C-scan ultrasonography in orbital diagnosis

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SUMMARY A C-scan imaging facility has recently been added to the ultrasonic system in use at Moorfields Eye Hospital, London. The technique is explained and typical C-scans are presented to demonstrate the normal orbital fat and optic nerve, together with selected pathological conditions in the orbit. The C-scan facility permits imaging of the orbital contents in the coronal plane. This coronal plane imaging, together with high resolution and sensitivity, makes this a useful technique for demonstrating orbital lesions and it is hoped helps in the accurate measurement of the diameters of the optic nerve along its length. The problems associated with C-scanning are discussed.

The coronal plane of the orbital contents is inaccessible to ultrasonic B-scan investigation because the surrounding orbital walls prove a barrier to the sound beam. This plane may, however, be imaged using a C-scan technique. The C-scan also provides a means of measuring the diameter of the optic nerve, for which purpose it is potentially more accurate than both A-scan and B-scan.

This paper presents preliminary results of clinical trials of a C-scan facility which has recently been added to the Moorfields ultrasonic system (Aldridge *et al.*, 1974). This system is also capable of A-scan, mechanical B-scan (McLeod *et al.*, 1977), and holographic imaging (Restori, 1977).

Methods

The coronal C-scan plane of the orbit, together with the horizontal and sagittal B-scan planes, are illustrated in Fig. 1. The method of scanning to obtain a C-scan is illustrated in Fig. 2.

The eye is anaesthetised with oxybuprocaine HCl drops and the eyelids are retracted with a Barraquer speculum. A focused 10 MHz transducer (focal length 46 mm and focal spot diameter 0.8 mm), is coupled to the eye by means of a bath (Purnell, 1966) containing saline at 36°C. A fixation light is used to reduce eye movements to a minimum. To complete the C-scan the transducer sweeps mechanically in a rectilinear fashion to cover a 4 cm square aperture in which the eye is centralised. Each 4 cm sweep of the transducer takes approximately 140 ms to complete. Either 80 or 160 transducer sweeps may be employed to produce a C-scan taking

11 or 23 s respectively to complete. C-scans compiled in 23 s contain more information than those compiled in 11 s and were the option chosen for all C-scans described in this paper. The transducer emits pulses of sound and, in the time interval between emission of pulses, returning echoes are received by the same transducer. Only echoes from within two pre-selected depths within the orbit are recorded, these depths being selected by earlier reference to the B-scan display (Fig. 3). The focal plane of the transducer is arranged to lie at the centre of these chosen depths. The resolution attainable, therefore, is dependent on the focal spot diameter of the transducer (0.8 mm for all C-scans described in this paper). The echoes from the pre-selected depths correspond to those received within a period of time (time-gate) a certain time after the emission of a pulse from the transducer. If the time-gate is kept narrow, that is the pre-selected depths are close together, a thin section of tissue may be imaged. The time-gate is normally set at 2 μ s which, assuming a short examining pulse of sound, is equivalent to 1.45 mm in thickness of orbital fat. The intensities of the recorded echoes are used to modulate the brightness of the spot of a cathode ray tube, which is driven in synchronism with the transducer. The C-scan images the soft tissues within the time-gate in the coronal plane and is recorded on Polaroid positive/negative film.

Results

To date 82 orbits have been examined using the C-scan in conjunction with the B-scan technique. C-scan examination was employed in all cases of suspected optic nerve lesions or for those lesions

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Fig. 1 Planes of B-scan and C-scan examinations

in which it was important to ascertain their position relative to the optic nerve. In addition, C-scan investigations were performed whenever there was some doubt about the nature or extent of an orbital lesion.

A normal C-scan section taken a few millimeters behind the globe is shown in Fig. 4. Individual lobules of fat can be delineated and the optic nerve is seen as an acoustically clear area. A variety of pathological changes in the orbit are demonstrated in Figs 5 to 8.

The C-scan in Fig. 5 displays a meningioma surrounding the optic nerve. The echoes arising from this mass represent sound scattered by the

tumour, possibly by psammoma bodies which were demonstrated histologically. These echoes were not demonstrated on the B-scan display. A lymphoma wrapped around the optic nerve is illustrated in the C-scan (Fig. 6). The optic nerve lies within

Fig. 2 C-scan imaging of the orbit

Fig. 3 B-scan section showing preselected depths (time-gate) in a normal orbit for C-scan examination

the clear area in the centre of the fat pad, and is surrounded by the acoustically homogenous lymphoma. As neither the mass nor the optic nerve gives rise to echoes the exact border of the nerve can only be surmised. The mass is seen to be lobulated. The attenuating properties of this mass, its homogenous nature, and the lobulated shape

which was well demonstrated on C-scanning, led to a correct preoperative ultrasonic diagnosis of lymphoma.

The distorted fat pad of a dysthyroid patient is shown in Fig. 7. The grossly enlarged superior rectus muscle is seen as an acoustically clear area above the optic nerve. The full extent of the enlarge-

Fig. 4 A normal fat pad in C-scan section

Fig. 5 Optic nerve meningioma in C-scan section

Fig. 6 C-scan section showing lobulated lymphoma around the optic nerve

Fig. 7 Fat pad of dysthyroid patient with enlarged superior rectus muscle seen directly above the optic nerve—C-scan

Fig. 8 Mass originating in the lacrimal gland shown in coronal C-scan plane

ment was determined by means of consecutive C-scan sectioning of the orbit. In Fig. 8 a large lacrimal mass is illustrated and its position in relation to the globe is demonstrated. The indentation of the superotemporal equator of the globe by the mass is clearly illustrated. Part of the mass gives rise to echoes, while other parts of the mass appear acoustically homogenous. This mass proved at surgery to be a lacrimal carcinoma lying within a cyst.

Discussion

Several authors (McCready and Hill, 1971; Northcote *et al.*, 1974; Suarez *et al.*, 1975) have discussed the possibility of employing a C-scan modality in medical diagnosis, but the technique has not been widely used. C-scanning of the orbit has proved to be particularly useful as it displays that plane in the fat pad which the surgeon progressively dissects during lateral orbitotomy. In addition, the position of lesions in relation to the optic nerve can be clearly demonstrated. The C-scan technique used in conjunction with the B-scan also permits three mutually perpendicular planes within the orbit to be visualised, such that the full extent and shape of a lesion can often be determined.

In the C-scan technique, the focal plane of the transducer is arranged to coincide with the plane to be imaged so that certain advantages accrue.

Firstly the power of the sound beam is at a maximum in the focal region, and thus the transducer is at its most sensitive here. This high sensitivity allows low amplitude echoes to be detected and, therefore, more information about the likely nature of a mass is received. Secondly, the sound beam is narrowest in the focal region, and equal to the focal spot diameter of the transducer. Consequently, since the resolution on the C-scan depends on the width of the examining sound beam in the imaged plane, resolution is optimised.

C-scan imaging employing strongly focused transducers, and hence having very small focal spot diameters, could be used as a means of measuring the diameter of the optic nerve with high resolution. It is intended to employ such transducers in a future study, correlating results with measurements taken at surgery. The C-scan has advantages over both B-scan and A-scan techniques for these measurements. The B-scan is limited by the width of the examining sound beam, and as transducers suitable for B-scan are only weakly focused, the resolution attainable is not as great as that possible employing a C-scan technique. The A-scan measurements are limited by the difficulty in arranging the sound beam to strike the optic nerve perpendicularly, a prerequisite for accurate A-scan measurement. Thus the diameter of the optic nerve tends to be overestimated.

C-scans are degraded by gross eye movements or by small involuntary movements (Coleman, 1971) occurring during construction of the image; for this reason attempts are made to keep such movements to a minimum. C-scans taking 11 s rather than 23 s to complete may be the option chosen for patients who find difficulty in holding the eye still. Because the orbital fat is more static than the eye, it is less susceptible to such degradation and thus lends itself to C-scan examination.

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