

# Mammographic Features of Breast Cancers at Single Reading with Computer-aided Detection and at Double Reading in a Large Multicenter Prospective Trial of Computer-aided Detection: CADET II<sup>1</sup>

Jonathan J. James, FRCR  
Fiona J. Gilbert, FRCR  
Matthew G. Wallis, FRCR  
Maureen G. C. Gillan, PhD  
Susan M. Astley, PhD  
Caroline R. M. Boggis, FRCR  
Olorunsola F. Agbaje, PhD  
Adam R. Brentnall, PhD  
Stephen W. Duffy, MSc

## Purpose:

To evaluate the mammographic features of breast cancer that favor lesion detection with single reading and computer-aided detection (CAD) or with double reading.

## Materials and Methods:

The Computer Aided Detection Evaluation Trial II study was approved by the ethics committee, and all participants provided written informed consent. A total of 31057 women were recruited from three screening centers between September 2006 and August 2007. They were randomly allocated to the double reading group, the single reading with CAD group, or the double reading and single reading with CAD group at a ratio of 1:1:28, respectively. In this study, cancers in the women whose mammograms were read with both single reading with CAD and double reading were retrospectively reviewed. The original mammograms were obtained for each case and reviewed by two of three experienced breast radiologists in consensus. The method of detection was noted. The size and predominant mammographic feature of the cancer were recorded, as was the breast density. CAD marking data were reviewed to determine if the cancer had been correctly marked.

## Results:

A total of 227 cancers were detected in 28204 women. A total of 170 cases were recalled with both reading regimens. Lesion types were masses (66%), microcalcifications (25%), parenchymal deformities (6%), and asymmetric densities (3%). The ability of the reading regimens to correctly prompt the reader to recall cases varied significantly by lesion type ( $P < .001$ ). More parenchymal deformities were recalled with double reading, whereas more asymmetric densities were recalled with single reading with CAD. There was no difference in the ability of either reading regimen to prompt the reader to correctly recall masses or microcalcifications. CAD correctly prompted 100% of microcalcifications, 87% of mass lesions, 80% of asymmetric densities, and 50% of parenchymal deformities. CAD correctly marked 93% of spiculated masses compared with 80% of ill-defined masses ( $P = .054$ ). There was a significant trend for cancers detected with double reading to occur only in women with a denser mammographic background pattern ( $P = .02$ ). Size had no effect on lesion detection.

## Conclusion:

Readers using either single reading with CAD or double reading need to be aware of the strengths and weaknesses of reading regimens to avoid missing the more challenging cancer cases.

©RSNA, 2010

<sup>1</sup>From the Aberdeen Biomedical Imaging Centre, University of Aberdeen, Aberdeen, Scotland. From the 2009 RSNA Annual Meeting. Received November 6, 2009; revision requested January 4, 2010; received February 5; accepted February 12; final version accepted February 23. Supported by a grant from Cancer Research UK. **Address correspondence to** J.J.J., Nottingham Breast Institute, Nottingham City Hospital, Hucknall Road, Nottingham NG5 1PB, England (e-mail: [jonathan.james@nuh.nhs.uk](mailto:jonathan.james@nuh.nhs.uk)).

Computer-aided detection (CAD) is used to aid in the interpretation of screening mammograms. The CAD system places prompts on the image to draw the attention of the reader to potential areas of concern, with the aim being to reduce observational oversights. In many countries, single reading of screening mammograms is normal, and CAD has been widely adopted. In the United States, it is estimated that 25%–30% of all mammographic interpretations involve the use of CAD (1). The ability of CAD to improve cancer detection rates remains controversial (2).

In the National Health Service Breast Screening Programme (NHSBSP) in the United Kingdom, double reading of screening mammograms is standard practice. Double reading has been shown to increase cancer detection rates by 4%–14% (3). This method of reading is more expensive than single reading and may be difficult to achieve on the grounds of cost and manpower limitations. Consequently, there has been interest in comparing single reading with CAD with double reading to see if the use of CAD can bring the results achieved with single reading up

to the level achieved with double reading (3–7).

To obtain robust evidence for the use of CAD in this way, the NHSBSP set up a multicenter prospective randomized controlled trial in which single reading with CAD was compared with double reading. In the recent Computer Aided Detection Evaluation Trial II (CADET II), researchers found that the two reading regimens had equivalent cancer detection rates (3). The vast majority of cancers detected in the study were picked up by the reader using CAD and by the double readers; however, some cancers were detected with one reading regimen and missed with the other. The relative accuracy of the two modes of detection has been described previously (3). The aim of this study was to evaluate the mammographic features of breast cancer that favor lesion detection with single reading and CAD or with double reading.

### Materials and Methods

The CADET II study was a prospective randomized trial in which single reading with CAD was compared with double reading as part of the NHSBSP. The study was approved by the South East Multi-Centre Research Ethics Committee, and written informed consent was obtained from all participants.

A total of 31 057 women were recruited between September 2006 and August 2007 at three screening centers (Nottingham, England; Coventry, England; and Manchester, England). The women were randomly allocated to have their mammograms read in one of three ways: In the first group, only double reading was performed (standard NHSBSP practice). In the second, only single reading with CAD was performed. In the third, both double reading and single reading with

CAD were performed. The randomization ratio was 1:1:28, respectively.

Mammograms were acquired with analog (nondigital) systems and screen-film mammography. All equipment met the quality assurance standards of the NHSBSP. The mammograms acquired in the women in this trial were digitized and analyzed with an ImageChecker DMax computer-aided detection system (version 8.1; Hologic/R2 Technology, Bedford, Mass). The software detection algorithm was set to operate at a detection sensitivity of approximately 88% for masses and 95% for calcifications, with corresponding false marker rates of 1.5 and 1.0, respectively, as was typical for four-film mammography.

The readers in the CADET II study were 17 radiologists (including J.J.J., M.G.W., and C.R.M.B.), two breast cancer clinicians, and eight technologists who were trained to read film images (radiographers). All readers met the NHSBSP standard of reading at least 5000 screening mammograms per year. Readers who performed single reading with CAD had a median of 6 years of screening mammography experience (range, 3–22 years; interquartile range, 4–14 years). In the double reading group, the first readers who performed double reading also had a median of 6 years of experience (range, <1 year to 22 years; interquartile range, 4–14 year), whereas the second readers had

### Advances in Knowledge

- The ability of single reading with computer-aided detection (CAD) and that of double reading to enable readers to correctly recall patients with breast cancer varies significantly according to the mammographic appearance.
- There is a greater propensity for double reading to recall cancers appearing as parenchymal deformities and for single reading with CAD to recall cancers appearing as asymmetric densities.
- Cancers detected by means of double reading but missed by a single reader using CAD are more likely to occur in women with a denser mammographic background pattern.
- Lesion size has no effect on cancer detection with either reading regimen.

### Implication for Patient Care

- Readers using either single reading with CAD or double reading need to be aware of the strengths and weaknesses of each reading regimen to avoid missing the more challenging cancer cases.

### Published online

10.1148/radiol.10091899

**Radiology 2010**; 256:379–386

### Abbreviations:

CAD = computer-aided detection  
CADET II = Computer Aided Detection Evaluation Trial II  
NHSBSP = National Health Service Breast Screening Programme

### Author contributions:

Guarantors of integrity of entire study, J.J.J., F.J.G., O.F.A.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, J.J.J., A.R.B.; clinical studies, J.J.J., F.J.G., M.G.W., S.M.A., C.R.M.B.; statistical analysis, O.F.A., A.R.B., S.W.D.; and manuscript editing, J.J.J., F.J.G., M.G.W., M.G.C.G., A.R.B.

Authors stated no financial relationship to disclose.

slightly less experience (median, 5 years; range, < 1 year to 22 years; interquartile range, 2–10 years). Less experienced readers were paired with more experienced readers for double reading. All the film images were independently double read or single read with CAD by different readers who were blinded to the recall decision made with the other reading regimen.

The primary outcome measures of the CADET II study were cancer detection rates and recall rates in the women whose film images were single read with CAD and double read. The details of the trial protocol and the results of this primary analysis have been published elsewhere (3).

Cancers were identified in the women whose mammograms were single read with CAD and double read. The original screening mammograms were obtained and retrospectively reviewed by two of three breast radiologists (J.J.J., F.J.G., M.G.W.; 9–18 years of experience reading screening mammograms in the NHS-BSP) in consensus. Patients with cancer in the other two arms of the CADET II study in which only double reading or only single reading with CAD was performed were not included. The size, predominant radiographic feature, and reading method used to detect the cancer were recorded. Breast density was determined by using a visual analog scale (8). The CAD prompt data were also reviewed, and a note was made as to whether the cancer had been correctly prompted with the appropriate CAD mark placed over the lesion.

We used  $\chi^2$  tests (global and trend tests) for statistical analysis, except when a small sample size indicated that these tests might be unstable, in which case nonparametric bootstrap  $\chi^2$  tests with 5000 replications were performed (9). When individual features were interpreted as significant ( $P < .05$ ), it was based on decomposition of the global  $\chi^2$  test statistic. Cases with missing data were excluded from statistical analysis.

## Results

A total of 227 cancers were detected in 28204 women whose mammograms were single read with CAD and double

**Table 1**

### Predominant Mammographic Feature of Cancer Cases and Recall Status by Reading Regimen

Lesion Type	Recall Status by Reading Regimen			Total
	Double Reading Only	Single Reading with CAD Only	Double Reading and Single Reading with CAD	
Mass	13 (48)	16 (59)	116 (70)	145 (66)
Calcification	6 (22)	7 (26)	41 (25)	54 (25)
Parenchymal deformity	7 (26)	1 (4)	6 (4)	14 (6)
Asymmetric density	1 (4)	3 (11)	2 (1)	6 (3)
Total	27	27	165	219 (100)
Unknown	2	1	5	8

Note.—Data are numbers of cases, and data in parentheses are percentages.

read. The overall cancer detection rate was 8.0 per 1000 women screened. The cancer detection rates for single reading with CAD and double reading were equivalent. (Detection rates were 7.02 per 1000 women screened and 7.06 per 1000 women screened, respectively).

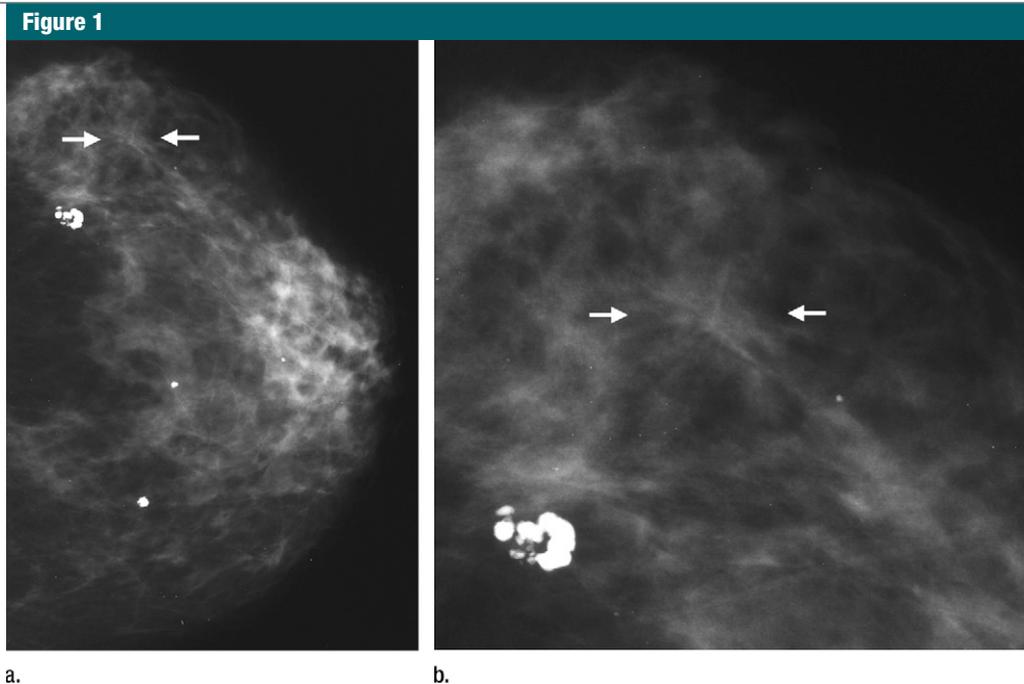
Table 1 shows the predominant mammographic features of all the cancer cases and the recall decision for each reading regimen. A total of 170 cases were recalled with both reading regimens, yielding a concordance rate of 74.9%. Masses were by far the most common lesion type (66%) and dominated the group correctly recalled with both single reading with CAD and double reading. The ability of readers to correctly recall cancers on the basis of mammographic appearance varied significantly between reading regimens ( $P < .001$ ). This was chiefly evidenced by a greater propensity for cancers appearing as parenchymal deformities to be recalled with double reading (Fig 1) and for cancers appearing as asymmetric densities to be recalled with single reading with CAD (Fig 2); however, it was not evidenced by a difference in the ability of readers using either reading regimen to correctly recall patients whose cancer manifested as masses or microcalcifications. It should be noted that the number of patients with asymmetric densities was small.

Table 2 shows the characteristics of cancer cases that manifested as mass lesions and the recall decision of each reading regimen. Single reading with CAD performed slightly better than

double reading in the detection of spiculated masses, but overall there was no significant difference in the ability of either reading regimen to detect different mass types ( $P = .20$ ).

CAD was significantly better at correctly marking microcalcifications than at correctly marking any other mammographic feature ( $P = .007$ ) (Fig 3, Table 3). In cases in which CAD marking data were available, CAD correctly marked all (100%) cases in which the predominant mammographic feature was microcalcifications and 87% of cases in which the predominant mammographic feature was a mass lesion. The ability of CAD to correctly mark masses and microcalcifications was significantly better than that of CAD to correctly mark parenchymal deformities ( $P < .001$ ). CAD correctly marked only 50% of the cancers that manifested as parenchymal deformities. The performance of CAD in correctly marking cancers that manifested as ill-defined masses was not as good as its performance in correctly marking cancers that manifested as spiculated masses (Table 4), with 93% of spiculated masses and only 80% of ill-defined masses being correctly marked ( $P = .054$ ).

There was a significant tendency for cancers to be detected with double reading but missed with single reading with CAD in women with a denser background parenchymal pattern ( $P = .02$ ) (Table 5). Neither the size of the mammographic abnormality ( $P = .32$ ) (Table 6) nor the number of flecks of microcalcification present ( $P = .2$ ) (Table 7)



**Figure 1:** Screening mammogram in a 63-year-old woman recalled for a 10-mm area of parenchymal deformity (arrows) in the lateral aspect of the left breast. **(a)** This deformity was seen in only the craniocaudal projection. **(b)** A magnified view of the parenchymal deformity is also shown. The case was recalled by the double readers but not by the single reader using CAD. The parenchymal deformity was not marked by CAD. Ultrasonography (US) revealed a 5-mm area of acoustic shadowing, and core biopsy was performed. Final pathologic analysis revealed a 10-mm ductal carcinoma, with a histologic grade of 1 and no involved lymph nodes.

had any effect on lesion detection with single reading with CAD or double reading.

### Discussion

The CADET II study showed that the cancer detection rates attained with single reading with CAD were equivalent to those attained with double reading. There were some cancers that were missed with one reading regimen but detected with the other. The results of this study suggest that there are radiologic features that favor detection with one reading regimen over the other.

Double reading and single reading with CAD performed equally well at recalling patients with cancer in whom the predominant radiologic feature was either a mass or a microcalcification. Double reading showed superior performance in the detection of cancers that manifested as parenchymal deformities. Single reading with CAD was better than double reading in the detection of cancers that manifested as asymmetric

densities, but it should be noted that the number of asymmetric densities was small and accounted for only 3% of the cancer cases. The poorer performance of CAD in the detection of architectural distortions has been reported (10–12). In one study, two different CAD systems detected less than half the cases of architectural distortion (10).

The performance of a single reader using CAD seems to be associated with the ability of CAD to correctly prompt the mammographic feature. In this study, CAD correctly prompted only 50% of the parenchymal deformities, whereas it correctly prompted 100% of cancers that manifested as microcalcifications and 87% of cancers that manifested as mass lesions. Parenchymal deformity is the third most common manifestation of malignancy on mammograms, and it is one of the most challenging radiographic features for the reader to detect (13). Even in the double reading setting, cancers that manifest as parenchymal deformities are frequently overlooked by readers and feature prominently in

studies that look at the radiographic features of interval and missed cancers in all age groups (14–19). An investigation of breast cancers diagnosed after arbitration of discordant double reading opinions also highlighted the difficulties readers have in identifying this abnormality (20). Despite these difficulties, double reading seems to offer the best prospect for detecting parenchymal deformities.

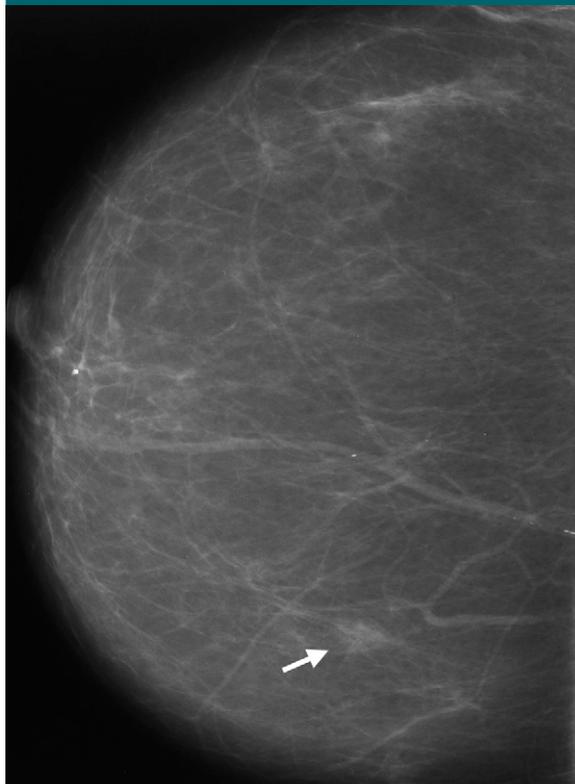
Lesion size had no effect on the performance of either reading regimen. Neither the size of a mass lesion nor the dimensions or number of flecks in a microcalcification cluster affected performance. The fact that lesion size has no effect on CAD performance has been described (21). In contrast, breast density does have some bearing on cancer detection, with a significant trend for double reading to perform better than single reading with CAD in women with denser background patterns. Whether the performance of CAD is affected by breast density is a controversial topic. Some studies have shown that the ability of CAD to correctly mark breast

cancers is unaffected by breast density, whereas one study showed a decrease in the sensitivity of CAD in very dense breast tissue (from 93.9% to 64.3%) (22–24). The differences may well reflect the case mix, with microcalcifications being consistently correctly prompted even in patients with dense background patterns. It is well established that breast density is affected by age. Studies of double reading in younger women have shown that parenchymal deformity is a more frequent sign of malignancy (16). This cannot be explained by pathologic features. It is probably the result of mass lesions that would appear spiculated in a fatty breast having the appearance of a parenchymal deformity in denser breasts because the central density of the mass becomes obscured by overlapping normal dense breast tissue; thus, only the spicules remain visible. Our results have shown the improved performance of double reading in the detection of parenchymal deformities. This may also explain the small but significant trend for double reading to perform better in patients with denser breasts.

It is probably not surprising that the performance of CAD in the detection of parenchymal deformities is inferior compared with the performance of CAD in the detection of microcalcifications and mass lesions. The CAD algorithms that generate the prompt data are heavily reliant on the presence of a central density for correct prompting. Parenchymal deformities by their nature lack a central mass, and unless the radiating lines are pronounced, they are unlikely to be prompted (10). This is to prevent too many false prompts from crossing the Cooper ligaments or overlapping normal tissue. It may be that further algorithm development is required to aid in the detection of parenchymal deformities, particularly in patients with denser background patterns.

The high sensitivity of CAD to correctly mark microcalcifications is not in doubt. We found that 100% of microcalcifications and only 87% of mass lesions were marked correctly. These findings are consistent with the findings of other studies (12,21,25,26). There was no significant difference in performance

Figure 2



**Figure 2:** Mammogram in a 60-year-old woman recalled for a small 8-mm area of asymmetric density (arrow) in the medial aspect of the right breast. The case was recalled by a single reader using CAD but not by the double readers. US depicted a small area of reduced echogenicity that was sampled for biopsy and found to be lobular carcinoma. Final pathologic analysis revealed a multifocal lobular carcinoma with a histologic grade of 2 and no involved lymph nodes.

Table 2

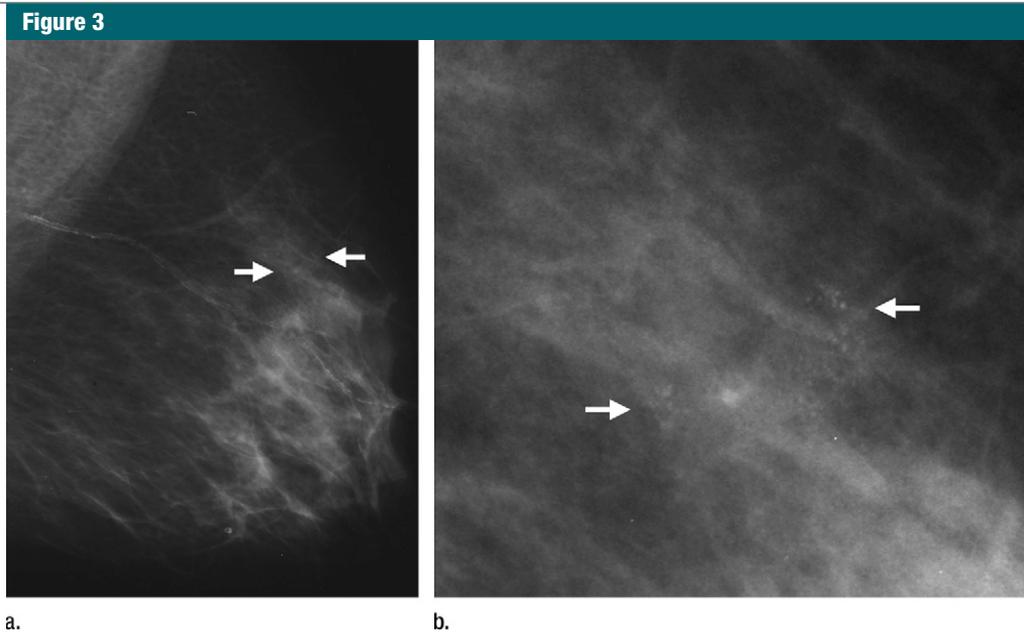
## Mammographic Features of Masses and Recall Status by Reading Regimen

Mass Characteristic	Recall Status by Reading Regimen			Total
	Double Reading Only	Single Reading with CAD Only	Double Reading and Single Reading with CAD	
Ill-defined mass	6 (50)	5 (31)	49 (42)	60 (42)
Well-defined mass	2 (17)	0 (0)	6 (5)	8 (6)
Spiculated mass	4 (33)	11 (69)	61 (53)	76 (53)
Total	12	16	116	144 (100)
Unknown	1	0	0	1

Note.—Data are numbers of cases, and data in parentheses are percentages.

between reading regimens in the detection of microcalcifications. Interestingly, despite the 100% correct prompting of microcalcifications, there were six malignant microcalcification cases that were not recalled by the single reader using CAD but were detected at double reading. If all the correctly placed calcification prompts had been acted on, single reading with CAD would have outperformed double reading in the detection of microcalcifications. In many retrospective studies of single reading with CAD,

the researchers assume that if a lesion is prompted, it will be recalled. Clearly, this is not the case. This prospective study, like others before it, has shown that correctly placed prompts are sometimes dismissed by the reader, and the patient is not recalled (4,27,28). It is the number of false prompts that adversely affects performance. False prompts may just distract the reader, or—because so many false prompts have to be ignored—it may be that correctly placed prompts are overlooked on occasion.



**Figure 3:** Screening mammogram in a 62-year-old woman with an area of microcalcifications (arrows) in the upper half of the left breast. **(a)** This finding was best seen in the oblique projection. **(b)** A magnified view of the area shows a 10-mm area of rather faint granular microcalcifications (arrows). The case was recalled by the double readers but not by the single reader using CAD. However, the CAD system correctly marked the microcalcifications on the oblique and craniocaudal projections. Stereotactic vacuum-assisted biopsy was performed. Final pathologic analysis after breast-conserving surgery revealed a 15-mm area of intermediate-grade ductal carcinoma in situ.

**Table 3****CAD Marking of Different Lesion Types**

CAD Mark on Region of Interest	Lesion Type				Total
	Mass	Microcalcifications	Parenchymal Deformity	Asymmetric Density	
No	17 (13)	0 (0)	7 (50)	1 (20)	25 (12)
Yes	117 (87)	48 (100)	7 (50)	4 (80)	176 (88)
Total	134	48	14	5	201 (100)
Unknown	11	6	0	1	18

Note.—Data are numbers of cases, and data in parentheses are percentages.

**Table 4****CAD Marking of Different Mass Lesion Types**

CAD Mark on Region of Interest	Mass Features			Total
	Ill-defined Mass	Well-defined Mass	Spiculated Mass	
No	11 (20)	0 (0)	5 (7)	16 (12)
Yes	45 (80)	7 (100)	66 (93)	118 (88)
Total	56	7	71	134 (100)
Unknown	5	1	5	11

Note.—Data are numbers of cases, and data in parentheses are percentages.

Overall, there was no difference between reading regimens in the ability of readers to correctly recall cancers manifesting as mass lesions. If different types of mass lesions are specifically looked at, single reading with CAD may be more inclined than double reading to detect spiculated mass lesions; however, this difference was not significant. This is explained by the improved ability of CAD to correctly mark spiculated masses compared with ill-defined masses. In this study, spiculated mass lesions were the most common mass subtype, accounting for 53% of the cancer mass lesions. Overall, CAD correctly prompted 87% of mass lesions; however, cancers that manifested as spiculated masses were marked correctly in 93% of cases, whereas only 80% of cancers that manifested as ill-defined masses were marked correctly. CAD algorithms are specifically designed to prompt this frequently occurring mass lesion with a high degree of accuracy because of its high positive predictive value for malignancy. The algorithm recognizes a combination of a central density and

**Table 5****Breast Density of Cancer Cases and Recall Status by Reading Regimen**

Breast Density (%)	Recall by Reading Regimen			Total
	Double Reading Only	Single Reading with CAD Only	Double Reading and Single Reading with CAD	
≤25	4 (14)	11 (41)	46 (28)	61 (28)
26–50	11 (39)	10 (37)	71 (43)	92 (42)
51–75	10 (36)	5 (18)	44 (27)	59 (27)
>75	3 (11)	1 (4)	4 (2)	8 (4)
Total	28	27	165	220 (100)
Unknown	1	1	5	7

Note.—Data are numbers of cases, and data in parentheses are percentages.

**Table 6****Cancer Size and Recall Status by Reading Regimen**

Cancer Size (mm)	Recall by Reading Regimen			Total
	Double Reading Only	Single Reading with CAD Only	Double Reading and Single Reading with CAD	
<15	14 (52)	15 (56)	73 (44)	102 (47)
15–30	13 (48)	9 (33)	73 (44)	95 (43)
>30	0 (0)	3 (11)	19 (12)	22 (10)
Total	27	27	165	219 (100)
Unknown	2	1	5	8

Note.—Data are numbers of cases, and data in parentheses are percentages.

**Table 7****Calcification Cluster Size and Recall Status by Reading Regimen**

Cluster Size	Recall by Reading Regimen			Total
	Double Reading Only	Single Reading with CAD Only	Double Reading and Single Reading with CAD	
Noncalcification cases	21 (78)	20 (74)	124 (75)	165 (75)
Small clusters (1–5 flecks)	0 (0)	0	3 (2)	3 (1)
Medium clusters (6–19 flecks)	3 (11)	6 (22)	13 (8)	22 (10)
Large clusters (>20 flecks)	3 (11)	1 (4)	25 (15)	29 (13)
Total	27	27	165	219 (100)
Unknown	2	1	5	8

Note.—Data are numbers of cases, and data in parentheses are percentages.

radiating lines as a highly specific predictor of malignancy.

Cancers that manifested as asymmetric densities were more likely to be detected with single reading with CAD

than with double reading. However, it should be noted that the number of asymmetric densities was small and accounted for only six (3%) of the cancer cases. Asymmetries represent

another challenging radiologic feature that is frequently misinterpreted and is a common cause of interval cancers (18,19). Asymmetries can also be a challenge to CAD algorithms, requiring the computer to potentially learn about both normal and abnormal relationships between left and right breast images (27). CAD performed well in this study, correctly marking 80% of the asymmetric density cases; however, the number of cases was small. Others have reported poorer performance of CAD in marking this type of lesion, with only 37% of asymmetric densities correctly marked (12). In our study, the failure of readers to detect a malignant asymmetry probably has more to do with an error of interpretation rather than an error of search and detection. The success of single reading with CAD for asymmetries may be due to the reader re-examining a prompted area more carefully after having previously dismissed it.

Several limitations need to be considered. In the CADET II study, researchers used analog mammography systems to acquire the images. The film mammograms were then processed through the digitizer of the CAD system. Digital mammography is becoming increasingly widely used for screening mammography. Further research would be needed to confirm that the results were applicable to an all-digital environment. The readers in the CADET II study included a mixture of radiologists, breast cancer clinicians, and technologists who were trained to read film images (radiographers), who performed both double reading and single reading with CAD. This reflects practice in the United Kingdom screening program, but it is different from the situation in many other countries, including the United States, where radiologist interpretation is the standard. There were newly qualified readers (>1 year of reading experience) in the double reading arm of the CADET II study. However, it is unlikely that this affected the performance of double reading, as inexperienced readers were paired with readers with more experience. The experience of the readers who performed single reading with CAD was comparable to that of the readers who

performed the first of two reads in the double reading arm of the study. All the readers who participated in CADET II were high-volume readers who fulfilled the NHSBSP standard of reading 5000 screen films per year. In addition, studies have shown that radiologists and appropriately trained radiographers have similar sensitivity in the detection of cancers on screening mammograms (29).

The CADET II study has shown that cancer detection with single reading and CAD is equivalent to that with double reading. The detection of cancers where the predominant mammographic feature was a mass or calcification was equivalent, but some radiologic features were better detected with one reading regimen over the other. Double reading performed better in the detection of cancers that manifested as distortions and in women with a denser background pattern. Single reading with CAD performed better in the detection of cancers in which asymmetric density was the mammographic feature. Readers using either single reading with CAD or double reading need to be aware of the strengths and weakness of each regimen, and they need to increase their vigilance to avoid missing these more challenging cancer cases.

## References

- Lindfors KK, McGahan MC, Rosenquist CJ, Hurlock GS. Computer-aided detection of breast cancer: a cost-effectiveness study. *Radiology* 2006;239(3):710-717.
- Fenton JJ, Taplin SH, Carney PA, et al. Influence of computer-aided detection on performance of screening mammography. *N Engl J Med* 2007;356(14):1399-1409.
- Gilbert FJ, Astley SM, Gillan MG, et al. Single reading with computer-aided detection for screening mammography. *N Engl J Med* 2008;359(16):1675-1684.
- Khoo LA, Taylor P, Given-Wilson RM. Computer-aided detection in the United Kingdom National Breast Screening Programme: prospective study. *Radiology* 2005;237(2):444-449.
- Taylor P, Potts HW. Computer aids and human second reading as interventions in screening mammography: two systematic reviews to compare effects on cancer detection and recall rate. *Eur J Cancer* 2008;44(6):798-807.
- Gilbert FJ, Astley SM, McGee MA, et al. Single reading with computer-aided detection and double reading of screening mammograms in the United Kingdom National Breast Screening Program. *Radiology* 2006;241(1):47-53.
- Bennett RL, Blanks RG, Moss SM. Does the accuracy of single reading with CAD (computer-aided detection) compare with that of double reading?: a review of the literature. *Clin Radiol* 2006;61(12):1023-1028.
- Duffy SW, Nagtegaal ID, Astley SM, et al. Visually assessed breast density, breast cancer risk and the importance of the craniocaudal view. *Breast Cancer Res* 2008;10(4):R64.
- Davidson AC, Hinkley DV. *Bootstrap methods and their application*. Cambridge, England: Cambridge University Press, 1997.
- Baker JA, Rosen EL, Lo JY, Gimenez EI, Walsh R, Soo MS. Computer-aided detection (CAD) in screening mammography: sensitivity of commercial CAD systems for detecting architectural distortion. *AJR Am J Roentgenol* 2003;181(4):1083-1088.
- Ko JM, Nicholas MJ, Mendel JB, Slanetz PJ. Prospective assessment of computer-aided detection in interpretation of screening mammography. *AJR Am J Roentgenol* 2006;187(6):1483-1491.
- Taplin SH, Rutter CM, Lehman CD. Testing the effect of computer-assisted detection on interpretive performance in screening mammography. *AJR Am J Roentgenol* 2006;187(6):1475-1482.
- Sickles EA. Mammographic features of 300 consecutive nonpalpable breast cancers. *AJR Am J Roentgenol* 1986;146(4):661-663.
- Burrell HC, Sibbering DM, Wilson AR, et al. Screening interval breast cancers: mammographic features and prognosis factors. *Radiology* 1996;199(3):811-817.
- Evans AJ, Kutt E, Record C, Waller M, Bobrow L, Moss S. Radiological and pathological findings of interval cancers in a multi-centre, randomized, controlled trial of mammographic screening in women from age 40-41 years. *Clin Radiol* 2007;62(4):348-352.
- Evans AJ, Kutt E, Record C, Waller M, Moss S. Radiological findings of screen-detected cancers in a multi-centre randomized, controlled trial of mammographic screening in women from age 40 to 48 years. *Clin Radiol* 2006;61(9):784-788.
- Warren RM, Young JR, McLean L, et al. Radiology review of the UKCCCR Breast Screening Frequency Trial: potential improvements in sensitivity and lead time of radiological signs. *Clin Radiol* 2003;58(2):128-132.
- Duncan KA, Needham G, Gilbert FJ, Deans HE. Incident round cancers: what lessons can we learn? *Clin Radiol* 1998;53(1):29-32.
- Daly CA, Apthorp L, Field S. Second round cancers: how many were visible on the first round of the UK National Breast Screening Programme, three years earlier? *Clin Radiol* 1998;53(1):25-28.
- Cornford EJ, Evans AJ, James JJ, Burrell HC, Pinder SE, Wilson AR. The pathological and radiological features of screen-detected breast cancers diagnosed following arbitration of discordant double reading opinions. *Clin Radiol* 2005;60(11):1182-1187.
- Brem RF, Hoffmeister JW, Zisman G, DeSimio MP, Rogers SK. A computer-aided detection system for the evaluation of breast cancer by mammographic appearance and lesion size. *AJR Am J Roentgenol* 2005;184(3):893-896.
- Brem RF, Hoffmeister JW, Rapelyea JA, et al. Impact of breast density on computer-aided detection for breast cancer. *AJR Am J Roentgenol* 2005;184(2):439-444.
- Birdwell RL, Ikeda DM, O'Shaughnessy KF, Sickles EA. Mammographic characteristics of 115 missed cancers later detected with screening mammography and the potential utility of computer-aided detection. *Radiology* 2001;219(1):192-202.
- Ho WT, Lam PW. Clinical performance of computer-assisted detection in detecting carcinoma in breasts of different densities. *Clin Radiol* 2003;58(2):133-136.
- Freer TW, Ulissey MJ. Screening mammography with computer-aided detection: prospective study of 12,860 patients in a community breast center. *Radiology* 2001;220(3):781-786.
- Malich A, Marx C, Facius M, Boehm T, Fleck M, Kaiser WA. Tumour detection rate of a new commercially available computer-aided detection system. *Eur Radiol* 2001;11(12):2454-2459.
- Astley SM, Gilbert FJ. Computer-aided detection in mammography. *Clin Radiol* 2004;59(5):390-399.
- Taylor P, Given-Wilson R, Champness J, Potts HW, Johnston K. Assessing the impact of CAD on the sensitivity and specificity of film readers. *Clin Radiol* 2004;59(12):1099-1105.
- van den Biggelaar FJ, Nelemans PJ, Flobbe K. Performance of radiographers in mammogram interpretation: a systematic review. *Breast* 2008;17(1):85-90.