Low-Dose Mammography[1]

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The authors describe an improved mammographic technique employing a single-emulsion film in combination with a high-definition intensifying screen. This technique significantly reduces the radiation dosage per exposure and enhances the contrast of the soft-tissue structures of the breast. Optimum film–screen contact is obtained by means of a vacuum cassette system. Short exposure times minimize motion unsharpness, favoring the preservation of radiographic detail.

INDEX TERMS: Breast Neoplasms, diagnosis • Films • Mammography, apparatus and equipment • Mammography, technique

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THERE IS no accurate information concerning the effects of irradiation on the breast as the result of routine mammographic examinations. An increased incidence of breast cancer has been reported among women undergoing multiple fluoroscopic examinations during treatment for pulmonary tuberculosis (3) and among Japanese women exposed during the bombing of Hiroshima and Nagasaki (8). A group of women treated with x rays for acute postpartum mastitis was found to have a greater incidence of breast cancer than a similar control group (4). However, none of these studies can be used to make comparisons with the much smaller surface doses that result from diagnostic mammography (2). Radiation exposure is of particular concern when large-scale screening projects designed for early detection of breast cancer are considered; a woman might undergo at least 20 studies during her lifetime.

In a program of annual periodic screening, Price and Butler (6) have shown that radiation and exposure time can be reduced by the use of nonscreen film and a single screen, vacuum-packed in a thin polyethylene envelope. We have reduced the radiation dosage still further, mindful of the need to obtain the maximum diagnostic information from the radiological procedure (1).

Accurate interpretation depends upon radiographic quality, *i.e.*, visibility of detail, particularly in the detection of significant microcalcifications and evaluation of the low-contrast soft-tissue structures of the breast. Currently accepted mammographic techniques employ either industrial or medical nonscreen film, both of which require relatively long exposures with correspondingly high radiation dosages and the risk of unsharpness due to patient motion. The use of a conventional double-emulsion film and intensifying screen system reduces the necessary exposure by at least 97% compared to that required for industrial film, but at the expense of a grainy image and unsharpness that some radiologists find unacceptable. There must be an optimum combination of factors which will provide minimal degradation of the radiographic image with no adverse effect upon diagnostic accuracy.

TABLE I: APPROXIMATE MAS at 30 KV (CRANIOCAUDAL VIEW OF AVERAGE-SIZED BREAST)

Type of Film	Relative mAs	Senographe (30.1 cm TFD)	Mammorex (68.9 cm TFD)
Single-emulsion film and intensifying screen	1	24 mAs 40 mA @ 0.6 sec.	125 mAs 100 mA @ 1.25 sec. (small focal spot)
Nonscreen film–medical (Osray–M)	2.4	60 mAs 40 mA @ 1.50 sec.	300 mAs 100 mA @ 3.0 sec. (small focal spot)
Nonscreen film–industrial (Kodak AA)	8	200 mAs 40 mA @ 5.0 sec.	1,000 mAs 250 mA @ 4.0 sec. (large focal spot)

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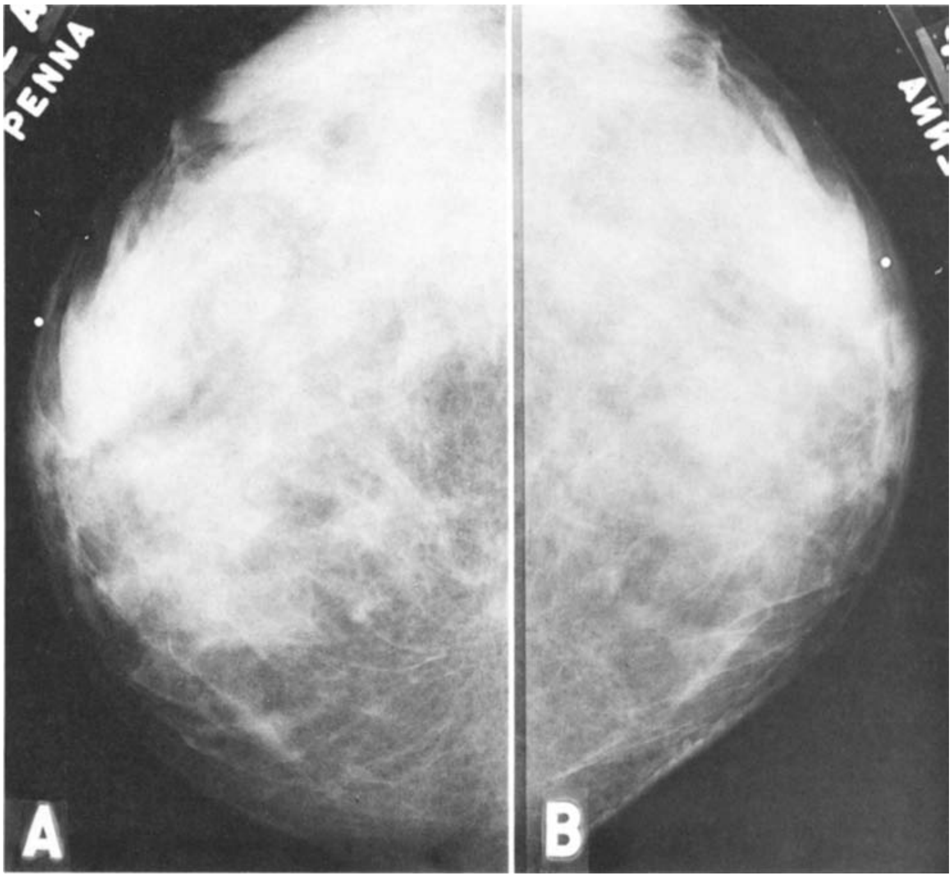

Fig. 1. Comparable craniocaudal views of the right breast (Senographe). A palpable mass is identified by the lead marker. A. Film–screen combination: 30 kV, 40 mA @ 0.5 sec. Note the sharp detail and enhanced contrast.
B. Kodak AA film: 30 kV, 40 mA @ 4.0 sec.

TABLE II: ADVANTAGES AND DISADVANTAGES OF THE TWO FILM–SCREEN SYSTEMS

Type of Film	Advantages	Disadvantages
Single-emulsion film–screen combination*	Low patient dose Enhanced contrast Rapid automatic processing Short exposure time Less motion unsharpness	Potential screen artifacts Minimal mottle
Nonscreen film (industrial type)	Grainless image	High patient dose Manual or prolonged automatic processing Long exposure time Motion unsharpness Overheating of x-ray tube

* Du Pont single-emulsion film and a single high-definition screen

FACTORS THAT AFFECT DIAGNOSTIC INFORMATION

Mottle: Inherent in radiographs is the element of "noise" or radiographic mottle, which is accentuated when screens are used. While the film grain and the screen structure contribute to the noise, the most important factor is quantum mottle, the result of fluctuations in the distribution of the x-ray quanta absorbed by the screens. There must be sufficient x-ray quanta to minimize such fluctuations and produce uniform film blackening. Rossmann (7) likens this phenomenon to the number of raindrops required to uniformly blacken a pavement. Only a few raindrops result in blotchy areas which disappear as more drops fall; analogously, the fewer quanta that are absorbed by the screen, the blotchier or noisier the film. Film speed is important; if a fast film is used, an image can be obtained with insufficient quanta but there will be objectionable radiographic mottle, while with a slow film radiographic mottle is reduced because it takes more quanta to form the image.

Sharpness: The use of screens introduces an element of unsharpness. With the conventional system of double-emulsion film and front and back screens, one factor is exposure of the emulsion on each side of the film from the screen in contact with the opposite side. This crossover exposure can be eliminated by the use of a single-emulsion film combined with a single screen. The intensifying screen should resolve in excess of 10 line pairs/

mm, which will ensure minimal loss of resolution.

Contrast: The breast is composed of soft tissue with low inherent contrast. Compared with nonscreen techniques, a film–screen system results in significantly improved contrast. However, conventional cassettes have not proved satisfactory as a means of housing the film and intensifying screen. Unless contact between the film and screen is maximum, contrast is lowered and sharpness is diminished. In addition, filtration due to the cassette material degrades the image, particularly in the low kV range.

TECHNICAL CONSIDERATIONS

A satisfactory combination of a relatively slow single-emulsion film and a high-definition screen which resolves in excess of 10 LP/mm was developed in conjunction with Du Pont. Optimum film–screen contact is obtained by wrapping them in interleaving paper to minimize static artifacts and placing them in a black, light-proof polyvinyl bag which is then vacuum-sealed by a Picker Vacuumatic. The resulting cassette is thin and slightly pliable compared with a rigid conventional cassette, and accurate positioning is easily accomplished. Previous experience has convinced us that radiographic quality is improved for any given mammographic film by the use of a molybdenum rather than tungsten anode tube, together with adequate compression of the breast. For several years we have used a Senographe unit with a molybdenum anode tube and filter, and we have recently had the occasion to evaluate the Picker Mammorex. Results have been eminently satisfactory with both units. Kilovoltage ranges are similar; moreover, since only short exposure times (0.5–2.0 seconds) are required, motion unsharpness is minimized. The differences in mAs readings reflect the differences in the target–film distances of the two units (TABLE I). The addition of phototiming, presently available with the Senographe, has resulted in more uniform film density.

DISCUSSION

The technique described here requires exposures approximately 1/8th of those needed for Kodak AA film. The advantages and disadvantages of the two methods are summarized in TABLE II. Not only is there no loss of radiographic quality compared to nonscreen mammography, but contrast is actually enhanced (Fig. 1) and breast microcalcifications are clearly visible (Figs. 2 and 3). Good darkroom technique is required to minimize screen artifacts. Dust particles are easily recognized as sharply defined white densities, and there should be little difficulty in differentiating them from calcium. Recorded skin radiation levels varied from 2.2 to 2.8 rads per film exposure, depending upon the size and composition of the breast. The dose reduction effectiveness is emphasized when comparison is made with doses ranging from 18.0 to 21.0 rads, similar to those reported by Palmer *et al.* (5), which we found necessary for adequate exposure of Kodak AA film. With this technique, repeated annual studies over a period of eight years would require no more irradiation than a single conventional examination.

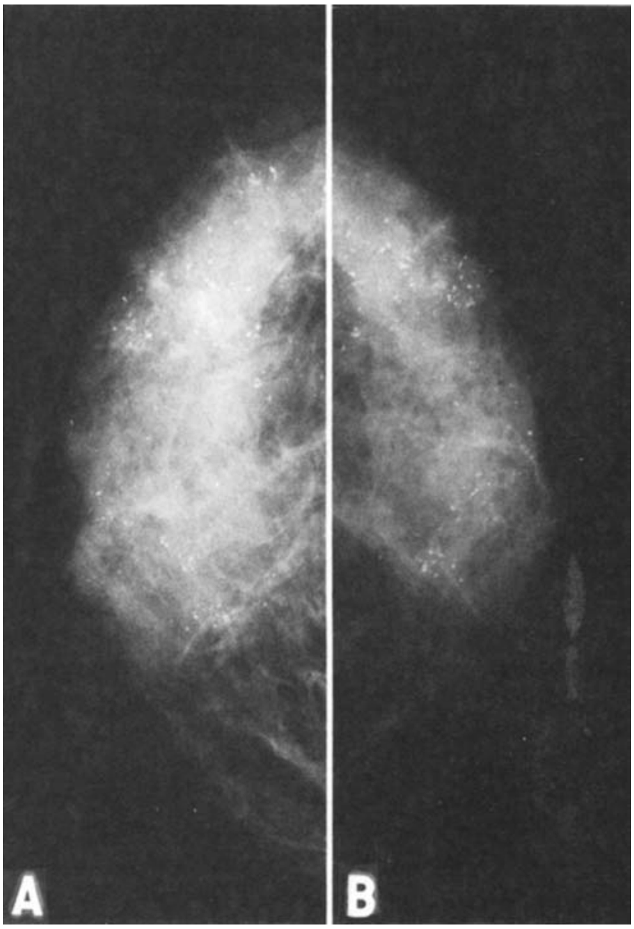

Fig. 2. Comparable craniocaudal views of the right breast (Mammorex). A. Film–screen combination: 30 kV, 100 mA @ 1.25 sec. (small focal spot). Malignant calcifications are sharply defined.
B. Kodak AA film: 30 kV, 250 mA @ 4.0 sec. (large focal spot).

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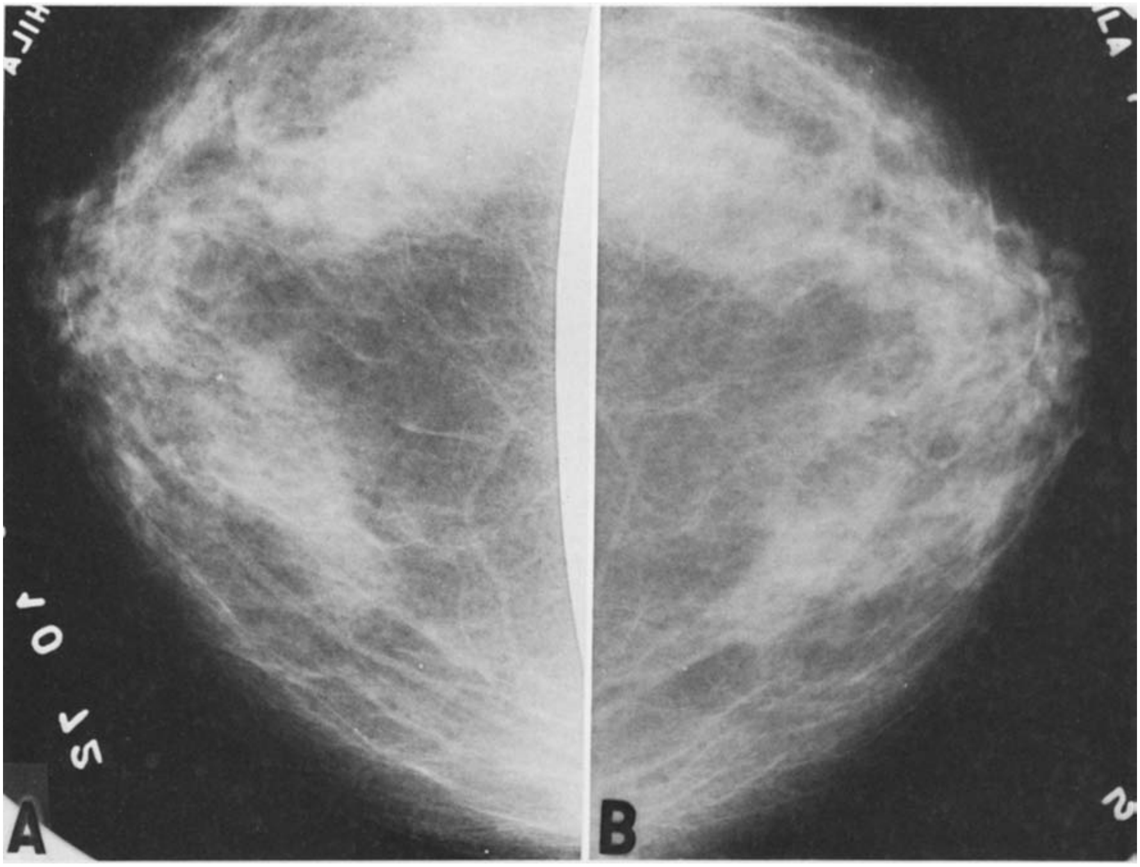

Fig. 3. Comparable craniocaudal views of the left breast (Senographe). A. Film-screen combination: 30 kV, 35 mA @ 1.0 sec. Note the clarity of the 3 small benign calcifications as well as the sharp detail and enhanced contrast.
B. Kodak AA film: 30 kV, 35 mA @ 8.0 sec.

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