NECK EXTRATHYROIDAL ACTIVITY
OF $^{99m}$Tc-PERTECHNETATE

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The measurement of thyroidal plasma clearance shortly after intravenous injection of $^{131}$I is complicated by the difficulty in distinguishing between uptake in the thyroid gland and extrathyroidal neck activity. We have used a scanning technique (1) to measure the contribution of this extrathyroidal activity to the neck uptake of radioiodide measured by an IAEA standardized collimator (2). Knowledge of these normal values of extrathyroidal neck activity has allowed us to routinely measure the thyroid uptake and plasma clearance at short-time intervals after radioiodide administration (3,4) as an index of the thyroid iodide trap. Technetium-$^{99m}$pertechnetate is being increasingly used as an alternative tracer to radioiodide in tests of thyroid function. In quantitative uptake measurements of $^{99m}$TcO$_4^-$, however, estimation of the extrathyroidal activity is essential. Measurements of $^{99m}$TcO$_4^-$ thyroid uptake must be made at short time intervals after the administration of the isotope when the extrathyroidal activity is high. This is because pertechnetate is not organically bound in the thyroid in man (5,6) and is therefore rapidly lost from the gland. Furthermore pertechnetate is concentrated to a smaller extent than iodide, and the ratio of neck activity to thyroid activity is consequently higher. In view of its clinical importance, the aim of the present study is to investigate the extrathyroidal activity in the neck after intravenous administration of $^{99m}$TcO$_4^-$. The mean extrathyroidal activity in 12 subjects measured using the scanning technique has been compared with the results obtained for radioiodide (1), and the rate of fall of this extrathyroidal activity has been compared to the rate of fall of plasma $^{99m}$TcO$_4^-$ activity.

METHOD

One millicurie of $^{99m}$Tc was injected intravenously into each of 12 patients. An area measuring $16 \times 16$ cm from below the chin to the sternal notch, was scanned 1 min later. This scan was completed in 4 min. Scanning was continued until 40 min after injection of $^{99m}$TcO$_4^-$, producing about five scans for each patient. The scanner used was a Picker Magnascanner V with a 5-in. broad-focus collimator using a line spacing of 0.85 in. and a scan speed of 100 cm/min. Venous blood samples were taken during the scanning procedure usually at 3, 8 and 15 min. These samples were separated and the plasma $^{99m}$Tc estimated in a NaI(Tl) well scintillation counter. Both the pulse-height analyzers of the scanner and the well scintillation counter were set to detect pulses equivalent to the energy range 120–160 keV.

CALCULATION

The method of estimating the true thyroid uptake of $^{99m}$Tc from the scintiscan is identical to the method previously described for $^{131}$I (1). The thyroid uptake was found by drawing a circle, usually of 4-cm radius round the gland and a semicircle of equal radius just below the gland. The semicircle was found in our previous study to have the same background as the thyroid circle, and hence twice the dots in the semicircle were subtracted from the dots in the thyroid circle to find the thyroid uptake.

A 15.8-cm circle was also drawn on the scan centered on the thyroid gland. This circle represents the volume seen by the standard IAEA collimator. The number of dots in the area represents the thyroid uptake plus the contribution of the extrathyroidal activity to the neck uptake measured by the standard IAEA collimated counter. This extrathyroidal activity was found by subtracting the thyroid dots from the dots in the 15.8-cm circle.

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Extrathyroidal activity (ETA) has been expressed both as a fraction of the radiiodide administered and as a fraction of the total-body extrathyroidal activity. The fraction of total-body activity not in the thyroid is a useful index because it will not depend on variations in the thyroid uptake.

RESULTS

The values of extrathyroidal activity expressed as a fraction of the dose administered are shown in Fig. 1 plotted against time after injection of $^{99m}$Tc.

![FIG. 1. Best-fit line to component of extrathyroidal activity seen by IAEA thyroid collimator. Extrathyroidal activity = 6.27 - 0.25t + 0.108t^2 - 0.00016t^3 % dose (t in min).](image)

To find the best fit line to these data a third-order polynomial was fitted by the method of the least sum of squares. The mean activity is thus found to decrease from 6.1% at 3 min to 4.8% at 20 min. Figure 2 shows the extrathyroidal activity expressed as a fraction of the body extrathyroidal activity plotted against time since injection. This means extrathyroidal activity is found to decrease from 6.7% at 3 min to 5.5% at 20 min. The rate of fall of plasma $^{99m}$TcO$_4^-$ activity is shown in Fig. 3 and the plasma activity as a percentage of body extrathyroidal activity is shown in Fig. 4. The plasma activity is seen to decrease more rapidly than the extrathyroidal activity. This is shown in Table 1 which gives the values of the third-order polynomial functions at 3, 5, 10, 15, 20 and 30 min after injection. Whereas the plasma activity falls to 59% of its 3-min level at 15 min, the extrathyroidal activity falls to 81% of its 3-min value at that time.
DISCUSSION

The ETA expressed as a fraction of the body extrathyroidal activity is preferable to the ETA expressed as a fraction of the administered activity because the former allows for differences in thyroid uptake between normal and hyperthyroid subjects. At 3 min the value of ETA (expressed as a fraction of body extrathyroidal activity) of $^{131}$I was 7.0% falling to 6.0% at 20 min (1), compared with 6.7% for $^{99m}$Tc at 3 min falling to 5.5% at 20 min. The differences are, however, not statistically significant due to the limited number of subjects. The mean value of $^{131}$I plasma activity (1) at 3 min was 0.0127 %/ml falling to 0.0064 %/ml at 20 min. These values are different from those for $^{99m}$Tc which fall from 0.0152% dose/ml at 3 min to 0.0089% dose/ml at 15 min. At 3 min after isotope administration the soft tissue-to-plasma ratio in the neck is in the ratio of 1.39-to-1 for I$^{-}$ to TcO$_4^-$-This ratio rises to 1.41-to-1 at 15 min after isotope administration.

The gamma energy for $^{99m}$Tc is, however, only 140 keV compared with the gamma energy of 360 keV for $^{131}$I. The gamma rays from the $^{99m}$Tc will therefore be absorbed more easily in the soft tissues of the neck. To study the magnitude of the absorption, we took a neck phantom and placed $^{131}$I and scanned. The same quantities of activity were then placed in the whole of the phantom and scanned. The $^{131}$I activity showed a drop of 9% on being redistributed in the body of the phantom while the $^{99m}$Tc showed a drop of 12%. The greater gamma absorption of $^{99m}$Tc is therefore not principally responsible for the high $^{131}$I-to-$^{99m}$Tc space ratios observed in the neck. Papadopoulos, MacFarlane and Harden (7) found a ratio of 1.22 for $^{131}$I muscle/$^{131}$I blood-to-$^{99m}$Tc muscle/$^{99m}$Tc blood at 1 hr after injections in rats. If we consider the space in the neck corresponding to the extrathyroidal activity, then at 3 min the space of $^{131}$I is 7.05/0.0127 (555 ml) and 6.05/0.0152 (398 ml) for $^{99m}$Tc. At 15 min the space of $^{131}$I is 770 ml and for $^{99m}$Tc 550 ml. This extrathyroidal activity must largely be in muscle and indicates that iodide is taken up preferentially to pertechnetate in muscle in a ratio of 1.41-to-1 at 15 min after isotope administration.

If the mean $^{99m}$Tc extrathyroidal activity is assumed to be 6.65% of body extrathyroidal activity at 3 min and 5.46% at 20 min, then the thyroid uptake of $^{99m}$Tc can be calculated. If the neck uptake is greater than 6.65% of the dose,

Neck uptake of $^{99m}$TcO$_4^-$ = of $^{99m}$TcO$_4^-$

at 3 min (U3) at 3 min (T3)

\[ \frac{6.65 \times (100 - T3)}{100} \]

i.e. Thyroid uptake

at 3 min = \[ \frac{U3 - 6.65}{0.934} \] % dose

At 20 min:

Neck uptake of $^{99m}$TcO$_4^-$ = of $^{99m}$TcO$_4^-$

at 20 min (U20) at 20 min (T20)

\[ \frac{5.46}{100} \times (100 - T20) \]

i.e. Thyroid uptake

at 20 min = \[ \frac{(U20 - 5.46)}{0.945} \] % dose.

If the neck uptake at 3 min is less than 6.65%, we must consider that this is all extrathyroidal activity and the thyroid uptake is negligible. Then $U20 = T20 + U3 \times 0.82 \times (100 - T20)/100$ % dose.

i.e. Thyroid uptake at 20 min =

\[ \frac{(U20 - 0.82 \times U3)}{(1 - 0.82 \times U3/100)} \] % dose.

### TABLE 1. VALUES OF THIRD-ORDER POLYNOMIAL FUNCTIONS AT VARIOUS TIMES AFTER INJECTION

<table>
<thead>
<tr>
<th>Time after injection of $^{99m}$TcO$_4^-$ (min)</th>
<th>Extrathyroidal activity (Value)</th>
<th>Extrathyroidal activity (%) total-body extrathyroidal activity</th>
<th>Plasma activity (% dose/ml)</th>
<th>Plasma activity (% body extrathyroidal activity/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Value</td>
<td>% 3-min</td>
<td>Value</td>
</tr>
<tr>
<td>3</td>
<td>6.1</td>
<td>100</td>
<td>6.7</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>5.8</td>
<td>95</td>
<td>6.4</td>
<td>96</td>
</tr>
<tr>
<td>10</td>
<td>5.2</td>
<td>85</td>
<td>6.0</td>
<td>90</td>
</tr>
<tr>
<td>15</td>
<td>4.9</td>
<td>81</td>
<td>5.7</td>
<td>85</td>
</tr>
<tr>
<td>20</td>
<td>4.8</td>
<td>79</td>
<td>5.5</td>
<td>82</td>
</tr>
</tbody>
</table>

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For the individual patient these values will be approximate. However, unless the extrathyroidal activity is measured in each case, these equations provide the best basis on which the early uptakes of $^{99m}$Tc can be studied.

**SUMMARY**

The contribution of neck extrathyroidal activity of $^{99m}$Tc-pertechnetate in the field of view of the standard IAEA thyroid collimator was measured in 12 patients using a scanning method. The mean extrathyroidal activity was 6.7% of the total-body extrathyroidal activity at 3 min after intravenous administration and 5.7% of the total-body extrathyroidal activity at 15 min after administration. These values were compared with measurements of the extrathyroidal activity of iodide (I), and it was found that the extrathyroidal space of iodide was 1.41 times the extrathyroidal space of pertechnetate 15 min after isotope administration. Equations have been formulated from these data to calculate thyroid pertechnetate uptake at 3 min and 20 min after intravenous pertechnetate administration.

**REFERENCES**


**SOUTHEASTERN CHAPTER**

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