Radioiodine Therapy for Well-Differentiated Thyroid Cancer: A Quantitative Dosimetric Evaluation for Remnant Thyroid Ablation After Surgery

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The influence of cumulative absorbed dose, initial dose rate and mass of the remnant thyroid tissue on outcome of radioiodine treatment was assessed to determine an optimum value of absorbed dose and initial dose rate predictive of successful ablation. **Methods:** In 87 patients with thyroid carcinoma treated with 0.85–9.55 GBq (23–258 mCi) of ^{131}I to ablate residual thyroid tissue, the cumulative absorbed dose and the initial dose rate were calculated. Following therapy, the parameters of radioactive iodine uptake and effective half-life were determined in each patient from the surface neck exposure rates measured using a beta/gamma exposure rate meter. Mass of the thyroid remnant was determined from rectilinear images after scatter correction obtained from phantom studies. **Results:** Sixty-eight patients showed complete ablation and 19 showed partial ablation of the thyroid remnant after radioiodine therapy. The cumulative absorbed doses delivered to the tissue in completely ablated and partially ablated groups were not significantly different ($0.6 > p > 0.5$). The initial dose rate delivered to the tissue in both groups, however, showed a significant difference ($0.05 > p > 0.02$). An initial dose rate of 3 Gy/hr or more completely ablated up to 5 g of tissue in 54 out of 62 patients (87.1%). Dose rate above 3 Gy/hr and cumulative doses above 300 Gy resulted in ablation in 50% of patients with more than 5 g of tissue. **Conclusion:** In patients receiving ^{131}I to ablate thyroid remnant, the initial dose rate and the tissue mass are determinants of successful treatment response.

Key Words: radioiodine therapy; absorbed dose; initial dose rate; differentiated thyroid carcinoma

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Oral administration of ^{131}I has been used to treat thyroid cancer for many years. There is still no consensus on whether radioiodine therapy is indicated in all thyroid carcinoma patients or on the ideal dose required to achieve ablation of residual thyroid tissue. Well-differentiated thyroid tumors generally run an indolent course, especially in patients under 40 yr of age, hence the doubt whether radioiodine ablation is significant in the reduction of mortality after a total thyroidectomy (*1–5*). Others (*6–10*) advocate the ablation of residual thyroid tissue with radioiodine after thyroid surgery. There is also no fixed policy on the dosage of radioiodine needed to effectively ablate the remnant thyroid tissue. Some physicians advocate conservative doses of 1.11 GBq (30 mCi) (*11–17*). The major advantages of using 1.11 GBq (30 mCi) or less for ablation are avoidance of an expensive hospitalization and reduced radiation exposure to extrathyroidal tissues, including bone marrow and gonads. Some physicians (*18–20*) advocate higher radioiodine doses, i.e., 5.55 GBq (150 mCi) or more for thyroid remnant ablation. This controversy indicates an arbitrary nature of administration of therapeutic doses of radioiodine. A significant relationship exists between the likelihood of successful ablation of thyroid remnants and the radiation dose delivered by ^{131}I to the thyroid remnants (*21–24*). Successful ablation of residual thyroid has been reported to occur with a single initial ^{131}I administration when treatment was standardized to a radiation dose of 300 Gy or more. On the basis of experience in the use of radioiodine to ablate all normal thyroid tissue in patients with angina pectoris and residual tissue in patients with thyroid cancer, it has been estimated that ablation can be reliably achieved with a dose of 500 Gy. Instead of giving a fixed quantity of radioiodine to all patients, it is possible to adjust the amount so that each patient receives a standard radiation dose to the residual thyroid tissue. The main advantage of individualized ablation is that no patient receives more whole-body radiation than is necessary, and no patient receives a dose of radioiodine that is inadequate to achieve complete ablation.

The two most important factors that determine cell destruction is the absorbed dose and the rate at which this dose is delivered, i.e., the initial dose rate (*25–28*). In our study, the cumulative absorbed dose and initial dose rates were calculated after administration of a therapeutic dose

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of ^{131}I. We measured the percentage uptake of ^{131}I, the effective half-life in the target tissue and the mass of the remnant thyroid. The aim of this study was to assess the cumulative doses and dose rates delivered to thyroid remnant to arrive at the optimal values to achieve good ablation. This information should ideally be obtained after giving therapeutic doses of radioiodine.

MATERIALS AND METHODS

Patient Selection

A total of 87 patients treated with radioiodine after thyroidectomy were selected. All patients were prepared for diagnostic ^{131}I studies by withholding thyroxine, all iodine-containing drugs and ointments and iodized salt for a minimum of 4 wk.

Diagnostic ^{131}I Studies

Diagnostic ^{131}I studies were performed after an oral administration of 37–74 MBq (1–2 mCi) of ^{131}I. After 24 or 72 hr, a neck scan was performed on a rectilinear scanner with 5 × 3 in. NaI(Tl) crystal. A 1:1 dot scan was obtained with factors optimized depending on the count rate. Based on the visual analysis of these scans, thyroid remnants were considered to be present when discrete ^{131}I uptake was noted in the thyroid bed on the first postoperative study. Abnormal uptake elsewhere in the body or neck was interpreted as metastatic disease. These patients were not included in this study.

Radioactive iodine uptake (RAIU) was measured by a conventional thyroid uptake probe and a standard iodine activity.

Mass of remnant thyroid was measured from the rectilinear scans. The volume of the residual tissue has been reported and estimated from the cross-sectional area of 'a' cm. The mass in grams being given by $m = (a)^{3/2}$. This assumes that the density of the tissue is 1 g cm^{-3} and that the tissue is equivalent to a cube of side $(a)^{1/2}$ (*29*). Using this formula, the calculated mass values were artificially high; at times mass values were as high as 50–70 g. It was difficult to evaluate the depth using information obtained from the surgeons regarding the thickness of tissue left behind during surgery, as it was empirical and differed from surgeon to surgeon. Also, the remnant tissue had been stimulated for 4 wk by the rising TSH levels making this estimate fallacious. Therefore, we felt that some other method was needed. Several patients who had received therapeutic doses of radioiodine were evaluated using a gamma camera 72 hr after background activity had reduced considerably. The aim was to obtain an idea about the depth of the residual tissue, as this was critical in measuring the volume. It was observed during our studies that the depth measured (as number of pixels) by reconstruction of the SPECT data bore a constant relation to the breadth (as a number of pixels) and was usually two-thirds of the breadth. Since most of the rectilinear scans showed residual tissue in the shape of an ellipse, we have calculated the volume using the formula:

$$\text{Volume} = 4/3\ \pi \frac{a}{2}\frac{b}{2}\frac{c}{2},$$

where a = length, b = breadth and c = depth of the tissue. Rectilinear 1:1 dot scans were used to measure these parameters.

The scatter correction factors were obtained by scanning several sizes of rectangular phantoms in a scattering medium (water) that contained concentrations of radioiodine varying from 0.15–11.1 MBq (4–300 μCi, which would correspond approximately to the amount of radioiodine trapped by the residual tissue). Correction factors for scatter were estimated and applied to the measurement of the dimensions of the residual tissue visualized on the dot scan obtained on a rectilinear scanner.

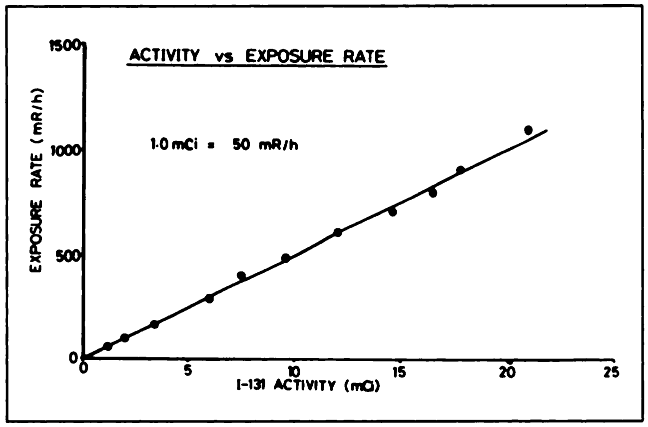

FIGURE 1. Relationship between amount of ^{131}I activity and exposure rate as obtained from thyroid phantom studies.

Therapeutic ^{131}I Studies

For calculation of radiation absorbed dose, it is essential to determine the parameters of RAIU in the target tissue, mass of the target tissue and the effective half-life of ^{131}I in the target tissue.

The validity of using a portable beta-gamma exposure rate meter (BGERM) for measuring ^{131}I in residual thyroid was established in four different ways:

1. Using a portable BGERM and neck phantoms containing varying quantities of ^{131}I, it was noted that surface exposure rate of 500 μGy/hr (50 mR/hr) was equivalent to 37 MBq (1 mCi) of ^{131}I.
2. An excellent correlation was observed ($r = 0.98$, $n = 18$, $p < 0.001$) when the RAIU in the neck obtained by BGERM method was compared with that obtained by the conventional probe method from a diagnostic ^{131}I dosage.
3. The RAIU in the neck obtained after therapeutic ^{131}I was compared with the RAIU in the neck from a diagnostic dose in the same patient. A good correlation was obtained between therapeutic and diagnostic RAIU value ($r = 0.85$, $n = 30$, $p < 0.001$) (*30,31*).
4. The calibration of the ionization chamber as shown in Figure 1 was linear in doses ranging from 37 to 925 MBq (1–25 mCi).

From the sequential measurements of exposure rate for 3 or more days over the neck using BGERM, the biological half-life of the therapeutic dose of radioiodine was determined after applying corrections for physical decay. The effective half-life (T_e) was then computed using the biological half-life.

This is one of the few studies where actual quantitation of RAIU and T_e have been carried out after administration of therapeutic quantities of ^{131}I and not extrapolated from information obtained with diagnostic studies.

Criteria for Therapeutic Administration of Radioiodine

Radioiodine was given for ablation of remnant thyroid when uptake of ^{131}I was greater than 0.1% and when discrete concentration was seen on the rectilinear scan images in the region of the thyroid bed.

Radioiodine Treatment

Radioiodine was given empirically in the initial part of the study based on the approximate size of thyroid remnant as seen on the rectilinear scan and the RAIU in the neck. The dosage administered varied from 1.85–9.25 GBq (50–250 mCi). In the latter part of the study, approximately 1.11 GBq (30 mCi) was given irrespective of the mass or RAIU in the neck.

Following therapy, all patients were hospitalized in an isolation room regardless of the radioiodine administered according to India's national regulations for handling radioisotopes. They were removed from isolation when the exposure rate at 1 m was 50 μGy/hr (5 mR/hr) or less.

Ablation Criteria

Diagnostic ^{131}I studies were repeated with 111–185 MBq (3–5 mCi) of radioiodine 4–6 mo after therapy. A rectilinear 1:1 dot scan of the neck was obtained routinely. Radioiodine uptake was measured by a conventional thyroid uptake probe. A chest x-ray and serum thyroglobulin were also routinely advised.

Ablation of the thyroid remnants was defined by neck uptake < 0.1% of the administered radioiodine, no visual evidence of radioiodine concentration on the 1:1 dot scan and normal or low (i.e., < 10 ng/ml) serum thyroglobulin.

The criteria for partial ablation was the visualization of discrete concentration of radioiodine in the thyroid bed even though RAIU could be < 0.1% at times. Uptake < 0.1% in the neck is generally accepted as meeting the criteria for ablation in spite of visualization of a discrete concentration of iodine, whereas in our analysis, we considered that such cases needed a second ablation dose.

Initial Dose Rate Calculation

The general expression for the dose rate in a tissue containing a concentration of 'C' MBq per gram of tissue emitting 'j' types of radiation with effective energies for the radiation of type j respectively is:

$$\dot{D} = 0.58C \sum_j \bar{E}\phi_j \text{ Gy/hr},$$

where $\bar{E}_j$ is the mean energy (in MeV) for radiation j and ϕ_j is the absorbed fraction in that specific tissue of the radiation type j.

It is assumed that the tissue dimension of the remnant is 5–50 mm, in which case all nonpenetrating radiations, such as beta particles and conversion electrons, are completely absorbed in the target tissue ($\phi_j = 1$) and the penetrating radiations e.g., 364 and 637 keV photons contribute only a small fraction of the total absorbed dose (i.e., $\phi_j = 0$) (*32*). Using ICRP data for analysis the dose rate to tissue containing 'C' MBq/g of ^{131}I is given by (*33*):

$$\dot{D} = 0.58 \times 0.19C = 0.11C \text{ Gy/hr}$$

Cumulative Absorbed Dose

Assuming a monoexponential washout of ^{131}I from the tissue, the T_e is calculated. Dose D to the tissue is calculated from the initial dose rate D_o (using the previous equation) as follows:

$$\dot{D} = 1.44T_eD_o \text{ Gy},$$

where $\dot{D}_o = 0.11C_o$ Gy/hr, where Co (MBq/g) is the initial (24 hr) concentration of ^{131}I in the tissue and is related to the total activity Q (MBq) administered to the patient as follows:

$$C_o = Qf/100 \text{ MBq/g},$$

where f is the percentage uptake per gram in the tissue at 24 hr.

RESULTS

Histological classification of the thyroid cancers in our study showed papillary and mixed (papillary and follicular) cancers in 60% and follicular cancers in 40% of the patients. The mean age of the patients was 35 ± 9.4 yr and male-to-female incidence was 1:2.

In the present study, the amount of ^{131}I administered ranged from 0.85 to 9.55 GBq (23–258 mCi) with a mean of 3.16 GBq (85.3 mCi). Six patients received 1.11 GBq (30 mCi) or less, 32 patients received between 1.11–1.85 GBq (30–50 mCi), 29 patients received 1.85–3.70 GBq (50–100 mCi), 8 patients received between 3.7–5.55 GBq (100–150 mCi) and 12 patients received 5.55 GBq (150 mCi) and above.

Of the 87 patients treated, 68 showed complete ablation and 18 showed partial ablation of the residual thyroid tissue. One patient did not show any response and was considered in the partially ablated group for analysis. The mass of the remnant tissue ranged from 1 g to 14.8 g (mean = 4.1 g). The RAIU ranged from 2.3% to 49.7% (mean = 17.7%). The T_e of ^{131}I in the tissue ranged from 10.3 hr to 192 hr (mean = 57.9 hr). The initial dose rate ranged from 2.4 Gy/hr to 64 Gy/hr (mean = 13.9 Gy/hr). The cumulative dose delivered to the tissue ranged from 59 Gy to 4208 Gy (mean = 1018 Gy).

Table 1 is an analysis of various parameters studied and the possible differences between the parameters in patients who showed complete and partial ablation of residual thyroid tissue. It is observed that in patients who responded with complete ablation, the dose of radioiodine administered was higher, the radioiodine uptake in the neck was lower, the mass of the residual tissue was smaller than in patients who had persistent tissue after treatment. The most significant was the effect of mass of tissue. The larger the mass, the poorer the response to radioiodine therapy. Interestingly, the cumulative doses of each group were not significantly different ($0.6 > p > 0.5$), but the critical determinant for obtaining a good response was the initial dose rate. The initial dose rate delivered in the completely ablated group was found to be significantly higher than the partially ablated group ($0.05 > p > 0.02$). The higher the dose rate achieved in the first 24–48 hr, the better the ablation response.

Table 2 shows an analysis of the effect of mass on the response to radioiodine therapy. When mass of the remnant tissue was less than 5 g, complete ablation was achieved in 56 out of 64 cases (87.5%). On the other hand, when mass was more than 5 g, complete ablation was achieved in only 12 out of 23 cases (52.2%). When the mass of the tissue was less than 5 g, no significant difference was observed in the therapeutic dose administered, RAIU, T_e, cumulative dose delivered and initial dose rate in completely ablated and partially ablated groups (A vs. B). Similarly, no difference was observed in the individual parameters when the mass of the tissue was more than 5 g (C

TABLE 1
Analysis of Various Parameters in Patients with Complete and Partial Ablation of Residual Thyroid Tissue after Radioiodine Therapy

Ablation status after radioiodine therapy	Therapeutic dosage of ^{131}I GBq (mCi) mean ± s.d.	%RAIU of the therapeutic dosage mean ± s.d.	Mass of the residual thyroid tissue (g) mean ± s.d.	Effective half-life of ^{131}I (hr) mean ± s.d.	Cumulative absorbed dose rate delivered mean ± s.d.	Initial dose rate delivered (Gy/hr) mean ± s.d.
Complete ablation (n = 68)	3.4 ± 2.4 (92.8 ± 66.3)	14.8 ± 11.9	3.5 ± 2.1	54.8 ± 34.9	1029 ± 836	15.3 ± 12.8
Partial ablation (n = 19)	2.0 ± 1.6 (55.3 ± 44.5)	22.5 ± 12.3	6.1 ± 3.7	79.3 ± 40.6	899 ± 722	8.3 ± 4.9
p value (Students' t-test)	$0.05 > p > 0.02$	$0.02 > p > 0.01$	$p < 0.001$	$0.02 > p > 0.01$	$0.6 > p > 0.5$	$0.05 > p > 0.02$

versus D), indicating that the possible nonresponse could be due to an individual sensitivity to radiation.

A comparison of the group with less than 5 g remnant tissue and the group with more than 5 g, showed that in patients who showed complete ablation, there was a significant difference ($0.05 > p > 0.02$) between administered doses, the dose being higher in the group with smaller masses. There was no significant difference (A versus C) in the T_e ($0.3 > p > 0.2$), RAIU ($0.2 > p > 0.1$) and cumulative dose delivered ($0.2 > p > 0.1$) in both the groups; however, the initial dose rate of the two groups was significantly different ($0.05 > p > 0.02$), the dose being higher in patients with less than 5 g of remnant tissue. This indicates that, for larger masses of remnant tissue, the effective initial dose rate cannot be achieved.

Table 3 is an analysis of the partial-response patients. Of the 19 patients, only 1 showed no difference in radioiodine uptake and mass values after treatment. All other patients showed a considerable reduction in the mass and uptake values, indicating that there was a good response in all these patients close to a complete response. Whether the response could have shown total ablation with higher doses or dose rates is a moot question.

Table 4 shows a relationship between the cumulative dose and dose rate. It is observed that, even at lower cumulative doses, the dose rate plays a significant role, because higher dose rates achieve better ablation than lower doses.

Using the conventional 300 Gy reported in the literature as a cut-off value, it was observed that 48 of 55 patients (87.3%) with less than 5 g remnant tissue mass showed a good or complete ablation of residual tissue, while only 9 out of 18 patients (50%) showed complete ablation with residual tissue greater than 5 g (*22*). Irrespective of the mass of the tissue, overall successful ablation was achieved in 57 of 73 patients (78.1%) at a cut-off value of 300 Gy.

When the dose rate of 3 Gy/hr was used as the cut-off value, it was observed that 54 out of 62 patients (87.1%) with masses less than 5 g showed complete ablation, while only 10 of 19 patients (52.6%) showed complete ablation

TABLE 2
Analysis of Various Parameters in Patients with Complete and Partial Ablation Relation to Mass of Residual Thyroid Tissue

Mass of the residual thyroid dosage tissue (g)	Ablation status after radioiodine therapy	Therapeutic dosage of ^{131}I administered GBq (mCi) mean ± s.d.	% RAIU of therapeutic dosage mean ± s.d.	Effective half-life of ^{131}I (hr) mean ± s.d.	Cumulative absorbed dose delivered (Gy) mean ± s.d.	Initial dose rate (Gy/hr) mean ± s.d.
< 5 g	Complete^{A} ablation (n = 56)	3.7 ± 2.6 (100.3 ± 70.1)	13.8 ± 11.4	52.3 ± 35.5	1092 ± 861	16.9 ± 13.4
	Partial^{B} ablation	2.5 ± 2.4 (68.4 ± 65.6)	20.8 ± 14.6	68.4 ± 44.8	1232 ± 951	11.7 ± 3.5
> 5 g	Complete^{C} ablation	2.1? ± 0.9 (57.8 ± 23.6)	19.9 ± 13.4	66.3 ± 30.6	732 ± 656	7.9 ± 5.9
	Partial^{D} ablation	1.7 ± 0.7 (45.8 ± 17.7)	23.8 ± 10.9	87.1 ± 37.4	656 ± 391	5.9 ± 4.5
p value Students' t-test	A vs. B	$0.3 > p > 0.2$	$0.2 > p > 0.1$	$0.3 > p > 0.2$	$0.7 > p > 0.6$	$0.3 > p > 0.2$
	A vs. C	$0.5 > p > 0.02$	$0.2 > p > 0.1$	$0.3 > p > 0.2$	$0.2 > p > 0.1$	$0.05 > p > 0.02$
	B vs. D	$0.3 > p > 0.2$	$0.7 > p > 0.6$	$0.4 > p > 0.3$	$0.1 > p > 0.05$	$0.01 > p > 0.001$
	C vs. D	$0.2 > p > 0.1$	$0.5 > p > 0.4$	$0.2 > p > 0.1$	$0.8 > p > 0.7$	$0.4 > p > 0.3$

TABLE 3
An Analysis of 19 Cases with Partial Ablation of Residual Thyroid Tissue

	% RAIU of therapeutic dosage mean ± s.d.	Mass of the residual thyroid tissue (gms) mean ± s.d.	Residual RAIU % of the pretherapy RAIU value mean ± s.d.
Before ^{131}I therapy	22.5 ± 12.3	6.1 ± 3.7	—
After ^{131}I therapy	1.0 ± 1.5	2.7 ± 0.9	3.7 ± 4.3
Level of significance (Students' t-test)	$p < 0.001$	$p < 0.001$	—

when the mass was greater than 5 g. Regardless of the weight of the mass, overall complete ablation was achieved in 64 out of 81 patients (79.0%) at an initial dose rate cut-off value of 3 Gy/hr.

Age, histological classification of the tumor type and sex did not correlate with outcome of treatment. In other words, the percentage complete ablation was not higher in younger or older patients, nor was ablation better in papillary or follicular carcinomas.

DISCUSSION

Since the introduction of oral radioiodine therapy in the treatment of thyroid cancer, the amount of radioiodine administered is often arbitrary. Attempts have been made to relate radiation dose with response in the form of ablation of remnant and metastatic tissue.

Reported dosimetric approaches (*21,22,32*) have relied on whole-body retention and lesion retention of ^{131}I predicted from pretherapy diagnostic studies. Comparison of pretherapy calculations and calculated radiation doses based on measurements after therapy have shown that there is an over-estimation of 10%–15% or more of the actual radiation dose, and in nearly one-third of the patients, the actual dose was somewhat less than the projected dose due to the shortened T_e of ^{131}I after therapy. These observations have also been confirmed by us (personal observations). Similar findings have been reported (*34,35*) where the actual dose delivered was 80% of the projected dose for ablation of thyroid remnants primarily due to the more rapid release than expected of ^{131}I at 3–7 days post-therapy.

In our study, the T_e of ^{131}I following therapy has been measured by a portable BGERM which has been calibrated and the results validated on several occasions with phantom studies and correlated with diagnostic thyroid uptakes both with the probe as well as BGERM. Daily measurements of ^{131}I retention in the remnant thyroid were made for three or more days, and T_e, thus quantitated, was used for dosimetric calculations.

Mass measurements were performed by using the 1:1 dot scan obtained on a rectilinear scanner. The measurements were validated by phantom studies and appropriate factors for scatter corrections were made; these were found to be simple and very useful. SPECT studies were performed on several patients after therapeutic doses of ^{131}I to establish the dimensions of the tissue.

Two important factors in the calculation of absorbed dose are effective half-life and the mass of the remnant tissue. In our study we measured the retention of the therapeutic doses of radioiodine in the remnant thyroid and found that the T_e varied from 10.3 to 192 hr. Since these measurements were obtained from therapeutic doses, the calculated dose is more accurate than the diagnostic dose. Secondly, mass measurement poses a great hurdle in the accuracy of dose calculations. By using a 1:1 rectilinear dot scan and appropriate factors for scatter correction obtained using several phantoms of different sizes containing concentrations of radioactivity varying from 0.15–11.1 MBq (4–300 μCi), a realistic measurement of remnant tissue has been attempted. The calculated mass varied from 1 to 14.8 g. Because of the large variations in RAIU, the mass and the T_e of ^{131}I in the remnant thyroid tissue, there was no correlation ($r = 0.00$) between the amount of radioiodine administered and radiation dose delivered to the tissue.

Reports indicate that one needs to deliver 300 Gy in order to achieve a good ablation of remnant thyroid tissue (*21,22*). Our studies indicate that this hypothesis holds true for tissues having a mass less than 5 g. We found that ablation can be achieved in 87.3% of the patients with 300 Gy or more in tissues of mass less than 5 g, but for tissues more than 5 g, complete ablation was observed in only 50% of the patients. This indicates that the mass is a critical

TABLE 4
Relationship of Cumulative Dose and Initial Dose Rate with Respect to Complete Ablation of the Residual Thyroid Tissue

Initial dose rate	Cumulative dose < 300 Gy (no. of cases %)		300–900 Gy (no. of cases %)		> 900 Gy (no. of cases %)	
< 3 Gy/hr	4/5	80	0/1	0	No cases	—
3–6 Gy/hr	3/4	75	6/10	60	1/3	33.3
> 6 Gy/hr	5/6	83.3	21/24	87.5	28/34	82.4

factor, and that one can anticipate poor results in patients with five or more grams of residual tissue.

We would also like to emphasize that the dose rate delivered in the first 24–48 hr is perhaps more important in achieving complete ablation of remnant thyroid than the total absorbed dose. This observation is being reported for the first time to the best of our knowledge in the study of thyroid cancer. According to a review (*25*), "As the dose rate is reduced, more and more sublethal damage may be repaired because the accumulation of injury is spread out over a longer period. Consequently, the cell-killing potential of a given dose of radiation decreases with decreasing dose rate. Below about 0.6 Gy/hr there is little dose rate effect, because by this time essentially all sublethal damage is repaired during the exposure and the residual cell-killing effect is due to nonrepairable injury." Hence, the dose rate delivery is a very important parameter of ablation response. The present study indicates a good response when the dose rate is above 3 Gy/hr and when the cumulative dose is lower than the optimal 300 Gy; a poor response was observed when dose rates were less than 3 Gy/hr, although total absorbed doses were above 900 Gy. Although the dose rate of ^{131}I decreases with time, the initial dose rate appears to be important in achieving a good ablation response; therefore, the final calculations of the individual therapy dose should consider the cumulative dose and the dose rate for effective modulation of therapy. Appropriate corrections should be made for the difference in effective half-life obtained with diagnostic doses for prior calculation of dose. Lastly, a very important but unquantifiable factor that should be considered when discussing radiation effects on tissue destruction is the individual's sensitivity to radiation. The role of nutrition, environmental factors, genetic makeup, predisposing factors such as iodine deficiency and several other unknown influences have yet to be studied and accounted for in our calculations.

CONCLUSION

From the present study, it appears that the initial dose rate, i.e., the rate at which the absorbed dose is delivered, and the mass of the remnant thyroid tissue are primarily responsible for a successful therapeutic response. Instead of giving a fixed quantity of radioiodine to all patients, it is possible to adjust the amount so that each patient receives a standard radiation dose and dose rate to the residual thyroid tissue.

The main advantage of individualized ablation is that no patient receives more whole-body radiation than is necessary. In addition, patients will receive an adequate amount of radioiodine to achieve complete ablation.

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(continued from page 7A)

FIRST IMPRESSIONS
Staghorn Calcus in a Left Kidney

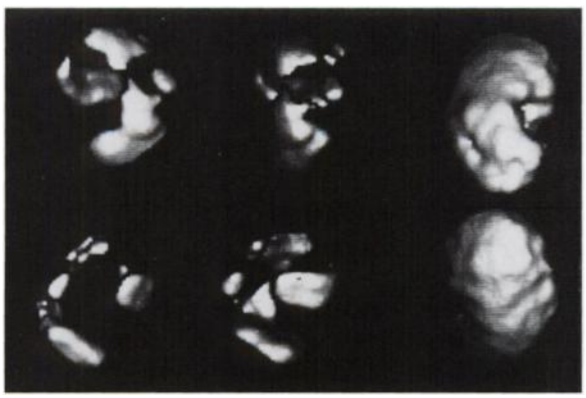

FIGURE 1.

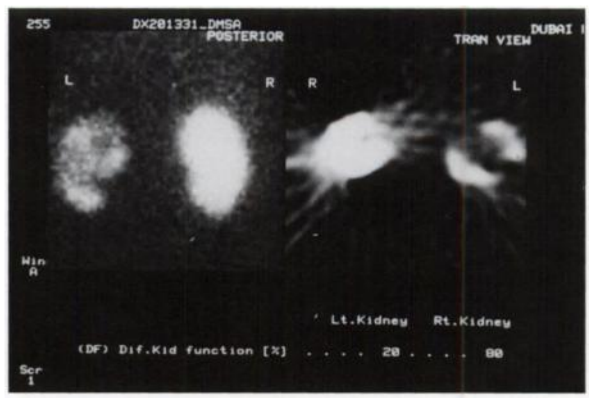

FIGURE 2.

PURPOSE

The DMSA study of a 77-yr-old male with staghorn calcus in the left kidney shows both kidneys at normal size. There is, however, reduced function on the left kidney, contributing to total renal function of only 20%, because of thinning parenchyma. Such patients usually exhibit dilatation of the hollow system with kidney enlargement. In this patient, pressure atrophy caused by a stone reduced the thickness of the parenchyma without kidney enlargement. Different three-dimensional views of the left kidney are seen in the left and middle columms in Figure 1 and the anterior and posterior views of the right kidney are in the last column. Figure 2 shows the posterior view of SPECT nonprocessed raw data and transaxial slices of both kidneys and quantification of function.

TRACER

Technetium-99m-DMSA, 150 MBq

ROUTE OF ADMINISTRATION

Intravenous injection

INSTRUMENTATION

General Electric Starcam XRT-4000

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