

Determination of the Volume of the Thyroid Gland by a High Resolutional Ultrasonic Scanner

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We developed a new ultrasonic scanner for the thyroid and, in this study, the estimated volumes of the thyroids by this scanner were compared with the weights of those obtained at operation. In this ultrasonic scanner, an annular array transducer was employed instead of the conventional single element concave transducer. The distance of the focused area by this transducer was as long as 5 cm compared to 1 cm by the conventional transducer; therefore, the image obtained by the new scanner was so clear that it was not difficult to draw accurately the outlines of the thyroids. The volumes of the thyroids were calculated by a computerized digitizer. The estimated volumes of the thyroids by the ultrasonic scanner were closely correlated with their weights calculated by adding the actual weights of the thyroids removed to the estimates of the thyroids left at operation. Their correlation coefficients were as high as 0.99. This suggests that this new ultrasonic scanner is very useful in the determination of the volumes of the thyroids, since the measurement is very accurate, simple, and reproducible.

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The accurate estimation of the size of the thyroid is very important for the evaluation and management of thyroid disorders (1,2). Changes in goiter size with treatment is still one of the best indicators for the prognosis of Graves' disease in spite of the development of many in vitro methods to predict the outcome of the disease (3). The accurate estimation of goiter size is also essential in radioiodine therapy of Graves' disease.

Although many methods for estimating thyroid size have been developed, some thyroid experts, especially surgeons, still believe their fingers are more accurate than any instrument. Even in well-known journals, the expressions of thyroid size have been quite different according to various investigators (4-6).

We have developed a new ultrasonic apparatus for the estimation of the size of the thyroid using a transducer of the Aloka Co. Ltd., Japan. In the present study, the estimated volumes of the thyroids obtained prior to

surgery by the new apparatus were compared to the weights of the resected thyroid glands or nodules.

PATIENTS AND METHODS

Patients

Studies were performed on 100 patients with thyroid disorders (67 patients with Graves' disease and 33 patients with thyroid adenoma) to estimate the accuracy of the volumes of the thyroid glands and nodules by the ultrasonic scanner. Ultrasonic scanning of the thyroid in these patients was carried out prior to operation. The weights of the Graves' thyroids were calculated by adding the surgeons' estimates of what had been left, to the actual weights of the thyroids which were surgically removed. Thyroid adenomas were weighed after removing tissues surrounding them. The echography of the thyroid, the determination of thyroid volumes from echogram, and the surgical measurement of thyroid weights were carried out by different doctors independently. Both results were compared and analyzed at the end of the study.

Normal subjects were 57 healthy volunteers (11 males and 46 females, 37-74 yr). None of them had signs or symptoms of thyroid disorders and none had a history of thyroid disorders. Their serum levels of T₃, T₄, free T₄, and TSH were within the normal range.

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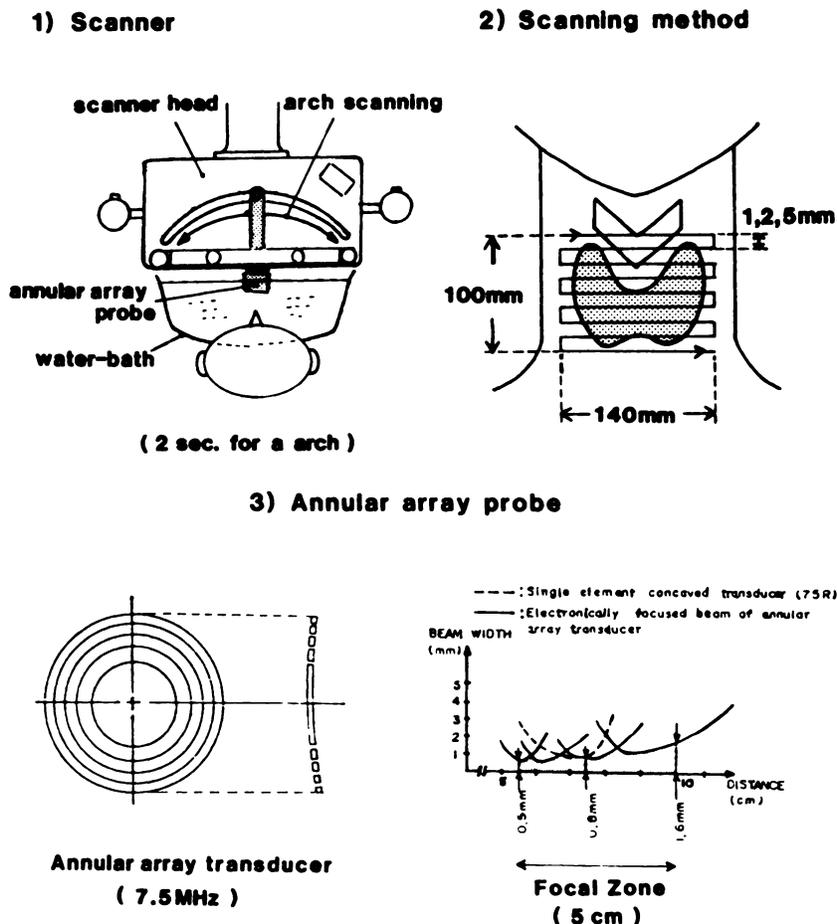


FIGURE 1
Mechanism of ultrasonic scanner with 7.5 MHz annular array transducer

Methods

Ultrasonic apparatus. The new ultrasonic apparatus and the computerized digitizer were developed recently for this study. Our new ultrasonic apparatus was composed of an ultrasonic scanner with a new transducer, an echo camera, and a computerized multiphoto camera. A computerized multiphoto camera* was connected to an echo camera to record the images of the cross-sections of the thyroid automatically. Aloka SSD-270 as an echo camera and Aloka ASU-46 as an ultrasonic scanner were employed. Figure 1 shows the mechanism of the ultrasonic scanner in detail. In this ultrasonic scanner, a 25-mm diameter 7.5 MHz annular array transducer was employed instead of the conventional single element concave transducer. The performance of the fixed focus transducer was optimized for both sensitivity and resolution in a small region about the focal point. An annular array was formed by creating five concentric rings of transducer materials that were electrically isolated from one another. Each array element had its own electronic amplifiers. A dynamic focusing control system combined signals from each array element creating an electronically variable lens. Therefore, the distance of focused area by this transducer was as long as 5 cm compared with 1 cm by the conventional transducer. The wide focused area of this new transducer was very important in obtaining clear images of the thyroid.

Procedure of echography. Patients were examined in the supine position, with the neck hyperextended. The transducer moved over the neck transversally 140 mm in the water bath,

making an arch with the speed of 2 sec per arch for the echo angle of incidence to the thyroid to be vertical, yielding an image of a cross-section of the thyroid. After making each image of a cross-section, the transducer moved automatically either 1, 2, or 5 mm longitudinally to produce many serial cross-sections of the thyroids with various sizes and shapes. In most patients, all images could be recorded on one film.

Measurement of the volume of the thyroid. A computerized digitizer was used to calculate the volume of the thyroid from the images of serial cross-sections. At first, the outline of the thyroid gland on the film of each cross-section was traced manually with a white marker. Then, the outlines of the thyroid on every cross-section were traced on the computerized digitizer and the computer calculated the volume of the thyroid by multiplying the traced areas of the thyroid by a given thickness such as 1, 2, or 5 mm. The thickness was changed according to the size of the thyroid gland or adenoma. Usually the thickness was determined to produce at least eight cross-sections of thyroid glands or adenomas, but the maximum thickness was 5 mm.

RESULTS

Figure 2 shows an image of a cross-section of a normal thyroid recorded on film and its scheme. The image of a cross-section by this scanner showed excellent resolution (7-11). The skin, thyroid, common carotid artery, internal jugular

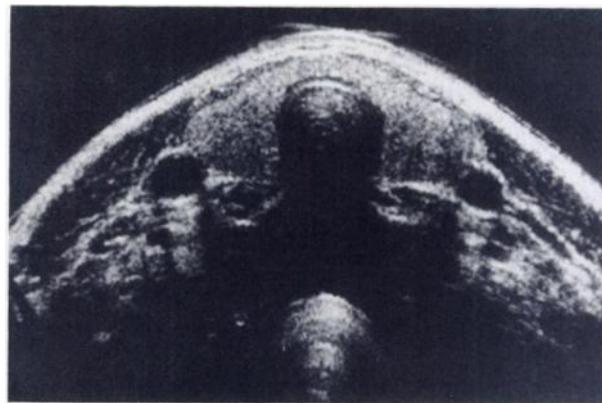
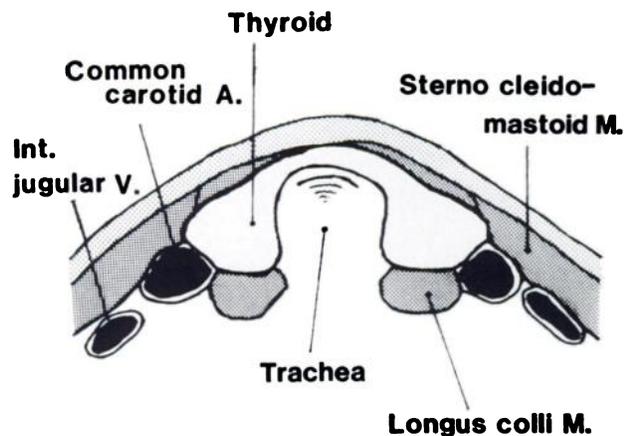


FIGURE 2
Image of cross-section of normal thyroid and its scheme

vein, sternocleidomastoid muscle, and longus colli muscle could be so clearly discriminated that it was easy to draw the outline of the thyroid.

Figure 3A shows an image of the cross-section of a Graves' thyroid. In this enlarged thyroid, the margins were clear and the echo density was homogeneous. Figure 3B shows an image of the cross-section of a thyroid adenoma.

In 100 operated patients, the comparison between ultrasonically determined volume and weight measured at operation was studied. Figure 4 shows the comparison between estimated volumes of Graves' thyroids and their total weights by logarithmic scales. In 67 Graves' patients, thyroid weights ranged from 27–221 g. The estimated volumes by ultrasonic scanning prior to operation correlated very closely with their total weights obtained at operation. A close correlation was found from thyroids as small as 25 g to those >200 g. The correlation coefficient was +0.980 ($p < 0.001$, $n = 67$). In the estimation of the volumes of Graves' thyroids it was important not to miss the top of each lobe and the possible presence of a pyramidal lobe. Figure 5 shows the comparison between the estimated volumes of adenomas and their actual weights. In 33 thyroid adenomas, their actual weights ranged from 3–146 g. The estimated volumes of adenomas correlated extremely

closely with their actual weights obtained at operation. From the size of several grams to >100 g, the difference between the estimated and actual values were <5% except one patient. The correlation coefficient was as high as +0.990 ($p < 0.001$, $n = 33$). Since these results suggested that the volumes of the thyroids obtained by this technique were very close to the actual weights, the thyroid volumes of the normal subjects were also measured by this technique. These normal subjects had a mean (\pm s.d.) thyroid volume of 13.4 ± 4.1 ml (range, 5.9–22.9 ml), a mean (\pm s.d.) body mass of 53.4 ± 8.2 kg (range, 40.2–77.4 kg), and a mean age of 53.2 yr. The thyroid volume to body weight ratio was 0.251 ± 0.075 ml/kg.

DISCUSSION

In this study of 100 operated thyroid disorders, we have shown that determination of the volumes of thyroids by a new ultrasonic scanner was extremely accurate.

The accurate estimation of thyroid volume is considered of value in the assessment of Graves' patients,



FIGURE 3
Cross-section images of various thyroid diseases. (A) Graves' disease. (B) Thyroid adenoma

especially in calculating the correct therapeutic dosage of radioiodine therapy. Furthermore, it is useful to assess changes in goiter size with thyroid hormone treatment (12-14) and to the epidemiological screenings of thyroidal enlargement (15-16). Previously, thyroid volume was estimated only by using the thyroid scintigram (17); however, the thyroid volume estimated by this method was inaccurate. There have been no adequate methods of measuring the accurate thyroid volume in vivo. The 7.5 MHz new annular array transducer that we have developed is formed by creating concentric rings of five array elements. As a result, this transducer has high resolution and a wide, focused area of the images of thyroids of various sizes and shapes. Using this transducer, thyroids that cannot be palpated are also visualized as a clear image.

We studied the accuracy of the ultrasonically determined volumes compared with various weights of thyroids in vivo. The surgical measurement of thyroid weights and the determination of thyroid volumes by computerized digitizer were carried out independently; the physician who calculated thyroid volumes from echo films did not see patients and, therefore, did not know patients' goiter size clinically until these data were compared and analyzed. The volumes by the ultrasonic scanner correlated extremely closely with their weights obtained at operation. In the present study, the image on each cross-section was traced manually and the

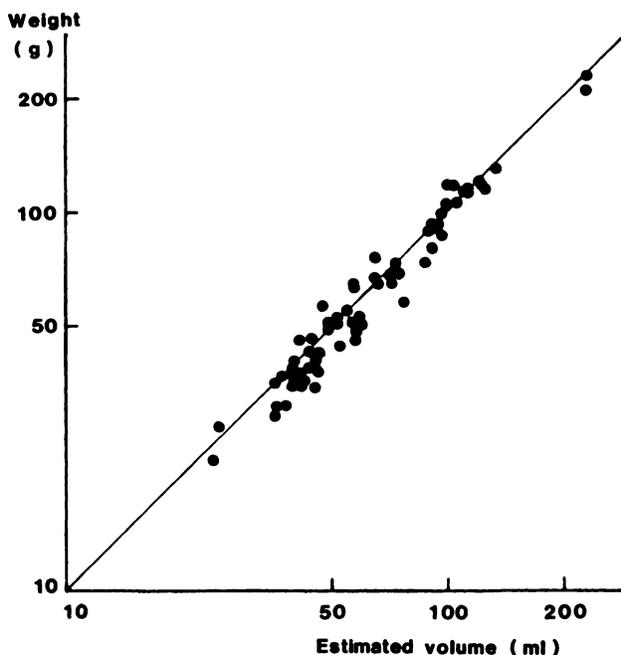


FIGURE 4
Correlation between estimated volumes of Graves' thyroids by ultrasonic scanner shown on abscissa and their total weights obtained at operation shown on ordinate. $n = 67$; $r = 0.980$; $p < 0.001$

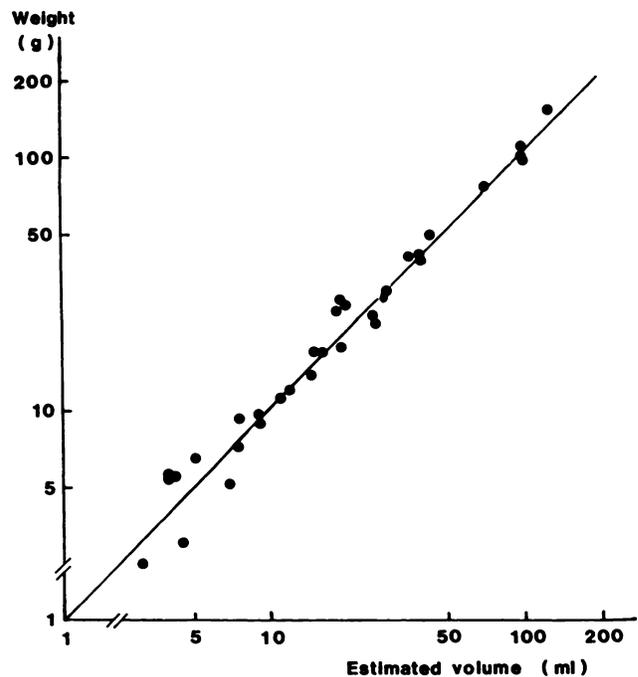


FIGURE 5
Correlation between estimated volumes of thyroid adenomas by ultrasonic scanner shown on abscissa and their actual weights obtained at operation shown on ordinate. $n = 33$; $r = 0.990$; $p < 0.001$

thickness of the cross-section was determined to produce at least eight cross-sections of thyroids and adenomas. Although there is no way to verify the absolute accuracy of manual tracing, the extremely close correlation may prove that the present technique is valid.

The mean normal thyroid volume by the ultrasonic scanner was 13.4 ml, which differed from the findings of Hegedus who reported 18.6 ml (6) or Yoshida who reported 19.0 g on autopsy study (18). It was speculated, however, that the thyroid volumes were influenced by body weight, age, and sex; a previous study demonstrated a significant positive correlation between thyroid volume and both body weight and age, with weight having the most pronounced influence (6). Subsequently, when the ratios of thyroid volume to body weight were compared, there was no significant difference between our study (0.251 ± 0.075 ml/kg) and the previous study (0.277 ± 0.067 ml/kg).

In conclusion, we have shown that this new ultrasonic scanner is very useful in determining the volumes of thyroid glands and nodules, since the measurement is very accurate, simple, and reproducible.

FOOTNOTE

* Sakura Co. Ltd., Japan.

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