Ultrasonically measured horizontal eye muscle thickness in thyroid associated orbitopathy: cross-sectional and longitudinal aspects in a Danish series

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ABSTRACT.
Purpose: **To analyse horizontal extraocular muscle findings by ultrasound and exophthalmometry in a tertiary endocrinology centre series of patients with thyroid associated orbitopathy (TAO).**
Methods: **The 90 thyroid patients included underwent ultrasonic measurement of horizontal eye muscle thickness by a B-scan based technique carried out in addition to their general ophthalmic evaluation. As an indicator of mainly advanced TAO, longterm prednisone or cyclosporine A was given to many of the patients, and drug-resistant visual loss indicated decompression surgery in four of the 90 patients. Thirty-four patients underwent repeated muscle recordings over 15–49 months; this allowed for cross-sectional analysis and the outlining of longitudinal trends.**
Results and Conclusions: **(A) Although marginally overlapping, all four muscle groups were significantly thicker in the study group than in normal control subjects. The mean of the sum of all four muscles was 16.8 mm (range 13.6–21.7 mm) in the control group versus 22.6 mm (range 15.5–36.4 mm) in the thyroid group. (B) Using the clinical NOSPECS grading, more advanced eye involvement was found to generally result in a higher exophthalmometric measurement of protrusion and eye muscle thickness. However, slender rectus muscles and/or normal exophthalmometric values might occur even in advanced orbitopathy. (C) Over a period of 2–4 years, only a few of 34 patients with satisfactory serial ultrasonic measurements returned to their premorbid ophthalmic status. Typically, the extraocular muscles kept their abnormal size after having become clinically quiescent (fibrotic). (D) We found no safe indication regarding disease stage, active or late, from the ultrasonic appearance of the muscle tissue. (E) Discrepancies between various normative eye muscle studies are discussed with regard to computer tomography and magnetic resonance imaging.**

Key words: thyroid associated orbitopathy – endocrine orbitopathy – exophthalmometry – extraocular muscles – ultrasound measurements – imaging methods – longitudinal evaluation

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Introduction

Most thyroid patients escape significant eye symptoms. Some, however, contract serious orbital involvement. As a clinical designation, the 'malignant exophthalmus' of the past has since been replaced by 'dysthyroid' or 'endocrine orbitopathy'. At present the most frequent label given to the autoimmune disease manifestation is 'thyroid associated orbitopathy' (TAO).

Despite its shortcomings, the NOSPECS system of grading has gained a certain foothold in clinical work (Werner 1977; Mourits et al. 1997). It does not allow for making a clear distinction between early (inflammatory) and late (fibrotic) phases of the disease, and it has been suggested that guidance should be taken from ultrasonic findings (Prummel et al. 1993).

B-scan ultrasonic evaluation of horizontal eye muscle thickness and acoustical texture was therefore added to the ophthalmic protocol in a recent Danish prospective PhD study of various thyroid disease entities (Zimmermann-Belsing 1999), the main focus of which was the role of thyrotropin receptor antibodies. The cross-sectional entrance data indicated that increased eye muscle thickness almost exclusively appeared in patients with Graves' disease, while patients with other thyroid diagnoses generally escaped the features of TAO (Zimmermann-Belsing et al. 2002).

The present study may be regarded an ultrasonographic extension of the above PhD investigation. However, more patients were included, all of whom had suspected or significant TAO. Further, the protocol allowed assessment of longitudinal aspects of the orbitopathy, and evaluation of ultrasonic evidence regarding 'fresh or fibrotic' rectus muscle affection, an issue of obvious importance for the choice of therapy (systemic immune-suppression or orbital surgical strategies).

Finally, the study addressed some apparently general limitations of current imaging techniques regarding normative external eye muscle findings.

Material and Methods

All ophthalmic recordings were made during 1997–2000. Ninety adult patients were consecutively referred from the Department of Endocrinology, National University Hospital (Rigshospitalet, Denmark), due mainly to eye symptoms and/or obvious orbital involvement. The study group included 76 females (age range 17–78 years, median age 45 years) and 14 males (age range 16–76 years, median age 44 years). Except for three cases of genuinely euthyroid orbital Graves' disease, all subjects had recent laboratory evidence of thyroid disease, and most were on current medication to control hyperthyroidism. Nine males and 18 females without thyroid disease, aged 24–60 years, were included as control subjects.

A full ophthalmic examination comprised a test of best corrected visual acuity (VA), in a traditional 6 metre Snellen set-up. Colour perception was tested with Ishihara's isochromatic plates. The following evaluations were also performed:

- tangent screen visual field technique using white object 3/1000 mm as standard;
- description of eye surroundings and eyelids;
- eye motility evaluation including red-green tests for diplopia around primary position, and red-glass test in the outer field;
- Hertel exophthalmometry (Rodenstock equipment, Munich, Germany in mm);
- digital evaluation of retrobulbar tissue resistance, graded from 0 to + + +;
- slit-lamp evaluation for bulbar injection, chemosis, evidence of corneal damage, and
- fundus evaluation by direct ophthalmoscopy.

A grading of the TAO according to the NOSPECS ranking was attempted in all cases. In NOSPECS, the initial N denotes *n*either signs *n*or symptoms. O is for signs *o*nly, usually as sympathetic over-tonus leading to eyelid retraction (stare), and apparently not more deep-set orbital involvement. The five final capitals (SPECS) denote significant TAO. The first S stands for *s*oft tissue involvement, puffy eyelids in particular; P stands for *p*rotrusion, E for *e*xtraocular muscle involvement, C for *c*orneal damage, and the final S denotes *s*ight loss due to optic nerve compression (Werner 1977; Mourits et al. 1997).

The largest diameter of the horizontal extraocular muscles was assessed by ultrasonic B-scan using NIDEK 2500 equipment (Aichi, Japan). A transbulbar horizontal sector scan was performed through the closed lid, from the nasal side when examining the lateral rectus muscle, and from the outer canthal region when imaging the medial rectus. The patients were asked to look straight ahead during the examination, and usually this could be secured by keeping the fellow eye open. The main setting of the equipment was at empirical tumour sensitivity (71–73 dB). Suitable sections were frozen on the screen when the transbulbar muscle stripe – which has lower acoustic reflectivity than the surrounding orbital tissue – appeared as distinctly and reproducibly as possible (Fig. 1). The thickest section of the muscle was then measured perpendicular to the muscle axis, using the callipers of the equipment (in mm, with the conversion based on a standard tissue velocity set to 1550 m/sec; Fig. 1). The vertical recti were measured only occasionally, not as a routine part of the procedure.

Acoustically, most horizontal recti were found to be shaped as regular bands and were therefore easy to measure. However, the muscles sometimes appeared to be tendon- or club-shaped, and some were difficult to discern from adjacent orbital tissue. With reference to this acoustic difference, intramuscular reflectivity was described as normal (rather low and easily discerned), intermediate (medium) or high (difficult to outline).

Only one experienced examiner (HCF) was responsible for all ultrasonic measurements, thereby securing

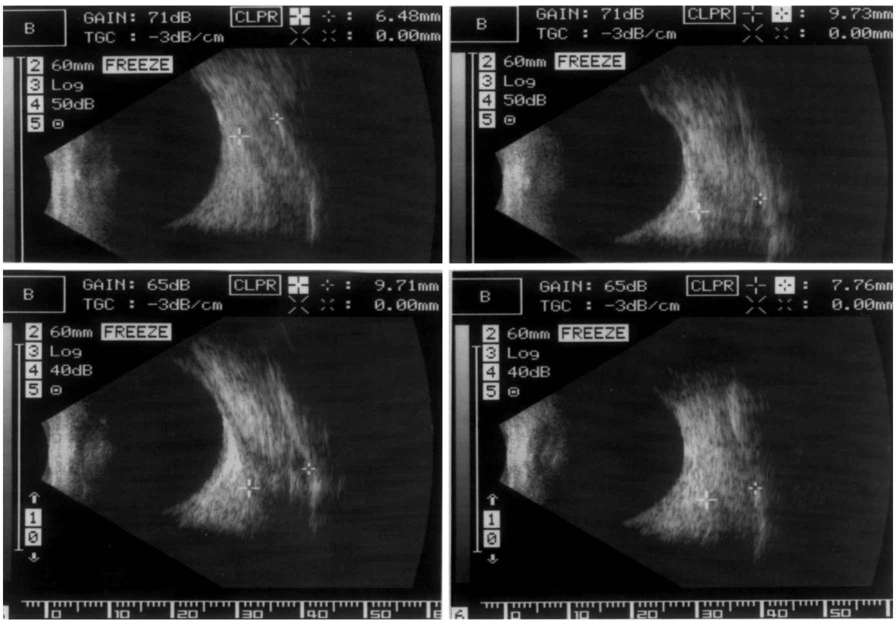

Fig. 1. Transbulbar ultrasonic B-scans (NIDEK) showing the darker muscle bands transversing the more whitish orbital tissue echogram behind the eyewall (right on images) opposite to the transducer position. Right eye measurements at top, left eye at bottom, with lateral rectus before medial rectus. The measurements given by the callipers are shown in the top window of the respective images.

homogeneity regarding technique and reproducibility. In a previous study (Zimmermann-Belsing et al. 2002), the day-to-day variation in a normal test person as estimated from 10 serial pooled measurements of the four recti over 2 years was 2.5%. Interobserver variation as relevant for the method employed has not been investigated.

Fifty patients were seen once or twice only. Fourteen attended three or four times, and nine underwent between five and seven examinations during the trial period. Seventeen patients underwent at least eight evaluations, clinically and by ultrasound. All 17 of these were categorized as at least 'E' (for eye muscle involvement) and seven of them also had reduced sight due to optic nerve involvement. Despite the long-term systemic anti-immune therapy given to all subjects with such advanced disease (prednisolone, cyclosporine A), four eventually required orbital wall decompression surgery.

The data were analysed using the NCCS97 statistical programme, by parametrical or non-parametrical standard tests according to the distribution and character of the data under study.

Results

NOSPECS rating and measuring results

The distribution of the NOSPECS categories is illustrated in Fig. 2. The graph depicts the association between NOSPECS and (a) exophthalmometry value, and (b) the pooled eye muscle size in the 90 patients. Almost half the patients had a grading of about E (for eye muscle involvement), and 15 were grouped in the two final categories of C and S.

Table 1 presents the horizontal rectus muscle values of the 27 control subjects as partly derived from our previous study (Zimmermann-Belsing et al. 2002). The table also gives the mean values of the male and female eye muscle measurements of the present sample. Generally, the TAO group mean values were above the upper range of the control group values. On average the single lateral recti and the medial rectus muscles were 0.08 mm and 0.3–0.4 mm, respectively, thicker in males than in females, but the overall trend towards higher values in males was not statistically significant. Accordingly, the following results do not specify the muscle findings according to sex but give them as pooled data.

Table 2 presents the individual horizontal rectus muscles measured, the pooled right and left bi-muscle status, and the sum of all four muscles in the TAO sample. In tests of the individual right and left eye pooled muscle thickness side differences, the mean value of 0.56 mm proved significant ($p = 0.0015$), suggesting a true right side predominance.

Table 2 also gives the exophthalmometry values. In parallel to the trend suggested for eye muscle thickness, the scores of affected males were slightly higher than those of females. In males, the right and left eye mean values were 21.5 mm and 21.3 mm, respectively; equivalent values in females were 21.0 mm and 20.8 mm, respectively. On a 0.05 level, however, the male/female and the right/left differences were not statistically significant.

The degree of TAO, as given by the NOSPECS grading, appeared to be significantly and uniformly associated with exophthalmometric values and with rectus muscle thickness. Measurements and gradings together confirmed that exophthalmometric and rectus muscle thickness values generally increase with more advanced endocrine orbitopathy (Fig. 2A and B). Figure 3 illustrates the positive correlation between exophthalmometry value and the sum of the two rectus muscles of the same side ($r = 0.68$ and 0.71, for right and left sides, respectively).

Further, the inner reflectivity of the muscles under study (normal, medium or high) was compared to the NOSPECS gradings and also to the estimated pre-examination duration of endocrine orbital involvement. Both showed a borderline positive trend, indicating that higher internal reflectivity was encountered more often when the orbital involvement appeared advanced and/or of longterm duration.

A weak trend likewise appeared between acoustic reflectivity and pooled muscle thickness. All three associations were significant, close to a 0.05 level (Mann–Whitney test), but with a considerable overlap between categories.

Longitudinal trends

Current evaluations were available for 17 patients with more severe TAO, thus allowing longitudinal trends to be outlined. Table 3 shows the 17 courses roughly defined by their starting and end point levels. Allowing for ultrasonic measuring errors and for physiological variation in muscle tone and eye position, the two values presented in the table were averaged from two to three consecutive measuring sets, from the start and end of the observation period, respectively. During the up to 4-year follow-up period, only six of the 17 subjects showed a pooled four-muscle change of at least 2 mm. An increase was observed in two subjects and a decrease in four. Accordingly, most subjects retained their increased external eye muscle measure.

Another 17 patients had at least three or four satisfactory measurements, allowing for a similar estimate of changes in eye muscle thickness over 1–3 years. Five of the 17 showed a change in pooled four-muscle thickness of at least 2 mm; three of these increased and two decreased. Quantitatively, the

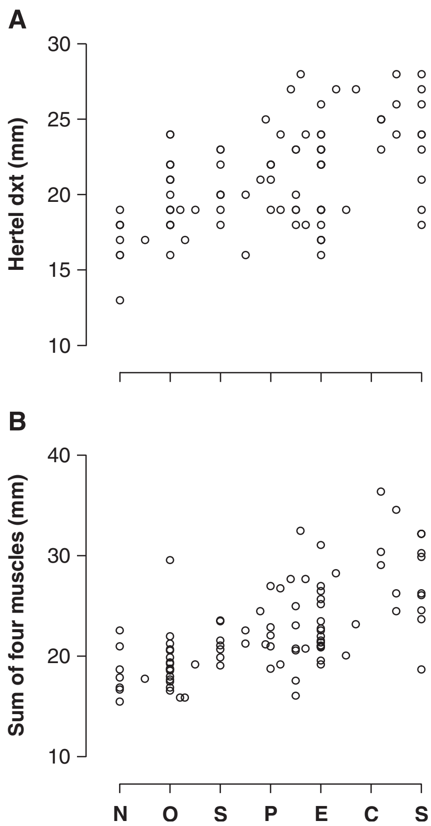

Fig. 2. Scattergrams showing the association between NOSPECS category and individual (A) exophthalmometry value (Hertel, right eye measurement shown), and (B) the subject's pooled eye muscle value (sum of all four horizontal muscles).

Table 1. Horizontal extraocular eye muscle thickness in normal adult males and females (left, $n = 9 + 18$) and in adult male and female TAO subjects (right, $n = 14 + 76$), given in mm, as mean value and range.

	Control group				TAO group			
	Males ($n = 9$)		Females ($n = 18$)		Males ($n = 14$)		Females ($n = 76$)	
Right lateral rectus (mm)	3.7	(3.2–4.4)	3.6	(3.0–4.9)	4.9	(3.6–6.4)	4.9	(3.2–8.8)
Right medial rectus (mm)	5.1	(3.8–6.6)	4.9	(3.8–6.2)	6.9	(4.8–11.4)	6.6	(4.1–10.6)
Left medial rectus (mm)	4.8	(3.8–7.0)	4.6	(3.7–5.6)	6.7	(4.4–11.0)	6.2	(3.8–10.8)
Left lateral rectus (mm)	3.7	(2.7–4.5)	3.5	(2.8–4.6)	4.8	(3.1–7.6)	4.7	(2.9–8.0)
Sum of all four mm	17.2	(13.8–21.7)	16.6	(13.6–19.9)	23.3	(17.8–35.4)	22.4	(15.5–34.6)

Table 2. Eye muscle thickness and exophthalmometry values in the TAO group, all given in mm. Males and females pooled ($n = 90$).

	Mean	(SD)	Median	(Range)
Right lateral rectus	4.8	(1.20)	4.5	(3.2–8.8)
Right medial rectus	6.7	(1.60)	6.4	(4.1–11.4)
Left medial rectus	6.3	(1.56)	6.1	(3.8–11.0)
Left lateral rectus	4.7	(1.06)	4.5	(2.9–8.0)
Both muscles, right	11.6	(2.42)	11.1	(7.9–17.8)
Both muscles, left	11.0	(2.46)	10.4	(7.2–18.8)
Side difference, both	0.6	(1.64)	0.5	(–5.9–5.2)
Sum four muscles	22.6	(4.60)	21.4	(15.5–36.4)
Hertel values right	21.1	(3.30)	21.0	(13–28)
Hertel values left	20.9	(3.43)	21.0	(12–28)

most marked changes were towards thicker muscles. Of the 34 subjects who underwent several ultrasonic measurements over time, 14 showed some change towards thinner muscles, four narrowly stayed within the ±0.1 mm range, and 16 showed an increase in the pooled horizontal eye muscle measurement.

Apparently regardless of the therapy given, whether immune-regulating and/or surgical (decompression), in more

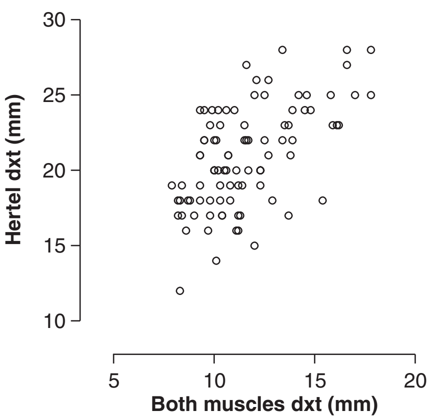

Fig. 3. The association between right eye pooled muscle thickness (lateral + medial rectus) value and corresponding Hertel exophthalmometry value. The regression line is $y = 10.3 + 0.93X$.

than half the patients an unfavourable natural history of eye muscle involvement could not effectively be redressed. Most patients retained some features of TAO and did not return to their premorbid ophthalmic status. As a consequence, in the present sample we have omitted all details regarding systemic medical therapy (antithyroid, anti-immune or other).

Figure 4 depicts serial observations of pooled four-muscle recordings in four selected patients. All four had used high doses of prednisone and cyclosporine A, although one of them had been given short-term treatment only (M50; euthyroid Graves'; no effect of treatment; developed diabetes). As typical exponents for the group, three showed only minor changes over time. However, one of these (F59) eventually showed a slight reduction in muscle thickness, although with no immediate response to early decompression surgery, at 3.5 months. The fourth patient, a 75-year-old man, showed a definite decrease, thus representing an exception to the general trend. He had first presented with severe protrusion and soft tissue swelling and almost immobile eyes (i.e. classical 'malignant exophthalmos'). Having refused decompression surgery, the patient made a marked clinical recovery over 1.5 years on prednisone and cyclosporine A and showed no relapse after withdrawal of the systemic therapy.

Discussion

TAO, exophthalmometry and eye muscle thickness: cross-sectional aspects

A previous Danish study reported a median Hertel exophthalmometry value of 16 mm in normal adults. In thyroid patients subdivided according to the presence or not of evidence of extraocular muscle involvement, the median values were 22 mm and 18 mm, respectively (Fledelius 1994). However, there was a marked overlap of ranges between groups.

In the present group of TAO patients, an association was found between exophthalmometry value and degree of TAO. The higher the NOSPECS grouping, the higher the general exophthalmometry level; this was valid also for external eye muscle thickness. At variance with the findings made by Schenone et al. (1998), we further found a significant positive correlation between eye muscle thickness and exophthalmometry recordings. As the outliers demonstrate, however, it should be stressed that serious orbitopathy occasionally appears with exophthalmometry levels and/or eye muscle thicknesses generally considered to be within the range for normal eyes.

The findings stress that imaging of the orbital structures cannot replace clinical evaluation but should primarily be regarded as a valuable adjunct when considering, for instance, surgical decompression of the orbit in serious disease. Increased extraocular muscle thickness, if present, will be demonstrated by all three imaging methods, but only computer tomography (CT) and magnetic resonance imaging (MRI) can directly depict apical eye

Table 3. Schematic representation of the 17 patients out of the full sample ($n = 90$) who had at least eight consecutive ultrasonic horizontal muscle measurements made during the trial period, ranked from lowest to highest measure. The individual entrance and final averaged (see text) pooled four-muscle values, Hertel value level and affection according to NOSPECS are given. Decompression surgery was performed in four of the 16 closely followed patients in the years shown.

Patient No.	Sex	Age	Regular follow-up (years)	Initial 4-muscle thickness (mm)	Final 4-muscle value (mm)	Uni- or bilateral (u/b) TAO	Max. Hertel exophth. value (mm)	Maximum degree of NOSPECS	Decompression surgery
1	f	55	3.4	19.2	18.7	b	17–17	S	2000
2	f	36	1.7	19.7	18.7	u	19–21	E	1997
3	f	50	2.6	22.2	22.2	u	18–24	E	
4	m	56	3.2	23.1	26.7	u	24–21	E	
5	m	51	3.4	24.5	25.2	u	21–24	E	
6	f	42	3.0	25.5	22.1	b	27–27	S	
7	m	44	3.6	25.6	23.4	b	24–24	E	
8	f	57	4.0	26.0	24.9	b	27–28	E	
9	f	42	2.9	26.1	26.0	u	27–23	E	1998
10	f	59	3.2	26.3	25.8	b	25–24	S	
11	f	55	3.5	26.3	28.1	b	23–21	E	
12	f	46	3.0	26.4	24.2	b	23–21	E	
13	f	35	3.2	27.0	25.6	b	27–26	E	
14	f	43	3.0	28.8	29.3	b	26–27	S	
15	f	63	3.7	32.1	34.9	b	28–28	S	
16	f	58	3.5	32.9	31.5	b	23–23	S	1997
17	m	76	2.6	34.0	24.8	b	23–25	S	

muscle crowding when optic nerve compression is suspected. Further, these two imaging methods give information regarding the bony walls of the orbit and the adjacent paranasal sinuses, of obvious importance when considering surgical decompression strategy.

Thickness of extraocular muscles: longitudinal aspects

We have not found any other studies on extraocular muscle diameter estimates followed over several years. This part of the study required patients for whom more than one set of measurements were made in order to represent start and end points and 34 of our study group qualified. These patients probably represented more selected cases of TAO and this should be kept in mind when assessing the results presented. Most longitudinal patients included thus maintained their abnormally high eye muscle measurements even after the peak of their clinical Rundle curve (Rundle & Wilson 1945), and some of them even increased these measurements when passing from the presumed early inflammatory to the late fibrotic stages.

By and large, the same conclusion was drawn from a recent study of TAO patients treated with systemic steroids and prospectively followed for 1 year (Kauppinen-Mäkelin et al. 2002);

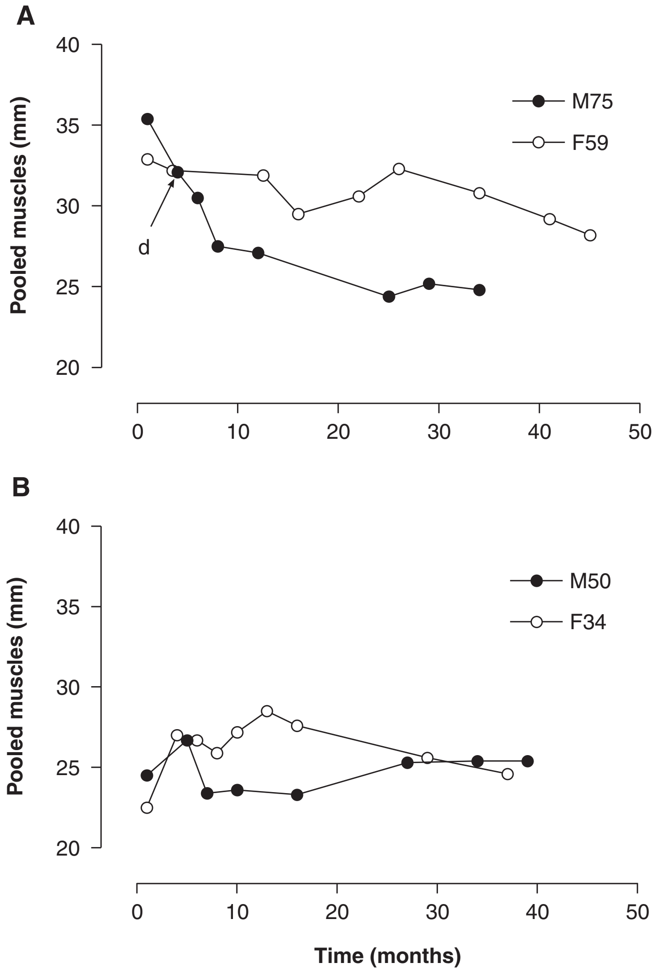

Fig. 4. Longitudinal recordings of pooled four horizontal muscle values in two males (M75, M50) and two females (F59, F34). The 59-year-old female had orbital decompression surgery performed at abscissa value 3.5 months (marked by d and arrow). The M50 male with genuinely euthyroid Graves' disease had high doses of systemic prednisone for 2 months. He developed diabetes and treatment was withheld, also due to 'no effect'. See also text.

repeated CT scans indicated no significant change in eye muscle thickness.

Own ultrasonic principle

As a simplified and quick routine process in thyroid patients referred for ophthalmic evaluation, for 6 years we systematically performed B-scan based measurements of the two horizontal rectus muscles on each side. The muscle band with the lower acoustic reflection is apparent by the horizontal transbulbar sector scan procedure, which gives the outline of the muscle contour. Assuming a mean ultrasonic tissue propagation velocity of 1550 m/sec, in most cases it was easy to make a measurement perpendicular to the muscular axis using the NIDEK 2500's built-in callipers.

We preferred the fuller depiction of the anatomic structure under study yielded by the B-scan over the A-scan technique. We thus felt less confident regarding the presumed muscle borderline spikes seen on the A-scan, and also regarding the quantifying of the amplitude pattern of inner muscle structure as given by the A-scan technique alone. In particular, we could neither ascertain whether the A-scan section was at the point where the muscle was thickest, nor secure the perpendicularity of the ultrasonic section. Otherwise, the physical shortcomings pertaining to reduced azimuthal resolution when not axial on the screen and focus/nonfocus of the beam seem to affect the two ultrasonic techniques similarly.

There is some probability that the measurement inconsistencies discussed below pertain mainly to such factors, which may be of even greater relevance when dealing with altered eye muscle contour and texture, as in orbital Graves' disease (TAO). When on B-scan the outer muscle contour appears not to be well defined; on A-scan it is probably even more difficult to specify which spikes are indeed the muscle borders. Nor can perpendicularity to muscle be achieved in the posterior orbit.

Reflectivity of extraocular muscle tissue as a clinical marker

Using the ultrasonic A-scan technique as elaborated by previous studies (Ossoinig 1979a & 1979b, Ossoinig & Hermsen 1983), Prummel et al. (1993) set focus on the inner reflectivity of the rectus muscles in TAO patients. It was indicated that fresh orbital activity was usually paralleled by a low inner acoustic reflectivity of affected eye muscle, possibly to help differentiate (early) inflammation from (late) fibrosis. As both pathologies can present with quite similar NOSPECS appearances, the importance of making an accurate diagnosis is evident, with regard, for instance, to the high and longterm prednisone doses often instituted as this therapy only benefits active inflammatory disease and not late fibrotic stages.

Sabetti et al. (1998) reported on similar findings, and the view is expressed also in the ultrasonic textbooks of Guthoff (1988) and Verbeek (2000). Muscle tissue reflectivity seemed to increase with fibrosis, suggesting that choice of therapy might generally be guided by reflectivity level. However, opinions on this are hardly unanimous. Increased reflectivity was thus reported as a general echographic sign in endocrine eye muscle involvement (Ossoinig 1984; Hasenfratz 1987; Given-Wilson et al. 1989) and apparently also comprised early disease, although this was not specified. Recently, Prummel et al. (2000) have modified their earlier views (Prummel et al. 1993), due to subsequent 'disappointing experiences' with ultrasound.

Our own experience is also mixed. In the present study, increased reflectivity was more often seen after longstanding eye muscle involvement, and it was mainly the lateral rectus that became difficult to single out from the surrounding orbital echoes. However, the correlations reported were weak and about half the cases of longstanding myopathy (of 3 years and longer) retained low reflectivity and were easy to depict by B-scan. It is our opinion, therefore, that reflectivity in the individual case should not be given much weight when attempting to distinguish active inflammatory orbitopathy from late and fibrotic stages. In this respect, knowledge of disease duration and individual clinical recordings will often be at least as indicative.

Normative extraocular muscle thickness estimates from the literature

Table 4 compares published measurements of eye muscles, representing an overview of the sporadic data available in the literature. Only data relating to the two horizontal rectus muscles have been selected in order to keep the information relevant to the scope of the present study.

Most of the studies quoted used ultrasound techniques, and mainly

Table 4. A review based on the literature on thickness of medial and lateral rectus muscles in normal adults. Values shown are mean values, except those marked * which were given as upper 95% confidence level values in the original presentations.

	Examining modality	Medial rectus	Lateral rectus
McNutt et al. 1977	US, A-scan	5.2*	5.12*
Jacobs et al. 1980	CT scan	3.7	1.3
Tane & Komatsu 1983	US A-scan	3.8	3.8
Komatsu & Tane 1995		3.5	3.4
Ossoinig & Hermsen 1983	US, A-scan	5.4*	5.3*
Willinski et al. 1984	US, B-scan	3.6*	3.6*
Reibaldi et al. 1988	US, A-scan	4.27	3.82
Given-Wilson et al. 1989	US, A-scan	2.9	
		4.07*	
	CT scan	'correlating with US'	
Byrne et al. (1991)	US, A-scan	3.5	3.0
Tamburelli 1993	US, A-scan	4.72	4.06
Demer & Kerman 1994	US, A-scan	4.66	4.22
		6.08*	5.18*
	MRI	4.5	4.76
		5.45*	5.91*
Pierro et al. (1998)	US, A-scan	5.5	4.8
Schenone et al. (1998)	US, A-scan	3.3	2.9
Tian et al. 2000	MRI	3.5	3.2
Lee et al. 2001	CT scan	3.9	3.6
Present investigation	US, B-scan	4.9	3.6
		6.3*	4.9*

with reference to the early A-scan technique (Ossoinig 1979b, 1984; Ossoinig & Hermsen 1983). Holt et al. (1985) gave no muscle diameter values in their comparative study of 10 patients but found ultrasonography more sensitive than CT scanning in thyroid patients. Demer & Kerman (1994) compared A-scan based ultrasound to MRI scanning, and a recent Swedish study gave further MRI information (Tian et al. 2000). The former study in particular put forward the opinion that the MRI technique was superior to ultrasound. The general impression of conflict between materials, however, also seems to apply to within-technique aspects, as apparent in Table 4. For instance, between the ultrasonic series there were differences up to factor two. Nor was agreement found between the MRI-based studies quoted (Demer & Kerman 1984; Tian et al. 2000). Other studies preferred CT determinations of extraocular muscle volume to muscle diameters alone (Feldon et al. 1985, Hallin & Feldon 1988). Practically, however, their method was laborious and exposed the patients to X-ray.

Apparently, the issue is not simple. On the one hand, uniform results in normal series would be in keeping with the consensus of many authors regarding the claim that there is 'no systematic relation proven' between eye muscle diameter and, for instance, age, sex and body stature, nor to right or left eye (McNutt et al. 1977; Reibaldi et al. 1988; Pierro et al. 1998; Tian et al. 2000). On the other hand, within each sample there will be some individual variation, but except for technical aspects presumably associated with the imaging method itself, we found no immediate explanation for the striking inconsistencies apparent in Table 4.

Conclusions

At present, evaluation of TAO should be based primarily on clinical grounds, and in our current setting the advanced imaging methods of CT and MRI were only occasionally asked for. The present critical evaluation of the literature regarding eye muscle size further demonstrates inconsistencies even between normative series, apparently irrespective of imaging method.

There is no doubt, however, that imaging of the orbital apex by CT and MRI has significant bearing on any consideration of surgical decompression for optic nerve compression.

We are continuing our current evaluation of eye muscles using the simpler ultrasound techniques as part of our routine practice in TAO patients. The method is cheap, can be done at the bedside and takes only a few minutes. The serial ultrasound scans further confirm that the protrusion is associated with soft tissue changes within 'normal anatomy' only, and effectively exclude other space-occupying lesions of the orbit.

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