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Timed Efficiency of Interpretation of Digital and Film-Screen Screening Mammograms

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Abstract

OBJECTIVE—Our objective was to compare interpretation speeds for digital and film-screen screening mammograms to test whether other variables might affect interpretation times and thus contribute to the apparent difference in interpretation speed between digital mammograms and film-screen mammograms, and to test whether the use of digital rather than film comparison studies might result in significant time savings.

MATERIALS AND METHODS—Four readers were timed in the course of actual clinical interpretation of digital mammograms and film-screen mammograms. Interpretation times were compared for subgroups of studies based on the interpretation of the study by BI-RADS code, the number of images, the presence or absence of comparison studies and the type of comparison study, and whether the radiologist personally selected and hung additional films; the same comparisons were made among individual readers.

RESULTS—For all four readers, mean interpretation times were longer for digital mammograms than for film-screen mammograms, with differences ranging from 76 to 202 seconds. The difference in interpretation speed between digital and film-screen mammograms was independent of other variables. Digital mammogram interpretation times were significantly longer than film-screen mammogram interpretation times regardless of whether the digital mammograms were matched with film or digital comparison studies.

CONCLUSION—In screening mammography interpretation, digital mammograms take longer to read than film-screen mammograms, independent of other variables. Exclusive use of digital comparison studies may not cause interpretation times to drop enough to approach the interpretation time required for film-screen mammograms.

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Keywords

digital images; digital mammography; efficiency; screening mammography

Digital mammography was first approved for use in the United States in 2000 [1], and since then has come into use in an increasing number of practices. According to statistics from the American College of Radiology, approximately 7% of U.S. mammography practices had at least one digital system as of April 2005 [1]. That percentage gradually rose to 33.6% by April 2008 [2]. Digital mammography offers savings in terms of image acquisition time and storage costs compared with film-screen mammography, and the Digital Mammography Imaging Screening Trial showed a small diagnostic benefit for digital mammograms compared with film-screen mammograms in women with dense breasts and women in age groups in which dense breasts are commonly encountered [3, 4]. An offsetting disadvantage is that digital screening mammograms take longer to interpret than film-screen screening mammograms [1, 5]. However, previous studies of interpretation times have not compared cases separately on the basis of the presence or absence of potentially confounding variables, such as the number of views or the presence or absence of comparison studies. We investigated how other variables affect comparative interpretation times for digital mammograms and film-screen mammograms. Previous studies have also suggested that conversion from film to digital comparison studies may speed interpretation times for digital mammograms. We compared interpretation times for digital mammograms having different types of comparison studies.

Materials and Methods

Four readers were timed by one of four trained observers while interpreting digital mammograms and film-screen mammograms using their usual methods. The interpretation times were recorded while reading actual clinical cases. Cases were not specially selected but constituted the assortment of screening mammograms available for reading when a study session was arranged. Readers interpreted both digital mammograms and film-screen mammograms but did not mix the two techniques in any one session. Institutional review board approval was obtained, and patient consent was waived.

Methods

Our study began August 19, 2006, and the last session was on May 10, 2007. Digital mammograms were viewed on a Stentor version 3.3 workstation (Philips Healthcare) with two 5-megapixel LCD (liquid crystal diode) monitors, and film-screen mammograms were prehung by film library staff with comparison films, if available, on a dedicated alternator (CrystalViewer, S&S X-Ray Products). When comparison studies for digital mammograms were on film, these were also prehung on a CrystalViewer alternator. Reports for both digital mammograms and film-screen mammograms were entered by the radiologist using an automated report-entering program (Mammography Information Management System, MagView) on a separate computer. All interpretations were performed at times when the workstation and alternator were working properly. All readers are attending diagnostic radiologists, board-certified by the American Board of Radiology, and qualified to practice

mammography in accordance with the Mammography Quality Standards Act. Three of those radiologists limit their practice to breast imaging. One has a more varied practice, approximately 10% of which is clinical time in screening mammography. The screening mammography case load during 2007 varied from 947 to 1,564 for the four readers (average, 1,254 cases). Experience in mammographic interpretation beyond residency at the beginning of this study ranged from 1 to 16 years (average, 10 years). Experience in interpreting digital mammography at the beginning of the study ranged from 9 to 18 months (average, 14 months). Our practice switched from the Senoscan workstation (Fischer) to the Stentor workstation in April 2006, so at the start of this study, each reader had had 4 months' experience with screening mammography on the Stentor workstation. Timed interpretations were performed in 43 batches, 17 for film-screen mammograms and 26 for digital mammograms, with the number of studies interpreted in each batch ranging from five to 26 (average, 11).

A trained observer recorded the beginning and end of the time required to interpret each case and enter the report into MagView. Report-entering time was included for two reasons: First, our radiologists often shift back and forth between examining the images and entering parts of the report, thus intertwining interpretation and reporting; and second, we wished to develop a sense of how long it took to finish groups of studies. Recorded times were taken from the Central Time Zone setting on the official U.S. government time Website (www.time.gov) and were recorded to the second. A program built into the data collection spreadsheet later calculated the elapsed time. Timing was continuous from case to case during a reading session. Readers gathered equipment and turned on the computers before timing started. If breaks were needed for interruptions unrelated to the ongoing screening interpretation, timing ended for that session, to resume later. Although our practice is in a teaching hospital, these interpretations were performed without the input of a resident or fellow. The interpretations constituted the actual final interpretation of each study. Reader 2 preferred to batch-enter normal reports into MagView for film-screen mammograms rather than entering them one at a time as the study was interpreted. The time required for entering each batch was separately recorded, averaged, and added back into elapsed time for the relevant examinations.

The timing observers also recorded the number of images per case, whether the study was unilateral or bilateral, the presence or absence of breast implants, whether the radiologist personally selected and hung films, and any unusual circumstances that may have prolonged the interpretation time. Observers did not record whether the radiologist manipulated window or level settings. On our workstation, adjustment of window and level settings is accomplished merely by pressure on the left mouse button and a wiggle of the mouse. Therefore, it can be too subtle to be consistently evident to an observer. Timing observers were instructed to be as unobtrusive as possible.

Statistical Analysis

Cases were considered to be aborted if the radiologist began to interpret them but stopped without entering a report. The number and causes of aborted studies were evaluated. Cases with recorded circumstances that may have prolonged reading time that would reasonably

have constituted grounds for declaring a break for an unrelated interruption were also excluded and were similarly evaluated for number and cause. Unilateral mammograms, mammograms in patients with breast implants, mammograms that were not primarily screening studies but rather completed a previous technically suboptimal screening mammogram, and one study for which beginning and ending times were entered incorrectly on the data sheet were all set aside and were not included in other statistical analysis for this report.

Interpretation times for the remaining examinations were compared using an analysis of variance with the JMP software package (SAS Institute). We considered the following variables: whether the examination consisted of four views or more than four views, whether the interpretation decision was BI-RADS 1 or 2 versus BI-RADS 0, whether the radiologist personally selected and hung additional films, the presence or absence of prior comparison studies, and the identity of the individual radiologist.

Results

Four readers initiated interpretation of 501 studies. Eight studies (five digital mammograms and three film-screen mammograms) were excluded because of circumstances that prolonged or may have prolonged interpretation time and that would reasonably have triggered a break in timing (Table 1). Twelve studies (six digital and six film-screen mammograms) were aborted (Table 2). One had a preliminary report crafted that was put on hold and would need further attention later. Three examinations were continuations of previous technically suboptimal studies. One was excluded because of a faulty data entry, and 19 were removed because they were unilateral or included patients with breast implants. There were 457 cases included in the analyses: 268 digital mammograms and 189 film-screen mammograms.

Mean interpretation times for the readers were as follows: reader 1, 251 seconds for digital mammograms versus 163 seconds for film-screen mammograms (difference, 88 seconds); reader 2, 171 seconds for digital versus 87 seconds for film-screen mammograms (difference, 84 seconds); reader 3, 236 seconds for digital and 160 seconds for film-screen mammograms (difference, 76 seconds); and reader 4, 300 seconds for digital and 98 seconds for film-screen mammograms (difference, 202 seconds). There was a difference of 129 seconds between the mean interpretation times of our fastest and slowest digital mammography readers and a difference of 76 seconds between our fastest and slowest film-screen mammography readers. Average interpretation time for all readers was 240 seconds for digital mammograms and 127 seconds for film-screen mammograms.

Thus, for all four readers, mean interpretation times for digital mammograms were greater than for film-screen mammograms, with the difference ranging from 76 seconds for reader 3 to 202 seconds for reader 4. There was no overlap of mean interpretation times. Our fastest reader of digital mammograms required 8 seconds longer, on average, to interpret each digital mammogram than our slowest film-screen reader needed to interpret each film-screen mammogram (Fig. 1).

Table 3 shows the results of the analysis of variance. Digital mammograms required longer to interpret than film-screen studies independent of the other studied variables. The differences between mean interpretation times for digital and film-screen mammograms ranged from 58 seconds for four-view examinations to 144 seconds for BI-RADS category 0 examinations. The differences were statistically significant in every case except those cases in which the radiologist personally selected and hung films ($p = 0.5329$).

Table 3 also compares interpretation times among digital or film-screen mammograms with regard to other variables. For both digital and film-screen mammograms, interpretation of studies with more than four views took longer than for those with only four views. Interpretation of BI-RADS category 0 cases took longer than BI-RADS 1 or 2 cases. Interpretation of cases took longer if the radiologist personally selected and hung films than if not, and interpretation also took longer when comparisons were present than when they were not. These differences were all statistically significant. For both digital mammograms and film-screen mammograms, the identity of the interpreting radiologist was also a significant variable ($p < 0.001$).

Twenty-five percent of digital mammographic examinations had four views (craniocaudal and mediolateral oblique of each side), and 75% had more than four views. On the other hand, 79% of film-screen mammographic examinations had four views and 21% had more than four views. The difference in the proportion of digital mammograms and film-screen mammograms having four rather than more than four views is statistically significant by the chi-square test ($p < 0.0001$). For digital mammograms, the average number of images for those studies with more than four views was 6.50, whereas for film-screen mammograms the average number of images for those studies with more than four views was 6.33. These numbers did not reach statistical significance by the Wilcoxon's rank sum test ($p = 0.37$).

Most digital mammogram cases with comparison studies (158/202, 78%) had only digital comparisons. The mean interpretation time for these studies was 204 seconds. Mean interpretation time for digital mammogram cases with only film comparisons (23/202, 11%) was 223 seconds, and mean interpretation times for the 21 (10%) digital mammogram cases having both film-screen and digital comparisons was 327 seconds. For calculation of these interpretation times, we excluded cases in which the radiologist hung films personally. The differences in interpretation speed between either digital-only or film-only comparison studies and combined digital and film comparisons was statistically significant ($p < 0.0001$), but the difference between digital-only and film-only comparisons was not statistically significant.

Discussion

Screening mammography, like other imaging techniques, has for decades been performed exclusively with analog film-screen technology. Full-field digital screening mammography, first approved for use in the United States in 2000 [1], is now used in an increasing number of practices. Digital mammography has proven equivalency in screening efficacy to film-screen mammography in most women [6–9], and in a multicenter trial has been shown to be

slightly more accurate than film-screen mammography in women with dense breasts and in pre- and perimenopausal women [3, 10].

However, digital mammography examinations are slower to interpret. Berns et al. [1] timed seven radiologists as they interpreted a total of 181 digital and 183 film-screen screening mammograms. The digital studies required an average of 2.0 minutes (120 seconds) to interpret compared with an average of 1.2 minutes (72 seconds) for film-screen studies. Berns et al. noted that the fraction of digital and film-screen cases with more than four images or requiring recall was not significantly different between digital mammograms and film-screen mammograms, but those authors did not separately analyze reading times for these subgroups of cases. A survey of members of the Society of Breast Imaging also found that it is the opinion of most respondents that it takes longer to interpret digital than film-screen screening mammograms [5]. Our study now concludes, on the basis of comparison of subgroups of cases, that the longer interpretation time of digital mammograms compared with film-screen mammograms is independent of other variables, including the BI-RADs category of the interpretation, whether the reader selected additional films and hung them personally, whether comparison studies were available, and whether the study consisted of more than four images.

Despite initial acquisition costs, digital mammography has economic advantages for the equipment owners over film-screen mammography in lowering storage and handling costs and in decreasing the time required to perform individual examinations [1]. For the interpreters of these studies, however, digital mammograms take longer to read than film-screen mammograms. The amount of difference varies from person to person, but a reasonable estimate based on both our data and the experience of Berns et al. [1] is that interpretation time will nearly double for digital mammograms compared with film-screen mammograms. Although interpretation time increases, the professional part of reimbursement may not. Medicare reimbursement for film-screen mammogram interpretation in our region is $34.64. Medicare reimbursement for digital mammogram interpretation is $34.26. A radiologist who takes 180 seconds average per digital mammogram (halfway between our combined average and that of Berns et al.) can read 20 digital mammograms in an hour and earn $685.20. A radiologist who takes 100 seconds average per film-screen mammogram (again halfway between our combined average and that of Berns et al.) can read 36 film-screen mammograms in an hour and earn $1,247.04. On the other hand, Medicare reimbursement for the technical part of mammography is $50.01 for film-screen mammograms and $101.09 for digital mammograms [11]. The economics, of course, will vary depending on where one practices, the payer mix, and the speed of the individual radiologists in the practice.

Among our tested factors, the need to select and hang films is one factor that slowed interpretation and that may to some extent be controllable. Therefore, radiologists wishing to streamline interpretation of screening mammograms would benefit from careful attention on the part of support staff to providing and organizing the hanging of adequate comparison studies on film. Organized, efficient hanging of film-screen mammograms would benefit both film-screen practices and practices in the early years of conversion to digital mammograms, when most comparison studies would be film-screen mammograms.

Other factors that slowed interpretation were having more than four images in the study, the presence of comparison studies, and BI-RADS category 0 interpretations. However, we would not suggest changes to practice policy based on these factors. The acquisition of additional images should be guided by balancing the need to image all the breast tissue and the need to minimize radiation dose rather than by concern about interpretation time. Although studies with comparison examinations took longer to interpret, a lack of prior studies was the most common cause for aborting a study, and some time was lost in each such case. Although BI-RADS coding of the studies did have an effect on interpretation time, a recall rate of approximately 7–10% is considered by many to be ideal for cancer detection; this is an adequate reason to strive for a reasonable recall rate independent of the possible effect of a higher recall rate on interpretation speed [12].

Berns et al. [1] suggested that interpretation time may drop when a practice moves past the stage at which digital mammograms are routinely compared with film. Although we are largely past that stage in our practice, we found that interpretation times for digital mammograms compared exclusively with prior digital studies (204 seconds) are still considerably greater than for film-screen mammograms (145 seconds for film-screen mammograms studies with comparisons, all comparisons for film-screen mammograms being on film), and only slightly less than for digital mammograms with film comparisons only (223 seconds). Thus, even when digital mammographic examinations are compared exclusively with prior digital studies, interpretation times remain significantly greater than for film-screen mammographic studies, either with or without comparisons. This is not entirely unexpected on the basis of the rest of our data because digital mammographic examinations with no comparison studies also took considerably longer to interpret than film-screen mammograms, either with or without comparisons (Fig. 2). The lack of any significant time savings with digital comparisons only may be partly because readers perform some of the same computer manipulations on the digital comparisons as they do on the study being interpreted. Our workstations do not automatically enlarge or pan through the relevant comparison view when these manipulations are performed on the images being interpreted. So if the reader wants a better look at a finding on the prior study, that image must be separately manipulated. A workstation that can link these manipulations may theoretically improve speed.

Another factor to consider is how long it takes to move away from film comparison studies. In our practice we prefer to compare with a study at least 2 years old. Therefore, for each patient a minimum of 2 years after acquisition of the first digital examination is required before we are content not to hang a film comparison. Furthermore, because most practices remain analog, patients bringing in outside studies for comparison usually, in our experience, bring film.

Our interpretation times were longer than those reported by Berns et al. [1] for both digital mammograms and film-screen mammograms. In comparing our methods with those of that study, a few possible explanations may be considered. One is that our digital workstation is different from theirs (Stentor vs GE Healthcare). Another is that we timed continuously from case to case, so we included both reporting time and the time needed to move the alternator for film-screen mammograms or to bring a digital mammogram up on the

computer. Berns et al. included reporting time but did not include the mechanical transition from one study to the next. In a separate study we found that the purely mechanical aspects of moving from one alternator panel to the next and moving from one digital mammogram to the next on the computer takes about 11 seconds per case and is slightly faster for film-screen mammograms on our equipment than for digital mammograms [13]. Another difference that may have increased our average interpretation times for digital mammograms was the high proportion of those examinations having more than four views in our study. In the study by Berns et al., digital mammographic and film-screen mammographic studies had a similar proportion of examinations with additional views. We also used different radiologists. Radiologists, like other people, are all unique individuals and have their own habits and methods that will affect interpretation speed. There was enough difference in the performance of our individual readers that four different readers would likely have given different results. Other authors have also found distinct differences in speed between individual readers [1, 14, 15]. We suspect, however, that the difference in results with different readers will be in the specific details, and the overall conclusions will remain the same, particularly because our results are in agreement with those of two previous articles [1, 5].

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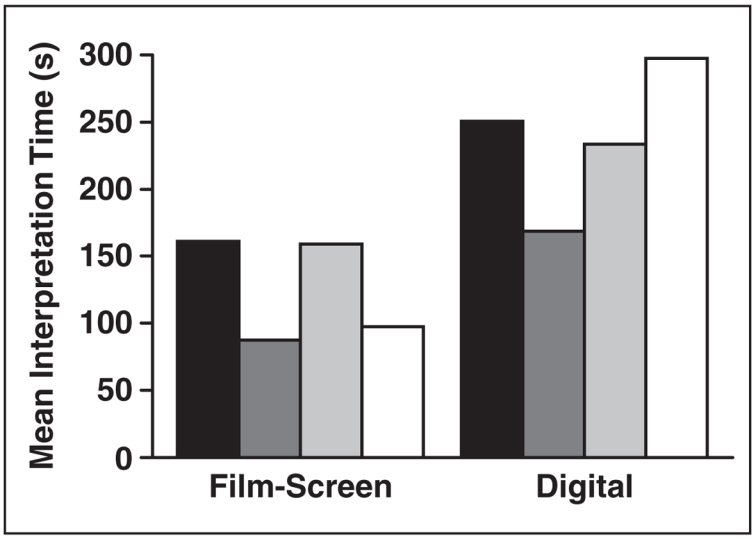

Fig. 1.
Mean times of four radiologists for interpretation of film-screen and digital mammograms.

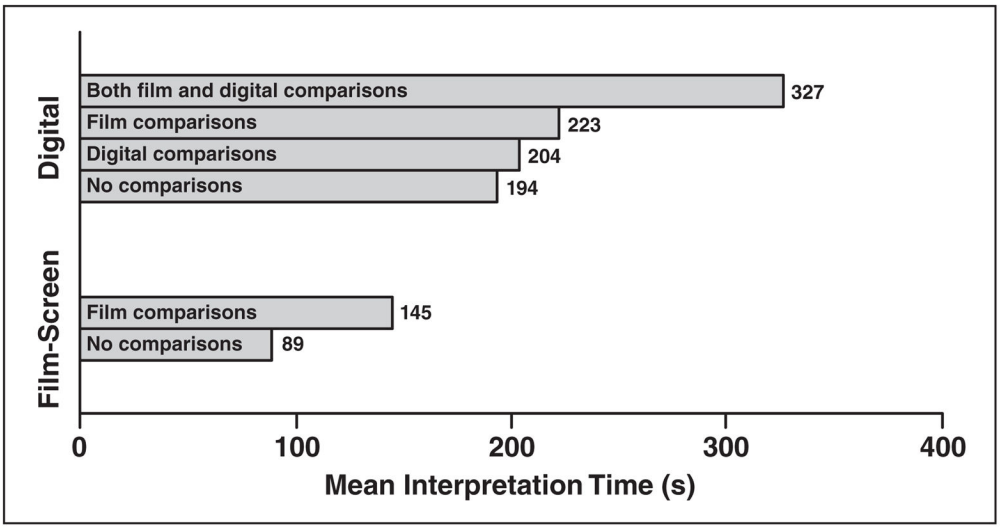

Fig. 2.

Mean interpretation times of film-screen and digital mammograms according to type of comparison studies.

TABLE 1

Studies Excluded from Analysis Due to Unusual Prolonged Interpretation Times[a]

Cause	Digital	Film-Screen	Total
Section chief wanted to talk about unrelated matters	1	0	1
Radiologist looked for a pen	0	1	1
Radiologist looked for a ruler	0	1	1
Technologist came in to talk about a different case	0	1	1
A pile of films fell over and the radiologist straightened it up	1	0	1
Computer used for entry of MagView[b] reports failed and had to be restarted	3	0	3
Total	5	3	8

[a] Examinations were interpreted and timed, but interpretation time was prolonged by an unusual circumstance.

[b] Automated report-entering program (Mammography Information Management System, MagView).

TABLE 2

Aborted Studies[a]

Cause	Digital	Film-Screen	Total
Images did not come up properly on PACS	3	0	3
Unspecified computer failure	1	0	1
Unspecified cause	2	0	2
Comparison study needed	0	6	6
Total	6	6	12

[a] Interpretation begun but abandoned without issuance of a report.

TABLE 3

Comparisons by Groups

Type of Examination	Four Views	More Than Four Views	*p*
Digital mammography	167 s	238 s	< 0.0001
Film-screen mammography	113 s	152 s	< 0.0001
p	< 0.0001	< 0.0001	
	BI-RADS Category 1 or 2	BI-RADS Category 0	
Digital mammography	202 s	353 s	< 0.0001
Film-screen mammography	110 s	209 s	< 0.0001
p	< 0.0001	< 0.0004	
	Films Hung by Radiologist	No Films Hung by Radiologist	
Digital mammography	320 s	214 s	< 0.0001
Film-screen mammography	201 s	117 s	< 0.0001
p	0.5329	< 0.0001	
	Comparison Studies Available	No Comparison Studies Available	
Digital mammography	226 s	194 s	0.0014
Film-screen mammography	145 s	89 s	0.0332
p	< 0.0001	< 0.0001	

Note—Unless otherwise specified, data are mean interpretation time in seconds.