

White Paper

Multimodality breast imaging using RapidFrame™

What's inside?

- How breast imaging is changing to use multiframe studies
- Display factors affecting radiologist productivity
- LCD limitations for moving images
- Understanding the Receiver Operator Characteristic (ROC)
- RapidFrame technology clinically demonstrated to improve visualization

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ABSTRACT

Breast screening and diagnostic workup increasingly use *multiframe* studies like ultrasound, MRI, and breast tomosynthesis. These bring an abundance of information to the radiologist, including real 3D information. To fluidly review and analyze these studies challenges radiologists as well as current workstations and display systems. RapidFrame is a technology that enables displays to accurately display moving and changing images. It overcomes the slow response of LCD displays that otherwise blurs moving images.

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1. INTRODUCTION

Breast screening provides early detection which leads to earlier and more successful treatment for breast cancer. Barco continuously looks to advance the systems used for breast screening and we've been thinking: What should we add to our displays, as people add new techniques to breast screening?

Breast imaging today includes:

- For all women screened: Mammography is the gold standard, evolving to include breast tomosynthesis. It has been shown to provide better cancer visibility (Andersson *et al.*, 2008), higher detection rate, and lower unnecessary recalls.
- For target populations: Ancillary modalities like breast MR and breast ultrasound, genetic testing, and extension of the screening age for mammography.

Breast imaging tomorrow may include: whole breast ultrasound, breast CT, and elastography where the tissue stiffness of the breast is mapped into a volume. Many imaging modalities can potentially be used; the effectiveness of these is continually being tested in hundreds of clinical trials.

All these modalities generate studies with large numbers of images; each image needs to be examined by a radiologist. There are display factors that affect radiologist productivity. Among those commonly understood are contrast, brightness, glare and picture resolution. Less explored are display factors related to moving and changing images: blur, uneven frame repeating, and blinking. Moving and changing images are blurred; this blurring masks details and slows the radiologist. This paper will explore these motion-related display factors and introduce a technology for maximizing the quality of changing images.

To summarize the requirements of multiframe viewing:

- Quickly change from one image to another without blurring
- Synchronize cine sequences to make display smooth and predictable
- Handle large amount of data displayed as static or changing image sequences

Dealing with the many images generated by 3D modalities is inconvenient, so what is the advantage? A 3D modality like breast tomosynthesis yields a better signal to noise ratio. With many thin images per volume, extraneous superimposed structures are minimized in each image, whereas with a simple projection modality like 2D Full Field Digital Mammography, all structures that are aligned in the projection are shown superimposed in one thick image. Consider *Figures 1 & 2* below:

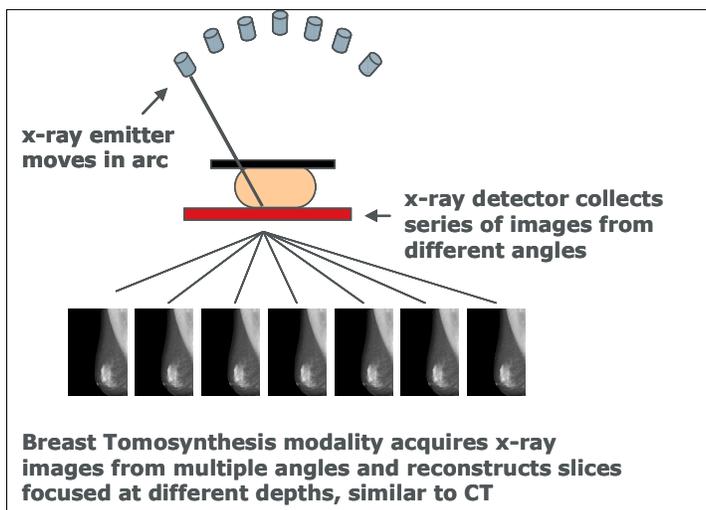


Figure 1

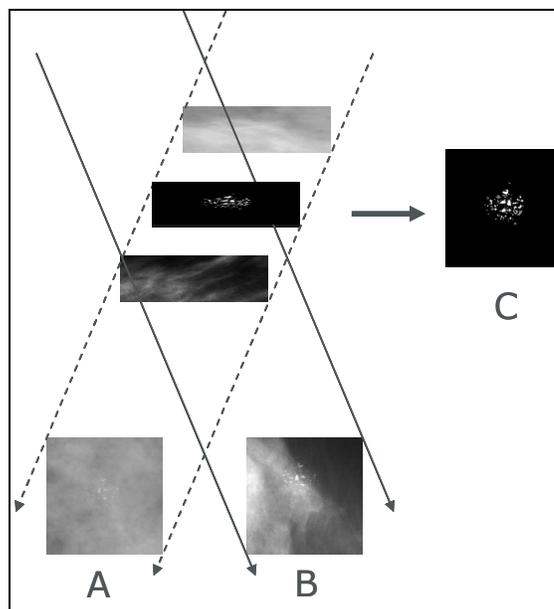


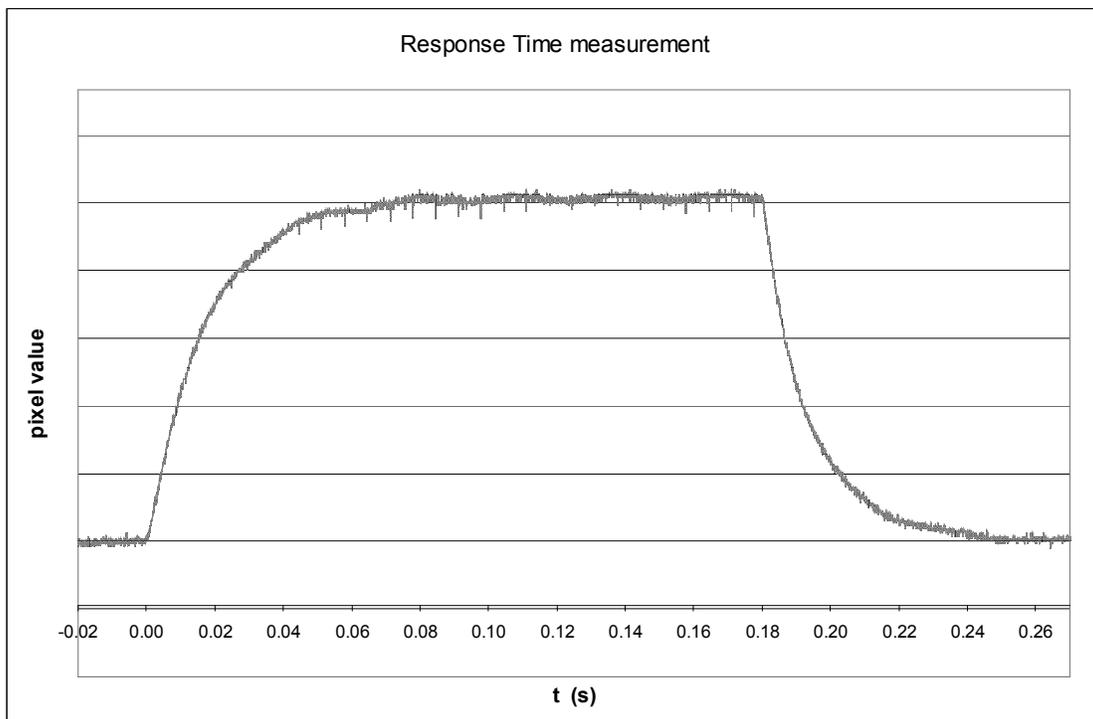
Figure 2

3D modalities acquire views from multiple vantage points, as shown in *Figure 1*. In *Figure 2*, the image acquired from one acquisition angle (B) could be superior to another (A). An even larger advantage comes when a thin layer (C) can be isolated and brought into focus by itself. These thin layers are mathematically reconstructed from the original data. Microcalcifications & masses that are indicative of disease are no longer overlaid with structures that are aligned in a projection, if these other structures are actually some distance from the objects of concern.

It is a challenge to get good performance. Good performance means not only traversing a study quickly, but getting accurate diagnostic results when you are done. There is a concern that current LCD technology may limit good performance as radiologists need to view more and more images everyday. The thin slices are often arranged in a stack of images that represents the complete volume. In stack mode, these images are often reviewed by flipping through them in a video or *cine* loop. "Stack-mode image display has the potential to allow radiologists to browse large three-dimensional (3D) datasets at refresh rates as high as 30 images/second. In this framework, the slow temporal response of liquid crystal displays (LCDs) can compromise the image quality when the images are browsed in a fast sequence" (Liang *et al.*, 2008). Barco's RapidFrame technology was developed to let people go quickly through images while preserving their natural visual acuity.

2. HOW RAPIDFRAME WORKS

To understand how RapidFrame works we first need to clarify a number of terms. **Frame rate** is how many times the screen is updated with new information. The inverse of frame rate is **Frame Time**, which is the minimum amount of time each frame is displayed. Mammography displays typically have 50Hz frame rate = 20ms frame time. **Response time** is the time it takes to get from one pixel value to another when the picture on the screen is changed. *Graph 1* below shows how when the pixel value is changed from low to high or from high to low, the display actually takes some time to reach the new value.



Graph 1

Measuring response time of a panel is straightforward:

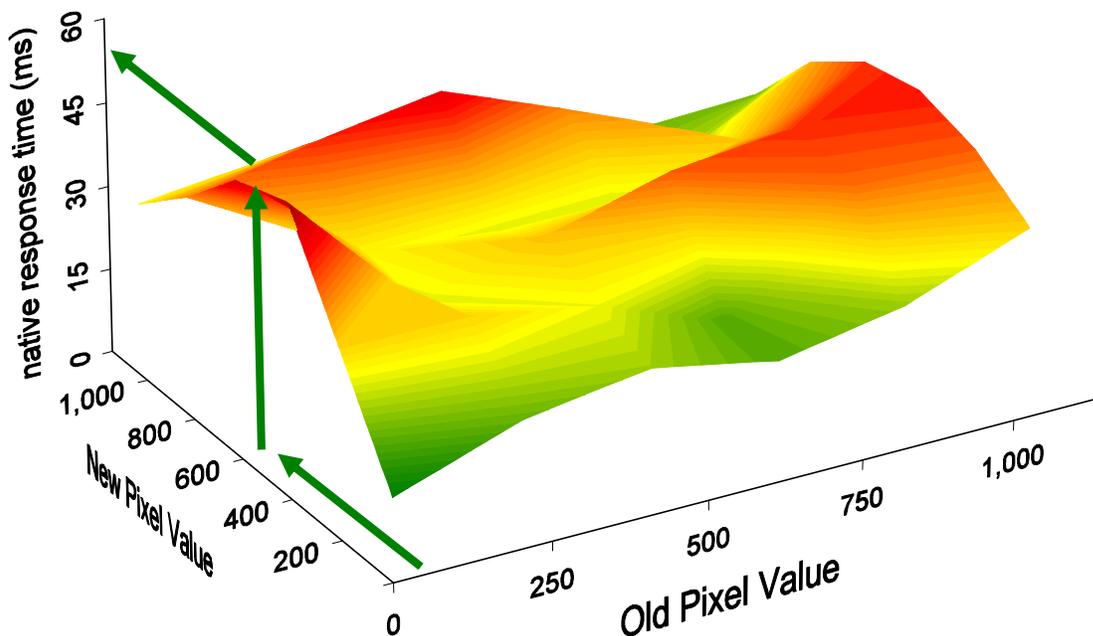
1. Start with one image on the display.
2. Change to a new image.
3. Measure how long it takes to get from the original image to the new image.

There are some nuances in this process: The camera needs to be very fast, many points need to be measured so you can see if there is overshoot, and everything needs to be well synchronized. From these measurements, it is possible to plot the response time of the display from one pixel value to another. If all the transitions were the same, it

would be a very simple graph, and could be summed up in a single number. It is often presented in this oversimplified manner on datasheets, (i.e. this product has a 12ms response time).

In actuality transition times vary enormously. The time it takes for the LCD panel to switch from near white to one gray value may be much greater than the time it takes to switch from near black to another gray value. In *Graph 2* below, transitions between all possible pixel values are shown. The transition time is shown as the height, where the lower axes depict the original pixel value and the new pixel value.

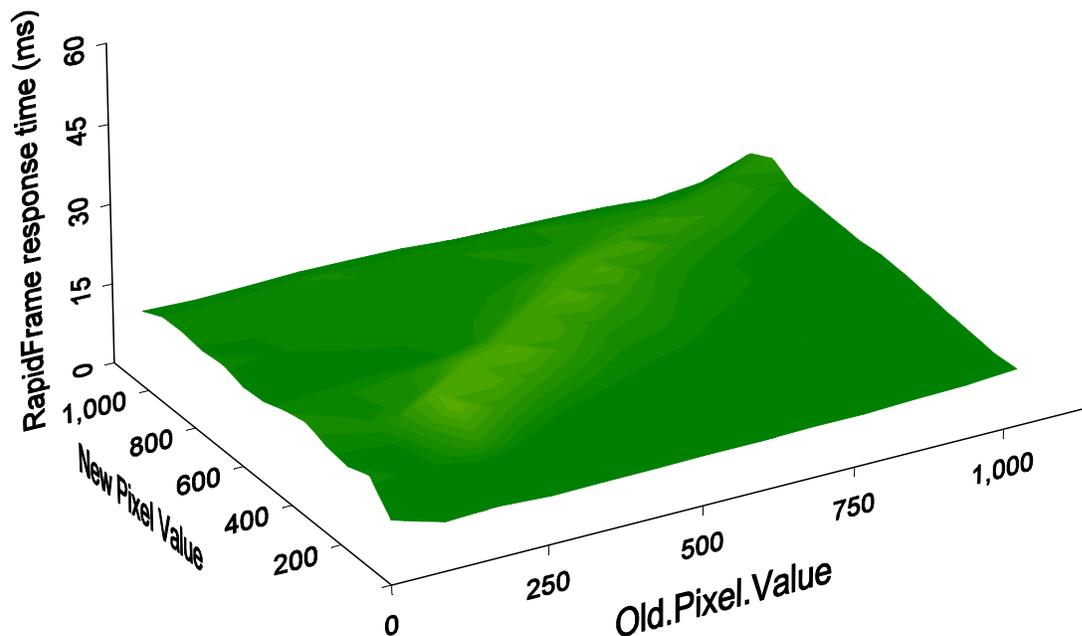
As an example, the transition from black to gray is also shown with green arrows on *Graph 2*: A change in pixel value from 0 to 128 takes 51ms. Since a display running at 50 Hz is refreshed with a new frame every 20ms, it takes $\sim 2\frac{1}{2}$ frame refreshes to reach the new target value when an image is changed.



Graph 2

It is obvious from this graph that the transition times vary quite a bit and many transitions are not completed in the 20ms available. The actual situation is even more challenging as the transition map changes significantly with temperature.

The challenge faced by RapidFrame was to get the transitions to occur at a uniformly faster pace, so that they would be completed within 20ms. Through a combination of mechanics, optics, and electronics, RapidFrame corrects the asymmetrical and slow response time of the typical LCD. *Graph 3* below shows the improved result.



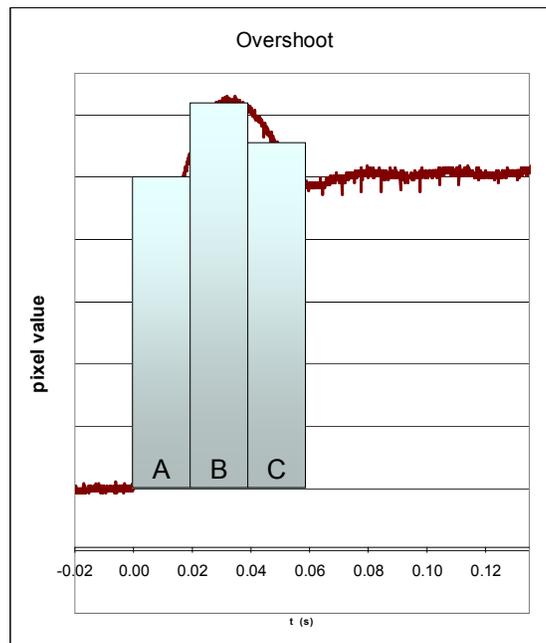
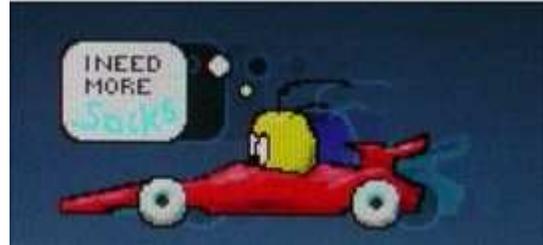
Graph 3

RapidFrame is aligned on each display in the factory and is adjusted automatically over the lifetime of each display by using a feedback mechanism. The quality assurance software MediCal QAWeb includes a special test to make sure the RapidFrame is working properly. No special software is required for the viewing application. A display with RapidFrame is driven in the ordinary fashion from a display controller using either DVI or DisplayPort cables. However, the choice of display controller is of great consequence.

A Barco MXRT display controller, which drives the display at 50 frames per second, is provided as part of the Mammo Tomosynthesis 5MP display system. It has up to 2GB of memory to hold large stacks of images. Using DirectX or OpenGL software interfaces along with RapidFrame, it is possible to synchronize the display of a cine loop with the refresh rate of the display. Each image {A, B, C, ...} can be displayed in an equal number of frames (i.e. ABCDE, AABCCDDEE). This makes for smooth motion, even when moving rapidly through a stack of images. Showing images for a constant number of frames matches details in the displayed image with the eye's predicted position for those details. Whereas when the number of frames varies for each image

(i.e. AABCDDE, AAABBCCDDD), the details are blurred and can even appear double while moving. The MXRT display controller has true 10-bit imaging and does not require a proprietary programming interface, using instead either standard OpenGL or DirectX. This allows application programmers to write a medical viewing application which takes full advantage of the MXRT display controller precision, and yet runs without modification on other display controllers.

Another problem that typically comes up is **overshoot**. Televisions address the problem of slow response time by adding substantial overshoot, even though some subsequent frames will display an exaggerated image, as shown on the right. This image¹ shows how a ghost image is created that is the aftereffect of compensation from the previous frame. This is shown in *Graph 4* below, where the desired value is more nearly reached in Frame A, but then Frame B and Frame C show a distorted image.



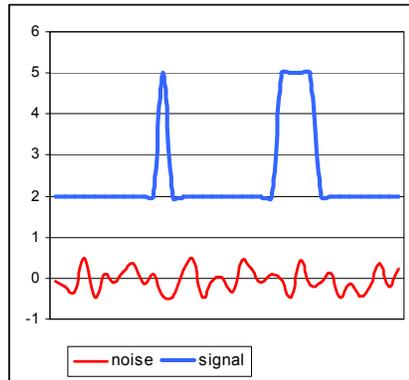
Graph 4

RapidFrame does not introduce noise into the image. As RapidFrame was developed, it was of critical importance to improve the performance of moving images without amplifying noise and without adding overshoot for any image values. On a television used for watching sports, to better see a fast moving ball, it may be an acceptable

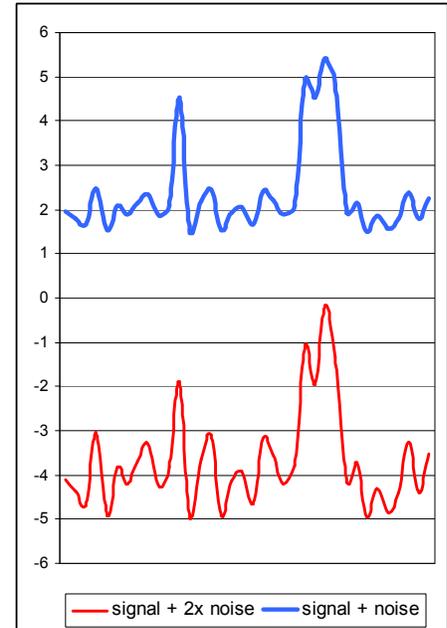
¹ From TFT Central, measurement of a consumer LCD display.

tradeoff to add some ringing artifact or to temporarily make details overly bright or dark. In medical images, we start with the assumption that any new form of distortion is unacceptable. Of particular concern is the noise from quantum mottle that is present to some extent in all x-ray images. This noise masks the signal (the signal being the objects one is trying to perceive).

When the size and shape of the noise is similar to the signal, there is a correspondingly large masking effect (Solomon, 1997). Microcalcifications are small, similar in scale to the quantum mottle. Examples of signal (blue) and noise (red) are plotted in *Graph 5*. The noise has been selected to be similar in size to the small signal. If the percentage of the noise is allowed to increase, it will be the small signal that is most affected, as shown in the red lower plot in *Graph 6*.



Graph 5 & Solomon, 1997). Microcalcifications are small, similar in scale to the quantum mottle. Examples of signal (blue) and noise (red) are plotted in *Graph 5*. The noise has been selected to be similar in size to the small signal. If the percentage of the noise is allowed to increase, it will be the small signal that is most affected, as shown in the red lower plot in *Graph 6*.



Graph 6

In addition, it has been shown that if the noise and signal are of comparable duration, the signal will be masked. (Van den Branden Lambrecht & Verscheure, 1996). This is particularly a concern for breast tomosynthesis, as the microcalcifications are presented only briefly during cine viewing. While certain response-time improvement technology would cause noise to increase, RapidFrame is a cautious technology that does not over-amplify quantum mottle.

3. RAPIDFRAME IMPROVES FFDM AND OTHER 2D IMAGES

For many studies, it is necessary to interact with images using zoom, pan, and the digital magnifying glass. Each of these tools changes the contents of the screen as it is being used. Software viewer features like *continuous zoom* present many sequential images in rapid succession to make interaction with the tool feel smooth. The *digital magnifying glass* is frequently used to inspect an area or follow a structure, especially on Full Field Digital Mammography (FFDM) images. Even though the underlying image is not moving, the image in the magnifying glass window is changing frequently. Many will observe that on a standard display, the image is only clear and sharp when they hold the tool still.



This still-image clarity can be preserved with the RapidFrame feature. As each new updated image is drawn by these interactive tools, RapidFrame makes sure that the target pixel values are reached immediately:

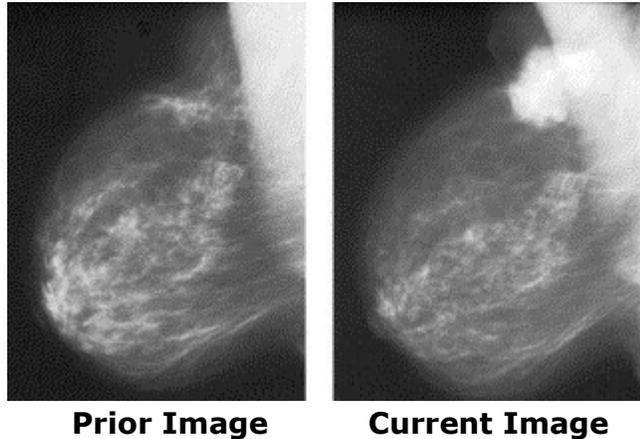
There is no need to freeze for a moment to let the image come into focus.

While an LCD display showing a static 2D image does not have a perceptible flicker, that same image flickers and throbs when panned across the screen. Eyestrain is reduced, if flicker can be eliminated (Vertinsky & Forster, 2005). This flicker is due to an asymmetric response time: An uncompensated liquid crystal cell will change more quickly from bright to dark than from dark to light. As the image is moved, every pixel is either getting brighter or darker (based on what was at each location in the previous frame). And taken altogether, moving thousands of pixels make whole regions of the image flicker as they move. RapidFrame corrects this asymmetry and eliminates the flicker.

4. OTHER WAYS RAPIDFRAME CAN BE USEFUL

Toggle Comparison:

It has been suggested that toggling back and forth between prior and current images may be the best way to detect temporal changes (van Engeland *et al.*, 2003). Most cases would be more subtle than the pair illustrated here, but it illustrates the possibility of comparing current and prior in this fashion. In this process, it is particularly valuable to have the difference presented suddenly; fading slowly from prior to current makes the difference less conspicuous. Like the CRT displays used in a similar toggle study at Radboud University in Nijmegen (Roelofs *et al.*, 2007), the RapidFrame technology can change the displayed image very suddenly to get the most advantage from this technique.



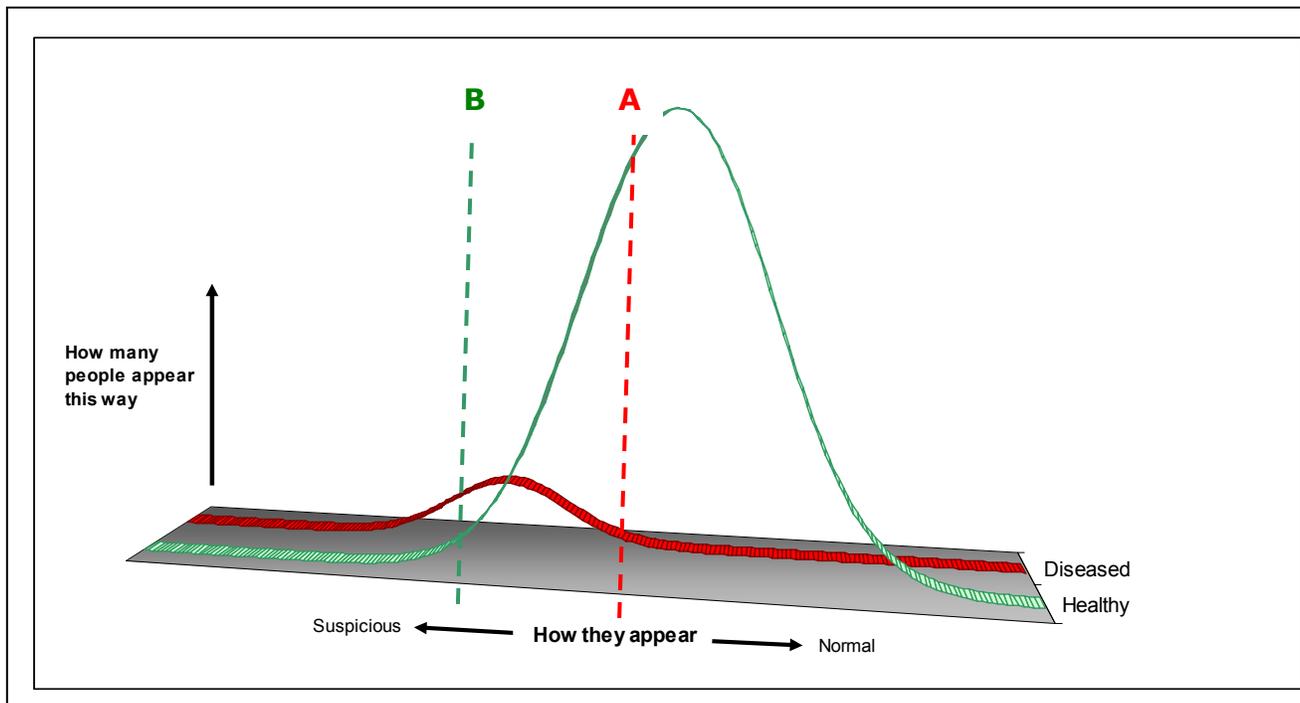
Ultrasound Cine:

Diagnostic Ultrasound breast exams are a typical part of patient care. The ability to use breast ultrasound for *screening* is an active area of investigation, with the ACRIN 6666 trial showing that additional cancers can be detected (Berg *et al.*, 2008). Most likely, it will prove to be quite efficient, provided the right equipment is used and provided that effective protocols are developed. One promising approach is automated whole breast ultrasound (Kelly *et al.*, 2010). The equipment scans the breast methodically, producing many image frames. To review these as a video can take several minutes of watching intently for anomalous structures. RapidFrame can eliminate blurring and make these frames sharp even when the video is reviewed very quickly.

5. CLINICAL TRIAL OF RAPIDFRAME WITH BREAST TOMOSYNTHESIS

A question is often posed when new equipment is introduced: “While I see the specifications are higher, is there any impact on clinical performance?” While clinical performance is a broad topic, it is straightforward to measure the performance of certain typical screening tasks like detection of microcalcifications (Zuley *et al.*, 2006). In the case of the RapidFrame feature, a study was conducted (Marchessoux *et al.*, 2011) to measure radiologist detection of calcifications in breast tomosynthesis studies following a similar approach to that used with digital mammography (Ruschin *et al.*, 2007). The detection rates using the original display model and the new model are summarized using an ROC curve that shows a significant advantage for the model equipped with RapidFrame. The original display model selected for the comparison was Barco’s widely-used Coronis 5MP Mammo.

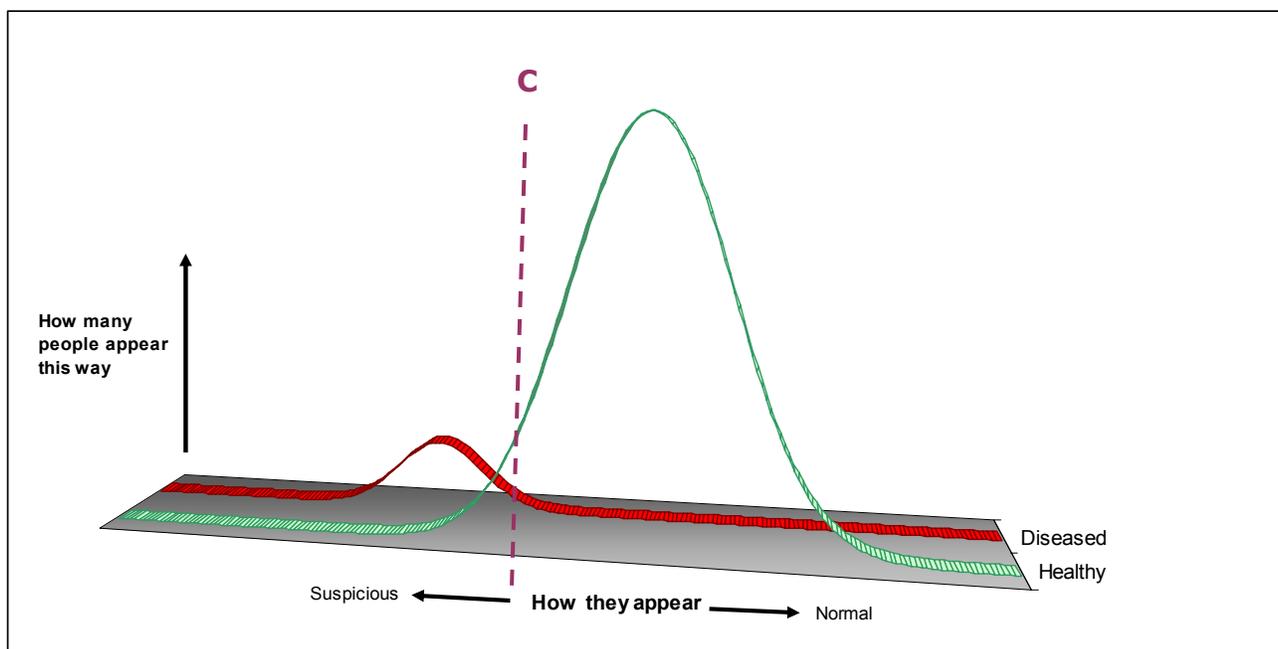
Understanding the Receiver Operating Characteristic (ROC) curve will help to explain some of the implications of the study. The *Receiver* is the person interpreting the test, and the *Operating Characteristic* is a description of how well the test works. Screening for breast cancer is far from perfect. Not only are some diseased people not detected, but many healthy people are recalled for further examination. Consider *Graph 7*,



Graph 7

showing a population screening test. There are two sub-populations {Diseased, Healthy} and, of these, the healthy population is much larger. The test for each

individual appears normal or suspicious, *to a degree*. That is to say that a test may appear *slightly* suspicious or *pretty* normal. Radiologists who are interpreting the test choose a point where they are comfortable operating on this horizontal axis. Which operating point is chosen? Why not choose the point that never recalls a person who is healthy, or the point where all diseased people are recalled? Unfortunately, in this realistic example, the point that recalls all the diseased cases also recalls 40% of the healthy population (dashed line A), while the point that never recalls a healthy person misses 70% of the diseased people (dashed line B). The radiologist chooses a compromise operating point, based on which test they are using and the population that they have. Referring to *Graph 7* above, they would likely choose an appropriate operating point somewhere in between A&B. Better would be to have an improved test that could distinguish the healthy population from the diseased population, as in *Graph 8* below.

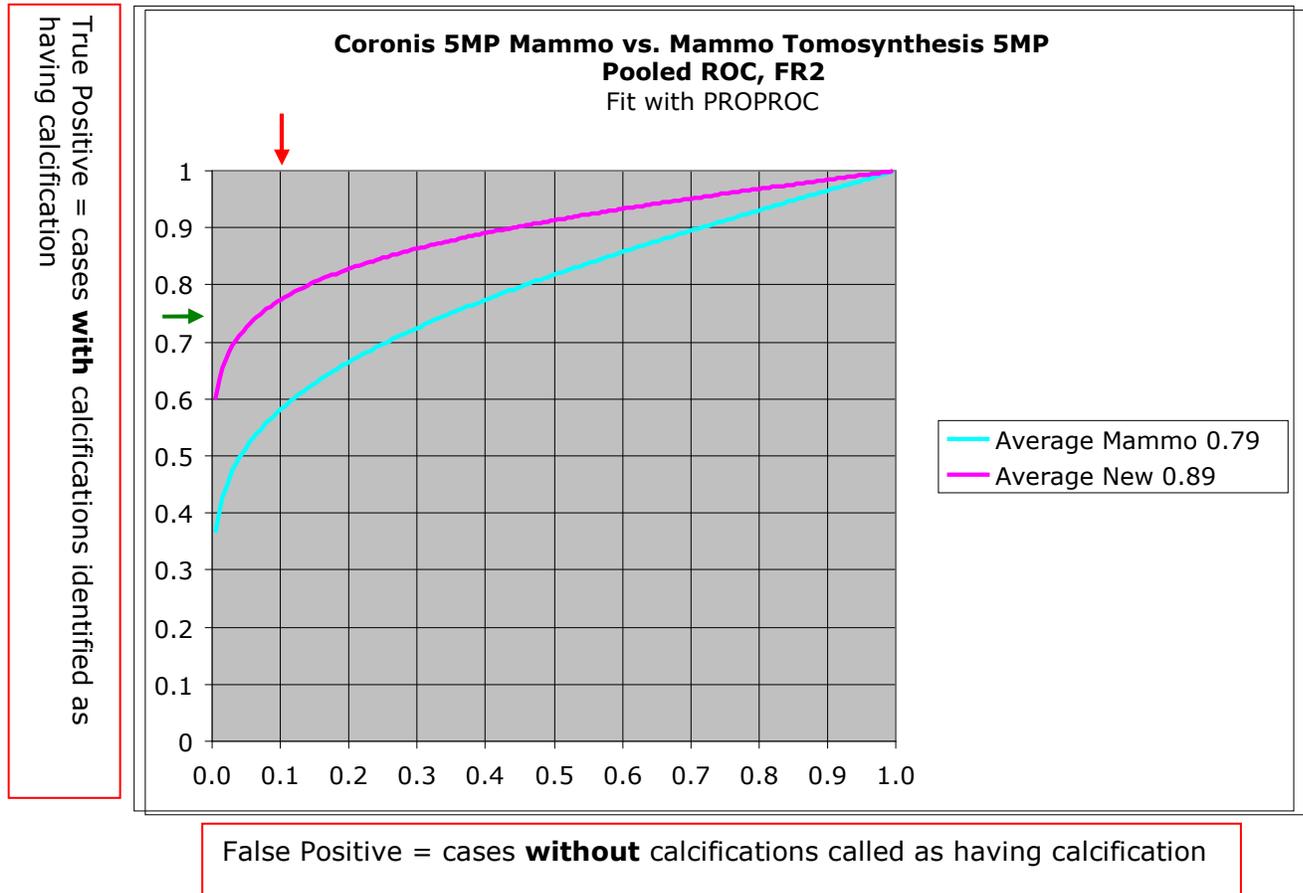


Graph 8

With this improved test, it is possible to pick an operating point that recalls most diseased people and very few healthy people (dashed line C). An ROC curve is a summary of all the operating points, showing the recall rate for healthy people on the x-axis and the recall rate for diseased people on the y-axis.

In the Marchessoux study, radiologists were looking for microcalcifications in tomosynthesis image stacks, some of which had microcalcifications and some of which did not. As the reconstructed slices briefly appeared during cine-review, anatomical structure and quantum noise added to the signal from the microcalcification, whether it was there or not. Some fraction of cases *without* microcalcifications were recalled,

making the horizontal coordinate; the vertical coordinate is the fraction of the cases *with* microcalcifications that were recalled. *Graph 9* below plots average operating points for the radiologists in the Marchessoux study.



Graph 9

Ideally, if the test were perfect, the entire ROC curve would be very high up on the vertical axis, meaning there are no operating points where detection of microcalcifications is low. Thus one way to summarize the overall quality of a test is to calculate the area under the ROC curve. This area is referred to as AUC (Area Under the Curve).

Now it is possible to analyse the result of the comparison between the two models. In *Graph 9*, the area under the curve is greater for the new display that has the RapidFrame feature. This advantage is summarized by the AUC of .896 which is greater than the AUC for the original display which had 0.797. Yet it is even more interesting to examine some specific points on the curve. The red arrow indicates a 10% extraneous recall rate of cases without microcalcification – this is considered an upper limit for

screening. At this recall rate, the detection rate for the original display is only 60%, but rises above 75% for the new display. The green arrow indicates a level of 75% detection: For the new display the extraneous recall is 9%, but for the display without RapidFrame the extraneous recall is >30%. The difference in the study was statistically significant.

During the study, improvement was realized by all the radiologists using RapidFrame. The reader with the least success on the original display showed the greatest improvement when using the new Mammo Tomosynthesis 5MP display with RapidFrame. Even though other readers started at a higher operating point when using the original display, they still experienced a marked improvement with the new display.

6. FINANCIAL IMPLICATIONS

There is a potential for better accuracy with wider use of multiframe imaging. Better accuracy not only has an obvious appeal to the patient, but there is a financial advantage as well. Inaccurate screening leads to further examinations, requiring more staff and equipment resources. At the same time, it is not practical to require the use of new modalities if the time it takes to interpret the studies grows dramatically. Most countries are limited as to how many resources they can apply to each segment of the healthcare system, and radiologists are certainly limited resources. Ideally, when new modalities are introduced, they will provide better patient outcomes and be more efficient to use. RapidFrame lets people move easily twice as fast through a stack of images without blurring, thus Barco is making these new modalities more efficient to use.

7. CONCLUSION

Modern breast imaging centers will interpret increasingly large numbers of multiframe studies. The ability to move quickly through these images will determine the efficiency of these modalities. Conventional LCD displays are limited as to how well they can display changing and moving images. They can add substantial blur to the displayed image and this has been shown to have a negative impact on conspicuity of medical details.

RapidFrame eliminates blurring and makes it easy to handle hundreds of frames fluidly. The positive effect on microcalcification detection in breast tomosynthesis has been found to be substantial and statistically significant. As people can readily observe the improvement in sharpness in any moving images, RapidFrame will be of benefit when looking at other 3D modalities. Additionally, regular digital mammography involves frequent use of tools that quickly change the image to be smooth and interactive. These changing images, too, are more accurate with RapidFrame – making them easier to see without stopping and waiting for the image to clear.

The MXRT display controller combines well with RapidFrame to allow synchronization and fast display of large studies, using legacy software as well as viewing software using modern open interfaces like OpenGL and DirectX.

Factory calibration and built-in feedback are provided with RapidFrame, giving it a long stable lifetime. This is monitored by Barco's QAWeb software.

Displays with RapidFrame, like Barco's Mammo Tomosynthesis 5MP, will show sharp images quickly, no matter how fast you move through your workflow.

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