

Surgical treatment for residual or recurrent strabismus

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Received: 2013-12-01

Accepted: 2014-06-11

Abstract

• Although the surgical treatment is a relatively effective and predictable method for correcting residual or recurrent strabismus, such as posterior fixation sutures, medial rectus marginal myotomy, unilateral or bilateral rectus re-recession and resection, unilateral lateral rectus recession and adjustable suture, no standard protocol is established for the surgical style. Different surgical approaches have been recommended for correcting residual or recurrent strabismus. The choice of the surgical procedure depends on the former operation pattern and the surgical dosages applied on the patients, residual or recurrent angle of deviation and the operator's preference and experience. This review attempts to outline recent publications and current opinion in the management of residual or recurrent esotropia and exotropia.

• **KEYWORDS:** esotropia; exotropia; recurrence surgery

DOI:10.3980/j.issn.2222-3959.2014.06.27

Wang T, Wang LH. Surgical treatment for residual or recurrent strabismus. *Int J Ophthalmol* 2014;7(6):1056-1063

INTRODUCTION

Residual or recurrent strabismus is common problem found after the strabismus operations. According to previous reports, the incidence of undercorrection and recurrence after the correction of esotropia varied from 20% to 40%^[1-3] and the incidence of undercorrection and recurrence after the correction of exotropia varied from 22% to 59%^[4-6]. Controversy continues to exist in recurrence factors that affect the outcome of esotropia after surgery. Simonsz and Kolling^[7] reported that age at surgery had significant effect on recurrence rate. On the other hand,

Trigler *et al*^[8] suggested that preoperative angle of deviation was a prognostic factor for the success of esotropia surgery. Simonsz and Eijkemans^[9] reported that the initial higher hyperopic refractive error and changes in refractive error were significantly associated with recurrence of esotropia. Rajavi *et al*^[10] recently suggested that lateral rectus underaction was found to be risk factors of reoperation and nystagmus might increase the risk of requiring reoperation for residual esotropia^[11]. Similarly, factors such as age, preoperative deviation, refractive error, lateral rectus incomitance are also involved in postoperative recurrence of exotropia. Lim *et al*^[5] demonstrated that increasing patient age at surgery was associated with lower recurrence rates after exotropia surgery. Gezer *et al*^[12] found that preoperative deviation and higher myopic refractive errors were the prognostic factors for the success of exotropia after surgery. Pineles *et al*^[13] reported that patients with lateral incomitance was at increased risk of requiring reoperation. Oh and Hwang^[14] suggested that early postoperative overcorrection minimized the tendency toward recurrence of exotropia. However, Choi *et al*^[15] and Pineles *et al*^[16] concluded that the results of initial overcorrection for the treatment of exotropia were unpredictable in the long-term follow-up. Recurrence rates increased with immediate postoperative overcorrection and undercorrection^[6, 13]. In 2010, Park and Kim^[17] reported that age at onset, age at surgery, preoperative exodeviation, oblique dysfunction, dissociated vertical deviation, postoperative alignment were not found to have statistically significant effects on recurrence rates of infantile exotropia after surgery. These findings were similar to the results of Koklanis and Georgievski^[18]. Because strabismus surgery affects not only simple ocular deviations but also complex neuromuscular and sensory systems, many pediatric ophthalmologists have to confront the frustrating postoperative problems and treat them with empirical surgical procedures. This review aims to outline the current viewpoints in the treatment of residual or recurrent strabismus by summarizing and evaluating difference surgical procedures.

A MEDLINE search was performed using the National Institutes of Health's PubMed interface for the relevant English language articles with the subject headings "residual esotropia" or "recurrent esotropia" and either "residual exotropia" or "recurrent exotropia" or "reoperation" or "secondary surgery" or "undercorrection" with all subheadings included. The articles of consecutive strabismus would be excluded by the authors for validity.

Table 1 Summary of surgical treatment for residual and recurrent esotropia

| Study | No. of patients | Mean follow-up (mo) | Preoperative esodeviation (PD) | Amount of surgery (mm) | Criteria for success (PD) | Successful rate (%) | Undercorrection (%) | Overcorrection (%) | Type of study |
|---|-----------------|---------------------|--------------------------------|--|---------------------------|---------------------|---------------------|--------------------|----------------|
| Posterior fixation sutures | | | | | | | | | |
| von Noorden ^[23] | 12 | 11 | 18-45 | BMR posterior fixation sutures | ±10 | 67 | 33 | 0 | Retrospective |
| Marginal myotomy | | | | | | | | | |
| Zak and Morin ^[28] | 22 | 36 | 14-40 | MM of MR(17cases); MM of MR+ILR resection(5cases) | ±10 | 27 | 73 | 0 | Retrospective |
| Mephee <i>et al</i> ^[29] | 70 | 6 | 15-60 | MM of MR +ILR resection 3.5-10 | ±10 | 51 | 34 | 15 | Retrospective |
| MR re-recession | | | | | | | | | |
| Mittelman and Folk ^[31] | 19 | 27 | 20-40 | 13.5 ^a | -14 to +8 | 95 | 0 | 5 | Case series |
| Biedner <i>et al</i> ^[32] | 10 | 30 | 14-60 | 13.5 ^a | ±10 | 90 | 10 | 0 | Retrospective |
| Felius <i>et al</i> ^[33] | 115 | 2.5 | 12-45 | 12 ^a | -8 to +10 | 85 | 11 | 4 | Retrospective |
| Rajavi <i>et al</i> ^[34] | 12 | 3 | 25-45 | 1.75-2.25 | ±10 | 67 | 33 | 0 | Clinical trial |
| BLR resection | | | | | | | | | |
| Biedner and Yassur ^[36] | 23 | 19 | 25-50 | 6-10 | ±10 | 52 | 39 | 9 | Retrospective |
| Gunasekera <i>et al</i> ^[37] | 25 | 37 | 16-40 | 4-8 | ±10 | 60 | 32 | 8 | Retrospective |
| Shin <i>et al</i> ^[38] | 30 | 12 | 20-75 | 4.5-8 | -5 to +10 | 77 | 16 | 7 | Retrospective |
| Jang <i>et al</i> ^[39] | 25 | 6 | 18-40 | 3.5-9 | ±10 | 68 | 28 | 4 | Retrospective |
| King <i>et al</i> ^[40] | 33 | 1.5 | 15-55 | 4.5-9.5 | ±10 | 61 | 33 | 6 | Retrospective |
| Mims and Wood ^[41] | 60 | 6 | 12-52 | 3-9.3 | -6 to +8 | 87 | 0 | 13 | Retrospective |
| ULR resection | | | | | | | | | |
| Olitsky <i>et al</i> ^[19] | 60 | 6 | 14-25 | 7-9 | ±8 | 90 | | | Retrospective |
| Rajavi <i>et al</i> ^[34] | 13 | 3 | 20-40 | 5-8.5 | ±10 | 54 | 46 | | Clinical trial |

PD: Prism diopters; BMR: Bilateral medial rectus; MM: Marginal myotomy; MR: Medial rectus; ILR: Ipsilateral lateral rectus; ^aMedial rectus re-recession from the limbus to the reinsertion; BLR: Bilateral lateral rectus; ULR: Unilateral lateral rectus.

SURGICAL TREATMENT FOR RESIDUAL OR RECURRENT ESOTROPIA

Residual or recurrent esotropia is a common problem following bilateral medial rectus recessions for esotropia. The surgeons had to perform secondary surgery according to previous surgical pattern^[19]. The surgical treatment for patients with residual or recurrent esotropia is controversial. Bilateral lateral rectus resection is recommended by some authors; others suggest marginal myotomy, Faden operation, unilateral or bilateral medial rectus muscle re-recession, or unilateral lateral rectus resection (Table 1).

Posterior Fixation Sutures and Pulley Posterior Fixation

Many pediatric ophthalmologists made use of posterior fixation sutures or Faden operation to treat some special type of strabismus including high accommodative convergence/accommodation ratio esotropia, dissociated vertical divergence, and nystagmus blockage syndrome^[20-22]. In 1982, posterior fixation sutures were performed on both previously recessed medial recti muscles in 12 patients with a persistent convergence excess-type esotropia by von Noorden^[23]. The operation reduced the deviation in all but one patient and was more effective at near than at distance fixation. The author thought that the surgical procedure had several advantages and no known disadvantages over the marginal myotomy^[23]. The outcome of bilateral medial rectus posterior

fixation sutures with or without central tenotomy (dissecting the central fibers of from the insertion of the medial rectus and allowing them to hang back 2-3 mm) was assessed as a secondary procedure for residual convergence excess esotropia^[24]. The authors concluded that bilateral medial rectus posterior fixation sutures with or without central tenotomy was a viable secondary procedure for residual convergence excess esotropia.

In 2004, Clark *et al*^[25] established a new technique named pulley posterior fixation which needed a suture to fixate the muscle belly directly to the pulley. The technique reduced the strength of the medial rectus muscle in its direction of action by hindering contraction of the muscle belly. Pulley posterior fixation was as effective as sclera posterior fixation at reducing near-distance disparity in convergence excess-type esotropia^[26, 27]. This surgical pattern effectively avoided possible scleral perforation and vortex vein injury^[27]. Clark *et al*^[25] retrospectively analyzed the outcome of pulley posterior fixation on 9 patients with recurrent and excess near esotropia after bilateral medial rectus recessions. The authors concluded that medial rectus pulley posterior fixation was an effective technique for correcting excess near esotropia after initial medial rectus recessions and could be regarded as safe and predictable surgical method to reduce medial rectus contractility, especially in situations that the

increasing amount of medial rectus re-recession became impractical and undesirable.

Medial Rectus Marginal Myotomy Although marginal myotomy is no longer a routine weakening procedure, it should not be completely abandoned, because it is a useful technique when an already recessed muscle requires additional weakening. In those rare cases in which conventional recession of a rectus muscle cannot be done because of retinal supports near the muscle insertion or because of scleral thinning, it may even be the primary procedure of choice. Zak and Morin^[28] retrospectively reported 22 patients with recurrent esotropia who underwent marginal myotomy of medial rectus as secondary surgery. The authors found that marginal myotomy combined with a resection of the antagonist rectus could achieve higher surgical successful rate and more stable surgical outcome than isolated marginal myotomy in the treatment of recurrent esotropia. McPhee *et al*^[29] retrospectively reviewed the outcome of 70 patients treated by medial rectus width myotomy combined with ipsilateral lateral rectus resections as a secondary surgical procedure. At a follow-up of 6mo, 51% (36/70) of patients were successfully aligned (± 10 PD of orthophoria). The authors believed that marginal myotomy combined with a resection of the antagonist rectus could achieve a successful and lasting effect as a secondary surgical procedure. Kim *et al*^[30] compared the results of a medial rectus marginal myotomy combined with ipsilateral lateral rectus resection of 5.5-8.0 mm with those of 2 mm medial rectus re-recession after bilateral medial rectus recessions. The authors concluded that a medial rectus marginal myotomy combined with ipsilateral lateral rectus resection was more stable and more effective than medial rectus re-recession in the treatment of undercorrection esotropia.

The marginal myotomy had some disadvantages including the difficult exposure of operation field, less quantitative preoperative design, hemorrhage and surrounding tissue adhesion postoperatively, permanent reduction of functional contractile elements with decreased muscle power, and overcorrection, although uncommon, could be difficult to correct^[29].

Medial Rectus Re-recession Mittelman and Folk^[31] firstly reported the results of medial rectus re-recession for treatment of undercorrected esotropia. Nineteen patients with residual esotropia following conventional maximum horizontal unilateral medial rectus recession-lateral rectus resection were treated by further recession of the medial rectus muscle to a point of 13.5 mm from the limbus. Six of these patients also underwent an 8 mm resection of the ipsilateral lateral rectus in addition to the medial rectus recession. The results showed that 95% of the patients obtained a successful outcome with one of the patients

overcorrected. Most of the patients showed some mild limitation of adduction after the surgery, but this deficiency was generally not a significant cosmetic or functional defect. The authors concluded that recession of the medial rectus muscle 13.5 mm from the limbus seemed to be a safe and effective method of treating surgically undercorrected esotropia. Biedner *et al*^[32] reviewed the results of re-recession previously recessed medial rectus muscle with reinsertion at 13.5 mm from the limbus in 10 patients with undercorrected esotropia. With the mean follow-up of 2.6y, 90% of the patients were acceptably aligned (any deviation ≤ 10 PD) at near and distance measurements, none of those was overcorrected. Although 60% of the patients showed mild limitation of adduction, the cosmetic and functional defect had not been observed. Felius *et al*^[33] retrospectively reviewed the outcome of 115 patients with recurrent esotropia who underwent bilateral medial rectus re-recessions (70 cases) for the average deviation of 23.9 PD and unilateral medial rectus re-recession (45 cases) for the average deviation of 15.3 PD. The authors advocated that the procedure seemed to be effective when done unilaterally in patients with 16 PD or less of esotropia and bilaterally in patients with 20 PD or more of esotropia. Rajavi *et al*^[34] prospectively compared the results of medial rectus re-recession with the results of lateral rectus muscle resection to correct residual esotropia during a mean follow-up of 3.1mo. The authors concluded that medial rectus muscle re-recession could be a substitute for lateral rectus muscle resection in patients with residual esotropia.

The advantage of medial rectus re-recession was that it remained an intact lateral rectus to provide a possibility for further surgery treatment; the disadvantages were: it lacked an accurate dosing of surgery, which might lead to a higher incidence of consecutive exotropia and mild underaction of medial rectus adduction. Wright thought the surgery could be applied to the patients with residual esotropia who underwent primary bilateral medial rectus recessions 5.0 mm or less with no limitation of adduction^[35].

Lateral Rectus Resection

Bilateral lateral rectus resection Bilateral lateral rectus resection was the most common surgical method for treating residual or recurrent esotropia^[36,37]. Shin *et al*^[38] found that bilateral lateral rectus resection was an effective surgical method for treating residual esotropia of less than 40 PD after bilateral medial rectus recession. Bilateral lateral rectus resection as a secondary surgical method was appropriate for the treatment of residual esotropia^[39]. King *et al*^[40] advocated that it was more stable and predictable than bilateral medial rectus re-recession and felt that except in cases where medial restrictive factors or obvious errors in magnitude of the original surgery were noted, bilateral lateral rectus resection was the surgery of choice in patients with

Table 2 Summary of surgical treatment for residual and recurrent exotropia

| Study | No. of patients | Mean follow-up (mo) | Preoperative exodeviation (PD) | Amount of surgery (mm) | Criteria for Success (PD) | Successful rate (%) | Undercorrection (%) | Overcorrection (%) | Type of study |
|---------------------------------------|-----------------|---------------------|--------------------------------|--------------------------|---------------------------|---------------------|---------------------|--------------------|----------------|
| UMR resection | | | | | | | | | |
| Ollitsky <i>et al</i> ^[19] | 21 | 6 | 16-25 | 5-6.5 | ±8 | 95 | | | Retros-pective |
| Kim and Kim ^[44] | 70 | 36 | 15-35 | 3-7 | ±8 | 81 | | | Retros-pective |
| Mims ^[45] | 45 | 24 | Up to 22 | 5 | -8 to +10 | 82 | | | Retros-pective |
| Chae <i>et al</i> ^[46] | 30 | 6 16 | 20-39 | 5-7 | <±10 | 80 77 | 20 | 0 | Retros-pective |
| Yang and Hwang ^[47] | 20 | 22 | 14-25 | 7-10 | -9 to +4 | 80 | 10 | 10 | Retros-pective |
| BMR resection | | | | | | | | | |
| Yang and Hwang ^[47] | 24 | 23 | 15-25 | 3.5-5 | -9 to +4 | 54 | 4 | 42 | Retros-pective |
| Chun and Rah ^[57] | 12 | 9 | 18-24 | 3-5.5 | <±8 | 83 | 17 | 0 | Retros-pective |
| ULR recession | | | | | | | | | |
| Lee <i>et al</i> ^[54] | 15 | 6 | 15-20 | 7-9 | <±10 | 93 | 7 | 0 | Retros-pective |
| Kim <i>et al</i> ^[55] | 19 | 32 | 20-25 | 9-10 | -9 to +4 | 63 | | | Retros-pective |
| Contralateral R&R | | | | | | | | | |
| Kim <i>et al</i> ^[55] | 20 | 31 | 20-25 | LR-rec 5-6 MR-res 4-5 | -9 to +4 | 65 | | | Retros-pective |
| BLR re-recession | | | | | | | | | |
| Yazdian and Ghiassi ^[56] | 16 | 26 | 12-60 | 15-17 ^a | -8 to +10 | 100 | 0 | 0 | Retros-pective |
| Chun and Rah ^[57] | 11 | 12 | 18-24 | 2-3 | <±8 | 82 | 18 | 0 | Retros-pective |

PD: Prism diopters; UMR: Unilateral medial rectus; BMR: Bilateral medial rectus; ULR: Unilateral lateral rectus; R&R: Recess-resect procedures; LR-rec: Lateral rectus recession; MR-res: Medial rectus resection; BLR: Bilateral lateral rectus; ^aMedial rectus re-recession from the limbus to the reinsertion.

undercorrected or recurrent esotropia following bilateral medial rectus recession. Mims and Wood^[41] found a linear regression equation that was " $2.39+0.25$ (mm MR recession)²+0.41 (mm LR resection)²=prism diopters of effect" for the amount of bilateral lateral rectus resection which was adopted for children who had previously undergone bilateral medial rectus recession with residual non-accommodative esotropia. The authors concluded that the use of linear regression equation helped patients to achieve a higher success rate for these secondary surgeries than conventional surgical "dose".

Unilateral lateral rectus resection Olitsky *et al*^[19] firstly reported the results of 7 to 9 mm unilateral lateral rectus resection in 60 patients for the treatment of undercorrected or recurrent esotropia with preoperative mean deviation of 19.7 PD (range 14-25 PD). At the follow-up of 6mo, the success rates were 90% (±8 PD) and none appeared a remarkable limitation of adduction. The authors concluded that unilateral lateral rectus resection was an effective method in the treatment of undercorrected or recurrent esotropia and it was predictable, stable in the immediate in postoperative period, and limited surgery to one eye. Nucci *et al*^[42] reported the results of unilateral lateral rectus resection in 35 patients for the treatment of small-angle residual esotropia after bilateral medial rectus recession with a 6mo follow-up. The authors concluded that resection of a single lateral rectus with a surgical dosage defined according to the double angle of strabismus was an effective surgical procedure for the treatment of small-angle residual esotropia

following bilateral medial rectus recession. However, Morrison *et al*^[43] recently reported the results of 38 patients who had undergone unilateral lateral rectus resections (24 cases) and bilateral lateral rectus resections (14 cases) for correcting residual or recurrent esotropia after 5.5-6.5 mm bilateral medial rectus recession. The authors concluded that individual responses to lateral rectus resection surgery for residual or recurrent esotropia after maximal medial rectus recession could be highly variable. They believe that unilateral surgery can be appropriate for residual esotropia of up to 15 PD. Larger deviations should likely be addressed with bilateral surgery.

SURGICAL TREATMENT FOR RESIDUAL OR RECURRENT EXOTROPIA

Residual and recurrent exotropia after successful extraocular muscle surgery is relatively common. Recurrence can occur shortly after bilateral lateral rectus recession and unilateral lateral rectus recession combined with medial rectus resection or years later. Some authors advocate that medial rectus resection (s) is used to correct residual or recurrent exotropia; others suggest unilateral lateral rectus recession or unilateral lateral rectus recession-medial rectus resection are performed to correct residual or recurrent exotropia in the fellow eye, and although rare, lateral rectus re-recession may be performed to treat patients who underwent inadequate bilateral lateral recession (Table 2).

Medial Rectus Resection Undercorrection or recurrence of exodeviation is common after bilateral lateral rectus recessions for intermittent exotropia, and these patients are

usually treated by bilateral medial rectus resections [19]. Wright advocated this procedure were performed for the patients with undercorrected or recurrent exotropia who had undergone more than 6 mm bilateral lateral rectus recessions [35]. Unilateral medial rectus resection also may provide satisfactory results when performed in patients with small to moderate angles of recurrent exodeviation.

Olitsky *et al* [19] reviewed 21 patients who underwent unilateral medial rectus resection for correcting undercorrected or recurrent exotropia (mean deviation, 16.6 PD). The mean correction amount for 5.0, 5.5, 6.0, 6.5 mm of unilateral medial rectus resections were 15.6, 16.7, 14.8, 21.25 PD respectively at the follow-up of 6mo. Ninety-five percent of the 21 patients were successfully aligned (any deviation ≤ 8 PD) and none appeared a remarkable limitation of adduction. Kim and Kim [44] reported 70 patients who had undergone unilateral medial rectus resection for treatment of undercorrected or recurrent exotropia (mean deviation, 22.24 ± 4.86 PD). At a follow-up of more than 6mo (mean 35.6mo), 84.1% of 70 patients were successfully aligned (any deviation < 8 PD). Mims [45] retrospectively reviewed 45 patients who underwent 5 mm unilateral medial rectus resection for the treatment of recurrent exotropia. During the follow-up of 2y, 82% of 45 patients were successfully aligned (-8 to +10 PD). Chae *et al* [46] retrospectively reported the results of 5 to 7 mm unilateral medial rectus resection in 30 patients with recurrent exotropia ranging from 20 to 39 PD with the mean follow-up of 16.4mo. The surgical success rate (any distant manifest deviation < 10 PD) was 76.7% at the final follow-up and the change in deviation each mm of resection was 3.53 ± 0.17 PD/mm. The authors concluded that unilateral medial rectus resection was an effective surgical method for the correction of small to moderate angle recurrent exotropia.

Yang and Hwang [47] compared outcomes after bilateral and unilateral medial rectus resection for the treatment of recurrent exotropia of 25 PD or less at distance after bilateral lateral rectus recession for intermittent exotropia. All surgeries were performed using the same surgical dosages whereas unilateral medial rectus resection was performed twice the value of each muscle in the bilateral medial rectus resection up to a maximum of 10 mm. The incidence of successful outcome and recurrence at last follow-up were not significantly different between the two groups, but the overcorrection rate was significantly lower after unilateral medial rectus resection than that was after bilateral medial rectus resection. The authors concluded that large unilateral medial rectus resection was a safe and effective procedure in the treatment of small to moderate angles of recurrent exotropia after bilateral lateral rectus recession. Suh *et al* [48] retrospectively analyzed the mean correction amount of per millimeter of medial rectus resection for recurrent exotropia

after bilateral lateral rectus recession, the difference in the effects between unilateral and bilateral resection, and the influence of previous lateral rectus recession on the effects of medial rectus resection. The authors concluded that effect of medial rectus resection per millimeter was variable, and the laterality and previous amount of lateral rectus recession did not influence the effect of medial rectus resection.

Medial rectus resection can be undertaken according to "standard surgical dosage table" which can achieve predictable outcome of treatment for small to moderate recurrent exotropia. Large unilateral medial rectus resection has more advantages than bilateral surgery, for instance, the lower rate of overcorrection, decreased surgery and anesthetic time, decreased postoperative discomfort, limitation of the risk of complications to one eye [47]. However, the effect of each mm of resection is so more variable that the surgeon will empirically perform the surgery for treating recurrent exotropia [48].

Unilateral Lateral Rectus Recession Recent studies suggest that unilateral lateral rectus recession is a safe, effective, predictable and stable surgical procedure for small-to moderate-angle exotropia [49-52]. The likelihood of the development of an overcorrection and the related complications associated with bilateral surgery is reduced [53]. Lee *et al* [54] compared the results of unilateral lateral rectus recession in 17 patients for the treatment of basic type exotropia (first operation group) with the results of unilateral lateral rectus recession in 15 patients for the treatment of recurrent exotropia (second operation group). The authors concluded that unilateral lateral rectus recession could lead to similar results in 15 to 20 PD exotropia for the first operation or recurrent exotropia. More recently, Kim *et al* [55] compared outcomes following contralateral lateral rectus recession ($n=19$) and recess-resect procedures ($n=20$) for treatment of recurrent exotropia of 20-25 PD after unilateral recess-resect surgery. The authors believed that contralateral lateral rectus recession was a safe and effective procedure for the treatment of recurrent exotropia of 20-25 PD after unilateral recess-resect surgery for intermittent exotropia, and with unilateral lateral rectus recession, the intentional overcorrection in the immediate postoperative period could be avoided.

Bilateral Lateral Rectus Re-recession In 2006, Yazdian and Ghiassi [56] firstly reported the results of 15-17 mm bilateral lateral rectus re-recession from the limbus to the reinsertion for the average deviation of 22 ± 11 PD (distance) and 21 ± 11 PD (near) in 16 patients with recurrent exotropia. All of patients had primarily undergone 5-7 mm bilateral lateral rectus recession. After a mean follow-up of 25mo, all the patients were successfully aligned (esotropia ≤ 10 PD and exotropia ≤ 8 PD) and the mean correction of each mm of re-recession was 7.5 PD. None was found underaction of

lateral rectus abduction. The authors concluded that bilateral lateral rectus re-recession to 17 mm from the limbus was an effective and alternative surgical procedure for the treatment of recurrent exotropia up to 33 PD. Chun and Rah^[57] retrospectively compared the results of 11 patients who had undergone bilateral lateral rectus re-recession with the results of 12 patients who had undergone bilateral medial rectus resection for correcting recurrent exotropia after underwent 5-9 mm bilateral lateral rectus recession for treatment of intermittent exotropia. The authors concluded that bilateral lateral rectus re-recession was a successful surgical procedure for correcting recurrent exotropia without leading to significant limitation of abduction.

Bilateral lateral rectus re-recession could conserve unoperated muscle to provide a possibility for further surgery treatment. However, its lack of predictability in preoperative design could lead to excessive re-recession followed by the limitation of abduction. Wright advocated that bilateral lateral rectus re-recessions (3.0 mm corrects about 20 PD) were suitable for the patients with residual exotropia who had primarily undergone bilateral lateral rectus recession (length < 6 mm) without restriction of abduction^[35].

ADJUSTABLE SUTURE USE IN RESIDUAL AND RECURRENT STRABISMUS SURGERY

In 1975, Jampolsky firstly described adjustable suture as a new technique which reduced the need for reoperation by improving alignment in the early postoperative period. This technique mainly had been used in complex strabismus such as restrictive or paretic strabismus, reoperation, thyroid eye disease and so on^[58-60].

Awadein *et al*^[61] retrospectively compared the results of adjustable sutures (primary surgeries, 202 patients; reoperations, 96 patients) with nonadjustable sutures (primary surgeries, 77 patients; reoperations, 21 patients) in children younger than 10y of age with esotropia and exotropia. At the follow-up of 3mo, the success rates (± 8 PD) of patients with adjustable sutures and nonadjustable sutures were 79% and 64% respectively ($P < 0.01$). In addition, the author separately compared the success rates of surgery using adjustable sutures versus nonadjustable sutures in primary surgeries and reoperations. The results showed that adjustable group had a higher success rate than nonadjustable group in primary surgeries (83% *vs* 69%, $P < 0.01$) and reoperations (72% *vs* 48%, $P < 0.04$). They concluded that the use of adjustable sutures could provide an improved success rate over nonadjustable sutures in eye muscle surgery in children aged 10y or younger. Mireskandari *et al*^[62] retrospectively evaluated the success of adjustable suture and nonadjustable suture strabismus surgery in primary procedures and reoperations. With the mean follow-up of 14.4mo in adjustable suture group and 12.6mo in

nonadjustable suture group, the surgical success rates (± 10 PD of orthophoria) had no statistically significant difference in patients undergoing reoperation of exotropia and esotropia. Zhang *et al*^[63] retrospectively compared outcomes after adjustable sutures and nonadjustable sutures in 100 patients who had undergone previous strabismus surgery with the mean follow-up of 32.7d and 33.8d respectively. The success rate (± 10 PD) was 65.7% for the adjustable sutures group versus 42.4% for the nonadjustable sutures group ($P = 0.0268$). The authors concluded that adjustable sutures were most effective in patients undergoing reoperations for childhood strabismus.

CONCLUSION

Surgical treatment of undercorrected and recurrent strabismus can be chosen by many pediatric ophthalmologists. Provided that errors of measurement and restrictive factors have been eliminated and further surgery is indicated, the surgeon may choose one of different surgical approaches which have been recommended for correcting residual or recurrent strabismus. Although numerous operation patterns have been developed for the treatment of residual or recurrent strabismus, there is not a standard protocol for the design of operation and the evaluation of clinical outcome. The choice of surgical procedure depends on the previous operation pattern and surgical dosages applied on patients, residual angle of deviation and the operator's preference and experience. Medial rectus re-recession can be applied to the patients with residual convergence excess esotropia who underwent primary bilateral medial rectus recessions 5 mm or less, and medial rectus posterior fixation sutures and pulley posterior fixation can be applied to same patients, especially in situations that the increasing amount of medial rectus re-recession became impractical. Bilateral lateral rectus resection is the most common surgical method for the treatment of residual or recurrent esotropia following bilateral medial rectus recession, while unilateral lateral rectus resection can be appropriate for small-angle residual esotropia of up to 20 PD. Marginal myotomy might be used in some rare cases in which medial rectus re-recession or posterior fixation sutures cannot be done because of retinal supports near the muscle insertion or scleral thinning, when an already recessed medial rectus requires additional weakening. Bilateral medial rectus resections can be applied to the patients with undercorrected or recurrent exotropia after bilateral lateral rectus recessions for exotropia, while unilateral medial rectus resection can be appropriate for small-angle recurrent exodeviation. Contralateral lateral rectus recession is a safe and effective procedure for the treatment of recurrent exodeviation of up to 20 PD after unilateral recess-resect surgery for exotropia. Bilateral lateral rectus re-recessions

might be the first choice for correcting residual divergence excess exotropia following bilateral lateral rectus recessions 7 mm or less. The use of adjustable sutures can provide an improved success rate in patients undergoing reoperations. Future prospective and randomized controlled studies with larger samples are needed to provide reliable information for guiding the design of operation style for residual or recurrent strabismus.

ACKNOWLEDGEMENTS

Conflicts of Interest: Wang T, None; Wang LH, None.

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