Ultrasound Imaging on Picture Archiving and Communication Systems

Are Radiologists Satisfied?

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Objectives—To evaluate whether picture archiving and communication systems (PACS) adequately satisfy radiologists' needs in ultrasound (US) imaging and which PACS functions may be inadequately implemented for handling US diagnosis.

Methods—An electronic survey was sent to the membership of the Society of Radiologists in Ultrasound asking them to rate their PACS experience for different modalities, judge the quality of various PACS functions having an impact on US practice and diagnosis, indicate if they felt a need for US-related PACS functions to be implemented or improved, and rate PACS-related improvements for different components of their US practice.

Results—Of the 161 respondents, 112 (70%) used a general radiology PACS. Of these respondents, only 53.2% gave a high rating to the US experience in PACS, significantly lower ($P < .0001$) than for computed tomography (85.2%), magnetic resonance imaging (84.4%), and radiography (83.2%). The functionality of US-specific display, image-processing, and data management PACS processes were graded significantly lower than basic PACS display functions. Only 0.9% of respondents highly rated PACS handling of 3-dimensional US volume data, whereas 92% highly rated the quality of the black-and-white US image display ($P < .0001$). Most respondents would like most of these US-specific functions implemented or improved, and most respondents stated that PACS has improved their US practice in different ways, although the contribution in more complex image analysis is lagging.

Conclusions—Radiologists with a special interest in US believe that the PACS experience for US is lacking. This research helps identify those specific tasks that may further improve work efficiency and diagnostic confidence.

Key Words—image processing; picture archiving and communication systems; ultrasound; work flow

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Abbreviations

CT, computed tomographic; MRI, magnetic resonance imaging; PACS, picture archiving and communication system; SRU, Society of Radiologists in Ultrasound; 3D, 3-dimensional; US, ultrasound

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Picture archiving and communication systems (PACS) have radically altered the organization of radiology departments and the practice of radiology compared with traditional film-based radiology. The perceived benefits of these changes have hastened the widespread adoption of this technology.

It appears that PACS-induced changes in reading room practice have been accepted so quickly and with little or no resistance because of cost savings and enhanced work efficiency,[1–5] including availability of new easily used tools in radiologic reading.[6] The ability to scroll through computed tomographic (CT) examinations as well as to reformat these studies in multiplanar and 3-dimensional

(3D) views, near immediate availability of radiologic examinations, and the ability to easily change window and level settings appear to contribute not only to reading efficiency but also to recognition of greater amounts of diagnostic information.[6–10]

We have observed that compared with other major radiologic imaging modalities, the handling of ultrasound (US) examinations has not been as fully integrated into the general radiology PACS environment. Informal discussion with colleagues led us to suspect that the practice of US has not benefited from PACS to the same degree as radiography, CT, and magnetic resonance imaging (MRI). To test this hypothesis, we performed an online survey of the membership of the Society of Radiologists in Ultrasound (SRU). It was reasoned that radiologists who belong to this society would have particular insight into the intersection of PACS and US.

Materials and Methods

An invitation to complete an online survey was sent to the 1000 members of the SRU in March 2009. The survey was designed to assess the opinions of respondents regarding the functionality of PACS in the practice of US imaging and to compare it with the PACS experience in plain-film radiography, CT, MRI, and nuclear medicine. The invitation was sent by e-mail, which contained a link to the survey (ConstantContact.com, Waltham, MA), which could be filled out only once. The survey was available to respondents for 3 months and was not open to the general radiology community. The Institutional Review Board approved this research for exemption certification.

As there are a variety of available working environments for radiology, including traditional film-based imaging, general radiology PACS, US-specific mini PACS, and hybrid PACS–mini PACS, respondents were asked to identify the imaging environment used in their practice of both radiology and US imaging.

After answering basic questions about the type and make of their PACS environment, respondents were presented with 4 sets of questions about their PACS experience:

1. *Rating the PACS Experience for US*—Respondents were asked to rate their overall experience using PACS in a variety of imaging modalities, including CT, radiography, US, nuclear medicine, and MRI, choosing 1 of 5 answer choices: "poor," "fair," "good," "very good," and "excellent."
2. *Grading PACS Functions Affecting US Reading*—Respondents were asked to grade how well their PACS handles a specific set of tasks. A set of PACS tasks was identified for evaluation because of their potential to affect US practice performance (Table 1). This set included basic image presentation tasks as well as more complex tasks involving manipulation of image information and data. Teaching file–type tasks were also included because of their potential in aiding US quality assurance. Respondents were asked to grade how well their PACS handles each of these tasks by selecting 1 of 6 answers: "don't know," "incapable," "poor," "fair," "good," and "excellent."
3. *Judging the Need for US-Related PACS Improvement*—Respondents were asked whether there was a need for PACS to improve certain tasks (by implementation or improvement) by choosing among 3 possible answers: "not needed," "needed urgently," or "needed but nonurgently."
4. *Assessment of PACS-Related US Practice Improvement*—A set of functions was presented to the respondents, who were asked whether the introduction of PACS had contributed to an improvement of their US prac-

Table 1. Ultrasound-Related PACS Tasks Assessed in the Survey

Task	Task Type
Capture and display of high-quality black-and-white US images	Basic diagnostic
Capture and display of high-quality color US images	Basic diagnostic
Measure structures on US images	Basic diagnostic
Annotate US images	Basic diagnostic
Capture and display US cine clips	Complex diagnostic
Use PACS to manage teaching file cases	Teaching file/quality assurance
Use PACS to save and find individual US images or cine clips for teaching file purposes	Teaching file/quality assurance
Rearrange the order of images in a displayed US examination	Work flow efficiency
Capture measurements from a US examination into a spreadsheet in the PACS	Work flow efficiency
Import, store, and manipulate US volume acquisitions	Complex diagnostic
Change the monitor configuration of the PACS review station	Work flow efficiency
Hide patient demographic data on US images	Teaching file/quality assurance

tice in each of these areas (Table 2). The possible answers were "no," "yes," and "maybe." The list was compiled to assess a range of components of a US practice that may be impacted by PACS, including functions affecting practice workflow, diagnosis, and quality assurance.

The question set "Rating the PACS Experience for US" was analyzed by comparing the percentage of highly favorable ratings for each radiologic modality in the list. Highly favorable ratings were judged to be the combined responses of the 2 most favorable categories ("very good" and "excellent"). Because it received the highest rating of any modality, PACS handling of CT was considered the standard against which other modalities were compared. The McNemar test was used to assess the statistical significance of the difference between results for CT and the other modalities. Statistical significance was set at $P < .05$.

The question set "Grading PACS Functions Affecting US Reading" was analyzed by comparing the percentage of respondents giving a high rating to each function. A high rating was judged to be 1 of the 2 most favorable categories ("good" and "excellent") out of a total of 6 choices. Because the handling of black-and-white images by PACS is a basic PACS function and because it received the greatest percentage of highly favorable ratings, it was considered the standard against which the other functions were compared. The McNemar test was used to determine the significance of the difference in results between this function and the other functions. Statistical significance was set at $P < .05$.

The question set "Judging the Need for US-Related PACS Improvement" was analyzed by assessing the percentage of respondents indicating a need (whether urgent or not) for new implementation or improvement of each listed PACS function. A compelling need for implementation or improvement was considered only if a majority of respondents indicated such a need. The statistical significance of "needed" responses was analyzed with a binomial test, comparing each set of results to a threshold response of 50% (above which would constitute a majority). Statistical significance was set at $P < .005$ because of multiple comparisons.

The question set "Assessment of PACS-Related US Practice Improvement" was analyzed by comparing the percentage of respondents indicating that PACS had definitely contributed to an improvement of their US practice for each listed practice function. The percentage response for immediate access to the US examination was considered the standard against which the other responses were analyzed because of a 95% response that PACS was responsible for an improvement in US practice in this area. The statistical significance of the difference between the percentage response for this standard and that for each of the other practice functions was assessed with the McNemar test. Statistical significance was set at $P < .05$.

Statistical analysis was performed with SAS version 9.3 software (SAS Institute, Cary, NC). Missing data in the analysis using the McNemar test were handled by pair-wise deletion. A respondent's answer was excluded from each statistical comparison when there was no answer in the comparison question. For example, if a respondent provided an answer about the level of satisfaction with PACS for CT but not for MRI, that respondent's answer was excluded from that statistical comparison. However, that respondent's answers could still be part of the statistical comparison of another set of questions when answers were given in each of those comparing questions. For example, even if excluded from the statistical comparison of satisfaction for MRI in PACS versus CT in PACS, that respondent's answers could be included in the statistical comparison of US in PACS versus CT in PACS if there was an answer for each.

Table 2. Ultrasound Practice Functions Potentially Affected by PACS

Function	Function Type
Provide the radiologist immediate access to US examinations	Work flow efficiency
Allow efficient comparison with previous and other modality examinations	Diagnostic accuracy
Increase efficiency of patient turnaround times	Work flow efficiency
Foster greater confidence in the quality of US examinations	Quality assurance/diagnostic accuracy
Enhance communication with sonographers performing US examinations	Quality assurance/diagnostic accuracy
Display consistently high-quality grayscale and color images	Diagnostic accuracy
Enhance availability of US examinations for referring clinicians	Practice efficiency
Review US cine clips	Diagnostic accuracy/work flow efficiency
Review US volume data	Diagnostic accuracy
Manage US teaching files	Quality assurance

Results

A total of 161 radiologists (16.1%) took the survey out of the 1000 SRU members who were invited. Of the respondents, 112 (70%) used a general radiology PACS. Since the goal of this research was the evaluation of the functionality of US-related tools in general radiology PACS, these respondents using a general radiology PACS formed the study population (Table 3). Fifteen (9%) of the respondents used a mini PACS designed for US use. The small size of this group made analysis difficult. Thirty-four (21%) of the respondents used a hybrid system with a US mini PACS connected to a general radiology PACS. There was ambiguity in the results of this last group since it was difficult to determine with certainty whether their responses referred solely to their experience with PACS or mini PACS or both. Therefore, this group was not analyzed further.

Figure 1 presents modality-specific satisfaction with PACS. The results for US and nuclear medicine were significantly lower than for CT. There was no significant difference in results for MRI and radiography compared with CT.

Figure 2 shows the percentages of respondents highly rating multiple PACS functions for reviewing US examinations. Except for capture and display of color images, the results for all of the functions were significantly lower than for capture and display of black-and-white images. There was no significant difference between results for the capture and display of color images and capture and display of black-and-white images.

Table 3. Picture Archiving and Communication Systems in Use by Respondents of This Survey

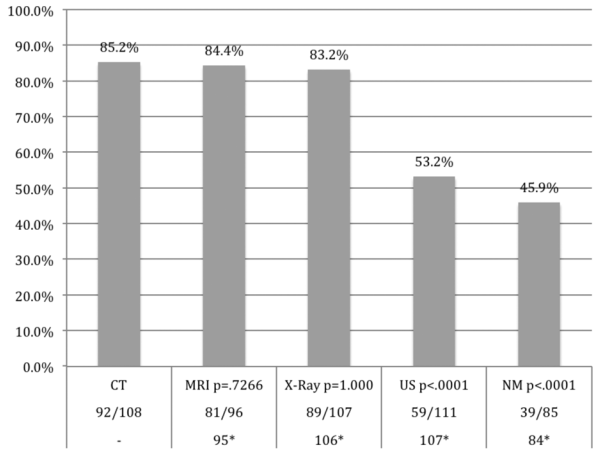
PACS	n
Centricity (GE Healthcare, Milwaukee, WI)	32/112
iSITE (Stentor) (Philips Healthcare, Bothell, WA)	21/112[a]
McKesson Radiology (McKesson, San Francisco, CA)	17/112[a]
Synapse (Fujifilm Medical Systems, Stamford, CT)	14/112[a]
IMPAX (Agfa Healthcare, Greenville, SC)	13/112
Emageon (Amicas, Boston, MA)	5/112
Unity (DR Systems, San Diego, CA)	3/112
Carestream (Eastman Kodak, Rochester, NY)	3/112[a]
IntelePACS (Intelerad, Westminster, CO)	2/112
ProVision (Cerner, North Kansas City, MO)	1/112
Infinitt PACS (Infinitt, Phillipsburg, NJ)	1/112
PowerServer (RamSoft, Toronto, Ontario, Canada)	1/112
Sectra PACS (Sectra, Linköping, Sweden)	1/112
Locally produced	1/112
Not specified	1/112

Numerators total more than 112 respondents because a number of respondents ([a]) listed the use of more than 1 PACS as a basis for their responses.

Figure 3 details the respondents' opinions of whether PACS needs to be improved for reviewing US examinations via the introduction or enhancement of certain functions. More than 50% of respondents indicated a need for improvement in the more complex PACS functions affecting US examination review (the 7 functions on the right side of the graph). Of these, results were significantly greater than 50% for rearranging the image order, teaching file management, teaching file image finding, and 3D volume capture and display.

Figure 4 presents the percentages of respondents indicating that PACS has definitely improved their US practice compared with that in a film-based environment in various practice functions. Ninety-five percent of the respondents thought that PACS contributed to US practice improvement by making US images immediately available after an examination. Compared with immediate access, significantly fewer respondents thought that their US practice had improved in diagnostic confidence, in cine clip review, in teaching file management, and in 3D volume capture and review. On the other hand, there was no significant difference between the results for immediate access to images and those for comparison with other modalities and older examinations, for quality image rendition, for patient turnaround, for availability of examina-

Figure 1. Percentages of survey respondents highly rating the PACS experience for a variety of imaging modalities. The percentages are based on the number of respondents answering this survey question (denominators) and the number highly rating the PACS experience for each modality (numerators). With the PACS experience for CT receiving the highest response, it was chosen as the standard against which the other modalities were compared. *P* values were based on this comparison. Asterisked numbers indicate the number of responses used for each McNemar test of statistical significance. NM indicates nuclear medicine.



tions to referring clinicians, and for communication with sonographers.

Discussion

Widespread implementation of PACS into radiology departments over the last 2 decades indicates recognition of the superiority of the digital image environment over the traditional film-based environment.[1–6] However, our survey reveals significantly lower radiologist satisfaction with PACS support for US compared with extremely positive satisfaction for PACS support for CT. In contrast, there was no significant difference between satisfaction with PACS support for MRI and radiography and that for CT.

Our data suggest that this lower level of satisfaction is not based on radiologists' concerns regarding basic image presentation and analysis functions such as accurate reproduction of black-and-white and color US images and mechanisms for measurement of structures on US images. Indeed, PACS performance of these basic functions was rated very highly by our respondents.

Dissatisfaction with PACS support for US appears to be due to a perception of inadequate PACS handling of more complex functions involving image and data processing and presentation. These functions include storage and reformatting of US volume data, capture of US examination measurements into an editable PACS spreadsheet, rearrangement of images by a reader of a US examination, display of US cine clips, annotation of images, and hiding demographic data. All of these PACS tasks were judged to be significantly less well performed compared with more basic image display and analysis tasks. Furthermore, our data indicate not only that radiologists give a low performance rating to these complex PACS functions but also that most want to see many of these functions introduced or improved.

Handling of teaching file functions (maintaining a teaching file database within PACS or saving or finding specific images or cine clips within PACS) was judged significantly less positively than basic image presentation functions and in need of improvement or implementation. Teaching file functions not only support the academic radiologist in teaching and publishing but also have the potential to support all radiologists in quality assurance and improved diagnostic accuracy.[11] Saving cases tagged by specific teaching file database fields may lay the foundation

Figure 2. Percentages of respondents highly rating multiple PACS functions (see Table 1). The percentages are based on the number of respondents answering each question (denominators) and the number of respondents highly rating each of these functions (numerators). *P* values indicate the significance of the difference between highly rated responses for each function and that of the most highly rated function (capture and display of high-quality black-and-white US images). Asterisked numbers indicate the number of responses used for each McNemar test of statistical significance. The most basic functions (left 3 bars) were all rated highly. A significantly lower percentage of respondents highly rated the more complex functions (right 7 bars). B&W indicates black-and-white; and TF, teaching file.

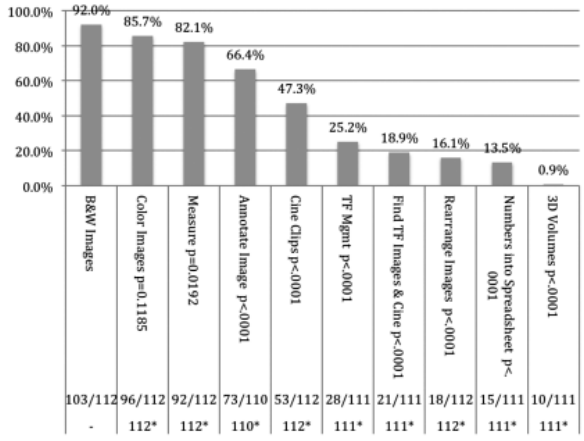
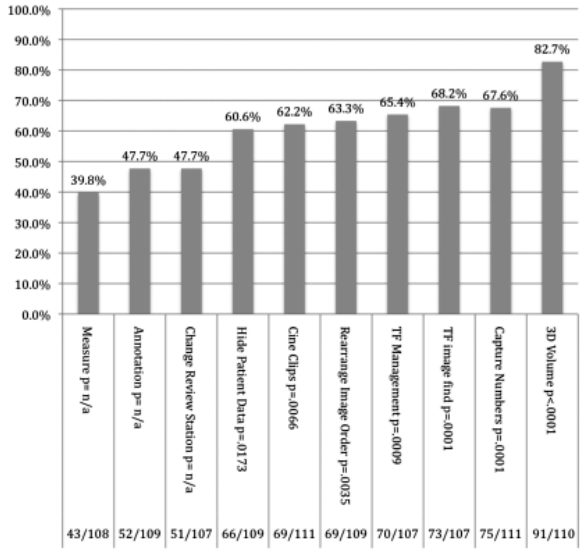


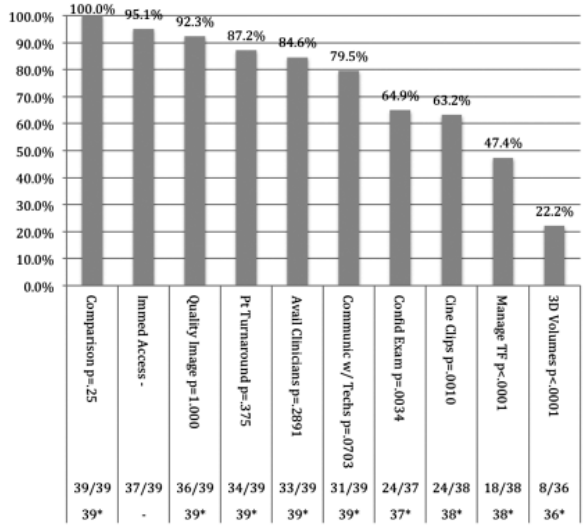
Figure 3. Percentages of respondents indicating the need for PACS to implement/improve various tasks (see Table 1). The percentages are based on the number of respondents answering the question (denominator) and number of respondents indicating the need for implementation/improvement for each task (numerator). Percentages of greater than 50% were viewed as representing a majority in support of improvement or introduction of a task. *P* values obtained with the binomial test indicate statistical significance of the difference between the percentage of respondents wanting to see a change and a threshold response of 50%. TF indicates teaching file.



for a PACS-based system to provide technical or diagnostic feedback to sonographers, positively impacting quality control in US departments.[12]

The introduction of PACS was overwhelmingly recognized by our respondents as improving the US practice environment, particularly in the immediate access to the US images at the conclusion of the US examination, the ability to easily and rapidly compare the current US examination with previous US and other modality examinations, as well as the consistent quality of US image display. A very large number of our respondents also indicated that PACS has improved the overall work flow efficiency of US departments with more rapid patient turnaround times and greater availability of the examinations to the ordering clinicians for review. On the other hand, a much lower percentage of radiologists believed that PACS has contributed to US practice improvement in the handling of cine clips and volume data as well as managing teaching file functions.

Figure 4. Percentages of respondents indicating that PACS had definitely improved their US practice in each of 10 practice functions (see Table 2) compared with a film-based environment. The percentages are based on the number of respondents answering each question (denominator) and number of respondents experiencing PACS-associated practice improvement (numerator). Fewer respondents answered this part of the survey than the other questions because of its placement in an optional second part of the online survey. Immediate access to the US examination was considered the standard against which all the other functions were compared. Asterisked numbers indicate the number of responses used for each McNemar test of statistical significance. A significantly lower percentage of respondents indicated PACS-based improvement in the 4 practice functions on the far right. Pt indicates patient; and TF, teaching file.



Nearly two-thirds of our respondents believed that PACS has resulted in an increase in diagnostic confidence in US examinations. Although this number represents an impressive PACS-related practice improvement, the result was significantly lower than for the responses rating practice efficiency and the fidelity of image display. Immediate access to examinations, improved communication with sonographers, and the fidelity of US image display, judged by our respondents to be enhanced by PACS, are likely major contributions to improved diagnostic confidence. On the other hand, PACS handling of 3D volumes and cine clips, which provide the radiologist with tools to independently review US anatomic data and make independent anatomic and pathologic assessments, was rated poor by our respondents. Ultrasound cine clips improve the signal to noise ratio of both normal and pathologic imaged anatomy, which results in improved diagnostic confidence.[13] Scrolling through stacked CT examinations has been shown to improve understanding of spatial relationships of imaged anatomy[6,14]; US may be able to accomplish the same result via the use of cine clips and review of 3D volumes.[15–17]

The rating of PACS functions is complex because of the multiple PACS brands evaluated in our sampling and the associated variation in availability and implementation of PACS functions. Some of the PACS, for example, could not handle cine clips at all, whereas other PACS stored and displayed cine clips with varying ease of review. Almost no PACS could process and reformat 3D US volumes, and when they could, it was only with proprietary software tied to a specific make of US machine. All PACS had image annotation available, but the annotation was often not directly scaled to the displayed size of the image frame, allowed no adjustments to be made to font size, style, or color, and could not be created as a layer, which could be hidden and viewed by the reader as needed.

Automatic rearrangement of the displayed image order and acquisition of measurements from a US examination into an editable PACS spreadsheet have the potential to improve the radiologist's work flow efficiency. It would be useful for the US machine software to tag each image with an anatomic descriptor and transmit that to the PACS. The radiologist could then simply push a button on the PACS to group together images of similar organs, anatomic regions, and/or planes of view or to automatically rearrange the order of images to parallel the order used for the report. Instead of hunting through a US examination to find measurements for reporting, having access to imported measurements from a US examination in a PACS spreadsheet would increase reporting efficiency and

accuracy. With an interactive and editable spreadsheet in PACS, clicking on a measurement could direct the radiologist to the source image for assessment of adequacy or editing. Ultimately, these measurements could automatically populate a structured report, resulting in increased reporting efficiency and accuracy.

By its nature, this research depended on the willing participation of a subset of the radiology community in a survey. As such, the results may not fully represent the opinions of the entire radiology community. Nevertheless, by selecting the members of the SRU, we think that the results reflect the opinions of radiologists most concerned about the specific needs of US in the PACS environment.

Survey data analysis may have potentially been limited by a lack of acquisition of respondents' yearly and case volume PACS experience for different radiologic modalities. However, the respondents appeared to have faithfully followed the instructions to answer questions about the various imaging modalities in PACS based on their own personal experience. The variable number of respondents answering the different questions in Figure 1 confirms this impression. Respondents were not provided with precise definitions of the various possible answers to the survey, introducing the possibility of a lack of consistency in the selection of answers. However, the answers were structured in a relative scale and appeared to be reasonably self-explanatory.

The results of this survey represent a snapshot of opinions about PACS from a few months in 2009, and it is possible that some of the concerns described in this research have been addressed by certain manufacturers since that time. However, yearly shares of PACS revenue according to manufacturers have not changed significantly from 2009 to 2012, suggesting little change in relative representation of manufacturers in the installed PACS base (N. M. Daher, principal analyst, medical imaging, Frost & Sullivan, Mountain View, CA, personal communication, October 29, 2012). In addition, it does seem to us from personal experience and from conversations with colleagues that much of what was thought to be lacking at that time is still lacking.

Picture archiving and communication systems offer multiple benefits to radiology departments and to the larger medical systems in which they operate.[18] When analyzed from the perspective of the radiologist, improved productivity is the most often described benefit.[2,3,19] The potential for PACS to enhance diagnostic accuracy has also been recognized.[6,8,9,20] By empowering radiologists to scroll through stacked CT examinations and to perform 3D CT reformatting on the fly, PACS has led to productivity and diagnostic accuracy gains in CT.[6–10] On the other hand, our research suggests that the development of PACS tools specifically targeted for US has been lagging. By rigidly constraining radiologists to read US examinations in virtually the same way as they have done in the pre-PACS film era, PACS and US manufacturers have failed to deliver the same potential for improvement in US image reading. Many of the US-related PACS tasks analyzed in this survey have the potential to correct this situation.[13]

Improving the PACS experience for US is likely a complicated endeavor and would require coordinated efforts by manufacturers of US machines and PACS and may also require new Digital Imaging Communications in Medicine standards. For this situation to begin to change, US and PACS companies must hear from radiologists that PACS is not adequately meeting their US practice needs.[21] This survey demonstrates that radiologists with special interest in US believe that the PACS experience for US is lacking. Furthermore, this research helps identify those specific tasks that may further improve US-related work efficiency and diagnostic confidence.

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