DIGITAL MAMMOGRAPHY: PRESENT AND FUTURE

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Abstract

Target List (Learning objectives): 1) To gain understanding of the techniques for obtaining digital mammograms. (2) To become familiar with the possible benefits of digital mammography (3) To learn about the technical challenges that must be overcome for digital mammography to be successful.

Digital mammography theoretically offers significant benefits compared with conventional film-screen mammography, not only in image quality and image management but also in detection and diagnosis by the use of CAD (1,2). To compete with conventional mammography, a digital system must equal the quality requirements established for the conventional system and offer significant advantages that alleviate existing shortcomings.

Digital mammography systems have been available since the beginning of the 80ies. So far the interest has been focused on the digital detectorsystem. Various new detector systems are now under development. However, the digital concept also postulates that the detector system is connected to the display and the storage media. No PACS system has yet been evaluated for digital screening. The high demand on very fast retrieval and presentation of images may be hard to solve in the near future. There are not yet any dedicated workstations available for soft copy interpretation. The demands from the users will also include integration with dedicated radiology information systems (RIS) and hospital information system.
Detectors
The image quality is dependent on the detector system used. The first commercially available full screen detector system was the stimulable phosphorous system pioneered by the Fuji Photo Film Corporation (Tokyo, Japan). This technique is based on a recording of images on imaging plates. The latent images created are read out at high resolution using a laser-stimulated luminance technique (3). In this system, which is now available at more than 3000 departments all over the world, it is possible to use a high resolution phosphorus plate with a 2370 x 1770 matrix array over 24 X 18 inch field with 10 bits (1024 levels) of grey scale discrimination per pixel. This give a spatial resolution of about 5 lp/mm compared with 16 lp/mm for a conventional film screen system. This difference is the main reason why many mammographers are still sceptical, despite a number of encouraging studies (4, 5, 6, 7, 8, 9). However, the contrast resolution of the digital mammography system available is superior to conventional film-screen systems and fact is often overseen by its critical opponents. This results in a more reliable and convenient image production with superior rendition of the skin edge, sub-cutaneous tissue and dense parenchyma while offering adequate micro-calcification reproduction(10).

The concerns about the image quality of the phosphorus plate system has encouraged a development of various new detector systems:

- CCD (Charge-couple-device) based detectors
- Scanning slot-beam detectors
- Amorphous silicon thin-film transistor (TFT) flat-panel detectors
- Amorphous selenium detectors

Pilot studies of these new systems shows promising results regarding improved image quality and reduction in patient dose (11, 12, 13, 14, 15).

Reduced radiation dose
The commercially available digital mammography system available has not shown any significant reduction in dose per image to the patient compared with the conventional film-
screen systems (16, 17). However, in clinical practice the more reliable image acquisition with the digital system, with fewer repeat exposures, results in dose savings.

**Image processing**

Another limitation of the film screen combination is that both contrast and density is non-linear while in digital mammography the response of the detector system is linear. With this data the images can be manipulated in real time on the work-station to promote detection and diagnosis of microcalcifications and subtle lesions, also in mammographically dense breasts. In digital mammography radiologists have freedom to manipulate the brightness and contrast and sharpness of images to maximise the visibility of all image details required. Together with the use of unsharp-maskings algorithms, adaptive histogram equalisation and manipulation of the grey scale, the interpreter can visualise clinical details across the full dynamic range of the image (2, 8).

**Simplified archival, retrieval and transmission**

Storing, tracking and retrieving film is one of the main problems in many radiology departments. Digital mammography offers a convenient but still too expensive solutions to all these problems (2, 8, 10).

**Rapid image display**

In digital mammography the image of the breast will appear more rapidly compared with conventional film screen systems. While the conventional processing time is about 5 minutes, the imaging plate system with process the images in half that time. In the new digital mammography system the images will appear almost in real time. However, no PACS system has yet been evaluated for digital screening. The high demand on very fast retrieval and presentation of images may be hard to solve in the near future. There are not yet any dedicated workstations available for soft copy interpretation. It is still an open question weather 1K, 2K or 4K monitors should be used for soft copy interpretation. The demands from the users will also include integration with dedicated radiology information systems (RIS) and hospital information system (HIS).
Computer aided diagnosis (CAD)
A lot of research is going on to present “artificial intelligence” software capable of helping the radiologist to identify suspicious areas of the breast. Pattern recognition systems, eye pattern tracking systems and neural networks these computer programs promise to reduce the level of false negative errors by pointing out areas of concern (1).

The diagnostic and economic advantages of CAD schemes for breast screening programs is obvious.

Telemammography
The digital technique allows easy transmission of images from one place to another by various forms of telecommunication. This will be beneficial for women living in rural areas. It is also possible to perform real time consultations in difficult cases between different hospital.

References
TELEMAMMOGRAPHY AND COMPUTER-AIDED
DETECTION/DIAGNOSIS: A PERSONAL PERSPECTIVE

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This is a synopsis of my personal perspectives on the present and future clinical roles of telemammography and computer-aided detection/diagnosis (CAD), based on current state-of-the-art technology. There has been rapid progress in clinical research involving both of these modalities over the past few years, which is likely to continue apace. Therefore, some of what is written here probably will have advanced from speculation to reality in the few months between now (February 1999) and the time that I present this material in lecture format. Instead of reviewing in detail the many advances that already have been made, which are described elsewhere in this syllabus anyway, I will concentrate on the current obstacles that limit widespread use of telemammography and CAD.

Telemammography

The transmission of mammograms for display at a remote site (telemammography) promises to facilitate a variety of new approaches to image interpretation. Using telemammography, imaging practices that operate at more than one site will be able to monitor and interpret all their mammograms (including diagnostic examinations) in a single location, or at least in a small number of centralized locations. This permits all or almost all examinations to be interpreted by those physicians in a group practice who have the greatest expertise, an important advance over standard procedure because more experienced interpreters produce more accurate results. Another application for telemammography is to facilitate second-opinion interpretation, by making off-site world-class mammography expertise accessible in real time to community-practice physicians.

However, just because it is now technically feasible to transmit mammographic images to remote locations, this does not mean that the procedure is already clinically practical. Indeed, there are several unresolved problems that must be overcome before telemammography will achieve widespread clinical use.

First, to be transmitted at the high degree of resolution needed for mammographic interpretation, images must be sent and received in digital format. This requires either the use of a full-field digital mammography unit or the digitization at high resolution of conventional film mammograms. The substantial costs involved in both of these
approaches have limited and will continue to limit the clinical acceptance of telemammography.

In addition, to be clinically successful, the interpretation of transmitted digital images must be done in real time, without a substantial reduction in throughput. This also involves considerable expense because rapid transmission of digital mammograms, which each are 40 Mbytes or larger, requires the use of very costly infrastructure (T1 or ATM communication lines and a high-speed network).

The need for rapid throughput performance also renders impractical the display of telemammography images in laser-printed hard-copy format. This type of image display is inherently slow because it adds to the procedures required for telemammography (image acquisition, computer processing, image transmission, image optimization [window/level, etc]) the several time-consuming steps of conventional film mammography as well (film exposure, chemical processing, mounting on viewboxes). The bulk of existing telemammography research involves this time-inefficient method of image display, but in routine clinical practice it will be difficult if not impossible to tolerate the resultant delay in throughput.

Rather, to achieve clinical acceptability, telemammography will require soft-copy image display on high-resolution monitors built into a user-friendly workstation. Important features of such a workstation include flexible display of up to 8 standard-resolution images (4 images from the current examination plus 4 images from a previous examination); a “smart” window-level function that automatically displays images at close to optimal settings; convenient user-operated tools for window-level and magnification; and a one-step process to archive already-viewed images using optimized image-display settings.

Also needed for telemammography applications is the simultaneous display of the same images on workstations at two different sites, with on-screen display of dual arrows, one controlled by a user at each site. This, combined with voice communication by telephone, will facilitate \( a \) real-time telemanagement of diagnostic mammography examinations between the technologist at the image acquisition site and the physician at the image interpretation site, and \( b \) real-time teleconsultation between physicians at two different sites. Prototype telemammography systems have already been constructed and pilot tested, but none are yet in general clinical use.

One must also remember that clinical studies have not yet been completed to demonstrate either comparable/superior diagnostic accuracy of off-site telemammography interpretation versus on-site interpretation of conventional film mammograms, or of the ability to conduct telemammography in a time-efficient manner.

In summary, despite the technical feasibility to perform telemammography interpretation at remote sites, several practical problems must be overcome before this
method achieves widespread clinical acceptance. In addition to the convincing demonstration that telemammography performance is equal to or better than that of conventional film mammography, we must also await the general deployment of full-field digital mammography units and user-friendly soft-copy display workstations, both at affordable cost. As is the case with CAD, although I believe that telemammography will eventually prove very successful, I am unsure of the time that this will take.

**Computer-Aided Detection/Diagnosis**

There is mounting evidence that computer-aided detection/diagnosis can be used to improve the performance of single-reader mammographic interpretation, functioning as an adjunct to rather than a replacement for physician interpretation. The rationale behind this adjunctive role is straightforward. Although CAD is capable of superior performance in detecting and characterizing several common mammographic findings that indicate the presence of breast cancer, there are still several types of findings for which CAD performance is clearly inferior to human interpretation (for example, identification of “developing densities” by comparing a current mammography examination with those done previously). Until CAD is shown to detect *almost all* potentially significant lesions that now are frequently detected in clinical practice, it is reasonable that physician interpretation will retain its primary role. Especially in the United States, where there is heightened concern about medico-legal issues, neither the manufacturers of CAD devices nor the practitioners who purchase and employ the devices will be willing to accept the malpractice exposure inherent in cases where a human observer would readily detect a cancer that is routinely missed by CAD. In this regard, one of the great strengths of CAD (its ability to produce highly reproducible results), actually may limit its clinical acceptability as a first-pass mammographic interpretation device, because the CAD program that missed an otherwise detectable breast cancer in actual practice will miss it over and over again during a courtroom demonstration.

For these reasons, CAD has been developed principally as a second-pass reader, to assist the human observer in refining mammographic interpretations that have already been rendered. To its great credit, CAD performs quite well in this regard. However, the gains so far demonstrated for CAD are of similar magnitude to those observed by “double reading” using two human observers, and the efficacy of CAD has not yet been directly compared to that of this more traditional type of double reading. This crucial comparison, which will need to be repeated with each major CAD-system upgrade, will determine to a great extent the scope of CAD’s clinical role, because it is unlikely that a mammography practice sufficiently interested in improved performance to purchase CAD, will complete the purchase unless CAD is at least as effective as double reading by human observers.
To this end, one must realize that there are many different types of double reading with which CAD must be compared. Efficient operation calls for two readers to work independently, with the first reader marking all detected findings using a wax crayon. Mammograms then are left mounted on a motorized viewer for the second reader. If the desired goal of double reading is to reduce the number of false-negative interpretations, the second reader concentrates only on non-marked areas. To reduce the number of false-positive examinations, the second reader concentrates only on marked areas. In this manner, a large number of cases can be double read in a very short time interval. Of course, one could choose to simultaneously attempt a reduction in both false-negative and false-positive readings, but this would be more time-consuming for the second reader and therefore a more expensive approach. Apart from the different goals of (and therefore different costs involved in) double reading, one must also consider the issue of differences in skill between the two readers. There is likely to be little benefit, and perhaps some harm, if the second reader is considerably less skilled than the first. The same, of course, would apply to CAD versus a single human observer.

The mammography facility deciding between double reading by CAD and by human observer will have to weigh not only the differential efficacy of the two approaches but also the differential costs. Such systematic comparisons have not yet been made. Costs for human-observer double reading will depend greatly on the efficiency with which it is performed, as discussed previously. The very high up-front costs involved in purchasing a CAD system will not compare favorably with that of human-observer double reading, but this may well be offset by relatively lower continuing costs for CAD (expendable supplies, service contract for maintenance, upgrades, etc). Reliable cost-comparison data are needed, not only from CAD manufacturers but also from independent investigators.

One must also consider a not-so-apparent cost of CAD: the time it takes for the physician-interpreter to decide whether or not to act on CAD output. Were CAD so efficient as to “mark” only lesions that required tissue diagnosis, this would not be an important consideration. However, current CAD successes have been achieved at the price of approximately one false-positive CAD mark per mammographic image (4 marks per screening examination). Of course, some images receive multiple marks and others receive none, but the great majority of examinations receive at least one false-positive mark. This requires the physician-interpreter to double read most of his/her own cases, just to assess the CAD marks. Fortunately, almost all of these marks are correctly judged to be false positive and therefore ignored, so the penalty to be paid is usually one of time (cost) rather than impaired specificity. On the other hand, the time-efficiency of CAD versus human-observer double reading is not as favorable as it might seem initially. Cost comparisons should include the differential amount of added physician-interpreter time required for both CAD and human-observer double reading. If the current time differential
is found to be relatively narrow, then computer classification methods may need to be improved (producing fewer false-positive marks without a reduction in true-positive marks) before a cost benefit can be demonstrated for CAD.

One final medico-legal issue concerning double reading must be considered, at least for practice in the United States. If double reading (whether by CAD or by human observer) is routinely used by a facility, then that same facility may face malpractice exposure for not employing double reading with other radiographic examinations (chest, double-contrast barium enema, etc) for which a second interpretation can also be expected to improve performance.

There also are practical limitations to the widespread clinical acceptance of CAD, because of its need to analyze mammograms in digital format. The time required to digitize the multiple film mammograms in a diagnostic examination, either before or after they are initially read by the physician, will greatly slow down the overall interpretive process, to the point where throughput may become affected to an unacceptable extent. This would also pertain to screening examinations that are interpreted while women are still in the mammography facility. Even for screening examinations that are interpreted in batches one day after examination, someone will have to take the time to digitize the numerous film mammograms overnight, in a designated sequence, and then afterwards mount the films on motorized viewers in exactly the same sequence for subsequent interpretation. For these reasons, the real-time use of CAD may require prior facility-wide purchase of full-field digital mammography units, thereby eliminating the step of image digitization and permitting prompt CAD analysis and display of findings. This will facilitate timely interpretation, and should not interfere meaningfully with throughput. However, if a mammography facility chooses to avoid full-field digital mammography because of the high attendant costs, this may also render CAD impractical, unless the facility is willing to abide by the inconveniences and costs of digitizing film mammograms.

In summary, it should be readily apparent that despite the impressive advances already demonstrated by CAD in several research studies, there are many factors which may limit its widespread clinical acceptance. I believe that it will eventually prove very successful, but I am less confident of the time that this will take than I am of the ultimate outcome.
ELASTICITY IMAGING

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Introduction

Most breast masses are still discovered by manual palpation, which provides a qualitative assessment of low-frequency tissue stiffness (Young's modulus, or strain induced for a given amount of applied stress) and other shear properties of tissues. These properties are very different from the bulk elastic modulus that governs propagation of ultrasonic waves. The elasticity of soft tissues depends both on their molecular composition (fat, collagen, etc.), and on the microscopic and macroscopic structural organisation of these components. Glandular tissue is firmer than the soft fatty areas of the breast. Abnormal tissue can be as much as seven times as stiff as surrounding tissue, as compared to differences of only a few percent for X-ray imaging. This potential for high contrast has lead to the development of methods for imaging tissue elasticity. No method does this directly, the basic principle of elasticity imaging being to use a conventional imaging modality to monitor the internal tissue displacement resulting from an externally applied force (i.e., palpation). Although elasticity imaging is therefore possible using magnetic resonance images for example, ultrasound is well suited to the task because it is real-time and because coherent speckle provides a tissue marker for tracking displacement.

Technical approaches to ultrasound elasticity imaging

Many alternative schemes now exist for elasticity imaging with ultrasound [1,2]; variations may arise from combinations of choices for whether

(a) the source of applied stress is static or dynamic (i.e. vibrational),
(b) motion of the ultrasound probe is used to apply the stress or a separate source of motion is employed,
(c) a shear or compressional stress is applied,
(d) displacement, strain, elastic modulus or some other quantity is imaged,
(e) the signal processing used to estimate strain or displacement is Doppler, speckle decorrelation, speckle tracking, echo texture analysis, or some other method,
(f) the scanning is mechanically constrained or freehand, and
(g) the stress is applied mechanically or by hand-induced motion.
Initially M-mode and, later, real-time B-mode scanners were used to observe relative echo motion in response to pressure applied with the transducer, providing diagnostic features of tumour stiffness and mobility and helping to recognise the tumour boundary [3, 4]. This subjective method is still in use today.

Although speckle decorrelation, Doppler processing and texture analysis methods have all been used to measure and image features of echo motion, perhaps the most extensively developed technique has been the application of speckle tracking algorithms to image internal tissue displacement in response to static external compression. The term elastography was coined for imaging axial tissue strain, obtained from the local gradients of displacement along the direction of the ultrasound beam, produced by a very small (2%) external compression of the tissue. This system, in which an ultrasound transducer was mounted on a modified mammography unit, has undergone substantial development since its first clinical trial [5] but even in its early form demonstrated exciting potential, showing that elasticity images have the following important properties:

a) excellent contrast resolution, due to a combination of high tissue contrast and pixel signal-to-noise ratio, or SNR (ranging from 4 to over 100, compared with about 2 for conventional ultrasound)
b) spatial resolution at least as good as conventional B-mode ultrasound scans,
c) display of new information that is not present in other types of images.

Although strain imaging is remarkably successful, especially when Young’s modulus varies only by small amounts and when small strains are employed, artefacts exist due to non-uniform stress distributions and variations in tissue compressibility. Young’s modulus (local stress divided by local strain) imaging by measuring the applied stress remains a tempting possibility but would require a complete understanding of the specific elasticity problem and full knowledge of the 3-D components of stress and strain at all points in the tissue. Progress is being made towards this goal using iterative methods that are beyond the scope of this paper. The Poisson’s ratio or compressibility (amount of lateral strain induced in association with a given amount of axial strain) of tissue may in principle also be evaluated if all three components of strain could be measured.

Image quality

Sources of noise in elasticity imaging are now being understood. Methods for noise reduction, still under development, include image averaging and incremental speckle tracking over multi-step compressions, least squares estimation of the gradient of displacement, global and adaptive local stretching of echoes to compensate for echo decorrelation, and constraining the tissue so as to restrict the number of components of strain. The limits of resolution of elasticity images are not yet well defined but echo displacements can be measured that are very much finer than the resolution of the ultrasound image data from which they are derived and the spatial resolution improves with every improvement in signal to noise ratio.
Psychophysical assessment

We are studying human observer performance for the task of elastic lesion detection by subjective relative motion assessment using real-time B-mode imaging, since this is already in routine clinical use and has an advantage in that both ultrasound echo and elasticity information are displayed in the one (real-time) image. Preliminary results indicate that (a) human observers perform well for large lesions, achieving elastic contrast thresholds approaching those published for detection by elastography, and (b) performance may be considerably enhanced by novel processing methods that we call tissue-centred scan conversion. In the latter, the real-time image display is re-sampled to compensate for transducer motion and average tissue distortion [6]. This method has also been shown to enhance ability to grade the relative stiffness of lesions, which may be important for differential diagnosis or monitoring tumour response to therapy.

Freehand elasticity imaging

Modern ultrasound examination allows a flexible, freehand, real time and interactive exploration of all parts of the breast. We have developed an elasticity imaging method that preserves and exploits this approach, which we believe should have widespread clinical impact even though it may be expected to suffer from more artefacts and yield poorer image quality than the mechanically constrained approach. Our early work demonstrated that hand-induced transducer motion can be a suitable method for applying the stress but the displacement estimation method would have to cope with the effects of using relatively large displacements and unintended lateral and rotational probe motion [7]. Recent results have shown that the performance of freehand elastography, in terms of signal to noise ratio, strain dynamic range and spatial resolution, can approach that of mechanical elastography although it is more variable.

We have now applied freehand elasticity imaging to a variety of breast masses in about 20 patients. Early results are confirming that in vivo freehand elastograms of the breast can be obtained using an unmodified ultrasound scanner interfaced to a computer. These images possess a spatial resolution approaching that of ultrasound B-scans and have already shown histologically confirmed features of breast masses that are not visible by any other imaging method.

Conclusion

Elasticity imaging, in one form or another, is likely to emerge as a new technique that will complement existing breast imaging modalities. Substantial development must take place before commercially available devices are to be available but meanwhile there is much to learn from the subjective freehand approaches to assessing tissue stiffness that are routinely employed in many ultrasound clinics. Extension of these methods, using tissue centred scan conversion and freehand elasticity imaging, will provide a means to practice elasticity imaging at low additional cost and without substantially modifying scanning equipment or technique.
References


NEW TECHNOLOGY FOR 3D BREAST ULTRASOUND

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Introduction
Diagnostic ultrasound is harmless to the human body and provides real-time diagnosis of the internal organs. In this respect, ultrasound has made the fastest technological advancement in the field of diagnostic medical equipment. After the development of real-time diagnostic technology in the 1970s', analog and color ultrasound have been widely used. In the 1990s', the entrance of digital and 3-D ultrasound scanners have brought about increased diagnostic efficiency and easier diagnostic methods in breast ultrasound over the 2-D ultrasound that has been in use for decades. Furthermore, the new technology has further raised the diagnostic capabilities and confidence in diagnosis of the breast.

Principles of 3-D Breast Ultrasound
1. 3-D Probe
For 3-D ultrasound scanning, the VOLUSON® probe with versatile 3-D application capabilities is provided. The basic theory behind volume scan can be explained through the "Fan Scan" method (fig 1). To optimize the volume box of the object of diagnostic interest, the user can control the angle, depth, and sweep speed.
2. **6 Features of VOLUSON530D Ultrasound**

2-1. *Surface Rendering*

VOLUSON530D's surface rendering function produces the form and exterior shape in 3-D that is extremely useful for morphologic studies. The 3-D s/w also provides a transparent mode, which allows one to examine bone, vessel, and tumor structures in more detail, matched with the structure's inherent characteristics (fig 2).
2.2. 3-D Multi-planar Imaging

In contrast to 2-D ultrasound, VOLUSON530D provides simultaneous views of A, B, and C planes after automatic scanning such that accurate acquisition of location data is possible (fig 3).
2-3. Coronal Plane View
This plane is impossible to view with existing 2-D ultrasound, but possible only in CT or MR. Thus, we can refer VOLUSON530D as CT ultrasound.

2-4. Fast Patient Scanning
The speed of volume data acquisition using VOLUSON530D depends on the scanning area and ranges from 0.2 to 2 seconds. Because faster patient scanning is possible, we have eliminated patient discomfort as a result of prolonged scanning.

2-5. Complete Diagnosis
A more accurate diagnosis is possible because VOLUSON530D stores the acquired volume data such that additional data analysis is possible even after the patient has left.

2-6. Precise Diagnosis
In examining the three-dimensional human anatomical structure, the ability to view images of the three planes allows useful anatomical diagnosis and automatic accurate volume calculations.

3. Clinical Applications

3-1. Morphologic & Multi-Sectional Information
In contrast to the existing 2-D ultrasound scanners that simply provide static planar information, VOLUSON530D provides images of the three planes for multi-planar
analysis and further allows one to study the morphology by using the 3-D images as a result of 3-D rendering.

3-2. 3-D Power Doppler

To differentiate between a malignant and benign mass, 2-D B/W ultrasound can be used to examine the shape and echo of the mass and color doppler is used to view the distribution of new vessels near the area of the mass. However, the VOLUSON530D provides the ability to examine not only the three-dimensional morphology, but also the internal echo strength and newly formed vessels near the structure. This is the greatest advantage in breast diagnosis using 3-D breast ultrasound scanners. For some patients, better results can be obtained using harmonic imaging technology.

Furthermore, the recently developed 3-D Power Histogram provides quantitative analysis between mass structure and nearby cells that assists in analyzing the malignant mass structure as it changes from diagnosis to treatment (fig 4).

Fig 4: 3D Power Histogram of malignant breast mass
3-3. 3-D Biopsy

Introduction of LIVE 3D™ allows one to verify the insertion process of the biopsy needle in real time and in three directions to accurately target the site of structure that is of interest of investigation. This will eliminate the need for multiple biopsy procedures using 2-D ultrasound to increase accuracy and decrease procedure time (fig 5).

![Fig 5: 3D US guided needle aspiration of cystic breast mass at multi-planar view](image)

3-4. VOCAL™

Accurate measurement of the mass volume is an important index in establishing the post diagnostic and treatment schedule.

Because VOLUSON530D provides width, height, and depth information from its Multi-planar view for automatic calculation, high data accuracy and confidence is obtained in contrast to 2-D ultrasound scanners (fig 6).
4. Conclusion

In addition to the clinical applications mentioned above, VOLUSON530D's PC software program PC-3D VIEW™ allows the sonographer to transfer the stored patient's scanned volume data freely to the doctor via PC, increasing the diagnostic efficiency as well as expanding into new fields of telemedicine's Tele 3D.

In other words, data communication of the compressed 3-D volume data and distribution of downloadable PC-3D VIEW™ from the Internet will promote cooperative relationships between health care institutions around the world.

Similar to the evolution of 2-D ultrasound scanners to Color Doppler ultrasound, I hope that a paradigm shift to 3-D ultrasound in diagnosis of the breast will occur and that 3-D ultrasound will be applied valuably in many different areas of breast diagnostics.
RECENT PROGRESS OF COMPUTER-AIDED DIAGNOSIS SYSTEMS IN MAMMOGRAMS AND ULTRASONOGRAMS

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1. Purpose

The purpose of this presentation is to overview recent progress of computer-aided diagnosis (CAD) systems developed for breast images. The CAD can be defined as a diagnosis made by a physician who takes into consideration the results of a computerized analysis of images and uses them as a "second opinion" in detecting and/or classifying lesions and in making diagnostic decisions (Fig.1).

2. Materials and Methods

The CAD scheme for breast images includes the preprocessing of the images, detections of lesions such as masses (Fig.2) and clustered microcalcifications (Fig.3), classification of the candidates, and postprocessing. A mammogram CAD system (Fig.4) consists of an image digitizer such as laser scanner, a workstation with a color CRT monitor, a large-volume hard drive, a high-brightness film light box, and a high-brightness B/W monitor (app. 2k x 2.5k). Mammograms are usually digitized at a 100- or 50-micron pixel size and 12-bit gray levels.

3. Results

The CAD system performance evaluated by databases is usually close to the values of 90% (85%) true-positive fraction for detection of clustered microcalcifications (masses) with 0.8 (1.5) false-positive findings per image, which suggests the mass detection is more difficult relative to the microcalcifications detection.

4. Conclusion

The CAD system could be an effective and beneficial tool for breast image diagnosis, and will be a necessary tool for image reading diagnosis in the near future. The CAD performance results for screening mammograms and ultrasonograms (Figs.5&6) by our
systems (refs. 1-14) will be discussed at the meeting.

Fig. 2 Flowchart for detecting masses in Gifu University

Fig. 3 Flowchart for detecting clustered microcalcifications in Gifu University

Fig. 4 Our CAD system for mammography
Fig. 5 Our ultrasonogram CAD system
Fig. 6 Detection performance and detection examples of our ultrasonogram CAD
References


