RIB ERASURE UTILIZING NINE-POINT SMOOTHING

The computer has been employed to erase ribs when imaging the myocardium with ^{99m}Tc-tagged phosphates (*1*). A simple and fast technique utilizing a smoothing function is capable of accomplishing this task. Requirements for the technique are the ability (A) to smooth a framed picture, (B) to add and subtract framed pictures element by element, and (C) to multiply a framed picture by a constant.

The rib images occur as a repetitive distribution of radionuclide; therefore, a large proportion of their spatial energy is grouped around a single frequency. Rib erasure is accomplished by processing the image in a manner that selectively rejects information about this frequency.

The smoothing algorithm employed was a nine-point uniformly weighted average. Smoothing removes or decreases high-frequency spatial information. If the image of the ribs can be repeatedly smoothed until the modulation at the basic rib frequency (ω_γ) is reduced to half its original value, then the technique can be employed efficiently. This can be explained in terms of one-dimensional transfer functions. Let $H(\omega)$ be the spatial frequency distribution describing the original image and $S(\omega)$ some operator formed by repeated smoothing the image such that $S(\omega_\gamma)H(\omega_\gamma) = H(\omega_\gamma)/2$. The following two equivalent equations mathematically describe the erasure technique (Technique 1):

$$[2S(\omega) - 1]H(\omega) = G(\omega) \qquad (1)$$

$$2S(\omega)H(\omega) - H(\omega) = G(\omega) \qquad (2)$$

Here $G(\omega)$ is the spatial frequency distribution of the resulting image. From Eq. 2 we see that if $\omega = \omega_\gamma$, then $G(\omega_\gamma) = 0$, the desired effect at ω_γ. However, at higher spatial frequencies Eq. 2 gives a negative value for $G(\omega)$, indicating a 180° phase shift in the frequency domain (Fig. 1A). The phase shift associated with Technique 1 can cause artifacts in the resulting image. The absolute magnitude of this operator would be useful, but this cannot be derived by simple addition and subtraction of smoothed images.

Another technique for rib erasure (Technique 2) which maintains proper phase information is described mathematically in the following equivalent equations:

$$[2S(\omega) - 1]^2H(\omega) = G'(\omega) \qquad (3)$$

$$[4S^2(\omega) - 4S(\omega) + 1]H(\omega) = G'(\omega) \qquad (4)$$

$$4S(\omega)[S(\omega)H(\omega)] - 4[S(\omega)H(\omega)] + H(\omega) = G'(\omega) \qquad (5)$$

Clearly, if $\omega = \omega_\gamma$ and $S(\omega_\gamma)H(\omega_\gamma) = H(\omega_\gamma)/2$, then $G'(\omega_\gamma) = 0$. For other frequencies $G'(\omega)$ is always positive; therefore no 180° phase shift occurs in the frequency domain. Technique 2 has a broader band of rejection.

The operator $S(\omega)$ represents the nine-point smoothing function applied "n" times. For a 64 × 64 matrix with an 11-in. field of view, n is of the order of 3 or 4, depending on the entire imaging system utilized. The smallest value of n should be tried first and successive values tested until the proper results are obtained. Adjustment of image size relative to the spacing of the display matrix may be de-

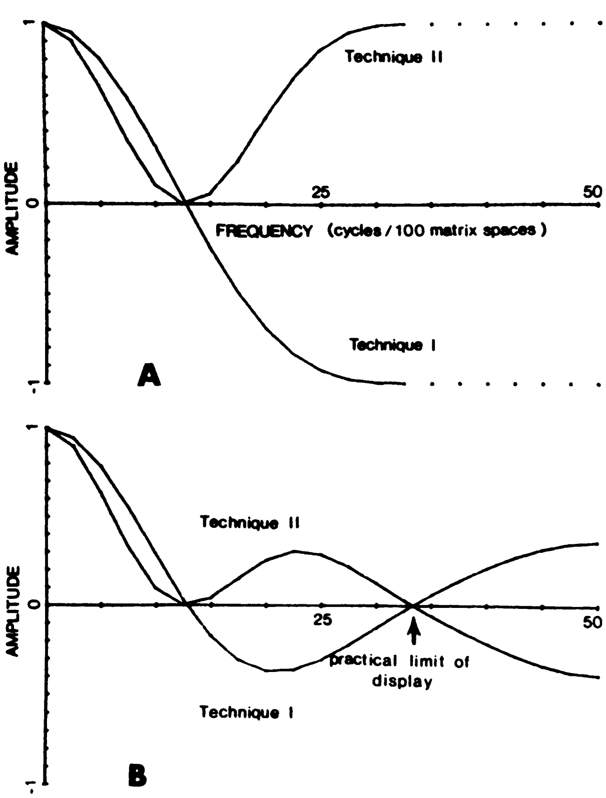

FIG. 1. Relative frequency responses of Techniques 1 and 2. (A) Without final smoothing; (B) with final smoothing.

sirable if satisfactory rib erasure is not initially achieved for a specific value of n.

In order to employ Technique 2, the following steps are suggested:

1. Smooth the original framed picture n times. Multiply this by 4 and store as $4S(\omega)H(\omega)$.
2. Smooth the result of Step 1 n times and store separately as $4S(\omega)[S(\omega)H(\omega)]$.
3. Add the original framed picture $H(\omega)$ to the result of Step 2. From this subtract the result of Step 1. Store the final image as $G'(\omega)$.

Note that the addition of $H(\omega)$ to $4S(\omega)[S(\omega)H(\omega)]$ is necessary prior to the subtraction of $4S(\omega)H(\omega)$. Otherwise, since the magnitude of $4S(\omega)[S(\omega)H(\omega)]$ is generally less than the magnitude of $4S(\omega)H(\omega)$, the result would be a negative number which the computer would probably round to zero.

One may wish to smooth the image once after the erasing technique has been employed. Figure 1B shows the frequency responses of Techniques 1 and 2 as altered by such smoothing. Figure 2 shows results of Technique 2 for a lateral view of a known infarct.

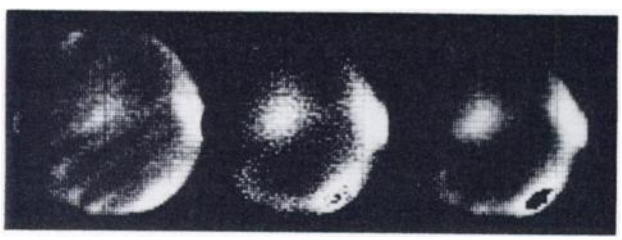

FIG. 2. Lateral view of known infarct showing original image (left), processed image (center), and processed image which has been smoothed once.

This technique is easy to utilize once the proper smoothing operator for the display matrix and image size has been determined. The broad rejection band compensates for variability in the rib spacing of each patient. Nor does the patient have to be oriented specifically along any axis, although a protocol should be followed once the technique is established. No complicated programming is necessary to employ the technique, although for convenience the sequence of operations could be stored on some computer systems for easy repetitive use. The execution time for the technique is less than 1 min on a Hewlett Packard 5407A Scintigraphic Data System utilizing a 64 $\times$ 64 display matrix.

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REFERENCE

1. STOKELY EM, PARKEY RW, LEWIS SE, et al: Computer enhancement of myocardial infarct scintigrams. In *Proceedings of the San Diego Biomedical Symposium 1974*, vol 13, pp 101–106

NOTICE OF NEXT ABNM CERTIFYING EXAMINATION

The American Board of Nuclear Medicine announces that its Fourth Certifying Examination in Nuclear Medicine will be held on Saturday, September 18, 1976.

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