PACS server and network uptime for proper functioning of the entire institution. The new server storage was thus configured to a redundant array of independent discs to provide some internal storage redundancy. There are ongoing discussions with the MOI administration to re-invest some of the financial savings in a backup server to improve image storage redundancy and disaster recovery preparedness.

**OUTCOMES**

We have successfully implemented a PACS at MOI in efforts to lower the cost and improve access to x-ray images. As of December 2014, x-ray images stored on the MOI PACS server were readily available for simultaneous viewing at 15 separate workstations (Fig. 1). From September 2014 to September 2015, more than 24,000 radiology studies were stored on the MOI PACS server (Fig. 2). This represents a total of more than US $60,000 in cost savings from replacement of hard-copy film during this period. The financial savings continue to accrue as the PACS is maintained and expanded at MOI.

**LIMITATIONS AND LESSONS**

We encountered several limitations and learned some lessons that may help others attempting to replicate the described PACS implementation.

In August 2012, the MOI administration had limited exposure to the PACS concept and were rightfully skeptical as to how PACS would perform in their underresourced setting. The utility and benefit of PACS was only fully appreciated after the installation phase was under way.
The conference room PACS workstation proved critical in gaining wider acceptance for PACS at MOI because the benefit was immediately experienced when digital x-ray images were projected on two 46-inch LCD display monitors in the large conference room, compared with hard-copy film on small light-view boxes previously. Therefore, an on-site demonstration of PACS earlier might have significantly shortened our planning phase, which took nearly 2 years.

Second, financial capital budgets are extremely constrained at public institutions such as MOI. Whereas the merits of PACS may seem obvious to the US radiology community, at MOI, financial constraints far outweigh any other consideration. For example, the full cost of a commercial PACS implementation initially presented to the MOI administration, including a 3-year software license, hardware, and maintenance contract, could be recouped within 12 months from the financial savings achieved from replacing hard-copy film. This scenario highlights the importance of making a strong business case for PACS implementation in developing countries as a means to improve access to x-ray images. Substantial and ongoing financial savings can be gained from an initial capital investment. MOI was fortunate to secure many of the prerequisite items through generous donations and some internal investments. The selected open-source PACS platform also did not require software license fees, which further lowered the economic barrier.

Third, one cannot assume easy access to DICOM data from imaging modalities. Most public hospitals in Tanzania have analog-only x-ray systems, requiring first an investment in CR systems or upgrade to digital x-ray systems before any PACS implementation. Even when an imaging modality is DICOM capable, vendors often require a separate license to enable DICOM transfer to the server. Fortunately, MOI already had a CR system capable of converting x-ray images into the DICOM format and a license to transfer the DICOM data. The ultrasound machine at MOI, however, lacked a license to transfer DICOM data to the PACS server. As PACS becomes widely adopted throughout Tanzania and East Africa, we believe that DICOM transfer to PACS should be enabled by default for all diagnostic imaging modalities.

CONCLUSION
The benefits of PACS far exceed the disadvantages and cost of hard-copy film. The ability to pan, zoom, save, retrieve, and compare images on PACS workstations has markedly improved the radiology resident learning experience at MOI. The growing PACS image archive is becoming an important research asset for MOI. The MOI administration and staff gratefully acknowledge these benefits and have continued to maintain and expand the described PACS implementation.

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