Published in final edited form as:

Am J Ophthalmol. 2010 December ; 150(6): 925–931.e2. doi:10.1016/j.ajo.2010.06.007.

Magnetic Resonance Imaging of Tissues Compatible with Supernumerary Extraocular Muscles

Monica R. Khitri, MD¹ and Joseph L. Demer, MD, PhD^{1,2,3,4}

¹Jules Stein Eye Institute and Department of Ophthalmology, University of California, Los Angeles, U.S.A.

²Department of Neurology, University of California, Los Angeles, U.S.A.

³Neuroscience Interdepartmental Program, University of California, Los Angeles, U.S.A.

⁴Bioengineering Interdepartmental Program, University of California, Los Angeles, U.S.A.

Abstract

PURPOSE—To determine by magnetic resonance imaging (MRI) the prevalence and anatomy of anomalous EOM bands.

DESIGN—Prospective, observational case series.

METHODS—High resolution, multi-positional, surface coil orbital MRI was performed using T1 or T2 fast spin echo weighting with target fixation control under a prospective protocol in normal adult subjects and a diverse group of strabismic patients between 1996 and 2009. Images demonstrating anomalous EOM bands were analyzed digitally to evaluate their sizes and paths, correlating findings with complete ophthalmic and motility examinations.

RESULTS—Among 118 orthotropic and 453 strabismic subjects, one (0.8%) orthotropic and 11 (2.4%) strabismic subjects exhibited unilateral or bilateral orbital bands having MRI signal characteristics identical to EOM. Most bands occurred without other EOM dysplasia and coursed in the retrobulbar space between rectus EOMs such as medial (MR) to lateral rectus (LR), or superior (SR) to inferior rectus (IR), or from one EOM to the globe. In two cases, horizontal bands from MR to LR immediately posterior to the globe apparently limited supraduction by collision with the optic nerve. All bands were too deep to be approached via conventional strabismus surgical approaches.

CONCLUSIONS—About 2% of humans exhibit on MRI deep orbital bands consistent with supernumerary EOMs. While band anatomy is non-oculorotary, some bands may cause restrictive strabismus.

© 2010 Elsevier Inc. All rights reserved

Corresponding Author: Joseph L. Demer, MD, PhD Jules Stein Eye Institute 100 Stein Plaza, David Geffen School of Medicine at UCLA Los Angeles, CA 90095-7002 Office Voice: (310) 825-5931. Office fax: (310) 206-7826 jld@ucla.edu.

Contributions of authors: design of study (JLD); conduct of the study (MR, JLD); collection of data (MR, JLD); management, analysis and interpretation of data (MR, JLD); preparation, review, and approval of the manuscript (MR, JLD).

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

The University of California, Los Angeles Institutional Review Board (IRB) approved this research protocol.

The authors indicate no financial conflict of interest.

Introduction

The normal human orbit contains six extrinsic oculorotary extraocular muscles (EOMs), the levator palpebrae superioris muscle, and the orbicularis oculi muscle. Abnormalities of the EOMs are believed rare. Numerical aberrations of the EOMs have been reported, consisting of both absences of rectus and oblique EOMs^{1,2} as well as supernumerary bands resembling EOMs. Sparse case reports exist describing these supernumerary EOMs, most of which have been discovered postmortem or intraoperatively.^{3–10} Sacks published one of the first reports describing anomalous EOM bands discovered by cadaveric dissection.⁴

Imaging of anomalous EOM bands has been limited because of their small dimensions as well as irregular courses and orientations. Indeed, until recently, EOMs themselves were difficult to characterize by imaging alone. EOM activity was indirectly inferred from clinical examinations, force generation testing, and electromyography. However, recent advances in orbital imaging with high resolution MRI have non-invasively clarified the functional orbital anatomy of living patients. Within the last decade, MRI has been able to directly demonstrate EOM locations, sizes, contractility, and innervation.¹¹ Demer *et al* illustrated the utility of high resolution MRI in detecting hypoplasia and misdirection of cranial nerves, as well as neurogenic EOM atrophy in strabismus caused by cranial nerve palsies.¹² In addition, MRI has been used to detect structural changes in Brown syndrome¹³ as well as widespread orbital dysinnervation in congenital fibrosis of the extraocular muscles (CFEOM).¹⁴ It seems reasonable to anticipate that anomalies in orbital anatomy would be more likely discovered by MRI than by cadaveric dissections.

Here, we demonstrate the utility of high resolution orbital MRI in detecting and characterizing supernumerary EOM bands. We present a series of cases in which high resolution MRI disclosed anomalous EOMs having a wide variety of morphologies, and discuss the potential clinical impact of these bands on ocular motility.

Materials and Methods

Between December 1, 1996 and December 31, 2009, a total of 118 orthotropic volunteers and 453 strabismic patients underwent high resolution orbital imaging under a prospective protocol designed to optimize image resolution using the best available methods at the time. We selected for detailed analysis those cases with evidence of anomalous EOMs. Written informed consent was prospectively obtained according to a protocol approved by the Institutional Review Board of the University of California, Los Angeles and in conformity with the Health Information Portability and Accountability Act. All subjects underwent complete ophthalmic examinations including visual acuity assessment, stereopsis, slit-lamp and funduscopy examination, and cycloplegic and/or manifest refraction.

High-resolution orbital MRI was performed using T1 or T2 fast spin echo weighting using a 1.5-T scanner (Signa; General Electric, Milwaukee, WI). A surface coil technique was employed for obtaining high-resolution orbital MRI with 2 to 3 mm image planes as previously described.^{15,16} Images were always obtained in quasi-coronal planes perpendicular to the long axes of each orbit, as well as in other planes as appropriate to individual findings. Each orbit of alert subjects was scanned during fixation of a central target by the corresponding eye; subjects too young for cooperation were scanned under general anesthesia. Digital MRI images were converted into a spatially calibrated, 8-bit tagged image file format with the use of locally developed software, and quantified with the program *Image J* (Rasband, W.S., *ImageJ*, U. S. National Institutes of Health, Bethesda, MD, <http://rsb.info.nih.gov/ij/>, 1997–2009).

To measure lengths of anomalous EOM bands, adjacent image sets were re-sliced along the paths taken by the bands. The cross-sectional area of each anomalous EOM band was computed using the “area” function of the *Image J* program after manually outlining the band's thickest portion. Cross-sectional areas of the rectus EOMs were similarly measured at their thickest portions. To avoid confounding the measurements by contractile changes in extraocular muscle size induced by varying eye position, measurements were taken in central gaze.

To compare the prevalence of the anomalous EOM bands between the strabismic population and non-strabismic population, Fisher's exact test was performed using Graphpad Prism for Windows (Graphpad Prism 5, Version 5.01, 2007).

Results

During the interval December 1996 to December 2009, a total of 118 normal subjects without strabismus and 453 strabismic subjects underwent high-resolution orbital MRI. Twelve of these subjects were identified who had a band consistent with one or more supernumerary EOMs. Bands had intensities equivalent to that of typical EOMs. Eleven of these subjects had underlying strabismus, giving a prevalence of supernumerary EOM bands in strabismic subjects of 2.4% and in normal subjects of 0.8%, a difference that was not statistically significant ($p=0.48$).

In Table 1, the anomalous EOM bands' sizes and courses are tabulated, as well as the cross-sectional areas of the rectus EOM in the corresponding orbits. Three subjects had supernumerary EOM bands connecting the vertical rectus muscles, four patients had bands connecting the horizontal rectus EOMs, one subject had a band connecting the LR to IR, one subject had a band coursing from the IR to the globe, and three subjects had bands connecting the levator palpebrae superioris to the superior oblique muscle (SO). In all cases, the anomalous EOM band had a smaller cross-sectional area than each of the corresponding rectus EOMs.

Review of Cases

Vertical rectus muscle connections

Case 1: This 14 months-old boy presented with congenital blepharoptosis and supranuclear palsy of upward gaze OU. He was orthophoric in central gaze. He was unable to move either eye above horizontal midposition on attempted supraversion. MRI revealed bilateral muscular bands connecting the temporal edges of the IR to SR in mid-orbit (Fig. 1).

Case 2: This 61-year-old man presented with fluctuating vertical diplopia, worsening with exercise. Harada-Ito surgery had been performed OS 5 years previously for left SO palsy. He had right hypertropia (4Δ in central gaze, 12Δ in infraversion). He also exhibited mild limitation of supraduction OU, abduction nystagmus OU with slow adduction saccades OU suggesting bilateral internuclear ophthalmoplegia. MRI demonstrated a muscular band between the temporal edges of the left SR and left IR posterior to the globe.

Case 3: This 16-year-old girl presented with a history of partially accommodative V-pattern esotropia. There was 20Δ esotropia in central gaze, with over-elevation in adduction OU but normal horizontal ductions OU. MRI demonstrated an accessory EOM band between the temporal edges of the right SR and IR posterior to the globe.

Horizontal rectus muscle connections

Case 4: This 60-year-old man presented with a diagnosis of thyroid ophthalmopathy. There was 25Δ esotropia and 12Δ left hypertropia in central gaze with moderate limitation to supraduction OD in adduction, and mild overdepression of the right eye in adduction. There was also mild limitation of abduction OU and mild limitation to infraduction OS in adduction. MRI demonstrated enlargement of all EOMs, sparing of the tendons, as well as a muscular band between the central portion of the left MR and the superior edge of the LR posterior to the globe. Notably, the patient had previously undergone a standard orbital MRI elsewhere that failed to detect this muscular band.

Case 5: This 18-year-old man was recruited as a normal control subject. He had a normal ophthalmic examination with no signs of strabismus, including a normal Hess screen test, normal ocular versions, and stereopsis of 40 seconds of arc. MRI demonstrated a muscular band connecting the central portions of the right MR and LR posterior to the globe.

Case 6: This 38-year-old woman presented with a history of an unspecified strabismus surgery at age 9 years, and also reported a daughter with strabismus. There was 17Δ right exotropia and 12Δ right hypotropia in central gaze, with limitation of supraduction above horizontal midposition, and mild limitation to infraduction OD. MRI demonstrated a hypoplastic right IR, and a band isointense to EOM connecting the inferior edges of the right MR to the superior edge of the LR posterior to the globe (Fig. 2). On supraversion, this EOM band appeared to contact the inferior edge of the optic nerve.

Case 7: This 22-months-old boy presented with a history of plagiocephaly, left ptosis, and inability to supraduct the left globe. On exam, he had 30Δ exotropia and 15Δ left hypotropia in primary gaze. The child was unable to supraduct the left eye above the horizontal midposition. High-resolution MRI demonstrated unilateral hypoplasia of the left IR and SR, as well as an anomalous EOM band connecting the inferior edges of the left MR and LR. Because of the patient's age and difficulty with cooperation, the orbits could not be scanned in eccentric gaze positions. During subsequent strabismus surgery, the surgeon (JLD) noted that resistance to passive supraduction OS persisted that after LIR disinsertion.

Other rectus muscle bands

Case 8: This 56-year-old man presented with a 3-year history of intermittent vertical diplopia and right head tilt. There was a left hypertropia (22Δ in primary gaze), limitation of infraduction in adduction OS, over-elevation of OS in adduction, and 8 degrees of relative excyclotorsion OS. MRI demonstrated an abnormal band isointense to EOM extending from the right LR to IR. In addition, the right LR was found to be inferiorly displaced; the SO muscles were normal and symmetrical (Fig.3).

Case 9: This 35-year-old woman had a history of 80Δ infantile esotropia and had undergone in succession: bilateral MR recession, bilateral LR resection, left IO recession, and bilateral LR recession. On presentation to this service, she had 25Δ residual esotropia, mild limitation of abduction OU, and mild over-elevation in adduction OU. High-resolution MRI demonstrated a muscular band coursing superotemporally from the temporal edge of the left IR to the horizontal equator of the globe (Fig. 4). Because this muscular band originated from the belly of the IR itself and not from the bony orbit, this band was clearly distinct from the inferior oblique muscle (IO).

Levator-trochlear Bands

Case 10: This 14-year-old boy originally diagnosed with partially accommodative esotropia had elsewhere undergone bilateral MR recession, bilateral LR resection, left IO recession,

bilateral LR recession, and left LR advancement with reattachment of a slipped right LR. At age 14 years, he was re-diagnosed with right type III Duane's syndrome with 18Δ right hypertropia and 25Δ exotropia in central gaze. There was globe retraction and narrowing of the palpebral fissure OD in adduction with moderate limitation of both adduction and abduction OD, and mild limitation to infraduction OD and moderate over-elevation OD in adduction. MRI demonstrated a band isointense to EOM coursing from the nasal edge of the left SR-levator complex to the SO near the trochlea deep in the orbit (Fig. 5). The left LR was dysplastic.

Case 11: This 52-year-old woman presented with a history of type III Duane syndrome OU, for which she had previously undergone three strabismus surgeries. There was lambda pattern strabismus with 6Δ left exotropia and 6Δ right hypertropia in central gaze, and marked retraction and palpebral fissure narrowing with adduction bilaterally. There was marked limitation of abduction OD with an inability to abduct past midline, and mild limitation of adduction OU. MRI demonstrated a band isointense to EOM coursing from the nasal edge of the left SR-levator complex to the SO near the trochlea. The right LR was split, with the superior portion having 29.3 mm² maximum cross-sectional area, and the inferior portion 25.5 mm².

Case 12: This 38-year-old man is the brother of Case 11. He presented with a history of type I Duane syndrome OD, and had previously undergone two strabismus surgeries. There was 12Δ esotropia and 10Δ left hypertropia in central gaze with narrowing of the right palpebral fissure on adduction. Abduction and supraduction were limited OD. MRI revealed a muscular band connecting the left SO-levator complex to the SO near the trochlea.

Discussion

We believe the present report to be the largest case series of supernumerary human EOMs, which in this series have been identified on high resolution MRI as having signal characteristics matching those of known EOMs. These supernumerary muscular bands occurred in numerous variations, most commonly as connections between two EOMs or between an EOM and the globe. The prevalence of these anomalous EOM bands is higher in the strabismic (2.4%) than the non-strabismic population (0.8%), but nonetheless such bands are not rare.

While varying in size, all the anomalous EOM bands in the present series were markedly smaller than adjacent EOMs. As a result, high resolution MRI was instrumental in facilitating recognition of these small structures. Some subjects had previously undergone standard MRI protocols that had failed to detect these anomalous EOMs. Perhaps if these EOM bands enlarge as a result of disease, they might become more readily discovered. One patient (Case 3) had thyroid ophthalmopathy, a condition wherein hypertrophy of muscular tissues may have facilitated imaging of the EOM band. In fact, a previously published case report described the CT scan finding of an anomalous EOM band originating from the orbital apex and inserting adjacent to the IR insertion in a patient with Graves' orbitopathy.³

It is also noteworthy that five of the current 12 subjects with bands in this study had CCDDs,¹² either Duane's syndrome or CFEOM. These forms of neuropathic strabismus are associated with multiple abnormalities of EOMs and their associated motor nerves.¹² Supernumerary muscular tissue may be regarded as an additional component of the CCDDs.

Other studies have similarly confirmed the occasional presence of supernumerary EOMs in cadavers as well as living subjects. Sacks described an EOM found in seven of 98 cadaveric orbits coursing between the medial portion of the levator palpebrae superioris and the trochlea which he termed the levator-trochlea muscle, likely very similar to the anomalous

muscular band found in cases 10 – 12.⁴ Similarly located anomalous EOM bands have been detected by other authors and given names such as the levator palpebrae superioris accessorius muscle, or muscle tensor trochleae of Budge.^{5,6} While this levator-trochlea muscle appears to be the most commonly recognized supernumerary EOM in the literature, case reports have documented others including a band between the IR and the globe,⁷ a band between the levator palpebrae superioris and the globe,⁸ and an accessory LR.⁹

The clinical impact of these supernumerary EOMs presumably varies depending on the size and location of the anomalous bands. Some of them probably have no significant influence on ocular motility. Case 5 in our study had normal ocular motility despite having an anomalous EOM band. However, in at least two cases (cases 6 and 7), the anomalous band appeared to cause restrictive strabismus. Both of these cases exhibited restriction to supraduction and had an anomalous muscular band coursing under the optic nerve, connecting the horizontal rectus EOMs. In case 6, the anomalous band probably restricts the range of supraduction by contact with the optic nerve. In case 7, because the patient was too young to perform scans in multiple gaze positions, the effect of the anomalous band on supraduction could not be imaged. However, intraoperative observation of sustained restriction to supraduction after IR release supports the notion that the anomalous band was indeed a substantial contributor to the patient's strabismus. Other prior reports have similarly suggested that these anomalous bands may be pathologic in some instances and have implicated them as causing restrictive strabismus, globe retraction, and eyelid retraction.^{6,8,10} Because these bands are often located deep in the orbit, they are difficult to access using traditional strabismic surgical approaches. However, preoperative recognition of their existence can better inform surgical management decisions, for example, by the insight that restriction from a band might persist after strabismus surgery.

Previous investigators have suggested that these supernumerary EOMs might be atavistic remnants of the retractor bulbi (RB) muscle that is present in lower mammals. The RB originates near the optic foramen and runs rostrally, forming a muscular cone covered by the overlying rectus EOMs. It is composed of four muscular slips and is mainly innervated by the abducens nerve and occasionally may receive branches from the oculomotor nerve.¹⁷ We do not believe that the supernumerary EOM bands found in our subjects are RB remnants since the bands originate from the EOMs themselves. These anomalous bands appear to share some similarities with the monkey accessory LR (ALR) muscle. The ALR, sparsely innervated by the abducens nerve, originates in the orbital apex and attaches to the globe between the SR and LR insertions. Unlike EOMs but similar to the anomalous EOM bands found in this study, the ALR lacks both an orbital portion and a connective tissue pulley.¹⁸ However, the currently described supernumerary EOM bands have different anatomic trajectories from the ALR and likely represent an aberration in rectus EOM development.

It is possible that these anomalous EOM bands represent EOM tissue that was never innervated during development. MRI did not visualize innervation of the anomalous EOM bands, although the motor nerve branches to the EOMs were clearly imaged. Neurogenic atrophy occurs when EOMs are denervated: monkey SO muscles underwent a 60% reduction in cross-sectional area with relative sparing of the orbital layer upon trochlear neurectomy.¹⁹ This suggests that the anomalous EOM bands may represent the atrophied residual orbital remnants of aberrant muscular tissue that either was never innervated or lost innervation during development.

As higher resolution orbital imaging is increasingly employed in the evaluation of strabismus, supernumerary EOMs will inevitably be encountered and may occasionally be significant contributors to strabismus. Recognition of these bands by imaging may be

helpful in guiding operative management of strabismus – in at least one published case, the supernumerary muscle was detected intraoperatively and prompted an abrupt change in surgical plan.⁹ Our study suggests that the presence of these EOM bands is sometimes associated with restrictive strabismus.

Acknowledgments

This study was supported by Grant Identification No. USPHS NIH EY08313, and Research to Prevent Blindness.

Biographies

Monica R. Khitri, M.D. has recently completed her residency in ophthalmology at the Jules Stein Eye Institute, University of California Los Angeles. She is starting her fellowship in pediatric ophthalmology and strabismus at Children's Hospital of Philadelphia.

Joseph L. Demer, M.D., Ph.D. is Chief of Comprehensive Ophthalmology and Professor of Neurology at the University of California Los Angeles. He holds the Leonard Apt Professorship, Directs the Ocular Motility Clinical Laboratory, and chairs the EyeSTAR Training Program.

With a Ph.D. in Biomedical Engineering, Dr. Demer has worked for more than 30 years on neural and mechanical factors regulating ocular motility, particularly MRI of the functional anatomy of extraocular muscles and orbital connective tissues.

References

1. Diamond GR, Katowicz JA, Whitaker LA, Quinn GE, Schaffer DB. Variations in extraocular muscle number and structure in craniofacial dysostosis. *Am J Ophthalmol* 1980;90(3):416–418. [PubMed: 7425058]
2. Taylor RH, Kraft SP. Aplasia of the inferior rectus muscle: a case report and review of the literature. *Ophthalmology* 1997;104(3):415–418. [PubMed: 9082265]
3. Baldeschi L, Bisschop PHLT, Wiersinga WM. Supernumerary extraocular muscle in Graves' orbitopathy. *Thyroid* 2007;17(5):479–480. [PubMed: 17542680]
4. Sacks JG. The levator-trochlear muscle: a supernumerary orbital structure. *Arch Ophthalmol* 1985;103(4):540–541. [PubMed: 3985834]
5. Amonoo-Kuofi HS, Darwish HH. Accessory levator muscle of the upper eyelid: case report and review of the literature. *Clinical Anatomy* 1998;11(6):410–416. [PubMed: 9800921]
6. Wylen EL, Brown MS, Rich LS, Hesse RJ. Supernumerary orbital muscle in congenital eyelid retraction. *Ophthalmic Plastic and Reconstructive Surgery* 2001;17(2):120–122. [PubMed: 11281584]
7. Von Lüdinghausen M. Bilateral supernumerary rectus muscles of the orbit. *Clinical Anatomy* 1998;11(4):271–277. [PubMed: 9652543]
8. Özkan SB, Çakmak H, Dayanir V. Fibrotic superior oblique and superior rectus muscle with an accessory tissue band. *J AAPOS* 2007;11(5):491–494. [PubMed: 17651998]
9. Park CY, Oh SY. Accessory lateral rectus muscle in a patient with congenital third-nerve palsy. *Am J Ophthalmol* 2003;136(2):355–356. [PubMed: 12888062]
10. Valmaggia C, Zaunbauer W, Gottlob I. Elevation deficit caused by accessory extraocular muscle. *Am J Ophthalmol* 1996;121(4):444–445. [PubMed: 8604741]
11. Demer JL, Miller JM. Orbital imaging in strabismus surgery. In: Rosenbaum, AL.; Santiago, AP., editors. *Clinical strabismus management: principles and techniques*. Saunders; Philadelphia, PA: 1999. p. 84–98.
12. Demer JL, Ortube MC, Engle EC, Thacker N. High-resolution magnetic resonance imaging demonstrates abnormalities of motor nerves and extraocular muscles in patients with neuropathic strabismus. *J AAPOS* 2006;10(2):135–142. [PubMed: 16678748]
13. Bhola R, Rosenbaum AL, Ortube MC, Demer JL. High-resolution magnetic resonance imaging demonstrates varied anatomic abnormalities in Brown syndrome. *J AAPOS* 2005;9(5):438–448. [PubMed: 16213393]
14. Demer JL, Clark RA, Engle EC. Magnetic resonance imaging evidence for widespread orbital dysinnervation in congenital fibrosis of extraocular muscles due to mutations in KIF21A. *Invest Ophthalmol Vis Sci* 2005;46(2):530–9. [PubMed: 15671279]
15. Clark RA, Miller JM, Demer JL. Location and stability of rectus muscle pulleys: Muscle paths as a function of gaze. *Invest Ophthalmol Vis Sci* 1997;(38):227–240. [PubMed: 9008649]
16. Clark RA, Miller JM, Rosenbaum AL, Demer JL. Heterotopic muscle pulleys or oblique muscle dysfunction? *J AAPOS* 1998;(2):17–25. [PubMed: 10532362]
17. Shimokawa T, Akita K, Sato T, Ru F, Yi SQ, Tanaka S. Comparative anatomical study of the m. retractor bulbi with special reference to the nerve innervations in rabbits and dogs. *Okajimas Folia Anat Jpn* 2002;78(6):235–43. [PubMed: 12126054]
18. Narasimhan A, Tychsen L, Poukens V, Demer JL. Horizontal rectus muscle anatomy in naturally and artificially strabismic monkeys. *Invest Ophthalmol Vis Sci* 2007;48(6):2576–2588. [PubMed: 17525187]
19. Demer JL, Poukens V, Ying H, Shan X, Tian J, Zee DS. Effects of intracranial trochlear neurectomy on the structure of the primate superior oblique muscle. *Invest Ophthalmol Vis Sci*. Feb 17;2010 Epub ahead of print.

Figure 1.

T1 coronal MRI of deep orbit of case 1 demonstrating bilateral anomalous EOM bands coursing between the temporal edges of the superior rectus (SR) and inferior rectus (IR). LR: lateral rectus; MR: medial rectus; ON: optic nerve; SO: superior oblique; SOV: superior ophthalmic vein; SR-LPS: superior rectus-levator palpebrae superioris complex

Figure 2.

T1 coronal (left) and sagittal (right) MRI of case 6, who had limited supraduction OD, demonstrating an anomalous EOM band coursing between the MR and LR in central gaze. On supraversion, the anomalous EOM band's position contacts the optic nerve (ON). Band: anomalous EOM band; IR: inferior rectus; LR: lateral rectus; MR: medial rectus; SO: superior oblique; SR-LPS: superior rectus-levator palpebrae superioris complex.

Figure 3.

T2 fast spin echo coronal MRI of case 8 showing an anomalous band coursing between the right inferior rectus (IR) and lateral rectus (LR). The right LR is displaced inferiorly. MR: medial rectus; ON: optic nerve; SO: superior oblique; SR-LPS: superior rectus-levator palpebrae superioris complex

Figure 4. T1 coronal MRI of case 9. Anomalous EOM band extends from left inferior rectus (IR) to the temporal globe. LG: lacrimal gland; LR: lateral rectus; MR: medial rectus; SR-LPS: superior rectus-levator palpebrae superioris complex.

Figure 5.

T1 coronal MRI of case 10. Anomalous EOM band connects left SR-levator complex to the SO near the trochlea. Also detected is a disorganized left lateral rectus (LR). IR: inferior rectus; MR: medial rectus; ON: optic nerve; SO: superior oblique; SOV: superior ophthalmic vein; SR-LPS: superior rectus-levator palpebrae superioris complex

MRI Measurements of Extraocular Muscles

Table 1

Subject	Age (yrs)	Sex	Underlying Condition	Eye	Muscle Band Course	Band Length (mm)	Band Cross-section (mm ²)	SR Cross-section (mm ²)	MR Cross-section (mm ²)	IR Cross-section (mm ²)	LR Cross-section (mm ²)
1	1.3	M	CFEOM Type III OU	OD	Temporal edges of SR and IR	17.1	7.1	31.4	37.1	27.1	32.0
1	1.3	M	CFEOM Type III OU	OS	Temporal edges of SR and IR	16.6	5.7	30.8	42.3	32.8	33.0
2	61	M	SO palsy OS, INO OU	OS	Temporal edges of SR and IR	14.9	3.1	44.2	34.5	35.5	35.8
3	16	F	Partially accommodative V esotropia	OD	Temporal edges of SR and IR	17.6	3.4	35.7	38.7	30.2	32.0
4	60	M	Thyroid ophthalmopathy	OS	Central portion of MR to superior edge of LR	19.2	4.0	42.7	51.4	46.3	43.5
5	18	M	Normal subject	OD	Central portions of MR and LR	16.9	4.2	42.6	37.1	24.6	42.4
6	38	F	Familial monocular vertical gaze deficiency	OD	Inferior edges of MR and LR	14.7	6.3	27.4	45.8	14.8	42.4
7	1.8	M	CFEOM Type III OU	OS	Inferior edges of MR and LR	12.8	5.2	8.13	17.5	6.14	24.7
8	56	M	Left hypertropia	OD	LR to IR	13.0	3.5	41.1	35.3	27.6	41.4
9	35	F	Infantile esotropia	OS	Superotemporal course from IR to temporal globe equator	15.3	3.6	35.3	25.1	27.3	45.3
10	14	M	Duane's syndrome OD, Type III	OS	Nasal course from SR-levator complex to SO near trochlea	7.7	4.6	26.9	42.6	33.5	37.4
11	52	F	Duane's syndrome OU, Type III	OS	Nasal edge of SR-levator complex to SO near trochlea	10.8	2.1	24.2	27.0	23.6	36.6
12	38	M	Duane's syndrome OD, Type I	OS	Nasal edge of SR-levator complex to SO near trochlea	7.2	3.0	24.8	24.7	27.1	17.7

CFEOM – congenital fibrosis of the extraocular muscles.

INO - internuclear ophthalmoplegia.