## THE AUTHOR'S REPLY

Levy quite correctly points out that the gain in signal-to-noise ratio (SNR) to be expected when using a Fresnel zone plate is dependent on the nature of the source intensity distribution. Only for a single point source can the large collection efficiency of the zone plate be translated directly into a corresponding reduction in dose or exposure time. This fact was discussed in our earliest publications (*1–3*) on this subject, and a simplified derivation of the SNR has recently been published (*4*). A very detailed treatment of quantum noise in zone plate imaging, taking full account of the spatial distribution of the noise field and the limited spatial bandwidth of the reconstruction system, has been submitted for publication (*5*).

Although Levy's mathematics is much oversimplified (most of his equations are not even dimensionally correct), his approach is sound. The result that the SNR gain g is related to the ratio of the intensity at the point of interest to the average inensity of the source is also correct. An equivalent statement is given in Ref. *3*. However, it definitely does not follow from this that "the nature of the image and the origin of the noise in nuclear medicine does not generally enable us to use the advantages" of the zone plate or that the "gain in SNR will be significant only for the point of the image far superior to the average of the image."

The difficulty here is in specifying just how this "average of the image" is to be computed. In fact, although Levy does not put limits on his integrals, they should be performed over a region approximately equal to the zone plate shadow (*5*). For example, with a 5-in.-diam zone plate used with a 10-in. diam Anger camera and unit magnification ($s_1 = s_2$ in the notation of Ref. *2*), the average must be taken over a 10-in. disk. For a uniform flood source of this size or larger, each point will have the same intensity as the average. The gain g will then be a little less than one and there will be a slight disadvantage to the zone plate compared with the equivalent pinhole. At the other extreme, for a point source, g is approximately equal to the collection efficiency advantage and can be as large as a thousand or so (provided, of course, that only quantum noise is present).

Real clinical situations usually lie between these two extremes. Perhaps liver and lung imaging, where the object nearly fills the field, approach the flood source limit, but certainly in bone, thyroid, and kidney imaging the area of the object is small compared with the area of the zone plate shadow and there will be a significant advantage to the use of a zone plate.

On the other hand, the overall usefulness of the zone plate should not be assessed on the exposure time advantage alone. In our laboratory we have been using the zone plate primarily with x-ray film as the detector (*3,6*). This combination is substantially *slower* than an Anger camera and collimator but offers advantages in resolution, simplicity, and portability and, as noted by Levy, tomographic capability. On the negative side, the photographic and optical processing is still somewhat tedious and time-consuming and there is the possibility of artifacts in the image (*3*). This camera has been used successfully in a variety of clinical studies (*7*) and is indeed capable of imaging large organs (*8*).

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## THE AUTHORS' REPLY

We greatly appreciate Dr. Levy's comments regarding the signal-to-noise (SNR) in coded aperture imaging and agree with his comments regarding the gain in SNR for strong sources with corresponding loss for weak sources.

In order to treat the problem completely, one must explicitly include the aperture code and source distribution as Dr. Levy indicates. Figure 1 gives some preliminary results of such an analysis performed for a stochastic aperture (*1*). The error kernel, E, normalized to the peak value of the point response function is shown plotted as a function of distance