XEROGRAPHY OF THE BREAST

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Xerography of the breast has many advantages over conventional mammography done with Eastman Kodak "M" Film. There is greater detail on the xerograms, and they are easier to produce and interpret. Xerography utilizes an electrostatic charge placed on a photoconductive surface (a selenium-coated aluminum plate) which is then exposed to radiant energy in the form of x-rays. The residual electrostatic charge is developed by spraying the plate with negatively charged powder. The image is then transferred to paper by pressure for permanence. A better image is produced by xerography with less radiation than is needed with conventional film mammograpy. With further development of the equipment, results of this new technique can be even more encouraging.

XEROGRAPHY OF THE BREAST HAS THE FOLlowing advantages over conventional mammography done with Eastman Kodak "M" film:

1. The detail is greater, and there is accentuation of significant structures.

2. Xerograms are easier to interpret and may lend themselves to screening programs.

3. All of the breast structures are recorded with clarity on one image.

4. They require less irradiation to produce.

5. The process is dry and carried out in a lighted room.

6. The procedure is quick, making the xerogram available for interpretation in 2 minutes.

A carefully controlled comparative study on a large series of consecutive cases to test the accuracy of xerography vs. film mammography has not been done. This is because the equipment at this time is not adequate to permit reliable operation on a day to day basis. The material available reveals an improvement in the diagnosis of malignant disease. The significant factor is that a more definite conclusion can be arrived at with xerography. The evidence of carcinoma is more obvious on the xerogram as is that of benign disease, i.e., the calcifications are more readily identified (Fig. 1). The margins of the tumor demonstrating spiculation stand out clearly (Fig. 2), and the sharply circumscribed mass with an area of compressed fat characteristic of benign lesions is also more definite (Fig. 3).

Consequently, there is a significant reduction in overcalling benign disease malignant. The false positive diagnosis requires a needless surgical procedure, and any method which reduces its frequency is of value.

A comparative study done by investigators at St. Vincent's Hospital in New York City[10] revealed a similar and high accuracy in correct diagnosis of malignant disease by both xerography and film mammography.

REVIEW

The xerox principle was discovered by Chester F. Carlson in 1937. It was developed at the Battelle Institute in Columbus, Ohio. There are many reports of its investigation in nonradiological literature; one is that by McMaster[7] in which he discusses and explains the technique.

Three papers have been published on its use in mammography.[4, 10, 13] They concluded that the technique had great promise but that difficulties with equipment precluded its widespread use.

The slow speed of xeroradiography when compared to conventional roentgenography performed with fast medical roentgenographic

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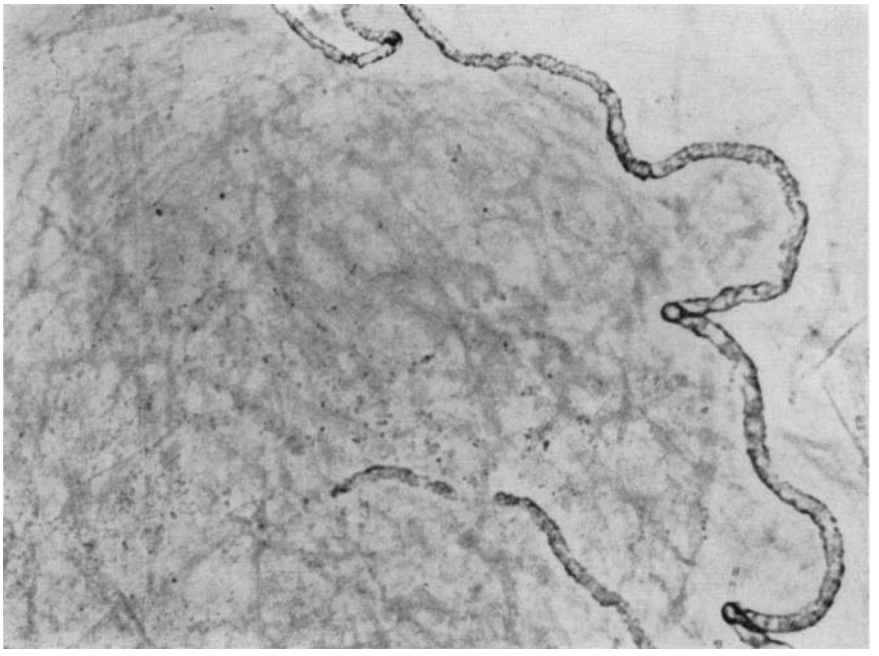

FIG. 1. Very small punctate calcifications denoted as dark spots. Most numerous to the left of the center of the illustration and toward the lower left-hand corner. Some of these measure only 0.01 cm. Many of the small calcifications could not be seen on the film mammogram. The serpiginous structure along the right hand side and above and below represents a calcified artery.

film and intensifying screens was cited by Roach and Hilleboe.[12] They concluded it would not have a place in general radiologic work because of this. Farmer et al.[3] discussed its use in therapy planning and cited the ability of xeroradiography to record soft tissue, bone, and air cavities with good detail on one image.

XEROGRAPHIC PRINCIPLE

Xerography utilizes an electrostatic charge placed on a photoconductor which is then exposed to radiant energy in the form of x-rays. The residual electrostatic charge is "developed" by a pigmented plastic powder of opposite charge. The essential element is

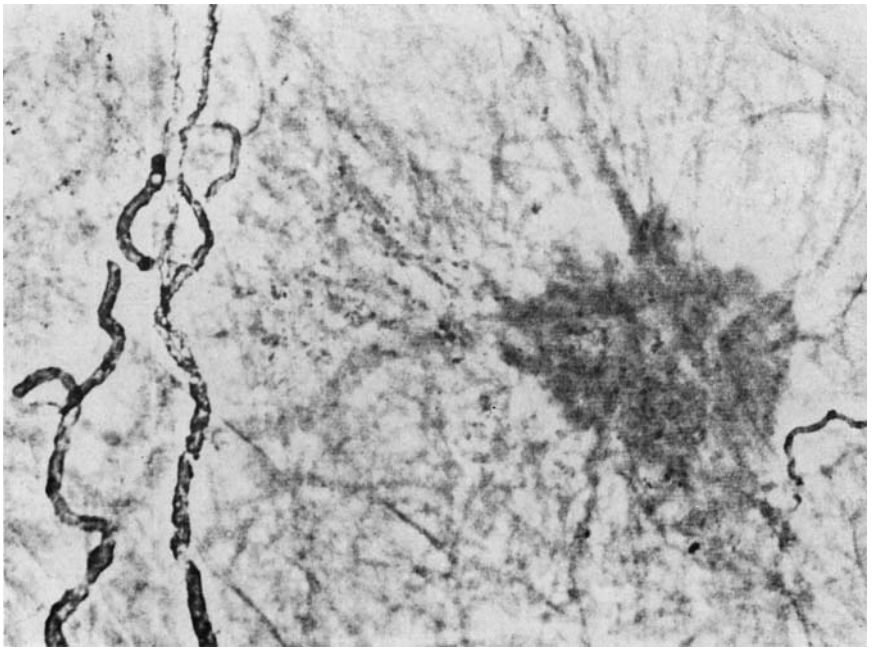

FIG. 2. Opposite breast to Fig. 1 containing a scirrhous carcinoma with small punctate calcifications outside the tumor area but also calcifications associated with the cancer seen within the tumor.

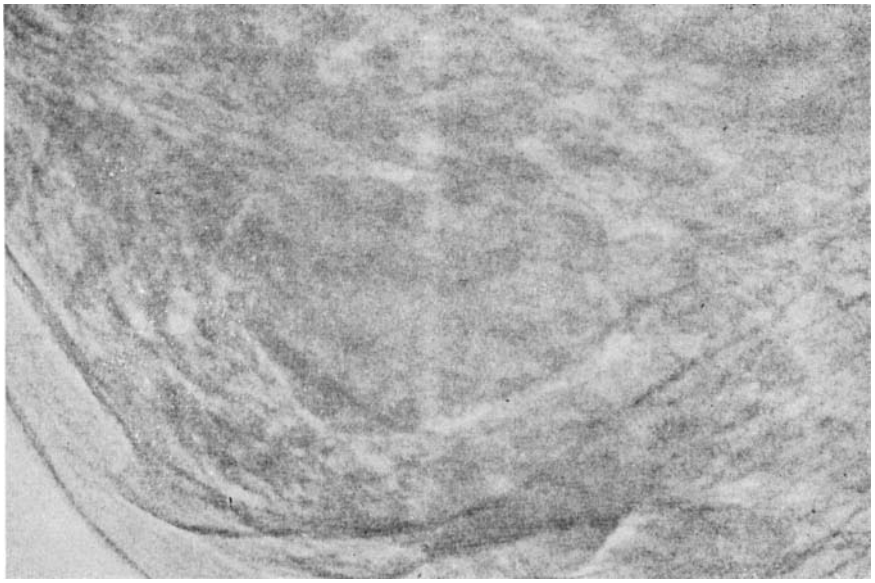

FIG. 3. Lobulated fibroadenoma in a dysplastic breast. The margins of the tumor are readily seen as being very sharp and distinct. The mass was nearly equally visible on the film mammogram in this projection. In the caudal projection of the breast it could be identified readily on the xerogram but not on the film (caudal not illustrated).

the plate. It is a sheet of aluminum coated with a thin layer of selenium, which is the photoconductor (Fig. 4).

A positive charge is placed on the selenium surface by electrostatic corona discharge. The plate is then used as one would a roentgenographic film, by placing it under the breast for the multiple projections. Selenium conducts the electrostatic charge from its surface according to the amount of irradiation striking and interacting with it. The remaining charge depicting the breast is made visible by spraying the plate with a negatively–charged blue plastic powder which adheres to the plate in amounts proportional to the residual positive charge. The usable image for interpretation is obtained by simply pressing a sheet of plastic–coated paper against the plate, and the powder adheres to it permanently.

An important feature of xeroradiography is the "edge-effect" or "adjacency-effect" (Fig. 5). This has two facets, both of which are important. Differences in potential remaining in the positive charge on the plate after irradiation have peripheries which are exaggerated by virtue of fringing electric fields being stronger. This makes masses and calcifications more visible and, in particular, emphasizes the margins, permitting a more accurate assessment of whether a particular area represents a benign or malignant process.

The second and not previously appreciated advantage of this method is that it acts somewhat like a grid. A problem in any radiographic procedure is to preserve detail of a structure at a considerable distance from the recording medium whether it be an xerographic plate or roentgenographic film. This is due to two factors, that of the penumbra of the x-ray beam (particularly important in mammography as a 2-mm focal spot is used) and the scattering media which is between the image being radiographed and the recording device.

The "edge-effect," by producing strong electric fields on the plate coinciding with

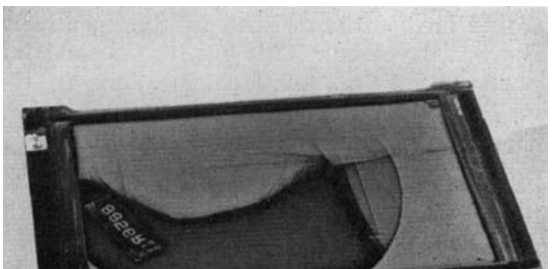

FIG. 4. The xerographic plate illustrated with the breast image on it is encased in a wooden cassette. A dark-slide fits into grooves on the inner aspect of the edges of the cassette to protect the selenium plate from light prior to development.

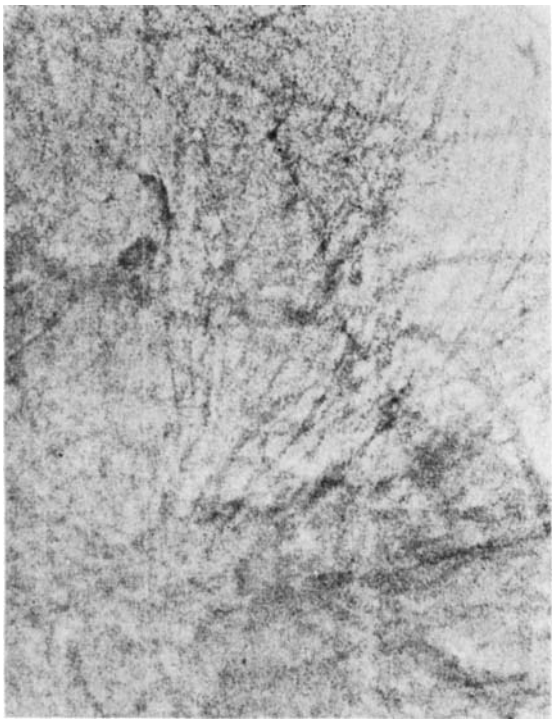

FIG. 5. The "edge-effect" is most marked in the case of sharp lines. There is a faint scirrhous carcinoma located near the lower left-hand corner. The very long lines of retraction, curvilinear, extending superiorly toward the upper right-hand corner are well demonstrated on the xerogram. Fewer lines could be seen on the film mammogram, and they were less readily identified.

masses within the breast, appears to "clean up" stray irradiation by taking developing powder (toner) away from areas of less strong charge produced in large part by scattering. One could "develop" this scatter irradiation by sufficient toner, but first the stronger fields would have to be satisfied by the negatively-charged developer. This has its practical importance in that small calcifications in the medial quadrant of the breast have more chance to be preserved and recorded through a dysplastic lateral quadrant by xeroradiography as opposed to film mammography.

EQUIPMENT

The present equipment is unsatisfactory in that it is subject to frequent breakdown, and it is difficult to obtain reproducible results on a day to day basis. It was constructed in the mid 1950's for field trial and has not been changed appreciably. The selenium plates available vary in quality. One must pay constant attention to developing time, as this can vary not only from day to day but from hour to hour. These are fundamental problems of a technologic nature, which can be easily solved by sufficient research and development by the manufacturer.

TECHNIQUE

The technique for producing an xerogram of a quality superior to an Eastman Kodak "M" film mammogram requires 60% less irradiation. It is somewhat similar to that required for film in that the best xerograms are produced with low kilovolts and high milliampere seconds. This is probably because selenium responds best to energies in the realm of 12–13 kv which is that amount required to remove an electron from the K shell of the atom. It is essential, therefore, minimal filtration be used.

The technique now used at this institution is as follows:

	KVP	MAS	Distance
Xerography	26–34	600	32″
Eastman Kodak "M" Film	30–34	1500	32″

Not only is the amount of irradiation to the patient reduced significantly, but also the amount of heat generated in the x-ray tube is much less. This is of practical importance in that damage to the tube is much less of a threat, and more rapid sequential exposures can be made by the technician without the 1½–2 minute wait now needed when working with the conventional film technique requiring 1500 mas.

The exposure factors depend on the type of selenium plate used. "Thin" photoconductive layers are slower than "thick" ones and furnish less contrast in the image. This is related to the number of carriers created in the selenium layer. A thick layer will be more likely to have interaction with the incoming x-ray merely because of the number of atoms available; and there may be some "slowing" of x-rays in the superficial part of the coating, permitting complete absorption. But with thin layers a similar level of energy may pass through the plate.

EXAMPLES

First, note that the xerograms as made now have a blue color. This can vary de-

pending on what the manufacturer cares to produce. Or the plastic-coated paper can be tinted and a white powder used if this proves of value.

The examples are shown to illustrate some of the features of this technique. One should observe there is a high local contrast; and all structures are visible on one image (Fig. 6, 7).

DISCUSSION

Xerography of the breast is superior to conventional film mammography by requiring less irradiation to produce, providing an image with good visualization of all breast structures, permitting a more efficient and economical operation and being easier to interpret in that there is accentuation of significant structures. Masses, veins, calcifications and sharp lines are all shown with high local contrast. There appears to be less loss of detail due to the penumbra of the x-ray beam.

The process is hampered by poor equipment and plate quality. A new semi-automated machine with excellent plates is needed as a starting point. Much work needs to be done on toners, paper for transfer, optimum plate-voltages, development techniques and many other facets of the process.

Thus, many of the limitations of the process can be corrected by the manufacturer, and our results can be even more encouraging.

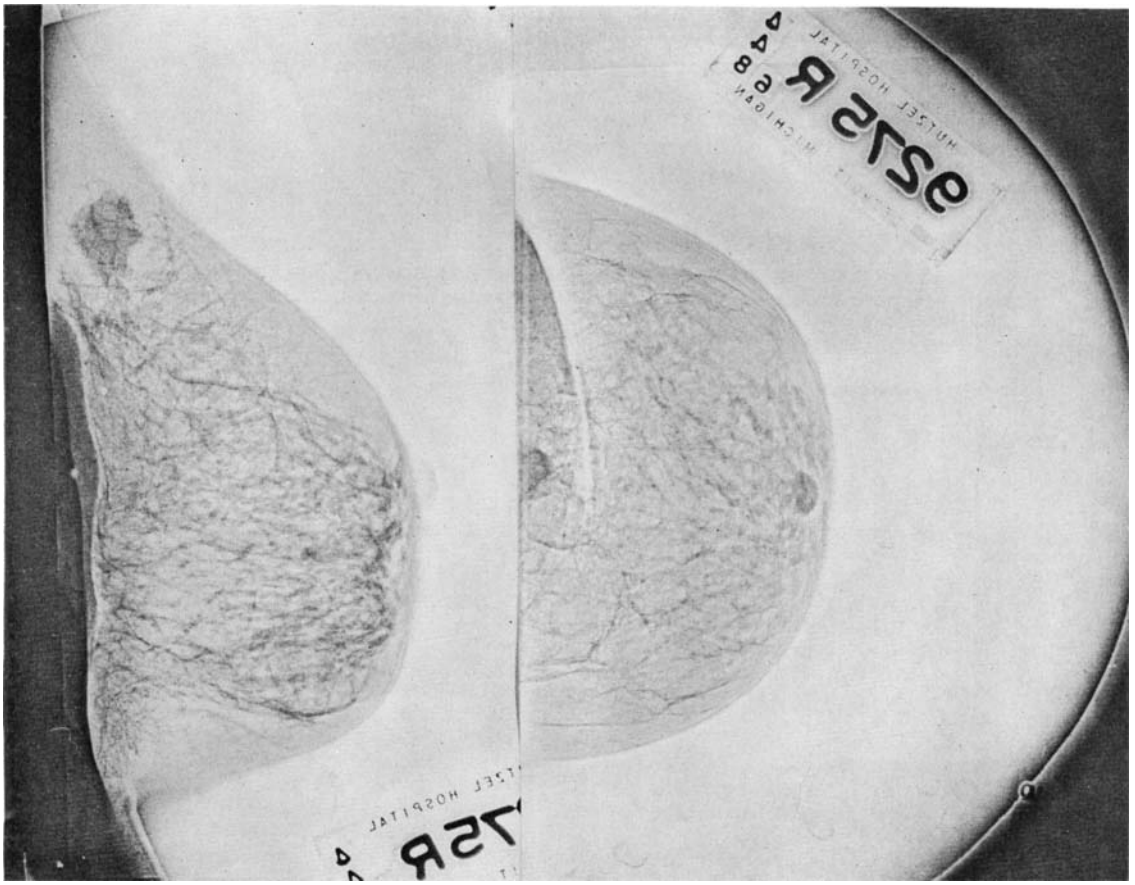

FIG. 6. Carcinoma in the upper quadrant noted as a mass lesion. One should note on the caudal film (right) the tumor can be seen demonstrating adequate recording of as many breast structures on this projection as can be seen in film mammography. Also to be noted is the prominent duct pattern which is often seen in carcinoma of the breast, especially the elderly nulliparous woman as is this 70-year-old woman.

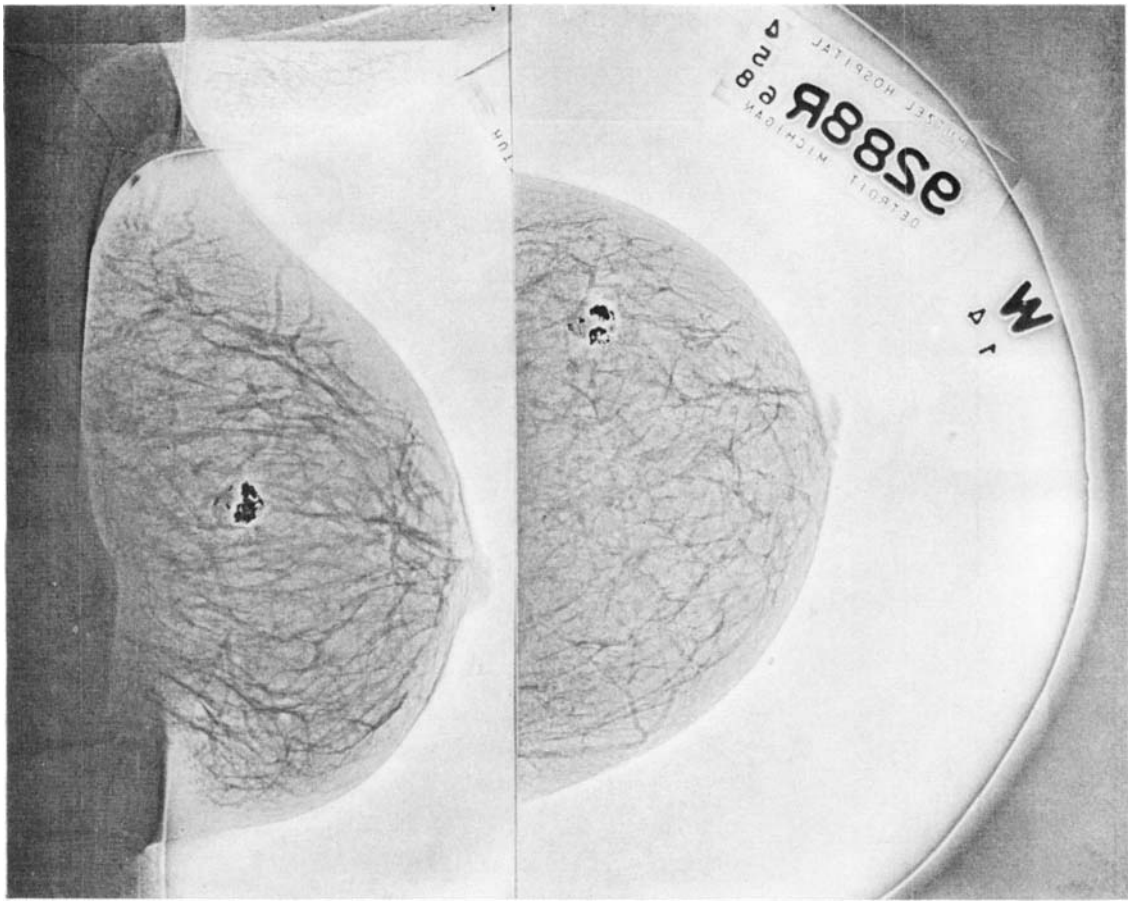

FIG. 7. Calcified fibroadenoma visible in the axillary quadrant and noted by the presence of irregular and very dense calcifications. One should note the evenness of the image with visibility of all structures from the nipple to the chest wall.

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