Ultrasonographic diagnosis of parathyroid glands and percutaneous ethanol injection therapy

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Abstract
The first choice for imaging diagnosis of parathyroid gland (PTG) abnormalities is ultrasonography with a high-frequency probe. The patient must be positioned correctly when performing either imaging or percutaneous ethanol injection (PEIT) of the PTG. The enlarged PTGs are examined by ultrasonic tomography using 3D measurements, and it is important to evaluate blood flow; the PTGs are hypervascular in comparison with a nodular lesion of the thyroid. Based on the 3D data, the estimated volume of the gland is calculated \((a \times b \times c \times \pi / 6)\), from which the volume of ethanol to be injected is determined. The operator performing the puncture should be skilled in interventional ultrasonography, including needle biopsy of superficial organs, because when the PTG enlargement is advanced, ethanol must be injected in several steps while checking for residual blood flow.

After locating the tip of the needle by ultrasonography, the ethanol is injected, the jet echoes that spread from the tip of the needle are confirmed, and when there is no leakage from the gland, a volume of ethanol corresponding to \(\sim 50\%\) of the volume of the enlarged gland is injected. If residual blood flow is observed, additional ethanol is injected at the site. After completion of PEIT of the PTG, colour Doppler imaging is repeated and, if there is no blood flow, then the procedure is considered to be successful.

Keywords: parathyroid gland; PEIT; ultrasonography

Introduction
Several types of imaging methods currently are available for the detection of abnormal parathyroid glands (PTGs). Non-invasive methods include ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI) and scintigraphy. The first choice for image diagnosis of parathyroid abnormalities is ultrasonography [1–4] because it is non-invasive, can be repeated easily and has sufficient sensitivity and accuracy for assessment of hyperplasia. A high-frequency probe is needed for ultrasonic examination of the PTG, and blood flow evaluation is important even when there is low blood velocity and low blood flux. It is also important that a specialist performs the ultrasonic examination.

In theory, the higher the frequency of the ultrasonic waves, the higher the resolution; however, the penetration of the ultrasonic beam is an inverse relationship. If the frequency of the ultrasonic waves is lower, the ultrasonic beam penetrates further and it becomes possible to scan more deeply. The high-frequency band from 7.5 to \(> 10\) MHz is used for superficial organs, including the PTG [5], and the ultrasonic beam needs to be focused \(\sim 1.5–3.0\) cm from the body surface to obtain the best images; multiple reflections are also important.

Parathyroid ultrasonography
Ultrasonic examination of the PTG is usually performed in the supine position, but to obtain an accurate image the neck must be extended sufficiently by putting a pillow under the shoulder of the patient. This position decreases the blind area hidden by the clavicle and sternum, and secures a spatial margin, making the operation of the probe easier.

A normal PTG measures \(\sim 6 \times 5 \times 2\) mm and should be well within the detection limit of the latest ultrasonographic apparatus. However, because of the presence of fat cells, normal PTGs have the same echogenicity as the thyroid gland, which makes them difficult to detect, but abnormal glands can be detected even if they are the size of normal glands. The size estimated by ultrasonography is reproducible and correlates with the actual gland weight. The only weak point of the procedure is that glands located...
behind the oesophagus, trachea or sternum cannot be detected. As the usual location of the PTGs is at the base of the thyroid gland, transverse scanning must be done first. The ultrasonographic images are obtained by moving the probe slowly from the head side to the caudal side along the bilateral common carotid arteries. When a nodular lesion that is thought to be a PTG is located between the trachea and the common carotid artery at the base of the thyroid, the probe is rotated $90^\circ$ to take an image of the gland. This manoeuvre results in changing the image from transverse to longitudinal scanning.

By stepping up this procedure, the reproducibility of the images of the PTGs in both cross- and vertical sections can be confirmed, which is important and useful for the differential diagnosis between PTGs, the long group of neck muscles and vascular structures.

**Fig. 1.** Enlarged parathyroid gland in secondary hyperparathyroidism caused by chronic renal failure.

**Fig. 2.** Abundant blood vessels are observed in the parathyroid gland in the left panel.

**Fig. 3.** Fusion 3D image of enlarged parathyroid gland in secondary hyperparathyroidism. Increased blood flow can be seen from all angles.

**Fig. 4.** A 3D image before PEIT is shown on the left and after PEIT on the right. When these images are compared, it is evident that there is no blood flow in the parathyroid gland after PEIT.
Ultrasonographic diagnosis

An enlarged parathyroid can be detected as a ‘hypoechoic mass lesion’ characterized by clear boundary structures, but sharing its capsule with the dorsal side of the thyroid. The internal echo of an enlarged PTG is lower than that of the thyroid, making differentiation between these glands easier. However, it can be echofree, similar to a cystic lesion, depending on the case. There are also many cases with flat PTGs.

In cases of both primary and secondary hyperparathyroidism, the form of the PTG can vary from ellipsoid to polyhedral and can merge with an adenomatous goitre; therefore, differential diagnosis between adenomatous nodules and an enlarged PTG is important in some cases.

Almost all cases of primary hyperparathyroidism resulting from adenoma or parathyroid hyperplasia with multiple endocrine neoplasms (MEN) have ellipsoidal or flat PTGs. On the other hand, in cases of secondary hyperparathyroidism with chronic renal failure under haemodialysis, the ultrasonographic images of the PTG are variable. When secondary hyperparathyroidism becomes serious, there can be increased size in many shapes [6–9]. In cases of nodular hyperplasia, the image can show single or multiple spheres, and daughter nodules can often be observed (Figure 1). The incidence of parathyroid cysts is comparatively high, and many of these are larger than parathyroid adenoma or hyperplasia. It is characteristically difficult to see a solid section in the peripheral area of parathyroid cysts, which can easily be distinguished from solid lesions by posterior echo enhancement.

Colour Doppler and percutaneous ethanol injection therapy (PEIT)

It is known that adenoma and hyperplasia of the PTG are hypervascular in comparison with a nodular lesion of the thyroid, which enables the differential diagnosis of PTG and nodular thyroid lesions, especially adenomatous goitre. Doppler ultrasonographic colour imaging can detect low-velocity blood flow and flux, and display the blood vessels in the PTG (Figure 2) [10,11].

The position of the patient is important when performing either ultrasonography or PEIT of the PTG, especially when lesions under the collar bone need to be imaged. By extending the neck sufficiently, a wide visual field can be achieved for imaging, and it also enlarges the space available for the PEIT.

After positioning the patient, the enlarged PTG is examined by ultrasonic tomography. The cross- and longitudinal sections of the gland are imaged, and 3D measurements (vertical and horizontal lengths, and thickness) are made. Based on the 3D data, the estimated volume of the gland is calculated, and the volume of ethanol to be injected is determined. The degree of blood flow is then examined using 2D and 3D colour Doppler imaging and, based on the 3D data, images are prepared to evaluate blood flow from all angles.

Using a fusion of 3D techniques, which combine individual 3D images in B mode with colour 3D images of the PTG, the gland is reconstructed and displayed. In the example shown in Figure 3, remarkable enlargement of the gland and increased blood flow can be seen from all angles.

When PEIT is performed, ultrasonic gel is applied directly to the lens of the probe, and the lens is covered with the latex cap, which enables continuous use of the probe and prevents risk of infection. The front of the neck is sterilized with povidone iodine and then the latex cap of the probe is sterilized. They are then re-sterilized with alcohol in the same manner.

It is best for three people to work together in performing PEIT: one to inject the ethanol, one to make the puncture, and an ultrasonographer, who should be an ultrasound technician specializing in superficial organs or a doctor qualified as a Board Certified Fellow of the Japan Society of Ultrasonics in Medicine. It is recommended that the operator in charge of performing the puncture should be skilled in interventional ultrasonography, including needle biopsy of superficial organs.

As was observed in the representative case, when the PTG enlargement is well advanced, ethanol must be injected in several steps while checking for any remaining blood flow. A needle was inserted into the centre of the lower left gland under ultrasonographic guidance. After locating the tip of the needle by ultrasonography, 0.02 ml of ethanol was injected. Jet echoes that spread from the tip of the needle were confirmed and, when there was no leakage from the gland, ethanol in a volume corresponding to ~50% of the volume of the enlarged gland was injected. After injection, any remaining blood flow from the head to tail side of the gland was checked. If residual blood flow is observed, additional ethanol is injected at the site.

After completion of PEIT of the PTG, colour Doppler imaging is used again to obtain 3D data, from which it is confirmed from all angles that there is no remaining blood flow in the gland (Figure 4). If there is no blood flow, then PEIT is considered successful.

References