The Impact of a Picture Archiving and Communication System on Nuclear Medicine Examination Interpretation

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Radiographic correlation is essential for many of the examinations performed in nuclear medicine. The purpose of this study was to evaluate the impact of a picture archiving and communications system (PACS) on the function and efficiency of a nuclear medicine department at a tertiary care institution. We evaluated 250 consecutive noncardiac nuclear medicine imaging examinations and asked the interpreting physician the following questions: (1) Was PACS used in the interpretation of the study? (2) Did the use of PACS expedite examination completion or aid in study interpretation? And (3) Did the use of PACS permit a definitive diagnosis to be made? PACS was accessed for correlative radiographic images in 155 of the 250 (62%) nuclear medicine examinations. Images available on PACS for review aided in study interpretation in 74% (115 of 155) of cases. The use of PACS was thought to expedite examination completion in 55% (86 of 155) of cases. The system was accessed but not operational in only 1% of cases (2 of 155). PACS provides reliable, rapid access to multimodality correlative radiographic images that aid in the interpretation of nuclear medicine examinations. Such systems also increase the efficiency of a nuclear medicine service by allowing timely and conclusive interpretations to be made.

KEY WORDS: picture archive and communication systems, computers, nuclear medicine.

THERE IS a well-recognized mutual dependence between radiology and nuclear medicine in examination interpretation. Abnormalities detected by radiographic imaging modalities often undergo scintigraphic evaluation to determine factors such as metabolic activity, multiplicity, and functional significance. Likewise, abnormalities detected on a scintigraphic examination often require further evaluation with a radiographic study to permit a more conclusive diagnosis. At many tertiary care institutions, this mutual dependence is hampered by physical separation within the hospital and poor film control.[1,2] Picture archiving and communication systems (PACS) offer a significant advantage over traditional film storage systems in providing timely access to the radiographic studies. This should result in more rapid patient diagnosis and a more efficient nuclear medicine service. In an attempt to better define the actual impact of PACS, we evaluated how frequently the system was accessed and its impact on examination interpretation within our nuclear medicine department.

MATERIALS AND METHODS

Facility

The study was performed in the Nuclear Medicine Service of a 450-bed facility that provides primary, secondary, and tertiary health care. The facility also serves as a level 1 trauma center for the City of San Antonio. Approximately 180,000 radiologic procedures are performed annually, including between 8,000 and 9,000 nuclear medicine examinations.

PACS System

A Medical Diagnostic Imaging Support (MDIS) radiology PACS system has been operational for approximately 2.5 years. The system was installed and is maintained by Loral Medical Imaging Systems (Hoffman Estates, IL). This system retrieves and displays most of a patient's radiographic examinations, as well as the final report of a study's interpretation. All digital storage phosphor radiographs, gastrointestinal contrast examinations, ultrasound, computed tomography, magnetic resonance, and angiographic examinations are stored as digital images on two Kodak Model 6800 optical jukeboxes (Rochester, NY). Each jukebox can store up to 100 10-gigabyte optical discs, for a raw capacity of 1 terabyte. Compression algorithms are used for storage of digital images in the permanent archive. Cardiac catheterization, echocardiographic, mammographic, and nuclear medicine examinations are not available on PACS. Hard copies of stored images can be provided on request, using a Kodak Ektascan laser printer (Rochester, NY).

A PACS workstation with two 21-inch, 1,152 × 880-pixel resolution computer monitors is located in the interpretation area of the nuclear medicine service. The workstation operates by using drag-down lists and a computer mouse. A specific patient can be accessed by using either their name or their social security number. Once a patient is selected, a chronological listing of their radiographic examinations and the type of examination appears on the screen. An option is available to select only studies from a specific imaging modality (eg, computed tomography [CT], magnetic resonance imaging [MRI], etc.). A specific study is selected by placing the mouse cursor on the examination desired and clicking the mouse button. Once the examination is selected, the completed radiographic report is presented on the screen. From the PACS workstation monitor

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the user can also determine if images are available for immediate review in the on-line working storage unit or if the images must be retrieved from the permanent archive. Images in the on-line working storage unit, including CT or MRI examinations, can be displayed in less than 30 seconds. Images stored in the permanent archive need to be retrieved before display. The amount of time required to retrieve an examination from archive is variable and depends on the priority assigned to the user who is requesting the study and the number of other users accessing the retrieval system. Radiologists and nuclear medicine physicians are assigned the highest priority by the PACS for study retrieval. Regardless of the type of study, retrieval from archive typically requires only 1 to 3 minutes.

Nuclear Medicine Department

The nuclear medicine department is staffed by three board-certified nuclear medicine physicians. Two of the three physicians are also board-certified radiologists. A Pinnacle computer system, maintained by Medical Digital Systems (Norcross, GA), is used for image processing and display. Images are also printed on film to allow other physicians to access the study. Images are archived on optical discs within the nuclear medicine department and are not available on the MDIS PACS system because of storage constraints. The dynamic nature of many of the scintigraphic examinations would require a large amount of storage capacity. It is anticipated that both static images and "snapshots" of dynamic nuclear medicine studies will be archived on the PACS system in the near future.

Study Design

We evaluated 250 consecutive noncardiac nuclear medicine imaging examinations and asked the interpreting physician to answer the following questions: (1) Was PACS used in interpretation of the study? (2) If PACS was used, did images available for review on the system expedite examination completion or aid in study interpretation? (3) If PACS was used, did images available on the system permit a definitive diagnosis to be made? Answers were recorded on a data sheet. Results were pooled, and statistics were determined based on the combined answers. The interpreting physician's identity was not recorded on the data sheet to maintain anonymity.

To assist the nuclear medicine physician in answering these questions, the terms were further defined. "Expedite exam completion" was defined as accelerating the time required to completion of the dictation by more than 30 minutes. "Aid in study interpretation" was defined as providing additional useful information that the nuclear physician would not have had access to in the absence of radiograph. A "definitive diagnosis" was defined as an increase in the diagnostic confidence in interpretation of the examination to a degree that further imaging, laboratory, or clinical data is not believed to be necessary, or the differential diagnosis was significantly refined by review of the PACS data.

Nuclear cardiac examinations were not included for purposes of this review, because correlative cardiac catheterizations and echocardiographic studies are not available on PACS.

RESULTS

PACS was accessed for correlative radiographic images in 155 of the 250 (62%) nuclear medicine examinations. In the other 95 cases, radiographic correlation was not thought essential for interpretation of the nuclear medicine study. In 124 of the 155 cases (80%) in which PACS was used, a pertinent radiographic examination had been performed and was available for review at the time of the interpretation of the nuclear medicine examination. The use of PACS expedited examination completion in 55% (86 of 155) and aided in study interpretation in 74% (115 of 155) of cases. PACS permitted a definitive diagnosis in 32% (50 of 155) of the cases in which it was used. The system was accessed, but not operational, in 1% of cases (2 of 155), which prevented image retrieval at the time of study interpretation. Bone scans accounted for 161 of the 250 examinations (64.4%), and PACS was accessed in the interpretation of 102 (63%) of these cases. Pertinent images available on PACS aided in bone scan interpretation in 65% (66/102), expedited examination completion in 25% (25 of 102), and permitted a definitive diagnosis in 31% (32 of 102) of cases. There were 28 ventilation-perfusion lung scans for which chest radiographs on PACS were reviewed for interpretation. There were 11 thyroid examinations, and correlation with images on PACS in four cases was believed to aid or expedite examination completion in each case. There were three Oncoscint examinations and one Octreotide examination. Correlative images available on PACS were felt to aid or expedite examination completion in each of these cases and permitted a definitive diagnosis in two cases. For PACS use based on examination type, see Table 1.

DISCUSSION

With the advent of imaging modalities such as CT and MRI, the use of radiologic procedures in patient evaluation has greatly expanded. Coupled with this explosion in radiologic services is the difficulty in keeping the radiology file room organized and making the images available to both the radiologists responsible for interpreting the examinations and the clinicians taking care of the patient.[1] When one group of consultants is in possession of the films, other cannot view the images, and hence patient care suffers.[1] PACS applies digital technology to the problems of film storage and inaccessibility. PACS expedites access to radiographic images, prevents image loss, and allows multiple physicians at different locations to view the same images simultaneously.[3]

Table 1. PACS Usage Based on Examination Type

Examination	Total Number	PACS Accessed for Image Interpretation	Percentage of Cases in Which PACS Used	Aided or Expedited Examination Completion	Definitive Diagnosis
Bone scan	161	102	63	66/102	32
Ventilation/perfusion	28	28	100	28/28	6
Thyroid	11	4	36	4/4	1
Renal	9	2	22	2/2	1
Hepatobiliary	6	2	12	0/2	0
Whole body iodine	6	1	17	0/1	0
Liver-spleen	5	2	40	2/2	2
In-111 WBC	5	4	80	3/4	1
Gallium	4	3	75	3/3	3
Oncoscint	3	3	100	3/3	2
Gastrointestinal bleed	2	0	0	0/0	0
Octreotide	1	1	100	1/1	1
Hemangioma	1	1	100	1/1	1
Miscellaneous	8	2	25	2/2	0
Total	250	155	62	115	50

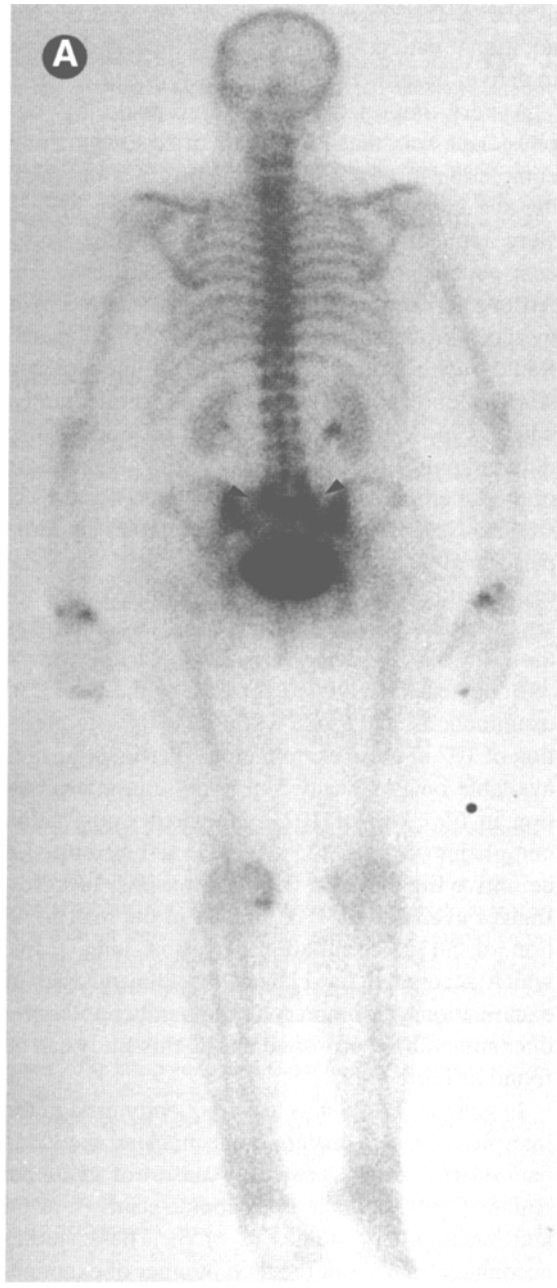
The radiology department at our institution provides an entirely filmless radiology service through the implementation of a hospital-wide PACS. All radiographic examinations, with the exception of mammography, nuclear medicine, cardiac catheterization, and echocardiography, are read from and stored in PACS. This system has proven to be an extraordinarily useful adjunct for the interpretation of nuclear medicine examinations. It is well recognized that radiographic correlation is essential for many of the studies performed in nuclear medicine. At many centers, timely correlation between the nuclear medicine and radiographic examinations is hampered by physical separation within the hospital and poor film control. These drawbacks are essentially eliminated by PACS so that a definitive diagnosis can be made, in many cases, on completion of the nuclear medicine examination.

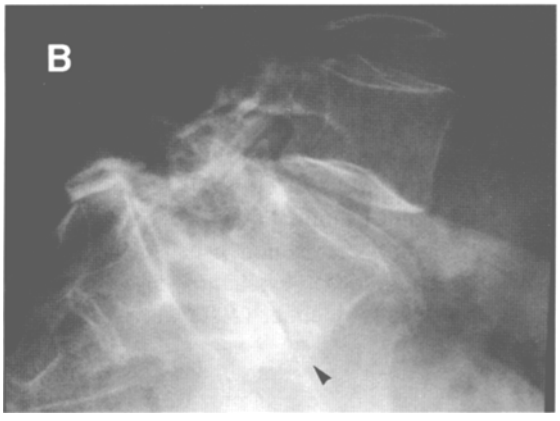
In our study, we found that PACS was frequently used by the nuclear medicine physician (155 of 250 or 62% of cases) to obtain correlative radiographic images for use during the interpretation of the nuclear medicine examination. Pertinent examinations were available on the system in 80% of cases (124 of 155). In those cases in which a pertinent image had not yet been performed, delays in diagnosis can be minimized in some cases if the patient can be sent at the time of the examination to the radiology department for a radiograph of the area of concern. Once completed, the radiograph is available for immediate review on PACS. No additional patient or support staff time is required to deliver or refile the images.

A very important observation made by our physicians was that PACS expedited examination completion in 55% (86 of 155) of cases in which the system was used. Because correlative images were frequently available on the system, the physician could avoid the delays created by trying to retrieve pertinent radiographs from the file room, or by repeating radiographs that could not be located. Radiographic examinations in the on-line working storage unit could be displayed immediately, whereas those that were archived on optical disc required only 1 to 3 minutes for retrieval regardless of the type of examination, including CT and MRI studies. Because radiographic correlation could be performed at the time of the nuclear medicine examination, PACS permitted a definitive diagnosis to be made in 32% of cases for which it was used (Fig 1).

Bone scans accounted for 161 of the total 250 examinations, and PACS was used in the interpretation of 102 of these examinations. Pertinent images available on PACS aided in bone scan interpretation in 65% (66 of 102), expedited examination completion in 25% (25 of 102), and permitted a definitive diagnosis in 31% (32 of 102) of cases. Images available on PACS aided in the interpretation of all 28 ventilation-perfusion lung scans, which accounted for 11% of the total number of examinations. A summary of the number and types of examinations performed during this study can be found in Table 1.

In general, PACS was less frequently used in the interpretation of certain other nuclear medicine examinations such as thyroid scans (4 of 11), renal studies (2 of 9), whole body iodine scans (1 of 6), and hepatobiliary studies (2 of 6). These studies accounted for 13% of the total number of examinations. Although the system was less frequently used in interpretation of these examinations, studies available on PACS were often useful to the nuclear medicine physician. Images available on PACS were believed to aid or expedite examination completion in each of the four thyroid scans for which the system was accessed. Comparison with the radiographic examination was deemed essential for examination completion because the patients had been referred for evaluation of nonpalpable nodules detected by either CT or ultrasound. Cor-





relative renal ultrasound examinations available on PACS aided and expedited examination completion of two cortical renal scans in patients referred for evaluation of sonographically detected defects suspicious for renal scarring.

Radiologic correlation was deemed unnecessary for interpretation in 95 of the 250 examinations (38%). Correlative images may have been available on PACS had they been required for interpretation of these examinations, but that information was beyond the scope of this article. Cases in which the system was not accessed included certain examinations interpreted as normal, such as a normal bone scan in a patient suspected of having a stress fracture, and studies in which a conclusive diagnosis could be made based on the scintigraphic appearance alone. For instance, in the appropriate clinical setting, an abnormal hepatobiliary study could be interpreted as consistent with acute cholecystitis in the absence of correlation with other imaging examinations. It should be noted that despite a normal nuclear medicine examination, radiologic correlation may occasionally still be required. Image review of a radiographic abnormality would still be necessary despite the lack of scintigraphic findings to ensure that the area of concern was appropriately evaluated.

A direct comparison with a traditional film-based storage system was not possible because our department is predominantly filmless. However, before the institution of PACS the chance of finding a film in the film library on request was only 38%. The average chance of finding both a patient's film and the report together was only 18% (Saarinen AO, internal operational review). Coupled with the lack of availability of comparison studies, one also must consider the amount of technologist or physician time lost while trying to locate the images. The lack of availability of comparison films previously contributed to reading delays and was thought to

Fig 1. Patient with history of malignancy presents with complaints of back pain. (A) Posterior image from a whole body bone scan demonstrates abnormal tracer uptake in the lower lumbar-sacral spine (small black arrowheads). (B) Plain film radiograph performed approximately 12 months earlier was available for review on the PACS system and showed severe degenerative changes at the level of scintigraphic abnormality (large black arrowhead). Nuclear medicine physician was able to confidently exclude metastatic disease at the time the study was performed.

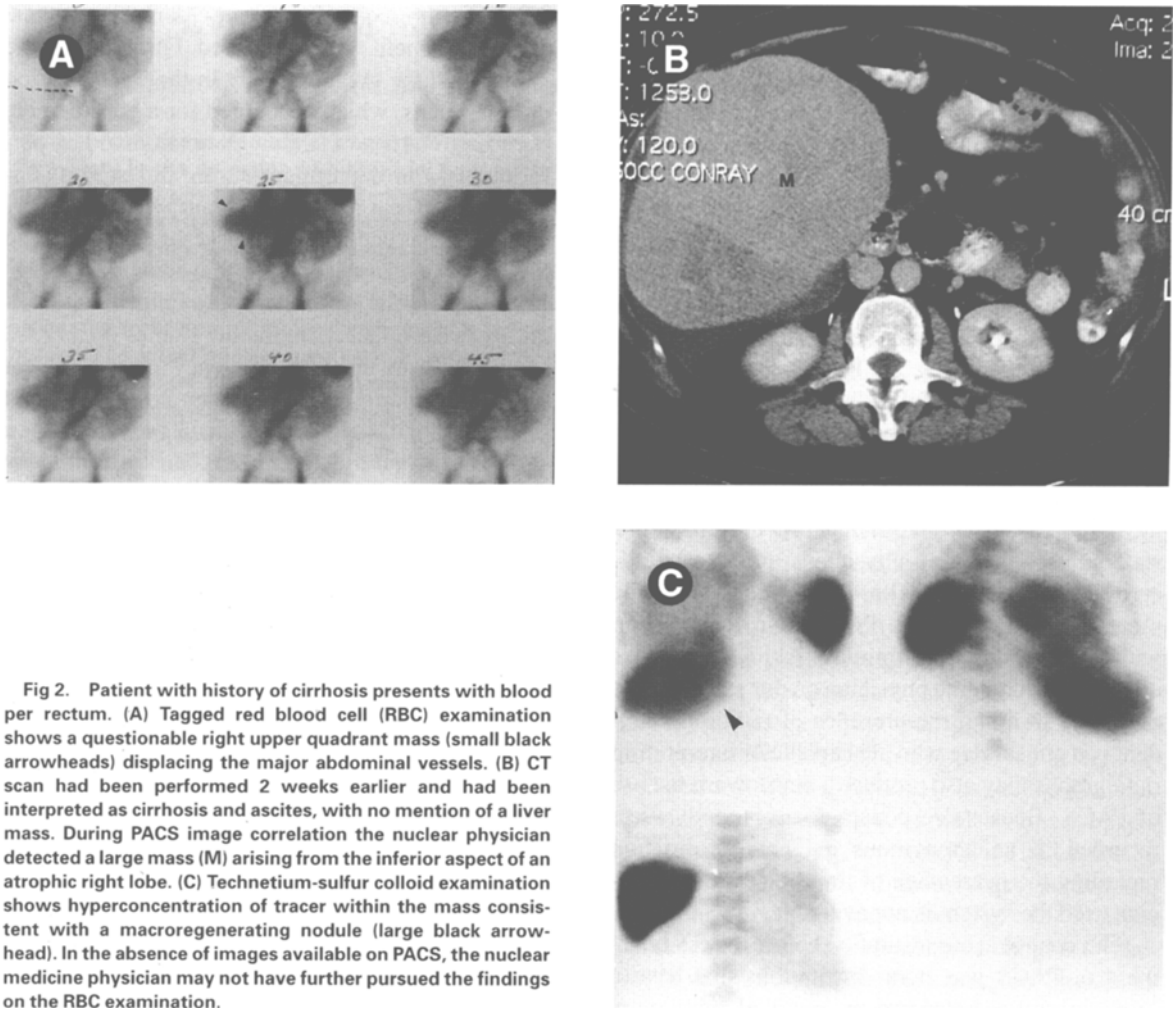


Fig 2. Patient with history of cirrhosis presents with blood per rectum. (A) Tagged red blood cell (RBC) examination shows a questionable right upper quadrant mass (small black arrowheads) displacing the major abdominal vessels. (B) CT scan had been performed 2 weeks earlier and had been interpreted as cirrhosis and ascites, with no mention of a liver mass. During PACS image correlation the nuclear physician detected a large mass (M) arising from the inferior aspect of an atrophic right lobe. (C) Technetium-sulfur colloid examination shows hyperconcentration of tracer within the mass consistent with a macroregenerating nodule (large black arrowhead). In the absence of images available on PACS, the nuclear medicine physician may not have further pursued the findings on the RBC examination.

produce a 20% productivity loss (Saarinen AO, internal operational review).

The PACS was extremely reliable. The system was found to be nonoperational in only 2 of the 155 exams for which it was used (1% of cases). The malfunction was related to a software error, and the problem was corrected by service personnel on-site within 1 hour. As with all computer systems, there are scheduled down-times for system upgrades and maintenance of PACS. These sessions are performed during the early morning hours so as not to conflict with patient care. During our study, scheduled down times did not conflict with system access during examination interpretation.

The PACS at our institution provides access to both the images and the completed radiographic report for a selected examination. Radiology information systems (RIS) provide on-line computer archiving and retrieval of radiology reports, but not on-line access to images. These systems are in service at many institutions. RIS can provide information regarding whether recent pertinent radiologic studies have been performed and a report of the interpretation of the study. Variability in the time between when the report is dictated, transcribed, and finally approved by the interpreting radiologist may delay access to the report of recent examinations. Depending on the degree of sophistication of the RIS and the dedication of file room personnel, the location of the examination may also be available on the system. Assuming that the appropriate images could be located, additional time and man-hours would still be required to retrieve the study from the file room and deliver it to the nuclear medicine service. If the films could not be located, access to the examination report

may still be a useful adjunct to examination interpretation. However, subtle lesions are sometimes not identified on the initial radiologic study and are discovered only retrospectively when reviewed in conjunction with the nuclear medicine examination. Additionally, the dictation skills of radiologists vary widely. Some radiologists fail to accurately describe the location of a lesion, creating confusion when interpreting the nuclear examination. Having the radiographic examination available for review is clearly superior to having only the written report (Fig 2). Therefore, although an RIS may be a useful adjunct to examination interpretation, it cannot be considered the equivalent of a PACS.

Certain factors may have produced a bias toward the use of PACS within our department. Two of our staff nuclear medicine physicians are also board-certified radiologists. These individuals may be more inclined to access PACS than a physician without this additional training. Although there is one nuclear medicine physician on our staff without radiology training, the presence of radiology residents on our service who are capable of interpreting radiographs may also produce a bias toward the use of PACS. Because responses for this study were recorded in an anonymous manner, information regarding the percentage of times a specific physician used the system is not available.

Film control at our institution before the establishment of PACS was poor. Institutions that have a more centralized department coupled with more efficient film control may not derive the same degree of benefit we experienced. Furthermore, the system had the greatest utility in the interpretation of bone scans, which accounted for a considerable portion (64.4%) of the total examinations performed by our department during this study. Centers that perform fewer bone scans will most likely derive some benefit from access to images on PACS, but not necessarily to the same degree that we experienced. Regardless, the immediate availability of pertinent radiographic studies on a PACS should help to increase efficiency in any nuclear medicine department. The hidden costs that result from lack of timely access to diagnostic images, such as increased patient stay and examination duplication, have been reported to be substantially reduced through the use of PACS.[4,5] The savings realized by individual centers will vary depending on the accessibility of the institution's film library and the number of lost films before the introduction of PACS.

CONCLUSION

The field of radiology is expanding rapidly in the area of digital imaging. PACS have the ability to provide rapid access to multimodality correlative radiographic images and can be an extremely valuable aid in the interpretation of nuclear medicine examinations. PACS also increase the efficiency of the nuclear medicine service by allowing timely and conclusive interpretations to be made, which ultimately results in improved patient care.

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