Breast Cancer Detection with Transillumination and Mammography

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This prospective study of 1239 women compares the breast cancer detecting abilities of state-of-the-art mammography and transillumination. Mammography was found to be the superior technique, detecting 80 (96%) of the 83 pathologically proven cancers, while transillumination detected only 44 (53%). Among cancers having the best prognosis, transillumination was even less accurate relative to mammography, detecting only 43% of malignancies that had not yet spread to axillary lymph nodes and only 19% of the nonpalpable cancers and cancers smaller than 1 cm, whereas mammography detected over 90% in each of these categories. None of the three cancers missed by mammography were detected by transillumination. Clearly, transillumination is not an acceptable substitute for mammography in the detection and diagnosis of breast cancer. Therefore, the current commercial promotion of transillumination seems to be premature.

Transillumination of the breast began over 50 years ago [1] and has enjoyed brief periods of clinical interest with each of several successive improvements in equipment design [2, 3]. The principal weakness of the technique has been its inability to differentiate malignant from benign breast masses reliably [4].

The current revival of interest in transillumination is based on the concept of preferential near-infrared light absorption by breast cancer, that is, that areas of malignancy will absorb more (and therefore appear to transilluminate less) near-infrared light than will benign tissues [5]. As a consequence, emphasis has shifted away from the viewing of transilluminated images directly by the human eye, which is insensitive in the near-infrared, and toward the use of recording devices that are specifically sensitive to near-infrared light, such as television cameras equipped with special silicon-target vidicon tubes [6, 7]. This modification permits real-time viewing of near-infrared-rich images on a standard television monitor, thereby allowing the examiner to make immediate adjustments in imaging factors to optimize image quality. Furthermore, electronic contrast enhancement of the video image also can be done to increase the likelihood of visualizing subtle lesions. Hard copies of transillumination images are made rapidly and readily, using either Polaroid film, a multiformat film camera, or videotape.

Most published experience with transillumination is anecdotal [7, 8], and many of the pilot clinical studies that are in progress provide little relevant data because they involve narrowly selected patient populations, small numbers of cancers, relatively advanced cancers, or because they do not involve comparisons with state-of-the-art mammography (Schipper H, Brown RE; Marshall V, Hamlett F, Williams D, Smith K; Merritt CRB, Sullivan MA; Davis L, Drexler B, Schofield G; Bartrum RJ Jr, Crow HC, unpublished data). Nonetheless, on the basis of these studies, transillumination units now are being promoted commercially as capable of detecting cancer at a rate approaching or equaling that of mammography. This study, although not limited to asymptomatic women being screened for breast cancer, was conducted using state-of-the-art mammography technique and does involve a sizable number of small and nonpalpable cancers. It is presented to
provide a more meaningful indicator of the clinical utility of transillumination for cancer detection than what now is being used for this purpose.

Subjects and Methods

The study population consisted of 1500 women undergoing mammography for indications ranging from suspected cancer to baseline or screening examination. Mammograms were obtained with the Elscint microfocus mammography unit (Elscint, Boston), using the small focal spot (nominal size, 0.09 mm; measured size, 0.14 mm) for all exposures. About 80% of the mammograms were done using screen-film technique, the rest with xeroradiography. Patients were entered into the study only after completion of the mammography examination, which included contact cranio-caudal and lateral projection mammograms of both breasts, any additional films (oblique views, magnification views) that were thought to be necessary [9], and a complete breast history and physical examination. Final diagnostic interpretation of the mammograms was made before selection for study. Criteria for selection were limited to willingness to undergo an additional transillumination examination and command of the English language sufficient to give informed consent.

Transillumination was done on the same day as the mammography examination using an imaging system operating with both visible and near-infrared light. The light source consisted of a rheostat-controlled tungsten-filament bulb incorporated into a hand-held torch that directed the light to the breast through a side-shielded curved Lucite rod (Profile AB, Malmö, Sweden). Transmitted light was recorded with a silicon-detector vidicon television camera (65 MK II Series, Dage-MTI, Inc., Michigan City, IN) sensitive to wavelengths of 400–1100 nm. All examinations were viewed in real time on a standard television monitor already in place in the radiology department. Images were taped simultaneously for archival purposes on a remote-controlled videocassette recorder (JVC, Victor Company of Japan, Tokyo).

Standard examination involved the imaging of both breasts in caudocranial, mediolateral, lateromedial, and several 45° oblique projections. Positioning of the light source and television camera was done with full knowledge of the results of the breast history, physical examination, and mammography to permit additional images to be made of areas of special interest. Interpretation was based on diagnostic criteria developed by previous investigators; specifically, the diagnosis of malignancy was suggested by the demonstration of one or a combination of findings (figs. 1–3): (1) a focal area of increased light absorption; (2) abnormalities in caliber, contour, and number of visualized superficial blood vessels; or (3) diffuse but substantial asymmetry in light absorption compared with mirror-image location in the opposite breast. Interpretations often were made at the time of transillumination on the basis of real-time television images observed by the examiner, but sometimes videotapes of examinations were reviewed later to clarify equivocal appearances.

Pathologic correlation was made for all patients who had a biopsy within 1 month of study to ascertain the histologic diagnosis and to verify that all mammographically suspicious lesions had been removed, sectioned, and evaluated by the pathologist. The size of each cancer was recorded as the greatest tumor diameter measured by the pathologist; in those few cases where this information was unavailable, cancers were sized by greatest diameter seen on mammograms.

Results

It became apparent soon after the study began that transillumination of the breasts is a highly operator-dependent examination, for the demonstration of subtle lesions can be achieved only with optimal positioning of the light source, breast, and television camera. It therefore was decided that the same individual who interpreted the examinations should also operate the imaging equipment (the author). After studying 200 patients, sufficient technical expertise was gained to produce images of diagnostic quality routinely; these first 200 examinations were considered to represent a "learning set"
and were not included in the data analyses that follow. Of the subsequent examinations, 61 also were judged to be technically inadequate and were excluded from the study. Usually this occurred in young women with small, firm breasts in whom parts of the light source could not be covered by breast tissue on one or several projections, resulting in saturation of the television image by light passing directly from the source to the camera.

Among the other 1239 patients studied, 76 women were found to have 83 pathologically confirmed breast cancers. Thirty-one (37%) were nonpalpable, 54 (65%) were smaller than 2 cm, and 21 (25%) were smaller than 1 cm. Table 1 indicates the relative abilities of mammography and transillumination to detect the cancers. For all the data breakdowns, mammography was found to be much more accurate, detecting over 90% of the cancers. Transillumination was at its best with the larger, more locally advanced cancers, but detected only 43% of the malignancies that had not yet spread to axillary lymph nodes and only 19% of the nonpalpable cancers and cancers smaller than 1 cm.

Transillumination did not detect any of the three cancers that were missed by mammography. One of these lesions (1.8 cm) was detected because it was palpable, another (0.6 cm) because elicited, nonbloody nipple secretions demonstrated malignant-appearing cells on cytologic examination, and the third (0.3 cm) was found adjacent to a palpable 2.5-cm fibroadenoma that was biopsied because of clinical suspicion of malignancy.

Detection of cancer by transillumination was highly dependent on the mammographic characteristics of the tumor (table 2). Transillumination identified 26 (84%) of the 31 lesions that were found by mammography by demonstration of a tumor mass without microcalcifications, but detected none of the 24 cancers that were discovered on mammography because microcalcifications alone were imaged.

Finally, the ability of transillumination to identify a cancer seemed to depend on the depth of the tumor beneath the skin. Although it proved difficult to make precise measurements of depth for most of the cancers, it was clear that transillumination was much more successful in imaging superficial lesions than it was in demonstrating deep ones, especially those deep to the retroareolar region close to the chest wall. Among the cancers detected by transillumination, all six of the nonpalpable lesions appeared to lie within 1.5 cm of the skin surface, and all four of the cancers smaller than 1 cm appeared to lie within 1 cm of the overlying skin. Conversely, four of the seven large (> 2 cm) cancers missed by transillumination were located close to the chest wall, and each of the other three was situated in the middle of a large breast, at least 2 cm from the skin surface.

**Discussion**

This study clearly shows state-of-the-art mammography to be superior to transillumination in the detection of breast cancer, especially those cancers that are most amenable to cure. Tumor size and axillary lymph node status are important prognostic indicators, and the mammography done in this

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**Table 1: Pathologically Proved Breast Cancers Studied by Mammography and Transillumination**

<table>
<thead>
<tr>
<th>Characteristics of Cancers</th>
<th>Detected by Mammography</th>
<th>Detected by Transillumination</th>
<th>Total Cancers</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancers</td>
<td>80 (96)</td>
<td>44 (53)</td>
<td>83</td>
</tr>
<tr>
<td>Palpability:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palpable</td>
<td>51 (98)</td>
<td>38 (73)</td>
<td>52</td>
</tr>
<tr>
<td>Nonpalpable</td>
<td>29 (94)</td>
<td>6 (19)</td>
<td>31</td>
</tr>
<tr>
<td>Size:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smaller than 1 cm</td>
<td>19 (90)</td>
<td>4 (19)</td>
<td>21</td>
</tr>
<tr>
<td>1.0–1.9 cm</td>
<td>32 (97)</td>
<td>18 (55)</td>
<td>33</td>
</tr>
<tr>
<td>2 cm or larger</td>
<td>29 (100)</td>
<td>22 (76)</td>
<td>29</td>
</tr>
<tr>
<td>No. of positive nodes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>56 (97)</td>
<td>25 (43)</td>
<td>58</td>
</tr>
<tr>
<td>One to three</td>
<td>14 (93)</td>
<td>10 (67)</td>
<td>15</td>
</tr>
<tr>
<td>Four or more</td>
<td>10 (100)</td>
<td>9 (90)</td>
<td>10</td>
</tr>
</tbody>
</table>

*Note—Numbers in parentheses are percentages.*

**Table 2: Detection of Breast Cancer by Transillumination as a Function of the Cancer’s Mammographic Characteristics**

<table>
<thead>
<tr>
<th>Mammographic Characteristics</th>
<th>Detected by Transillumination</th>
<th>Not Detected by Transillumination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass only</td>
<td>26 (84)</td>
<td>5 (16)</td>
</tr>
<tr>
<td>Mass + calcifications</td>
<td>18 (72)</td>
<td>7 (28)</td>
</tr>
<tr>
<td>Calcifications only</td>
<td>0</td>
<td>24 (100)</td>
</tr>
<tr>
<td>Missed by mammography</td>
<td>0</td>
<td>3 (100)</td>
</tr>
</tbody>
</table>
study far outperformed transillumination in detecting the smallest cancers and those that had not yet spread to axillary nodes (Table 1).

An even more important consideration in evaluating breast imaging techniques is their ability to demonstrate nonpalpable cancers, that is, those tumors that would otherwise go undetected. Here again transillumination was found to be inferior (Table 1). Indeed, the major deficiency of transillumination seems to be its relative inability to detect very small and deep-seated cancers, just those malignancies that tend to be nonpalpable.

These discouraging results are at variance with much of what has been reported. Several underlying differences between studies may account for the discrepancy in results: specifically, differences in experimental design, mammography technique, and transillumination technique.

In this study, the patients were unscreened, and both mammography and transillumination were done on all subjects. In some of the other studies, however, mammography was not done on all transillumination patients, resulting in exclusion from study of some cancers that would have been detected by mammography alone, thereby causing transillumination performance to appear falsely enhanced. In still other studies, transillumination was done only on selected mammography patients, again causing some mammography-positive but transillumination-negative cancers to be excluded.

In the current study, mammography was done in a manner designed to maximize diagnostic accuracy; namely, images were taken with state-of-the-art equipment; interpretations were made by an experienced, dedicated mammographer fully aware of the findings of a complete breast history and physical examination; and interpretations were made while the patient was still in the mammography suite, so that correlative physical examination and/or additional mammographic views could be obtained whenever necessary. Such a rigorous approach to mammography, not done in any of the other reported transillumination studies, is thought to increase the detection of subtle cancers [10, 11]. This probably accounts for the sizable number of small and nonpalpable cancers included in our patient population and may also help explain why transillumination performed so poorly in our study.

It also must be noted that our transillumination equipment did not contain the dual-wavelength subtraction capability of some commercially available units (Merritt CRB, Sullivan MA; Bartrum RJ Jr, Crow HC, unpublished data). However, although this expensive capability may improve the contrast in transillumination images [7], it does nothing to overcome the major limiting factor in breast transillumination, impaired resolution due to light scattering [12]. Therefore, it is unlikely that our results were substantially affected by the lack of dual-wavelength imaging, but the degree to which this may have occurred is unknown.

ACKNOWLEDGMENT

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REFERENCES

This article has been cited by:

1. Mary S. Newell, Anna I. Holbrook. Emerging Technologies in Breast Imaging 427-448. [Crossref]
2. David Boas. Functional Imaging with Diffusing Light 311-356. [Crossref]
4. Lawrence W. Bassett, Richard H. Gold. History of Breast Imaging 3-24. [Crossref]
5. Kalle Kotilahti, Timo Kajava, Tommi Noponen, Jenni Heino, I. Nissilä, Toivo Katila. Near-Infrared Spectroscopic Imaging. [Crossref]
15. Manfred Säbel, Horst Aichinger. 1996. Recent developments in breast imaging. Physics in Medicine and Biology 41:3, 315-368. [Crossref]
23. Maximilian Reiser, Wolfhard Semmler. Thorax und Gefäße 383-481. [Crossref]
25. P. C. Jackson, H. Key, P. N. T. Wells. Transillumination Imaging 101-115. [Crossref]
27. E. A. Sickles. Imaging Techniques Other than Mammography for the Detection and Diagnosis of Breast Cancer 127-135. [Crossref]
28. H. Pulvermacher, A. Weichmann, W. Waidelich. Grundlagenuntersuchungen zur Transillumination 472-477. [Crossref]
30. D. David Dershaw, Michael Osborne. 1989. Imaging techniques in breast cancer. Seminars in Surgical Oncology 5:2, 82-93. [Crossref]
31. H. Key, P.C. Jackson, P.N.T. Wells. 1988. New approaches to transillumination imaging. Journal of Biomedical Engineering 10:2, 113-118. [Crossref]
36. W. R. Castor, F. I. Jackson, T. Hunt. Multimodality Breast Imaging: The Value of Diaphanography 59-68. [Crossref]
37. E. A. Sickles. Computed Tomography Scanning, Transillumination, and Magnetic Resonance Imaging of the Breast 31-36. [Crossref]
40. S. Fantini, K.T. Moesta, M.A. Franceschini, H. Jess, H. Erdl, E. Gratton, P.M. Schlag, M. Kaschke. Instrumentation and clinical applications in frequency-domain optical mammography 2741-2744. [Crossref]