Insertion Slanting Strabismus Surgical Procedures

Burton J. Kushner, MD

Insertion slanting recessions or biased resections have been reported to be useful for treating A- and V-pattern strabismus, convergence insufficiency, and convergence excess esotropia. Paradoxically, good results have been reported with methods that are opposite in nature. For example, some researchers would recess the medial rectus muscles and slant the superior pole of each muscle back farther than the inferior pole (Simonsz/von Graefe method) for a V-pattern esotropia, and others would slant the inferior poles back farther (Bietti method). The Simonsz/von Graefe method seems to be based on sound concepts of oculomotor mechanics. The Bietti method has been justified based on a misquoting and misinterpretation of previous work by Alan Scott, MD. Probably neither method contributes substantially to the outcome of strabismus surgery because sarcomere remodeling should rapidly negate the effect of the slanting. Most likely it is the recession or resection itself that affects the outcome.

Arch Ophthalmol. 2011;129(12):1620-1625

The terms A-pattern and V-pattern strabismus are used to describe vertically incomitant horizontal strabismus in which there is a substantial difference in magnitude of the deviation between the midline upgaze and midline downgaze positions. A patient has an A pattern if the eyes are more converged (more esotropic or less exotropic) in upgaze than in downgaze and a V pattern if the eyes are more converged in downgaze than in upgaze.

In 1897, Duane1 published what is probably the first report of a V pattern when he described a patient who had bilateral fourth cranial nerve palsies. It was not until Urrets-Zavalia2,3 described what is now known as the A and V patterns in 1948 that the general importance of measuring strabismus in upgaze and downgaze in the midline positions became recognized. In 1951, Urist4 brought attention to A- and V-pattern strabismus in the English language. Although numerous treatment approaches had initially been proposed for the A and V patterns,5 2 approaches suggested by Knapp6,7 have been most predominantly used: (1) weakening of the oblique muscles if they are overacting (inferior oblique muscles for V patterns and superior oblique muscles for A patterns) and (2) vertically transposing the horizontal rectus muscles if there is no substantial oblique muscle dysfunction.

In 1970, Bietti8 described a procedure that consisted of performing a slanted recession of the horizontal rectus muscles to treat A and V patterns. It consisted of selectively recessing the superior and inferior poles of the horizontal rectus muscles asymmetrically to produce a slanted orientation of the new insertion. Subsequently, other researchers9-14 reported good results with this technique. However, in 2008, van der Meulen-Schot et al15 reported good results with an insertion slanting procedure in a series of patients with A or V patterns in whom they slanted the muscle in the opposite manner to that performed by Bietti and others. The fact that essentially opposite approaches could produce good results presents a conundrum that challenges our basic understanding of eye muscle physiologic features and strabismus surgery. In a thoughtful editorial on

Author Affiliation: Pediatric Ophthalmology and Adult Strabismus, Department of Ophthalmology and Visual Sciences, University of Wisconsin, Madison.
this subject, Bothun\textsuperscript{16} addressed some possible explanations for this apparent conundrum. However, a review of the previous publications and the underlying assumptions that the researchers made to justify their approach sheds further light on this subject. To understand this subject, a review of extraocular muscle mechanics is helpful.

EXTRAOCULAR MUSCLE MECHANICS

The principles underlying rectus muscle transpositions for treating A and V patterns are shown in Figure 1 and Figure 2. When an eye moves into upgaze or downgaze, a mild amount of slack is induced in 1 edge of each horizontal rectus muscle because the end of the insertion to which that edge attaches moves posteriorly in the orbit—the superior edge slackens in upgaze and the inferior edge in downgaze. Scott\textsuperscript{17} calculated that when the lateral rectus muscle moves into downgaze, the length of the inferior edge will shorten from 40.0 to 37.1 mm; the superior edge will lengthen slightly from 40 to 41.5 mm. If a muscle is infraplaced, there is even more slack in the muscle in downgaze than when the muscle has not been transposed, as seen in Figure 1. In upgaze, there is more stretch and increased tension in the muscle fibers compared with in downgaze.

Figure 1. When an eye is in downgaze, there is a slight amount of shortening and slack induced in the inferior fibers of a horizontal rectus muscle and a slight increase in length and tension in the superior fibers.

Figure 2. View of globe depicting horizontal rectus muscle and its relationship to its insertion after various surgical procedures and in different vertical gaze fields. A, If a horizontal rectus muscle is infraplaced, there is more shortening and slack induced in the muscle in downgaze than when the muscle has not been transposed, as seen in Figure 1. B, In upgaze, there is more stretch and increased tension in the muscle fibers compared with in downgaze.

contractile force,\textsuperscript{18} an inferior transposition weakens the muscle’s action mostly in downgaze. Thus, for medial rectus muscles, an inferior transposition would be an appropriate procedure for treating a V-pattern esotropia.\textsuperscript{8,7}

In 1857, von Graefe wrote, “If the internal rectus is efficiently cut in the upper part, the muscle perceives less resistance when activated and will move back and down. The vertical rotary axis will take on a deviation to the inside and the muscle will take on a downward direction” (translated from the original German text).\textsuperscript{19(p260)} With this, von Graefe was describing the fact that tenotomy to slant the superior pole of a horizontal rectus muscle posteriorly infraplaces the muscle’s insertion. Much later, several investigators\textsuperscript{17,18,21} carried this concept further by determining that for mathematical modeling one can consider the rectus muscles as inserting at a point in the middle of their insertion. Yet, if there is unequal tension along the edges of the muscle, one can still consider the insertion as being a point, but the position of the point shifts toward the edge under greater tension (Figure 3 and Figure 4). Thus, slanting the insertion of a horizontal rectus muscle so that the superior pole is recessed more than the inferior pole, as seen in Figure 4, is akin to inferiorly transposing the muscle. In theory, this type of muscle slanting could be used to treat a V-pattern esotropia if performed on the medial rectus muscles or an A-pattern exotropia if performed on the lateral rectus muscles because it is similar to an inferior transposition.

INSERTION SLANTING PROCEDURES

The article by van der Meulen-Schot et al\textsuperscript{15} in 2008 describes good results with recession and insertion slanting surgery in a series of 52 patients with A- or V-pattern esotropia or exotropia in whom they slanted the recessions in a manner consistent with the aforementioned principles described by von Graefe and others (Simonsz/von Graefe method). For a V-pattern esotropia, they recessed and slanted the superior pole of the medial rectus muscles back farther than the inferior pole and applied similar reasoning for A-pattern esotropia and for A- or V-pattern exotropia. However, the recession and slanting procedure previously described by Bietti\textsuperscript{8} in 1970 involved slanting the rectus muscle insertions in an opposite manner to that used by Simonsz and coauthors. Bietti also described good results in his series of 68 patients with A and V patterns. For example, for V-pattern esotropia, Bietti recessed the inferior pole of the medial rectus more than the superior pole and vice versa for A pat-
terms (Bietti method). Subsequent to Bietti’s publication, numerous investigators9-14 reported using the principles of the Bietti method to successfully treat A and V patterns. Other researchers extrapolated from the concept of the Bietti method to treat convergence excess esotropia22-25 or convergence insufficiency exotropia,26-28 in some cases expanding the principles to include biased resections (resecting more from the superior or inferior aspect of the muscle, respectively). Of the numerous investigators reporting results using the Bietti method, only Russsmann9 and Choi and Hwang29 found it to be ineffective.

JUSTIFICATIONS FOR THE BIETTI METHOD BY BIETTI AND SUBSEQUENT RESEARCHERS

Bietti justified his approach by stating, “I thought it to be appropriate, in moderate cases (between 10 and 20 PD [prism diopters]) of A-V pattern to use a way, based on an entirely empirical concept, of weakening more than one part of the horizontal action, relative to the other one, in the same direction in which the insertion is shifted vertically”8(p582) (translated from the original Italian). He did not offer a mechanistic explanation as to why recessing the inferior pole of a medial rectus muscle would give more effect in downgaze than in upgaze. He did, however, cite Boeder20 as hypothesizing that there might be selective segmental innervation to the horizontal rectus muscles in upgaze or downgaze. According to this hypothesis, there might be increased active contraction of the inferior portion of the medial rectus in downgaze, and, hence, selectively recessing the inferior pole of that muscle’s insertion would produce more weakening in downgaze. Boeder20 speculated about this, but he did not attempt to prove this concept. Although Bietti primarily justified his method on empirical grounds,9 subsequent investigators have tried to explain the approach on specific mechanical factors. Reviewing these articles reveals that they are based on either misquoting or misinterpreting the 1975 study by Scott.17 Ohba and Nakagawa quoted Scott as saying “…horizontal muscle tensions are different between upper and lower margins of the muscle with different directions of gaze; i.e. horizontal tension at the upper margin is stronger than at the lower margin in the case of upward gaze.”12(p433) In fact, Scott said essentially the opposite. He wrote, “In 30 degrees upgaze the lower fibers stretch from 40 mm to 41.5 mm and the upper fibers relax from 40 mm to 37.1 mm which puts the entire strain on the lower fibers (more so if they are stiff).”17(p186-187) This misquote was repeated by subsequent investigators. A 1990 study27 correctly cited Scott’s findings but misinterpreted their implications. It properly reported the fact that the muscle fibers will shorten on the edge of a horizontal rectus muscle toward the direction the eye rotates, for example, superior fibers shorten on upgaze; however, the authors incorrectly interpreted that to mean that the shorter fibers were under greater tension. Subsequently, numerous other researchers10,11,14,16,26 repeated this same misinterpretation. In fact, muscle fibers that are passively shortened are under decreased tension. This is the basis for the weakening effect of an extraocular muscle recession or the force vector changes after transposition seen in Figure 2.

Numerous investigators10,11,14,16,26 have claimed that insertion slanting procedures have a less adverse effect on torsion than do standard transposition procedures. The concept that insertion slanting procedures have a less adverse effect on torsion, however, is unfounded. In 1 study,26 the effect of muscle

Figure 3. A, Mathematically, one can consider a rectus muscle to insert at a point (black dot) at the middle of its insertion. B, If there is unequal tension along the edges of a muscle, as occurs with a slanting procedure, the muscle still can be thought of as inserting at a point (black dot), but the point shifts toward the edge under greater tension. If the superior pole of the muscle is slanted back, the point shifts toward the inferior edge, which is akin to infraplacing the muscle.

Figure 4. V-pattern esotropia. A, Treatment of a V-pattern esotropia according to the Bietti method. The superior poles of the medial rectus insertions are slanted back. B, Treatment of a V-pattern esotropia according to the Simonsz/von Graefe method. The inferior poles of the medial rectus insertions are slanted back.
transposition to treat A or V patterns on objective fundus torsion was studied prospectively and found to be small. There was only 2.5° to 3.5° of torsional change per eye after surgery, which was never clinically noticeable. On the other hand, I study recently examined a patient who had previously undergone a biased resection of the right medial rectus muscle (resecting the inferior fibers only) combined with a slanting posteriorly of the nasal fibers of the right inferior rectus muscle. This would inferiorly transpose the medial rectus muscle and temporally transpose the inferior rectus muscle according to the Simonsz/von Graefe method of reasoning. Immediately after surgery, the patient reported diplopia secondary to a subjective exocyclopia. It is unclear whether the torsional diplopia would have resolved as a result of sarcomere remodeling because the next day the surgeon performed a Harada-Ito procedure on the ipsilateral superior oblique muscle to decrease the extorsion. Similarly, Spielmann intentionally used insertion slanting surgery to induce a torsional change.

In summary, for the identical A and V patterns, different researchers would do opposite forms of insertion slanting, yet both groups report good results (Figure 4). Although Simonsz and coworkers cited numerous other researchers who reported success with the Bietti method of insertion slanting, they did not comment on the fact that their own approach was opposite to the method that the previous researchers used. How can we reconcile the contradictory treatment approaches have been reported to be equally successful?

POSSIBLE EXPLANATIONS TO RECONCILE THE CONUNDRUM

1. Perhaps vertically shifting the force vector of the horizontal rectus muscle (via either transposition or slanting) has no affect on A and V patterns. I doubt this to be the case for several reasons. In the past, I have seen 3 different patients in whom their previous ophthalmologist inadvertently transposed horizontal rectus muscles in the wrong direction to treat an A or V pattern, for example, resected medial rectus muscles and transposed them downward to treat an A-pattern exotropia. In all 3 patients, the A or V pattern was substantially worse after surgery. In addition, Edward Buckley, MD, described (written communication, March 12, 2003) a useful procedure for treating convergence insufficiency exotropia in the absence of an A or V pattern. He intentionally transposes the horizontal rectus muscles in a direction to create a V pattern, which will decrease the exotropia in the near downgaze reading position, for example, transpose lateral rectus muscles downward or medial rectus muscles upward. I have used this approach in 7 patients and have routinely obtained 6 to 7 PD of V-pattern shift, indicating that vertical transposition of the horizontal rectus muscles can create a pattern strabismus when none previously existed. Finally, computer modeling using Orbit (Eidactics, San Francisco, California) shows an A- or V-pattern shift with vertical transposition of the horizontal rectus muscles; however, a 60° slant backward of the superior pole of the lateral rectus muscles combined with a 2-mm recession produces a negligible A- or V-pattern shift (Alan Scott, MD, written communication, August 28, 2010). This negligible A- or V-pattern shift seen on computer modeling with a slanted recession is in the direction predicted by the Simonsz/von Graefe method and opposite to that predicted by the Bietti method.

2. Possibly, there are methodological or design flaws that can explain the contradictory results with the 2 methods: Most studies of slanting procedures had relatively short follow-up for evaluating the outcome of a strabismus surgical procedure. The only study that found the Bietti method to be ineffective had an average follow-up of 38 months after surgery, which was substantially longer than the others. In addition, as Bothun pointed out, most of these studies lacked adequate control of measurement methods and did not use a masked observer. These omissions could introduce bias.

3. Possibly, it was the recession or resection of the extraocular muscles that was primarily responsible for the surgical effect, irrespective of muscle slanting: Bothun observed that one thing all previous studies of insertion slanting have in common is that the operated muscles were either recessed or resected, and he suggested that possibly it was the recession or resection that produced the effect irrespective of insertion slanting. Years earlier, Urist had argued that just recessing or resecting horizontal rectus muscles would have a positive effect on A and V patterns. It is possible that insertion slanting played no role in the results obtained in the published series of insertion slanting surgery. Our understanding of sarcomere remodeling suggests that within weeks of an insertion slanting procedure, the edge tension difference should be equalized and the effect of the slanting negated (Figure 5). This should not happen to the same degree with muscle transposition procedures with which the increased slack in the muscle mainly occurs when the eye is in an eccentric gaze, as seen in Figure 2, and is under more normal tension in the primary gaze field. Bothun reviewed 70 previously reported cases of slanting re-
cessation or biased resection to treat convergence excess esotropia or convergence insufficiency exotropia, respectively, in which there was no A or V pattern preoperatively. Of the 70 patients, only 1 was reported to have developed an A or V pattern after surgery. If insertion slanting has a measurable effect on patterns, one would expect that it would have induced patterns in more of these patients. This contrasts with my aforementioned experience in which vertical transposition of the horizontal rectus muscles will predictably induce a pattern in patients with convergence insufficiency.

4. Possibly, there is selective innervation to the superior and inferior edges of the horizontal rectus muscles, with the inferior edge stimulated more in downgaze and the superior edge stimulated more in upgaze: This has been speculated on by Bietti and Boeder as possible causes of A and V patterns. In fact, recent studies of the neuromuscular remodeling of sarcomere remodeling. The main effect comes from the resection or reinsertion. The published reasoning to support the Bietti method is based on a misinterpretation of the existing literature and does not make sense given what is known about oculomotor mechanics. The resection or reinsertion procedure probably works despite the slanting.

Submitted for Publication: March 17, 2011; final revision received April 9, 2011; accepted April 13, 2011.

Correspondence: Burton J. Kushner, MD, Pediatric Ophthalmology and Adult Strabismus, Department of Ophthalmology and Visual Sciences, University of Wisconsin, 2870 University Ave, Ste 206, Madison, WI 53705 (bkushner@wisc.edu).

Financial Disclosure: None reported.

Funding Support: This study was supported by an unrestricted grant from Research to Prevent Blindness Inc.

Additional Contributions: Emilio Campos, MD, assisted by translation of the Italian literature and Ingrid Krause, CO, assisted by translating the German literature.

REFERENCES


Ophthalmic Images
Ichthyosis and Corneal Scarring
Anique Therese Eugenie Spijkers, MD
Allegonda van der Lelij, MD, PHD

An 11-year-old girl from Somalia has congenital lamellar ichthyosis. She has been blind since childhood because of corneal scarring and vascularization from exposure due to severe cicatricial entropion. Ultrasonography has shown a phthisis bulbi (shrunken eye) of both eyes. Ophthalmic treatment besides lubrication is considered ineffective. Dermal topical treatment with emollients and salicylic acid, aimed at reducing hyperkeratosis and moisturizing the underlying skin, was not very effective.