## Title

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# Graded Vertical Rectus Tenotomy For Small Angle Cyclovertical Strabismus in Sagging Eye Syndrome

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## Abstract

**Background/Aims—**Graded vertical rectus tenotomy (GVRT) is postulated as effective for small angle vertical heterotropia. We aimed to determine dosing recommendations for GVRT in sagging eye syndrome (SES).

**Methods—**This was a retrospective, observational study of surgical outcomes for GVRT from 2009–2014 in a single surgeon's academic practice. There were 37 (20 women) patients of average age 68±10 (standard deviation, SD) years with comitant or incomitant hypertropia ≤10Δ caused by SES. The main outcome measure was the dose-effect of GVRT required to correct intra-operative hypertropia.

**Results—**Pre-operative average central gaze hypertropia measured 4.7±2.2Δ. Three patients underwent repeat GVRT for residual or consecutive hypertropia, 1 undergoing it twice. All surgeries were analyzed, increasing the total operations to 41. The inferior rectus (IR) tendon in the hypotropic eye was operated in 32 eyes and the superior rectus (SR) tendon in the hypertropic eye in 9 eyes. Mean tenotomy was 68±19% of tendon width. Hypertropia was always eliminated intraoperatively by progressive GVRT. Mean hypertropia was 1.1±1.6Δ at average 93 days post-operatively. Linear regression demonstrated that 3–6Δ hypertropia correction requires 30–90% graded tenotomy ($R^2$=0.32, P<0.0001), but with substantial individual variability. Undercorrection necessitated reoperation in 10% of cases.

**Conclusions—**GVRT precisely corrects hypertropia of up to 10Δ, but because of variable effect, should be performed with intraoperative monitoring under topical anesthesia.

### Keywords

Sagging eye syndrome; graded vertical rectus tenotomy; small angle strabismus; heterotropia

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## Introduction

Diplopia due to small angle hypertropia can be disabling for patients and frustrating to strabismus surgeons.[1–3] Traditionally, prismatic spectacles have been preferred for hypertropia ≤10Δ because recessions and resections commonly overcorrect the strabismus. [1, 2] However, disadvantages of prisms include weight, chromatic aberration, and problematic cosmesis.

The need for predictable surgery for small angle hypertropia has been recognized.[4, 5] Good results have been obtained from graded horizontal rectus tenotomy for small angle pattern strabismus, and vertical rectus tenotomy.[1–4, 6] However, predictive surgical nomograms are lacking for tenotomy dosage. This study aimed to develop quantitative guidelines for surgical dosage in small angle hypertropia, and to evaluate re-operation rate.

Sagging eye syndrome (SES) is a recently recognized orbital connective tissue degeneration leading to degeneration of the LR-SR band ligament, inferior sag of the LR pulley, and limited supraduction. [7, 8] SES is a major cause of small angle hypertropia in the elderly.[7] Because conventional surgery might over-correct the small hypertropia typically associated with SES, GVRT may be elected for patients with hypertropia due to SES.[7] This retrospective study evaluated the alignment effect in GVRT in SES.

## Materials & Methods

With approval of the Institutional Review Board at University of California, Los Angeles, retrospective analysis was performed of consecutive patients with small angle hypertropia due to SES who underwent GVRT by a single surgeon (JLD) between 2009–2014 at Stein Eye Institute. No other concurrent cyclovertical surgery was performed. Summarized data included visual acuity, refractive error, stereopsis (Titmus Fly), motility examination including Hess screen testing, fundoscopic evaluation, and clinical evaluation of saccades. Heterotropia was measured at distance and near by alternate prism and cover testing. Fundus torsion was objectively determined by slit lamp measurement of angle between the fovea and optic disc center. [9–11] We prefer objective fundus torsion measurements to avoid artifacts of sensory adaptations. [7]

The diagnosis of SES was supported by clinical findings of adnexal laxity, blepharoptosis, limited supraduction, and greater excycloposition in the hypotropic than hypertropic eye.[7] Where other pathologies were clinically plausible, SES was confirmed by surface coil magnetic resonance imaging for demonstration of characteristic greater inferior displacement of the lateral rectus muscle in the hypotropic than hypertropic orbit.[7]

The inferior rectus (IR) was chosen for GVRT when hypertropia was vertically concomitant or greatest in infraversion. The superior rectus (SR) was chosen when hypertropia was greatest in sursumversion, or absent in infraversion. Temporal GVRT was chosen for the IR and nasal GVRT for the SR.

Progressive GVRT was usually performed under topical anesthesia using eye drop administration of 1% lidocaine hydrochloride injectable solution. An anesthesiologist

monitored surgery, and administered minimal doses of propofol or alfentanil so that patients remained alert during intra-operative adjustment. [12–14] Surgery comprised limbal conjunctival incision, hooking the entire tendon, bipolar cautery, and stepwise incremental scissors tenotomy at the scleral insertion 30–90% of tendon width (Fig. 1A–C). Initial tenotomy was conservative, about 30 % of tendon width, slightly undercorrecting with the initial dose to avoid intraoperative overcorrection. The contingency for intraoperative overcorrection would have included partial re-suturing to the sclera, but absent overcorrection, was never performed. The percentage of tendon to be tenotomized was estimated relative to overall tendon width. Surgical effect was assessed immediately by cover testing in the operating room with the patient seated upright wearing the required refractive correction using targets at near and distance. If hypertropia persisted, further 5–10% increments of GVRT up to a maximum of 90% were added with monitoring of alignment. Ciliary vessels were mobilized by blunt dissection and spared in selected cases (Fig. 1D).

We also analyzed outcomes of unilateral adjustable IR recession in the hypotropic eye of 7 cases with SES who had average hypotropia of 17.4± 7Δ. Mean IR recession of 3.0±0.8 mm reduced the immediate post-operative hypertropia to nil.

Statistical analysis was performed using Student's t test. Regression analysis was calculated using GraphPad Prism software (La Jolla, CA, USA). Parametric statistics were employed to describe stereopsis data for illustrative purposes.

## Results

GVRT was performed in 37 patients with hypertropia due to SES.[7, 15] Average patient age was 68±11 years (±SD); 17 patients were male and 20 female. All had experienced symptomatic diplopia for an average of 1,556±2,166 days (approximately 4.5 years) preoperatively. Prismatic spectacles of mean 4.5±2.0Δ vertical power had been used by 10 patients (24%). Mean visual acuity was 0.05±0.14 logMAR with mean spherical equivalent refractive error of −0.8±1.8D. Mean pre-operative stereopsis was 446±688 arcsec in 32 patients in whom it was measured. Mean pre-operative central gaze hypertropia was 4.6±2.1Δ.

Pre-operative fundus torsion was measured in 37 patients, all of whom exhibited significantly greater excycloposition in the hypotropic (mean 12.5±5.7°) than hypertropic (5.9±4.6$^{o}$) eye ($P<0.001$).

Previous blepharoplasty had been performed in 15/41 (36.6%) patients. Another patient with SES had undergone previous scleral buckling for retinal detachment (RD) in the hypotropic eye. One patient with SES and divergence paralysis esotropia underwent simultaneous adjustable medial rectus recession in both eyes, [15] and IR GVRT was added when 4Δ hypertropia persisted intra-operatively after esotropia was corrected.

Topical anesthesia was employed in all patients. One patient had recurrent hypertropia and twice underwent GVRT again in the same muscle. Reoperations were analyzed as fresh events for statistical analysis, total surgeries to 41.

The mean GVRT, including SR and IR surgeries, was 68±19% of tendon width at the insertion. In every case, the intraoperative hypertropia was abolished, and no patients were overcorrected. Figure 2 demonstrates the correction as a function of percentage of tendon width divided. Data were linearly fit (Fig. 2), showing that 3–6Δ hypertropia correction requires 30 to 90% graded tenotomy ($R^2$=0.32). The 95% confidence interval for slope of the fit was 0.0348–0.0954Δ/% tenotomy. This was compared in 7 cases of SES treated by ipsilateral adjustable IR recession for 17.4±7.0Δ average preoperative deviation. Mean IR recession of 3.0±0.8 mm had mean regression effect of 4.9Δ/mm; the coefficient of determination $R^2$ was 0.32, identical to that for GVRT.

Temporal IR GVRT was performed in 30 hypotropic eyes, and nasal SR GVRT in 7 eyes. Out of three re-operated patients, 1 had a primary SR nasal GVRT, and reoperation consisted of contralateral temporal IR GVRT in two sequential procedures. In 2 patients, primary surgery had been temporal IR GVRT of the hypotropic eye followed by nasal SR GVRT of the relatively incyclotropic, hypertropic fellow eye.

Hypertropia in eccentric gazes could be measured accurately in 20 patients, of whom 17 underwent temporal IR GVRT, and 3 nasal SR GVRT. Hypertropia prior to temporal IR GVRT was vertically concomitant, averaging 4.6±4.6Δ in supraduction and 3.9±3.4Δ in infraduction; post-operatively hypertropia in supraduction was concomitantly reduced to 0.6±1.5Δ (P=0.0009) and infraduction to 0.2±0.5Δ (P<0.0001). Statistical comparisons are necessarily limited for nasal SR GVRT because only three patients underwent the procedure; in these, average preoperative hypertropia was vertically incomitant, averaging 9.0±0.7Δ in supraduction but only 1.3±2.3Δ in infraduction. Following nasal SR GVRT, hypertropia in supraduction was reduced to 2.7±1.2Δ (P=0.1), and in infraduction to 1±1.7Δ (P=0.43).

Follow-up an average of 21 days after surgery in 30 patients demonstrated 0.1±0.3Δ mean hypertropia. Follow-up at 93 days (3 months) in 24 of these demonstrated 1.1±1.6Δ mean hypertropia. Follow-up at average of 227 days (8 months approximately) in 13 patients demonstrated 2.0±2.2Δ mean hypertropia, including 3 patients with hypertropia undercorrection requiring further surgery. At re-operation, conjunctival scarring was modest, with the previously divided tendon firmly adherent to the sclera along a roughly diagonal line. An average 2.7±1.4Δ undercorrection was exhibited in 10 cases at about 93 days after surgery. These late undercorrections probably reflect the progressive nature of the connective tissue degeneration in SES.

Heterophoria measured most recently was considered to be the late follow-up deviation. Late hypertropia averaged 1.0±1.7Δ after 226.5±236 days (approximately 7 months). Mean post-operative stereopsis was 96±58 arcsec at late follow-up in 27 patients where it was measured. Most patients did not undergo pupillary dilatation for measurement of fundus torsion, but in 8 who did there was a significant increase in excycloposition of the hypertropic eye from 5.9±4.6° to 12.1±5.4° post-operatively ($P=1.3\times10^{-6}$), so that it was post-operatively not significantly different from the mean excycloposition of 10.1±4.1° noted concurrently in the unoperated fellow eye (P=0.15).

## Discussion

A more finely dosed surgery is obtainable by GVRT than by recession, and resembles insertional slanting except that the partially severed tendon is neither completely disinserted, nor its margin sutured. [4, 6, 16–19] Biomechanical studies indicate little transverse force coupling among the parallel fibers of extraocular tendons, so GVRT acts in direct proportion to the proportion of fibers divided.[20] The disinserted portion of the tendon retracts in slanted fashion. [4, 16] Mechanisms proposed for the action of insertional slanting include both passive changes in tendon insertion and active innervational factors.[6, 16, 20, 21]

We initially reasoned that by performing temporal IR tenotomy in a hypotropic and excyclotropic eye as is seen in SES,[7] tension of nasal fibers would be maintained despite slackening of temporal fibers. (Chaudhuri Z, Clark R, Demer JL. Horizontal rectus pulley heterotopy correlates with cyclovertical strabismus in sagging eye syndrome. Paper presented at ARVO 2012; Fort Lauderdale, FL, 6339: 386). This effectively shifts the net force at the IR insertion nasally, equivalent to recession with nasal transposition, which was expected not only to correct hypotropia but also to produce incycloduction. Analogously, nasal SR tenotomy slackens the nasal fibers, equivalent to recession with temporal transposition of the insertion, was theorized to produce infraduction with excycloduction. However, post-operative cycloposition exhibited an opposite trend, implicating other factors such as shift in position of the effective muscle origin at the pulley towards the intact fibers. Similarly directed transverse shifts in both the muscle's functional origin at the pulley, and the scleral insertion of the remaining fibers, would negate the initially postulated torsional effect. Therefore, therapeutic torsional effects may be obtained from GVRT.

Temporal IR tenotomy in the hypotropic eye could be combined with nasal SR tenotomy in the hypertropic eye to increase the maximum correctable hypertropia. However, this combination was not done concurrently here, although it was performed sequentially with good results.

The present study confirms and extends prior reports[1–3] of general efficacy of tenotomy in small angle cyclovertical strabismus by providing a scheme for surgical dosage. Correction of 2Δ hypertropia requires on average about 40% tenotomy, 4Δ with 60%, and 6Δ with 80%. This is similar to Scott's suggestion that 60–70% tenotomy corrects 4Δ hypertropia. [3] However, substantial response variability argues for step-wise performance of surgery. Current data are insufficient for quantitative recommendations for hypertropia exceeding 8Δ. While the maximum deviation corrected by this procedure was 10Δ with 90% tenotomy, hypertropia of this magnitude might preferably be managed using conventional adjustable suture recession.

A significant advantage of GVRT is its technical ease, making it suitable for topical anesthesia. Vessel sparing is often possible. Central partial rectus tenotomy has been performed transconjunctivally. [1] Claimed advantages of central tenotomy include intact tendon poles, maintaining normal wide rectus insertions and comitant effects.[1, 3] However, the incomitant effect of marginal GVRT can be exploited to correct laterally incomitant

strabismus. [2] Current findings suggest that temporal IR GVRT produces about 6° excyclotropia.

Of 41 primary cases of GVRT performed for hypertropia due to SES in this series, three required additional surgery for undercorrection. The long follow-up of these three patients probably reflects continuing diplopia. Out of the remaining patients, only 10 followed up at about 8 months. It may be concluded that GVRT is unlikely to overcorrect hypertropia, but roughly 10% likelihood of additional surgery for undercorrection may be anticipated. In comparison, for adjustable IR recession performed by the same surgeon, 3.0±0.8 mm average recession produced 17±7Δ immediate reduction in average hypertropia, corresponding to about 4.9Δ correction per mm IR recession. Regression analysis for both adjustable IR recession and GVRT indicated that surgical dose accounts for only about 30% of post-operative effects. The similar but limited predictability of both procedures argues for adjustable technique, but for hypertropia less than 5Δ, the relatively powerful adjustable IR recession requires unrealistically precise operative positioning to a fraction of 1 mm to achieve the precision easily controlled by GVRT. Of course, GVRT can readily be converted intra-operatively to IR recession should correction be insufficient after maximal tenotomy.

The present study had 7 months average follow-up, sufficient to evaluate the full healing response, since surgical exploration of reoperated cases of GVRT demonstrated firm adhesion of the initially divided tendon regions. However, since SES caused the strabismus, continued progression of this degenerative connective tissues disorder might be anticipated to cause hypertropia recurrence in cases that require reoperation. Such recurrences are more reflective of the underlying pathology of SES than of inherent limitation on effectiveness of GVRT.

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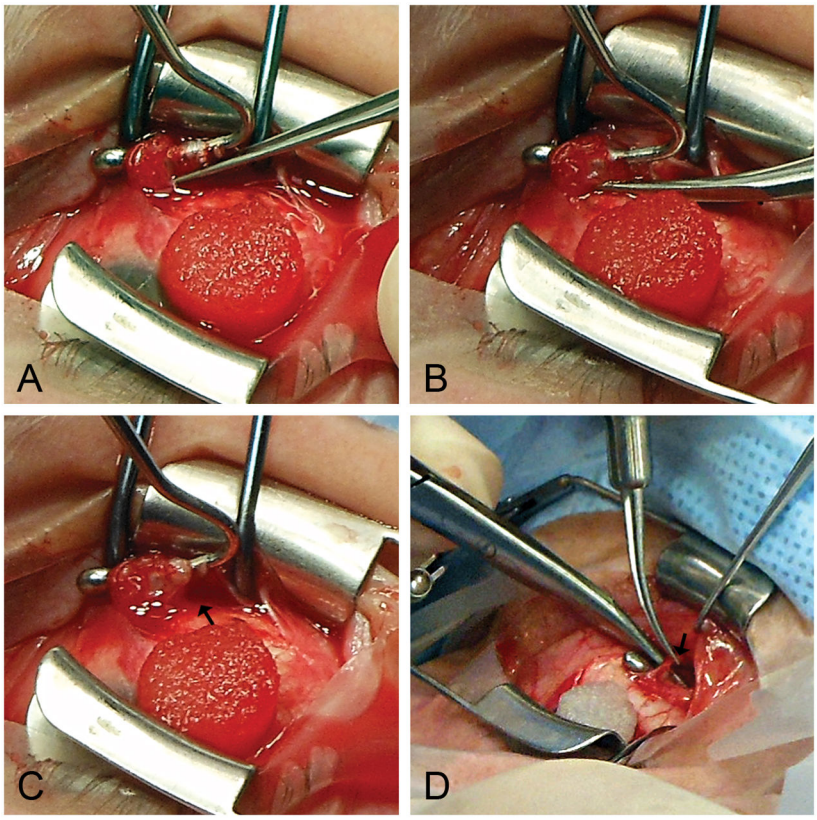


**Fig. 1.**

(A to C). The inferior rectus (IR) tendon is partially divided after limbal conjunctival incision and bipolar electrocautery, over a percentage of total tendon width at the insertion. 1 D: The procedure can be performed after dissecting beneath vessels, thus sparing them.

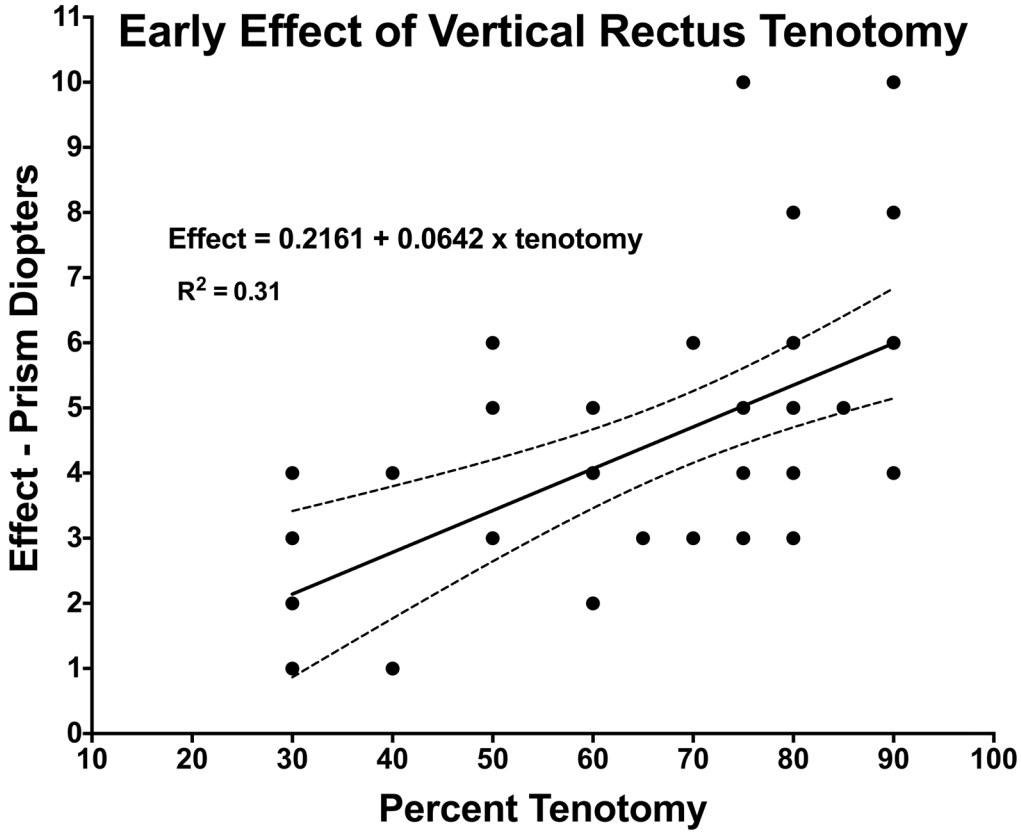


**Fig. 2.**

Linear regression demonstrating intraoperative surgical effect of percentage inferior or superior rectus GVRT on hypertropia in 37 cases. Some symbols overlap. Dotted lines indicate 95% confidence interval of the fit.