Effects of Lesion Conspicuity on Visual Search in Mammogram Reading[1]

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Rationale and Objectives. The goal of mammography screening is to detect breast cancer at early stages, but because of the complexity of the breast parenchyma and the variability of signs of the disease, many cancers go unreported when initially visible on the mammogram. We compared the visual search strategy used by experienced mammographers in a case set where they examined both the mammogram in which a malignant mass was discovered at screening mammography and the most recent prior mammogram.

Materials and Methods. Four experienced mammographers participated in this experiment. They read a case set of 20 two-view mammograms, of which 15 contained a malignant mass and 5 were lesion-free, in two trials. For each of the cancer cases, two versions were shown to the observers: the one in which the cancer was reported in the clinical practice, called the "current" mammograms, and the most recent prior. Each trial had a balanced mix of current and prior mammograms. In addition, the same set of lesion-free cases was shown to the observers in both trials. The eye movements of the observers were tracked, and visual search parameters such as time to hit the location of the malignant mass, dwell, and mean pupil size in the location of the cancer were collected. Statistical analyses were used to determine whether there were differences between the current and prior mammograms.

Results. A total of 66% of the malignant masses in the current mammograms and 57% in the priors attracted some amount of visual attention. From these, 71% yielded a report on the current mammograms, but only 40% on the priors. In the cases where the observer saw the malignant mass, they did so within 2 seconds of image display, regardless of whether the mammogram was current or prior.

Conclusion. Most unreported malignant masses attracted some amount of visual attention, but it was in the processing of the information extracted in the location of the lesion that most errors occurred. In our experiment, approximately 70% of the total time used by the observers for visual scan of the cases was spent gathering information to corroborate the hypothesis already formed by the radiologist.

Key Words. Eye movements; mammography; visual perception.

Breast cancer is one of the main causes of morbidity and mortality for women in the United States. In recent decades the incidence of this disease has increased sharply (1,2), but mortality rates have stabilized or decreased (1–3). This combination of factors suggests a substantial improvement in prognosis (4). Moreover, early cancer detection is a fundamental element for long-term survival (5–8). In 2004, nearly 40 million mammograms were expected to be performed in the United States (9). However, the prevalence of cancer in the screening population is only 4–5 cancers/1,000 cases (10), which makes the radiologists' detection task very difficult. Compounding

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this are several factors involved in cancer detection, such as the complexity of the breast parenchyma (11), the subtlety of the initial signs of the disease (12), and the experience level of the radiologist (13). Combined, these factors contribute to the radiologists' ability to disembed possible findings from the background and to determine, both by using comparisons of the possible findings with selected areas of the background and an internal database gained through personal experience of viewing actually positive and negative mammograms, whether the finding needs additional workup. Furthermore, this detection/interpretation task has to be performed effectively, at a cost of a reasonable number of false-positive decisions. Hence, radiologists have to set up an internal compromise between what to recall and what to let go; perhaps because of this compromise, it has been shown that 5%–69% of breast cancers are not reported when initially visible on a mammogram (14).

In mammography, gaze duration at a given location has been shown to correlate with decision outcome at the location (15,16). Nodine et al (16) compared visual dwell of expert mammographers and less experienced radiology residents in the location of reported and missed cancers. They showed that most breast lesions were detected by the mammographers within 25 seconds of viewing the image, and that prolonging visual search after that point increased the risk of a false alarm. In another study, Nodine et al (17) used eye-position tracking to determine whether retrospectively visible cancers that were missed at screening were a result of faulty visual search (that is, the location of the cancer never attracted the eye), or a result of faulty perception/decision making criteria (in the cases in which the eye was attracted to the location of the lesion, but the radiologist ultimately dismissed the location as not containing a relevant finding). The authors used a test set that included mammograms depicting retrospectively visible cancers that were not reported at screening, which were called "retrospective" cases, and cancer cases that were reported by the radiologist at screening, which were called "prospective" cases. They concluded that most retrospectively visible cancers did not attract any amount of visual attention, a result that seems to suggest that faulty visual search is the main factor in explaining these misses. However, because this study used different cases in the prospective and retrospective groups, it is possible to argue that the results may have been biased by mismatch in the selection of the cases for each group. In other words, visual scan of the same lesion, but in two different mammograms—one belonging to the retrospective group, the other to the prospective group—was not compared. Such a comparison is necessary to determine how the conspicuity of the lesion affected the radiologist's perceptions on the case. Furthermore, Nodine et al's study used both masses and microcalcification clusters in its data set of cancer cases, which introduced an additional component of variability to the results, because the visual search strategy used to identify masses relies on how much the finding stands from the background, whereas the one used to identify microcalcifications relies on systematic scanning.

The purpose of this study is to compare the differences in the visual search strategy used by experienced mammographers when searching for the same malignant mass depicted in two conditions: in the mammogram in which the mass was discovered at mammography screening, and biopsy confirmed it to be cancer, called "current" images; and in the most recent prior mammogram, in which the mass was retrospectively deemed to be visible, but it was not reported by the radiologist at the time the case was read at screening, called "prior" images. Using this paired test set, we will determine the effects of lesion conspicuity on visual search, because the lesions in the prior cases are less conspicuous than the ones in the current cases. This is important because understanding how visual search changes as a function of lesion conspicuity gives us insights into the radiologist's perceptual/decision making strategy, and hence can provide us with a better understanding of where the perceptual link failed, thus allowing detected cancers to go unreported.

MATERIALS AND METHODS

Selection of the Mammograms

Using a large database of digitized cases available at our institution, we selected a case set of 20 two-view (craniocaudal and mediolateral oblique) mammogram cases. Of these, 15 cases contained one malignant mass, visible in one or two views, and 5 cases were lesion free and had been stable for 2 years. All cancer cases were confirmed by biopsy. In addition, all of the cancer cases contained two sets of mammograms: the ones in which the lesion was reported at mammography screening, and additional work-up revealed it to be cancer, called the "current" mammograms; and the most recent prior mammograms, in which the lesion was deemed retrospectively visible but was not originally reported, which we called the "prior" mammograms. To keep the comparison cases