A mathematical analogue to calculate the counts from ^{32}P in the choroidal blood during the ^{32}P uptake test

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SUMMARY A mathematical model has been developed to assess the contribution of ^{32}P in the blood in the choroidal vessels to the count obtained from the eye during the ^{32}P uptake test. Applying the model at 48 hours after the administration of ^{32}P it was found that, at this time, between 4% and 7% of the control count on the eye was due to ^{32}P activity in the choroidal blood.

In a previous paper¹ the authors described their experience of the ^{32}P uptake test in the diagnosis of intraocular malignancies and discussed some of the factors affecting the uptake. The ^{32}P test is based on the differential accumulation of radioactive phosphorus between neoplastic and non-neoplastic tissue following an intravenous injection of the isotope. Counts are recorded from a site on the surface of the eye, overlying the lesion, and from a control site on the eye. The ^{32}P uptake is the difference between the test and control counts expressed as a percentage of the control count. In a recent review of the literature² threshold values for a positive test were shown to have varied between 30 and 150% according to different investigators, but now a figure of around 60% is most frequently used. Several investigators have discussed the reliability of the test and stressed the need for accurate localisation of the probe.³⁻⁶ Various matters such as the rate of phosphorus uptake in uveal melanomas⁷ and the relation between ^{32}P counts and histological features⁸⁻¹⁰ have been investigated.

An aspect of the ^{32}P test which has received little attention relates to the source of the control counts. An uptake of 100% for example implies that there are half as many counts recorded over control tissue as from a site which overlies a malignant tumour. The counts from ^{32}P in normal tissue are therefore not negligible in comparison with those from a malignant tumour. The activity recorded on the surface of the eye depends on the distribution of isotope in the tissue below the detector. A knowledge of this distri-

bution is important, and one aspect which should be investigated is the extent to which the control counts are due to radioactivity in the blood. It is important to know to what extent blood borne ^{32}P affects the count on the sclera so that due regard may be given to vascularity. It is, however, difficult to assess the contribution of the vascular component to the control counts,^{4,11} and to facilitate this a mathematical model has been developed to estimate the effect of the ^{32}P activity in the choroidal blood on the control counts.

Materials and methods

A brief outline of the method may help in the understanding of the use of the model. Blood is withdrawn from an antecubital vein from a patient who has received ^{32}P , and the sample is counted by placing the same probe as used on the eye in contact with the blood in a suitable chamber. It is assumed that the concentration of ^{32}P in the blood is uniform throughout the body, so that the concentration of isotope in the blood sample is the same as in the blood in the vessels of the choroid. It is further assumed that the attenuation of β particles is the same in ocular tissue and in blood. The count recorded from the blood sample may be thought of as being derived from a series of bands at different levels within the sample. The contribution of each band to the total count recorded from the blood sample is obtained from the model. One of the bands in the blood sample is at the same distance from the probe as the choroid in the eye. The model determines the fraction of total blood sample count that is derived from the band which corresponds to the choroid. On the assumption that blood is the major component of the choroid, this

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Column

	1	2		36	37	38		73	74	75		109	110	
Row 1	.	.	----	.	.	. ----		.	.	.	detector	.	points	
2	.	.	----	.	.	. ----		.	.	.	----	.	source	
													points	
35	.	.	----	.	.	. ----		.	.	.	----	.	.

Fig. 2 Equation used to determine the counts at an arbitrary detector point from an arbitrary source point.

ACTIVITY AT DETECTOR POINT (0.5, c)
FROM UNITY STRENGTH SOURCE POINT (a, b) =

$$e^{-0.0139 \sqrt{[c-b]^2 + (a-0.5)^2}} \times \frac{1}{360} \times \left[\tan^{-1} \frac{a-0.5}{(c-b-0.5)} - \tan^{-1} \frac{a-0.5}{(c-b+0.5)} \right]$$

μm , the choroidal points are represented by the third row of the matrix. The ratio of the counts derived from the choroid to counts obtained from a uniform source distribution is the ratio of the activity numbers of the third row to the total of all the activity numbers. A uniform source distribution may be achieved by using an arrangement similar to that of Fig. 1 to count blood from a patient who has received ^{32}P , with the eye probe in contact with the blood sample. In 4 patients undergoing ^{32}P tests, 48 hours after an intravenous dose of $500\ \mu\text{Ci}$ of ^{32}P , test and control eye counts were measured, and at the same time venous blood was withdrawn from an antecubital vein. These blood samples were placed in a container, and radioactivity was determined by placing the detector in contact with this blood.

Results

The measured radioactivity from blood samples in 4 patients varied from 557 to 837 counts/100 s.

In the model the counts derived from the third row of the matrix, which corresponded to the choroidal layer, comprised 4% of those from a uniform distribution. The third and fourth rows of the matrix each contributed 4% to the total count, so that the exact location of the choroid did not appreciably affect the final conclusions. Thus, the predicted contribution to the control site count derived from blood in the choroid ranged between 24 and 36 counts/100 s (Table 1).

The counts recorded at the control site in the 4 patients ranged between 337 and 707 counts/100 s.

Table 1 Results from 4 patients showing the ^{32}P activity in blood sample, the predicted choroidal contribution to counts recorded on the eye, and counts recorded from a control site in the unaffected eye

Counts recorded from blood sample (c/100 s)	Predicted choroidal counts recorded on eye (c/100 s)	Counts recorded from ocular control site (c/100 s)
577	25	707
557	24	337
837	36	672
720	31	634

Discussion

In assessing the normal choroidal thickness in the living eye regard was given to evidence from histology and ultrasound. Histological sections can be misleading in this respect because of blood loss from the tissue before fixation. A figure of around $200\ \mu\text{m}$ for choroidal thickness has been obtained from histological studies.¹³ More recently ultrasound measurements in living eyes have shown that choroidal

thickness is about $400\ \mu\text{m}$.¹⁴ If the choroidal blood is regarded as a uniform layer $200\ \mu\text{m}$ thick, $400\ \mu\text{m}$ below the surface of the eye, according to the model, about 6% of the control counts at 48 hours are due to ^{32}P in the blood. The choroid, of course, contains a proportion of extravascular tissue and cannot be considered as being uniformly composed of blood. However, provided there is an accumulated depth of $200\ \mu\text{m}$ of blood between 200 and $600\ \mu\text{m}$ below the surface of the eye, the predicted contribution is not significantly affected. If the choroidal blood were treated as a uniform layer $400\ \mu\text{m}$ thick, separated by $400\ \mu\text{m}$ of tissue from the detector, its contribution would increase to around 11%. Thus, the model predicts that the control counts are not primarily vascular in origin, although an increased choroidal circulation may affect a borderline uptake. The results suggest that some tissue other than blood in the choroid is retaining phosphate, thus accounting for the relatively high uptake levels at control sites.

The mathematical analogue described in this paper is useful because of the paucity of experimental information. It is particularly difficult to obtain a direct measurement of the contribution of blood-borne ^{32}P to the counts recorded on the sclera during an uptake measurement. The model may also be applied to distributions of ^{32}P other than those detailed. The interpoint spacing may be reduced if greater resolution is required provided the number of points is increased to maintain the overall dimensions of the matrix. The model is applicable to other postinjection times provided blood is withdrawn and counted by the eye probe. The application of the model to non-vascular ^{32}P may be made only if the concentration and distribution of isotope in the nonvascular component are known.

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