

# Outcomes of a simplified, fixed surgical dosage calculation for uncomplicated, horizontal, concomitant strabismus in adults

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**Purpose:** The aim of this study was to evaluate the outcomes of a simplified, fixed surgical dosage calculation for uncomplicated, horizontal, concomitant strabismus in adults. **Methods:** Outcomes analysis of a fixed-dose calculation method for uncomplicated, horizontal, concomitant strabismus in adults ( $\geq 18$  years) wherein 1-mm recession/resection equals 2 PD for lateral rectus and 3 PD for medial rectus. This was a retrospective case series. **Results:** The mean age of the patients was  $28.50 \pm 8.43$  years, the mean amount of preoperative deviation was  $35.16 \pm 9.97$  PD, the mean expected correction was  $36.26 \pm 9.49$  PD, and the mean correction achieved was  $35.92 \pm 10.74$  PD. There were 22 monocular exotropias, six monocular esotropias, eight alternate divergent squints, and two alternate convergent squints. There were 20 cases of sensory strabismus (54.28%). There was no statistically significant difference between the expected correction and correction achieved ( $P = 0.519$ ), meaning that our fixed-dose calculation method was effective. Thirty-five out of 38 patients had successful outcomes as per our criteria of less than 10-PD deviations from straight in primary position. Therefore, the success rate achieved by this procedure was 92.10%. There was no statistically significant correlation between age and the amount of deviation ( $P = 0.611$ ). **Conclusion:** Our case series had a high postoperative success rate in terms of motor alignment. It is hoped that this simplified, fixed-dosage calculation method would help the numerous novice strabismus surgeons, make their starting steps easier and give them the confidence to do strabismus surgeries. They can modify the dosages later as per their own experiences.

**Key words:** Concomitant adult strabismus, fixed surgical dosage, horizontal strabismus

It is always a challenge for novice strabismus surgeons to decide how much to recess or resect in strabismus surgery. They depend on the surgical dosage tables given in books by different authors.<sup>[1-8]</sup> However, the surgical dosages given in books are only guidelines. These are recommended to be modified by the surgeon's own experience.<sup>[5,6]</sup> Moreover, the amount of correction per mm surgical recession or resection is always given as a range. Novice strabismus surgeons have difficulty in deciding the exact amount to choose from the range given as a guide.

It is said that correction achieved for the same amount of deviation is different in different hands. Therefore, each surgeon has to modify his/her surgical dosages with experience. Different authors suggesting different surgical dosages for the same amount of deviation indicate that outcome of strabismus surgery is variable. This may be because there are different types of strabismus in different age groups.

However, usually, beginners in strabismus surgeries start their surgeries in adults with horizontal, uncomplicated concomitant strabismus. Therefore, we wanted to see if a fixed surgical dosage would work in such situations. If it works,

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it would make it easier for novice strabismus surgeons to calculate the surgical dosage, remove their hesitancy, and give them the confidence to start doing strabismus surgeries. To the best of our knowledge, there is no publication available in literature for this.

## Methods

This was a retrospective study conducted at a tertiary care center in India. The study adhered to the principles of the declaration of Helsinki, 1964. Institutional ethics committee clearance was given for this study. Medical records of adult patients undergoing surgery for uncomplicated, horizontal concomitant strabismus during the period from April 2014 to April 2021 and who were operated by a single surgeon and available for a minimum of 3 months follow-up were reviewed and included.

Exclusion criteria were children ( $< 18$  years), incomitant strabismus such as palsies, re-operations, surgeries done in stages, oblique and vertical strabismus, incomplete data, patients not completing follow-ups, adjustable suture surgeries, nystagmus, botulinum toxin injection, and microphthalmos.

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The prism bar cover test or Krinsky test was used to measure the amount of deviation. The fixed dosage calculation was done in the following manner: for medial rectus (MR), 1-mm recession or resection equals 3 PD, and for lateral rectus (LR), 1-mm recession or resection equals 2 PD. If the amount of deviation was less than or equal to 40 PD, the recession-resection was done in only one eye, that is, in the non-dominant eye. If the amount was more than 40 PD but less than 60 PD, three muscles were intervened wherein two muscles were tackled in the non-dominant eye and one muscle in the dominant eye. These were done in the same sitting. If the deviation was equal to or more than 60 PD, four muscles were intervened. These also were carried out in the same sitting.

For example, for a 30-PD exotropia (XT), the non-dominant eye would be operated using the fixed dosage calculation with LR recession of 6 mm plus MR resection of 6 mm [(6 × 2) + (6 × 3) = 30 PD]. This can also be calculated as LR recession 7.5 mm plus MR resection 5 mm (15 + 15 = 30 PD) as per the need (if more effect is desired from LR) or surgeon's choice in any arithmetic combination, as long as the target correction is achieved. Similarly, for a 40-PD XT, the non-dominant eye would be tackled with 8-mm LR recession plus 8-mm MR resection (16 + 24 = 40 PD). In the same way, calculations can be done with fixed dosage combinations for the other amount of deviations. Table 1 shows the suggested surgical dosages for the correction of esotropias (ET) by the fixed, surgical dosage calculation method. Similarly, Table 2 shows the suggested surgical dosage for the correction of exotropias (XT) by the same method. These may be calculated differently using the fixed dosage calculation by any arithmetic combination as long as the target correction is achieved.

Surgeries done by a single surgeon only were included. Fornix-based conjunctival incisions were made. The muscles were dissected meticulously. The intermuscular septum and epimuscular fascia were dissected meticulously under direct vision, and excess Tenon's capsule around the muscle were carefully excised so that there are no undue adhesions or forces that might alter the action of the muscle apart from that is desired from only the muscle. The maximum limit for recession or resection was kept at 8 mm. A successful outcome was defined as final postoperative alignment of less than 10 PD of straight in the primary position.

The data were first entered into Microsoft Excel spreadsheets and were then transferred to SPSS software for analysis. Using the Kolmogorov-Smirnov test, the data were analyzed to see whether they had normal distribution. For the data showing normal distribution, continuous variables were expressed as the mean ± standard deviation. Student's *t* test was used to compare the means of characteristics between the male and female groups. Paired *t* test was used to find out if there was any difference between the correction expected and postoperative correction achieved. Statistical analysis was carried out using the SPSS software package (SPSS for Windows, version 22.0; SPSS, Inc., Chicago, IL, USA). *P* < 0.05 was considered statistically significant.

Patient profile, preoperative diagnosis, type and amount of surgery done, expected correction, correction achieved, and outcome of the surgery were documented [Table 3]. Only the motor alignment in primary position was assessed at the end of 3 months as the data for sensory outcomes were inadequate.

**Table 1: Suggested surgical dosages for correction of esotropia by simplified, fixed surgical dosage method**

Amount of deviation (PD)	Non-dominant eye ET		Dominant eye ET	
	LR recession	MR recession	MR recession	LR recession
25	5	5	-	-
30	6	6	-	-
35	7	7	-	-
40	8	8	-	-
45	6	6	5	-
50	5.5	7	6	-
55	6.5	6.5	7.5	-
60	6	6	6	6
65	7	7	6	6
70	7	7	7	7

\*PD – Prism Diopters, ET – Esotropia, LR – Lateral Rectus, MR – Medial Rectus. The surgical dosages may be calculated differently using the fixed dosage calculation by any arithmetic combination as long as the target correction is achieved

**Table 2: Suggested surgical dosages for correction of exotropia by simplified, fixed surgical dosage method**

Amount of deviation (PD)	Non-dominant eye XT		Dominant eye XT	
	LR recession	MR recession	MR recession	LR recession
25	5	5	-	-
30	6	6	-	-
35	7	7	-	-
40	8	8	-	-
45	7	6	-	6.5
50	8	7	-	6.5
55	8	7.5	-	8
60	6	6	6	6
65	7	7	6	6
70	7	7	7	7

\*PD – Prism Diopters, XT – Exotropia, LR – Lateral Rectus, MR – Medial Rectus. The surgical dosages may be calculated differently using the fixed dosage calculation by any arithmetic combination as long as the target correction is achieved

## Results

The mean age of the patients was 28.50 ± 8.43 years (range: 18–47 years). There were 20 males and 18 females. The mean amount of preoperative deviation was 35.16 ± 9.97 PD: (range: 15–60 PD). The mean correction expected was 36.26 ± 9.49 PD (range: 18–64 PD), and the mean correction achieved was 35.92 ± 10.74 PD (range: 18–74 PD). There were 22 monocular exotropias, six monocular esotropias, eight alternate divergent squints (ADS), and two alternate convergent squints (ACS). Out of the 22 monocular exotropias, nine patients had right XT and 13 had left XT. There were 20 cases of sensory strabismus (54.63%). There was no statistically significant difference between the expected correction and correction achieved (*P* = 0.519). Thirty-five out of 38 patients had successful outcomes as per our criteria. Therefore, the success rate achieved by this procedure was 92.10%. There was no significant correlation between age

**Table 3: Patient profile, diagnosis, amount of pre-operative deviation, type of surgery done, correction expected, and correction achieved**

Age (Yrs)	Sex	Visual Acuity		Diagnosis	PBCT/ Krimsky (PD)	Amount of Recession - Resection done (mm)								Correction Expected (PD) (CE)	Correction Achieved (PD) (CA)	Difference (PD) (CA-CE)
						OD				OS						
						LR		MR		MR		LR				
						Rec	Res	Rec	Res	Rec	Res	Rec	Res			
25	F	6/6	6/6	ACS	25	-	-	4.0	-	4.5	-	-	--	25.5	25.0	-0.5
25	M	CF1M	6/9	RXT, S*	35	8.0	-	-	6.5	-	-	-	-	35.5	34.0	-1.5
45	M	6/12	CF1M	LXT, S*	40	-	-	-	-	-	8.0	8.0	-	40.0	28.0	-12.0
18	M	HM	6/6	RXT, S*	35	8.0	-	-	6.5	-	-	-	-	35.5	36.0	0.5
29	M	6/6	CF1M	LXT, S*	25	-	-	-	-	-	5.0	6.0	-	27.0	25.0	-2.0
30	M	6/6	CFCF	LET, S*	25	-	-	-	-	5.0	-	-	7.0	29.0	26.0	-3.0
22	F	6/6	6/6	LET	50	-	-	5	-	6	-	-	8	49.0	49.0	0.0
28	F	6/6	6/6P	LXT	28	-	-	-	-	-	5.0	7.0	-	29.0	28.0	-1.0
25	F	6/6P	6/6P	LXT	52	7.0	-	-	-	-	6.0	8.0	-	48.0	48.0	0.0
18	M	6/9	6/36	LET, S*	60	-	8.0	7.0	-	5.0	-	-	6.0	64.0	74.0	10.0
29	F	6/6	CF1M	LXT, S*	30	-	-	-	-	-	6.0	7.0	-	32.0	32.0	0.0
47	M	6/6	6/60	LXT, S*	35	-	-	-	-	-	6.5	8.0	-	35.5	35.0	-0.5
28	M	6/9	6/9	ACS	51	-	7.5	6.0	-	6.0	-	-	-	51.0	50.0	-1.0
30	F	6/6P	6/6P	ADS	45	7.5	-	-	6.5	-	-	6.0	-	46.5	46.0	-0.5
40	F	6/9	HMCF	LXT, S*	30	-	-	-	-	-	6.5	7.0	-	33.5	33.0	-0.5
19	M	6/9	6/6	RXT	30	7.0	-	-	5.5	-	-	-	-	30.5	30.0	-0.5
25	M	6/6	No PL	LXT, S*	40	4.5	-	-	-	-	6.0	8.0	-	43.0	40.0	-3.0
46	F	6/6	CFCF	LET, S*	25	-	-	-	-	5.0	-	-	6.5	28.0	30.0	2.0
30	M	6/6	HMCF	LET, S*	30	-	-	-	-	-	5.5	7.0	-	30.5	28.0	-2.5
45	F	6/6	6/6	ADS	45	7.0	-	-	6.0	-	-	6.0	-	44.0	44.0	0.0
18	F	6/6	6/6	ADS	45	7.0	-	-	6.0	-	-	6.5	-	45.0	45.0	0.0
29	F	6/6	6/6	ADS	45	6.5	-	-	-	-	6.0	7.0	-	45.0	45.0	0.0
18	M	CFCF	6/6	RXT, S*	15	-	-	6.0	-	-	-	-	-	18.0	18.0	0.0
34	M	6/6	CFCF	LXT, S*	30	-	-	-	-	-	6.0	7.0	-	32.0	30.0	-2.0
23	M	6/36	6/6	RXT, S*	30	6.0	-	-	6.0	-	-	-	-	30.0	30.0	0.0
25	M	CF1M	6/6	RXT, S*	28	6.0	-	-	6.0	-	-	-	-	30.0	30.0	0.0
24	M	6/6	6/6	RXT	30	6.0	-	-	6.0	-	-	-	-	30.0	30.0	0.0
38	M	6/36	CF1M	LXT, S*	45	4.5	-	-	-	-	7.0	8.0	-	46.0	46.0	0.0
24	M	CFCF	6/6	RXT, S*	18	-	-	-	6.5	-	-	-	-	19.5	18.0	-1.5
22	F	6/6	6/6	ADS	40	8.0	-	-	7.0	-	-	-	-	37.0	36.0	-1.0
35	F	6/6P	6/6	LXT	45	5.0	-	-	-	-	6.0	7.5	-	43.0	42.0	-1.0
26	F	6/6	6/6	ADS	35	-	-	-	-	-	7.0	7.0	-	35.0	45.0	10.0
33	F	6/6	6/6	LXT	42	5.0	-	-	-	-	6.0	7.0	-	42.0	42.0	0.0
30	F	6/6	6/6	ADS	40	8.0	-	-	8.0	-	-	-	-	40.0	40.0	0.0
30	F	6/6	6/6	ADS	40	8.0	-	-	8.0	-	-	-	-	40.0	40.0	0.0
40	M	CF3M	6/60	RXT, S*	40	7.0	-	-	6.0	-	-	6.0	-	44.0	44.0	0.0
22	F	6/9	6/6	ADS	27	-	-	-	-	-	5.0	7.0	-	29.0	28.0	-1.0
20	M	6/6	6/6	LET	27	-	-	-	-	5.0	-	-	6.0	27.0	26.0	-1.0

OD–Oculus Dexter, OS–Oculus Sinister, PBCT – Prism Bar Cover Test, PD – Prism Diopters, LR – Lateral Rectus, MR – Medial Rectus, Rec – Recession, Res – Resection, ACS – Alternate Convergent Squint, RXT – Right Exotropia, S\* – Sensory strabismus, LXT – Left Exotropia, LET – Left Esotropia, ADS – Alternate Divergent Squint, CFCF – Counting Finger Close to Face, HMCF – Hand Movement Close to Face

and the amount of deviation ( $P = 0.611$ ). Similarly, there was no statistically significant correlation between age and the correction expected (0.482) or the correction achieved (0.92).

There was no significant difference in the age, preoperative PBCT, correction expected, and correction achieved between

the males and the females with  $P = 0.673$ ,  $P = 0.654$ ,  $P = 0.545$ , and  $P = 0.461$ , respectively.

Sample pre- and post-operative 9 gaze photos for esotropia are given in Fig. 1a and b, respectively, and for exotropia in Fig. 2a and b, respectively.





**Figure 1:** (a) Preoperative 9 gaze photos of a case of esotropia; (b) Postoperative 9 gaze photos of the case in Fig. 1a

## Discussion

It appears that there is no consensus regarding the amount of surgery to be done for different angles of strabismus.<sup>[9]</sup> There is no fixed-dosage calculation method available so far. Different authors give different surgical dosage tables for the same amount of deviation in strabismus.<sup>[1-8]</sup> They give these only as a guide and recommend the surgeons to modify by their own experiences. Some others suggest correction per mm of recession or resection dosage in a range and not in a fixed number. Stallard proposed that per mm recession of MR gives a correction of 3–4 PD, and LR recession gives a correction of 2–3 PD plus 25% advantage when both the eyes are done in the same sitting.<sup>[10]</sup> We see here that the correction proposed is in range. Thus, a novice strabismus surgeon would be perplexed what number to choose from the range. For example, in the range of 2–3 PD, the novice surgeon gets confused about whether to choose 2, 2.5, or 3 PD; similarly, for the 3–4 PD range.

Therefore, we set out to see if a simplified, fixed surgical dosage calculation for uncomplicated, horizontal concomitant strabismus would work in successfully correcting the deviations in adults. What we found was that this could, in fact, do so. In our study, there was no statistically significant difference between the expected correction for deviations and the correction achieved ( $P = 0.314$ ). This means that our fixed-dose calculation method of 1-mm recession/resection equals 2 PD for LR and 1-mm recession/resection equals 3 PD for MR is effective for different horizontal, uncomplicated concomitant strabismus in adults with a success rate of 92.10%.

Sensory strabismus constituted a large portion of our study population (54.28%) [Table 3]. In such cases, as there is no visual stimulus for fixation in the eye with poor vision, we overcorrected slightly in most cases, taking into account the fact of late postoperative drift that is likely to occur. Therefore, our expected (target) correction was slightly more than the actual deviation in these cases. It is said that target postoperative alignment in exotropia should be between orthophoria and 8 PD of esotropia as exotropic deviations tend to be unstable and generally increase over time.<sup>[6]</sup>

In adult strabismus, according to Kushner, even with one surgical procedure, most patients can be successfully treated and satisfactory alignment is achieved in 80% of patients.<sup>[11]</sup> Apart from this, adult strabismus surgery is relatively low-risk virtually devoid of any serious complications. The success rate in that study was up to 80%, probably because they included all types of strabismus. However, our case series had only uncomplicated, concomitant horizontal strabismus cases. Therefore, the success rate was much higher.

There are multiple factors that affect the outcome of strabismus surgery.<sup>[9,12-14]</sup> According to Abbasoglu *et al.*,<sup>[9]</sup> the older the patient at the onset of deviation, the smaller the effect of the surgery. A similar effect was demonstrated by Kushner *et al.*<sup>[14]</sup> Therefore, as our patients were adults, our surgical dosages tended to be more as compared to other authors, especially if more than 40 PD, anticipating that the surgical effect would be lesser in adults. As multiple factors influence the surgical outcome, we meticulously dissected the



**Figure 2:** (a) Preoperative 9 gaze photos of a case of exotropia; (b) Postoperative 9 gaze photos of the case in Fig. 2a

intermuscular septum and the epimuscular fascia under direct vision, and the excess Tenon's capsule around the muscles was carefully excised so that there are no undue adhesions or forces that might alter the action of the muscle apart from that is desired from only the muscle. This might have also helped us to get the desired effect by a constant dosage calculation.

In our cases, we preferred to limit recessions and resections up to 8 mm [Table 3]. Large recessions or resections cause alteration in the palpebral aperture of the eyes. There are other complications too, such as inadvertent scleral perforation and the crippling effect of surgery when the recession approaches "maximum amount".<sup>[15,16]</sup> Therefore, as a routine, we preferred three or four muscle surgeries for deviations more than 40 PD. It is advised to keep the resections of medial rectus to less than 8 mm to minimize the risk of alteration in the palpebral apertures of the eyes.

Adjustable sutures are found to be associated with significantly fewer re-surgeries in horizontal muscle strabismus surgeries.<sup>[17]</sup> We did not include adjustable suture surgeries as we feel that adjustments postoperatively would not reflect the true assessment of the effectiveness of our calculation. Moreover, adjustable suture is not a preferable surgery technique over nonadjustable suture in cases of simple and predictive strabismus.<sup>[18]</sup>

Maino *et al.*<sup>[19]</sup> reported neurogenic etiologies as the most common cause for strabismus in elderly patients, apart from thyroid eye disease and iatrogenic causes that were on the rise.

In our cases, sensory strabismus was the most common cause for strabismus in adults. The visual acuity in these cases was very poor. Cases with good visual acuity such as ADS tend to have good fusion too. In such cases, the correction tended to be more accurate. Surprisingly, there was a case of ADS where we could not achieve the target correction despite good vision (case no. 30). When there is poor vision and poor fusion, the correction tended to be less accurate, like in the cases of sensory exotropias in our series.

Apart from the cosmetic realignment of eyes, many other benefits have been found following strabismus surgeries. These may be restoration of binocular single vision, unexpected recovery of sensory fusion, binocular visual field expansion in cases with esotropias, and economic or psychological benefits once the ocular alignment is restored.<sup>[11,20-22]</sup> However, in our cases, we could not report the sensory functions due to lack of data.

Some authors felt that axial length of the eyeball and refractive error make a difference in the outcome of strabismus surgery.<sup>[13]</sup> However, we did not include these in the data as Kushner *et al.* did not find any significant improvement in the prediction of surgical response in their study.<sup>[14]</sup>

There are certain limitations to our study. First, it is a retrospective study. Second, our study has a short-term follow-up. It is known that the angle of deviation of strabismus post-correction changes its alignment after a certain period of time depending on the type of strabismus and duration



of follow-up. Therefore, studies with longer follow-ups are suggested. Third, our study could not include the sensory outcomes. It would also be interesting to see the effects if these are also included.

## Conclusion

In conclusion, we have provided the outcomes of a simplified, fixed surgical dosage calculation for uncomplicated, horizontal, concomitant strabismus in adults. Our case series had a high postoperative success rate in terms of motor alignment. We sincerely hope that our method of fixed dosage calculation would help the numerous beginners of strabismus surgery, make their starting steps easier, and give them the confidence to do the surgeries. They can modify the dosages later as per their own experiences.

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## Conflicts of interest

There are no conflicts of interest.

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