1. Techniques for the estimation of red cell volume;
2. Techniques for the estimation of plasma volume;
3. The measurement of packed cell volume;
4. The assessment of automated blood volume equipment;
5. Sequential blood volume estimations;
6. Estimation of total blood volume as the sum of red cell plasma volumes;
7. Presentation and analysis of results;
8. The radiation dose which the patient receives during these investigations.

The purpose of the document is to enable measurements obtained in different centers to be reliably compared with each other. The document has been published (*Br J Haematol* 25: 801–814, 1973) and will also be published in a number of national journals.

L. SZUR
H. I. GLASS
ICSH Panel on Radioisotopes in Hematology
Hammersmith Hospital
Shepherds Bush, London, England

SECTION SCANNING USING ORTHOGONAL TANGENT CORRECTION

I read with interest the article by Kuhl, et al, Quantitative Section Scanning Using Orthogonal Tangent Correction (*J Nucl Med* 14: 196–200, 1973). The OTC technique has been developed with the aim of producing a matrix which is compatible with all of the tangent values, and preliminary reports of this work (*1,2*) suggested that the method would give much better pictures than conventional section scans. This has not been convincingly demonstrated.

The authors' description of the technique is so abbreviated that it is difficult to see how to apply it in practice. For example, the formula for the orthogonal tangent correction factor is given explicitly only for the center cell P_{33}. There is no statement of which tangent values to choose in the general case P_{ij}, nor any suggested method of dealing with those matrix cells whose positions correspond with junctions between tangent cells. In addition, in Fig. 6, scans at 45 and 135 deg of the matrix resulting from the first step are shown as giving uniform tangent values. This is clearly wrong. Scanning a uniform square distribution at 45 deg gives a triangular response which leads to a final matrix very different from Fig. 8. Thus either the tangent values of Fig. 6, or the OTC formula, or both, are incorrect.

The example in Figs. 1 through 8 may give the misleading impression that in the absence of noise etc., the OTC technique can calculate the original distribution exactly. However, a single line of activity at right angles to one of the tangents is a very special case, possibly the only one (apart from a point source) where this can be done. In the general case, the final pattern is only one of a large number of solutions which are compatible with all of the tangent values and this introduces the possibility of significant distortions in the final picture. A hollow square or at least an L-shaped distribution would have been a more realistic pattern with which to test the accuracy of reconstruction.

It is unfortunate that the authors did not investigate the problem of statistical noise. However, the magnitude of the errors involved in a scan of the bottle phantom can easily be estimated. Each correction factor in the OTC technique requires multiplication by four independent tangent values giving a total of 46 multiplications, each of which involves a significant error (about $\pm 3\%$ for a typical tangent value of 1,000 counts). In contrast to this, the DSA technique requires simple addition of 12 tangent values. Thus the OTC method could generate significant artifacts and will certainly give a much noisier picture than the DSA method. This is borne out by the results in Fig. 11, where a bottle which contributes 10,000 counts to the scan has a range of $\pm 50\%$ in estimated contents. Even this large range is an underestimation of the errors which could occur in practice because the fractional counts per bottle were calculated by comparison with a uniform-concentration phantom. This maneuver not only allows for attenuation in a way which would be difficult to repeat in a clinical situation but conceals any possible systematic distortion of the final picture caused by the processing.

The clinical scans of Fig. 10 appear to demonstrate the superiority of the OTC technique. However, Kuhl (*3*) has previously shown brain section scans, using the DSA technique with 15 deg interval angle, which were incomparably better than the DSA scan of Fig. 10 and considerably smoother than the OTC scan. Figure 10 in fact proves very little about the OTC technique because it is impossible to tell how much of the apparent detail is due to real structures and how much is due to the high noise level produced by the processing. A more meaningful comparison would have been between DSA and OTC

reconstructions of the bottle phantom data where the actual distribution of activity is known. In addition, a direct rectilinear scan of the phantom, with the same total counts as the section scan, would have given a useful standard of resolution and noise-level against which various methods of section reconstruction could have been judged.

Although I appreciate the authors' desire to present both technique and results in a single short paper, I feel that a much more complete description of their work is necessary before the OTC method can be properly assessed.

G. D. S. NEILL
Eastern Regional Hospital Board
Dundee, United Kingdom

REFERENCES

1. KUHL DE, EDWARDS RQ, RICCI AR, et al: Quantitative section scanning using orthogonal tangent correction. *J Nucl Med* 13: 447–448, 1972

2. KUHL DE, EDWARDS RQ, RICCI AR, et al: Quantitative section scanning. In *Medical Radioisotope Scintigraphy*, Vienna, IAEA, 1973, pp 347–353

3. KUHL DE, SANDERS TP: Comparison of rectilinear vertex and transverse section views in brain scanning. *J Nucl Med* 11: 2–8, 1970

LIMITATIONS OF ORTHOGONAL TANGENT CORRECTION

In their recent paper, Quantitative Section Scanning Using Orthogonal Tangent Correction (*J Nucl Med* 14: 196–200), Kuhl, et al have presented a method which represents a significant improvement over their previous methods of additive tomographic reconstruction. Of particular importance is the apparent quantitative accuracy of the technique since any truly quantitative method of section imaging represents implicitly a solution to the problem of quantitative three-dimensional imaging (*1*).

The authors have presented some very impressive experimental data to substantiate the quantitative accuracy of their method. They have, however, failed to justify rigorously the mathematical basis of the technique and have thus apparently overlooked the fact that Orthogonal Tangent Correction (OTC) does not yield a general solution to the reconstruction problem which is quantitatively accurate for all classes of "pictures". [For the sake of brevity, terminology shown in quotation marks will follow the definitions given in our recent review of techniques for tomographic image reconstruction (*1*)]. This can be demonstrated by showing that there exists a class of "pictures" which OTC cannot reconstruct with quantitative accuracy.

Hypothesis: for any "picture" which contains one or more elements p_{ij} of zero value surrounded by picture elements with positive, nonzero values such that the "real ray sums" of all "rays" of all "projections" containing p_{ij} are nonzero and positive, the corresponding point p^r_{ij} in the reconstruction by OTC will be nonzero.

Proof: let us assume that p_{ij} is represented by point P_{33} in the OTC paper of Kuhl, et al, Figs. 5–7. Then following the terminology of their paper, P_{33} Corrected will be the point p^r_{ij} in the final reconstructed image. P_{33} Corrected is given by:

$$\frac{\frac{A_3}{\Sigma A_n} \times \frac{B_3}{\Sigma B_n}}{\frac{C_3}{\Sigma C_n} \times \frac{D_3}{\Sigma D_n}} \times P_{33}$$

where

$$P_{33} = \frac{A_3}{\Sigma A_n} \times B_3 \text{ from a previous step.}$$

By the terms of our original hypothesis, none of the values in these equations can be zero or negative. If this is so, it is obvious that P_{33} Corrected must be nonzero as hypothesized. This proof can be extended for any number of sets of orthogonal "projections" without altering this result.

This limitation of the OTC method is characteristic of reconstruction techniques that either lack a subtractive step or in which there is no possibility of negative numbers occurring during the calculation. An analogous situation arises in Kuhl's earlier SSA and DSA methods (*2*).

This limitation of the OTC method does not appear to be a trivial case since many real clinical situations duplicate the hypothetical model presented. Examples include the necrotic centers of some tumors, cystic lesions, and abscesses.

At least two other groups of investigators have discovered additive reconstruction (*3,4*), both apparently independently of either Kuhl's work or each other's. Both Herman (*5*) and Vainstein (*4*) have studied the properties of additive reconstruction and devised techniques for improving its performance. Among these is the use of a subtractive step in the final image processing which does allow the recovery of zero values at points buried within the "picture".

Even with these suggested improvements additive reconstruction appears to be a poor alternative to