Rapid B-scanning of the vitreous

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SUMMARY Ultrasonic examination is an essential investigation in most patients awaiting vitrectomy. Rapid B-scanning of the vitreous is described utilising a new system capable of high resolution and good tonal quality. Several patterns of haemorrhagic invasion of the vitreous cavity are illustrated, together with detachment, collapse, and retraction of the vitreous gel.

Diagnostic ultrasound has been used for many years for the investigation of ocular and orbital diseases (Oksala, 1963; Baum, 1964; Purnell, 1966; Ossoinig, 1972; Coleman, 1972; Bronson, 1972). Examination methods currently available include A-, B-, C-, and M-scanning and ultrasonic holography. Apparatus capable of ophthalmic A-, B-, and C-scanning and holography was designed by Aldridge *et al.* (1974) and has been on clinical trial at Moorfields Eye Hospital for the past three years. A report of its use in the investigation of orbital lesions is to be published shortly (Restori and Wright, 1977). This paper presents our experience of real-time B-scanning of the vitreous cavity, particularly in patients being considered for vitrectomy.

Material and methods

EQUIPMENT

A 10-MHz focused transducer is mechanically scanned in rectilinear fashion, each 4-cm sweep constituting a B-scan section. Each sweep takes approximately 140 milliseconds to complete, thereby permitting fast, almost real-time imaging of the globe. A remote button (sited near the display oscilloscope) controls the level of the B-scan section, which can be varied over a distance of 4 cm. This level is displayed on a millimetre scale and can be conveniently compared with the position of the central B-scan section, that is, the section with the strongest corneal echoes. B-scans may be taken in horizontal, sagittal, and oblique planes, and the 4-cm-square scanning aperture can be completely investigated in a few seconds. Variable system

controls include gain, transmission pulse duration, scanning speed, and a swept gain facility to compensate for sound attenuation in the globe and orbit.

The system is capable of good resolution and is remarkably free of artefacts. The scanning mechanism has been built to a high standard of rigidity and precision, and the instantaneous position of the transducer is transferred to the display tube with minimum error. These are design criteria for holographic imaging and undoubtedly contribute to the quality of the B-scan display.

Adequate sensitivity and accurate echo registration allow weak echoes to be detected and displayed. The dynamic range of the system is 40 dB, and an amplifier to compress this 40 dB into the 20 dB dynamic range of an oscilloscope would improve the grey scale appearance of the B-scan display.

A time-gate has proved useful in selecting echoes for amplitude quantitation from any B-scan section. The A-scan suffers no signal processing except optional rectification and envelope detection. Polaroid Landpack film (type 107C) is used to obtain a permanent record of both A- and B-scan displays; however, many of the grey tones are lost to Polaroid film and essential dynamic information is difficult to capture on still photographs.

TECHNIQUE

The eye to be investigated is anaesthetised with oxybuprocaine HCl (Benoxinate) drops and the eyelids are retracted with a Barraquer speculum. The patient lies supine on a movable couch, and the transducer is coupled to the eye by means of a Steridrape bath (Purnell, 1966) containing Ringer's solution at 36°C. The eye is positioned to lie in the centre of the 4-cm-square scanning aperture, and is

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Fig. 1 Rectilinear scanning in horizontal plane

scanned transversely at 1-mm intervals, initially with the patient looking straight ahead (Fig. 1). Further scanning is then carried out during lateral and vertical deviations of the patient's gaze, thereby increasing the amount of data obtained from the equatorial regions of the eye. If necessary, sagittal scanning is also performed, for example, to localise radiolucent intraocular foreign bodies in 3 mutually perpendicular planes.

In dynamic studies the direction of gaze is changed suddenly, and after-movements of the echoes are observed for several seconds.

CLINICAL CORRELATION

Ultrasonic findings have been correlated with ophthalmoscopic and biomicroscopic appearances wherever possible, for example, during vitrectomy performed or witnessed by one of the authors (D. McL.).

Results

The vitreous cavity is the space behind the posterior lens capsule and zonule and internal to the inner limiting lamina of the ciliary epithelium, retina, and optic disc. This space is normally occupied by the vitreous body, a relatively homogeneous aqueous gel, so the vitreous cavity is normally spheroidal on serial B-scanning (apart from the lenticular indentation anteriorly) and is acoustically 'empty'.

Acoustic changes in the vitreous have been classified as follows:

I. ABNORMAL CONTENTS OF THE VITREOUS CAVITY

The presence of echoes within the vitreous cavity indicated:

- (1) persistence (or hyperplastic persistence) of primary vitreous structures (Fig. 2a);
- (2) change in the physicochemical structure of the vitreous body, for example, senile or myopic degeneration; or
- (3) invasion or infiltration of the vitreous by substances, cells, or other particles normally foreign to this cavity (Fig. 2b).

II. CHANGE IN THE VOLUME AND SHAPE OF THE VITREOUS CAVITY

The volume of the vitreous cavity was increased in myopic and buphthalmic eyes, an asymmetrical enlargement being interpreted as a staphyloma. Likewise in aphakia the vitreous cavity incorporated the posterior chamber, communicating with the anterior chamber via the pupil.

The volume of the vitreous cavity was reduced in microphthalmic eyes and in phthisis bulbi (where choroidal thickening compounded the effect of scleral shrinkage on vitreous volume). An asymmetrical reduction in volume typically resulted from surgical explants and orbital tumours, and also from detachments and tumours of the retina and choroid (Fig. 2c).

III. CHANGE IN THE VOLUME AND SHAPE OF THE VITREOUS BODY

The vitreous body commonly occupied rather less than the total volume of the vitreous cavity, separating from its surroundings anterior and/or posterior to its firm annular attachment to the pars plana and peripheral retina (the 'vitreous base'). The vitreous cavity thus became divided into compartments—that is, the vitreous gel (formed vitreous) and prehyaloid or retrohyaloid spaces (fluid vitreous)—and the shapes of these compartments were mutually interdependent. In many cases abnormal vitreo-retinal adhesions precluded complete posterior detachment of the vitreous from the retina (Fig. 2d).

B-scanning of the vitreous cavity was most commonly performed as part of the work-up of potential cases for vitrectomy, and ultrasonic evaluation in these patients was particularly directed towards:

- (A) localising and identifying material which had invaded the vitreous cavity;
- (B) determining the presence of compartments within the vitreous cavity; and
- (C) defining the borders of the vitreous cavity, in particular detecting the presence of a retinal detachment.

Fig. 2 Classification of vitreous disorders

- (a) Left eye: persistent hyperplastic primary vitreous
- (b) Left eye, deviated nasally: invasion of vitreous by haemorrhage, densest posteriorly
- (c) Right eye, deviated nasally: ciliochoroidal detachment tethering at scleral spur and vortex ampulla
- (d) Left eye: dense intragel haemorrhage; foreign body track and vitreoretinal adhesion nasally; thickened anterior and posterior hyaloid membranes

(A) INVASION OF THE VITREOUS (Fig. 3)

Extraneous intravitreal material gave rise to either localised or more generalised echoes from the vitreous cavity:

(1) *Localised echoes.* Inflammatory cells forming a vitreous abscess or granuloma produced a collection of medium-amplitude echoes, as did haemorrhages into relatively solid vitreous gel. Clotted blood was often confined within vitreous 'tracts' or other intragel compartments (Fig. 3a), and in many cases the site of bleeding could be located by serial scanning of the globe (Fig. 3b). Stronger and more discrete echoes arose from glial or fibrovascular tissue proliferating as a sequel to haemorrhage in the gel, for example, along the track of a perforating foreign body (Fig. 2d). Similarly, sheets of glial or fibrovascular tissue arranged as epiretinal mem-

branes gave rise to high-amplitude echoes which tended to flatten the concavity of the vitreoretinal interface (Fig. 3b).

Collections of high-amplitude echoes also resulted from intravitreal foreign bodies or a posteriorly dislocated lens.

(2) *Dispersed echoes.* Uveitis and vitreous haemorrhage often resulted in low-amplitude echoes disseminated within the vitreous cavity (Fig. 3c), a picture also seen occasionally in degenerative syneresis. In general, inflammatory cells could not be distinguished ultrasonically from red blood cells, and the amount of acoustic change was less than that expected from the degree of opacification of the media to light.

Dispersed high-amplitude echoes were typical of asteroid hyalitis.

Fig. 3 *Invasion of the vitreous*
 (a) *Left eye, deviated temporally; dense haemorrhage in anterior gel; fine vitreous membrane tethering posteriorly*
 (b) *Left eye: haemorrhage from fibrovascular proliferations; epiretinal membrane flattens concavity of vitreoretinal interface posteriorly*
 (c) *Right eye: dispersed echoes in vitreous gel.*
 (d) *Right eye, deviated temporally: diffuse echoes from blood in retrohyaloid space extending into the central gel*

(3) *Diffuse echoes.* Invasion of the vitreous cavity by inflammatory or red blood cells sometimes gave rise to diffuse low-amplitude echoes by scattering of sound, producing a relatively uniform echo density (Fig. 3d).

(B) POSTERIOR VITREOUS DETACHMENT (Figs. 4 and 5)

Separation of the vitreous body from the retina was often demonstrable, especially in patients with an associated invasion or infiltration of the vitreous cavity. There were two basic acoustic patterns indicative of vitreous detachment:

(1) *A thin sheet of echoes along the posterior hyaloid interface*, usually inserting into the retina just anterior to the equator. This pattern was typically found in those diabetic patients in whom a

relatively immobile membrane spanned the posterior part of the vitreous cavity, often attached to the optic disc region by a thick rigid stalk. Echoes from the posterior hyaloid membrane were of lower amplitude and more discrete than the echoes from fibrovascular tissue on the posterior aspect of the hyaloid membrane (Fig. 4a).

In senile and myopic posterior vitreous detachment irregular low-amplitude echoes arose from the mobile posterior hyaloid, while vitreous retraction—that is, gross anterior contraction and immobilisation of the gel (Fig. 4b)—was usually associated with high-amplitude echoes from a taut posterior hyaloid membrane.

(2) *Localisation of diffuse or dispersed echoes to one or other vitreous compartment*, the other compartment being clear or containing a different echo

Fig. 4 *Posterior vitreous detachment*

(a) *Right eye: irregular echoes from posterior hyaloid membrane; fibrovascular stalk arising from disc*

(b) *Left eye, deviated nasally: aniridic and aphakic; gel retraction and haemorrhage; thickened immobile anterior and posterior hyaloid membranes*

(c) *Left eye: dense intragel haemorrhage and two vitreoretinal adhesions*

(d) *Right eye, deviated nasally: diffuse echoes from blood in retrohyaloid space and clear gel*

density (Fig. 4c and d). Thus, intragel echoes were often bounded by a clear retrohyaloid space (Fig. 4c), or an acoustically clear gel was delineated by diffuse echoes from the retrohyaloid space (Fig. 4d). In some patients the vitreous gel was immobile (Fig. 4d) or moved without significant change in contour, indicating gel contraction without collapse. In other cases, however, jerky after-movements of the posterior hyaloid interface characterised gel mobility. Extreme mobility of the gel was seen in myopes with a bleeding retinal tear and in most cases of vitreous haemorrhage due to retinal branch vein occlusion; such a pattern signified posterior vitreous detachment with gel collapse (Fig. 5a and b).

Echoes arising from one or other vitreous compartment did not necessarily fill that compartment. For example, a gradual settling of a retro-

hyaloid bleed over the posterior pole sometimes occurred during the course of ultrasonic examination in the supine position (Fig. 5c). More commonly an apparent 'compaction' of intragel echoes along the posterior hyaloid interface resulted in a thick membrane with a discrete, smooth, posterior surface (Fig. 5d), and at vitrectomy a dense non-fibrotic 'ochre' membrane was found. Such membranes were characteristically mobile, though the thicker the membrane the more restrained the gel after-movements became. No ultrasonic evidence of compaction of blood from the retrohyaloid space on to the *posterior* aspect of the hyaloid interface has been observed to date.

The degree of contraction of gel volume, the extent of residual vitreoretinal adhesion, and the mobility of the gel were all variable. In eyes with a

Fig. 5 *Posterior vitreous detachment*

(a) *Left eye, not deviated: intragel haemorrhage temporally; clear retrohyaloid space nasally.*

(b) *Same eye as 5(a), deviated nasally: intragel haemorrhage now on nasal side; clear retrohyaloid space temporally*

(c) *Left eye: dense haemorrhage in retracted gel and thickened posterior hyaloid membrane; retrohyaloid haemorrhage sediments on to posterior retina*

(d) *Left eye: dense intragel haemorrhage showing 'compaction' posteriorly and tethering at the macula—an ochre membrane*

minimally contracted mobile vitreous body the gel tended to settle against the retina under the influence of gravity in the supine position. In such cases dynamic testing was necessary in order to separate the vitreous and retina and to identify points of true vitreoretinal adhesion, which might be extremely tenuous, for example, after neovascularisation due to retinal branch vein occlusion. Tumours or retinal detachments underlying the haemorrhage could also be discovered in this way.

(C) DETACHMENT OF THE RETINA (Fig. 6)

Detached retina produced a regular continuous sheet of high-amplitude echoes which encroached on the vitreous cavity. When the detachment was extensive and bullous, the membrane typically showed undulating after-movements on dynamic

testing and was usually characterised by attachments at the ora serrata and optic nerve head (Fig. 6a and b). The site of communication between the vitreous cavity and the subretinal space in eyes with rhegmatogenous retinal detachment was detected only in cases of giant retinal tear or dialysis (Fig. 6c and d). The subretinal space was generally clear, though subretinal haemorrhage or tumour was occasionally present.

In many eyes there were also acoustic signs of invasion of the vitreous cavity by red blood cells or pigment cells (Fig. 6b) or evidence of posterior vitreous detachment (Fig. 6a and d). In traction retinal detachments a taut posterior hyaloid membrane typically inserted into the height of an immobile elevation of the retina. Alternatively, if the detachment resulted from transgel traction-band

Fig. 6 *Detachment of the retina*

(a) *Left eye: detached retina tethers at the disc and ora serrata; mobile posterior hyaloid membrane*

(b) *Left eye, deviated nasally: totally detached retina; pigment invasion of gel.*

(c) *Left eye: giant traumatic retinal dialysis; gel attached to folded temporal retina and pars plana; shallow nasal retinal detachment*

(d) *Right eye: giant retinal tear; folded-over temporal retina at disc; detachment nasally; gross gel retraction and taut posterior hyaloid membrane*

(e) *Right eye, deviated nasally: vitreous retraction; epiretinal fibrosis; 'morning glory' retinal detachment; retinal cyst*

(f) *Left eye: retinal detachment secondary to anterior vitreous traction; pars plana is detached but posterior retina is flat; posterior vitreous detachment (mobile on dynamic testing)*

formation or from severe contraction of epiretinal membranes, the posterior hyaloid could be quite mobile. In eyes with massive preretinal retraction fibrous proliferation along the posterior hyaloid interface typically resulted in a taut, immobile sheet of high-amplitude echoes across the vitreous cavity (Fig. 6*d* and *e*). Associated epiretinal membrane formation was suggested by retinal immobility together with thickening and shortening of the retina (Fig. 6*e*), while in some cases the epiretinal membranes were discernible between the retinal folds.

Detached retina was usually readily differentiated from a vitreous membrane, which generally gave rise to an irregular sheet of echoes of lower amplitude and greater mobility than retina with discrete or absent attachments posteriorly (Fig. 4*a*). Similarly, although elevation of the neuroepithelium sometimes extended anterior to the ora serrata in traction retinal detachments (Fig. 6*f*), there was seldom any real source of confusion with a choroidal detachment (Fig. 2*c*). However, some difficulty was experienced in differentiating a very shallow traction detachment of the posterior retina from epiretinal fibrous tissue or a taut fibrous minimally detached posterior hyaloid membrane. Similarly, a dense posterior hyaloid membrane tethered by a wide adhesion to the optic nerve-head sometimes simulated a total retinal detachment. In such cases particular attention was paid to dynamic and tonal features such as signs of compaction.

Discussion

Recent advances in vitreous surgery have provided an added impetus to improving the ultrasonic assessment of the vitreous cavity. The B-scan method, which provides a cross-sectional image of the interior of the globe, is undoubtedly the most useful technique in the investigation of patients awaiting vitrectomy. Standardised A-scan systems (such as the Kretztechnik 7200 mA) provide quantitative data on intraocular echoes such that detached retina can be differentiated from a vitreous membrane in many cases (Ossoinig, 1972). However, vital dynamic and topographic characteristics of vitreous pathology are much more readily determined by rapid B-scanning, and we use the A-scan to provide supplementary information in relatively few cases.

Although contact scanning offers certain advantages in respect of preparation time and patient acceptability, water-bath coupling eliminates problems associated with working in the near-field of the transducer and also permits echoes from the anterior segment to be displayed. Furthermore, a wide linear transducer excursion allows landmarks on both sides

of the globe to be represented simultaneously, providing a good field of view of both anterior and posterior structures with minimal geometrical distortion of the display. One potential problem of linear scanning, of course, is the inability to display flat structures which are not at approximately normal incidence to the sound beam. This can be overcome by examining the eye in different directions of gaze, so structures become more favourably orientated to the beam. Thus, compound scanning capability has been found to offer no real advantage in the assessment of the vitreous cavity.

The Moorfields system combines several features essential for complete ultrasonic assessment of the vitreous cavity, in particular real-time imaging and good tonal quality. Furthermore, resolution is maintained despite spontaneous eye movements and during dynamic testing. In our hands the limited real-time scanning facility and lack of tonal quality of the Sonometrics Ophthalmoscan are considerable drawbacks to adequate previtrectomy assessment. The possibility of operator-induced errors (such as overwriting) from a manual scanning system, unless used in conjunction with a scan converter, is a further disadvantage.

With the Moorfields B-scan system dynamic vitreoretinal interrelationships can be graphically illustrated in a variety of conditions. Thus the independent mobility of the vitreous gel and the posterior edge of giant equatorial retinal tears may be contrasted with the attachment of vitreous gel to detached pars plana and peripheral retina in giant traumatic retinal dialyses. In other rhegmatogenous detachments the process of vitreous retraction can be followed, the posterior hyaloid changing from a thin mobile interface to a taut fibrous membrane (designated a 'cyclitic' membrane in some of the ultrasonic literature). When associated with a funnelled 'morning glory' retinal detachment, echoes from this membrane contribute to the so-called 'triangle sign' (Fuller, 1976), which has been considered to indicate inoperability of the retinal detachment by vitrectomy and membranectomy. Nevertheless such detachments can sometimes be re-attached by silicone oil injection into the retrohyaloid space. We believe gross shortening and fixed folding of the retina are the best guides to inoperability.

Finally, repeated B-scanning has also allowed the development of posterior vitreous separation to be followed in cases of haemorrhagic invasion of the gel. Such patients often complain of a further reduction in vision some time after initial visual loss, and dynamic testing suggests that a centrifugation or compaction of intragel particles has occurred owing to increased gel movement following vitreous detachment. We hesitate to use the term 'organised

vitreous membrane' to describe such an arrangement of haemorrhage, since 'organisation' implies massive fibrovascular invasion and immobilisation of a long-standing haemorrhage, none of which features characterises ochre membranes.

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