Outcome of two-muscle surgery for large-angle intermittent exotropia in children

Ki Won Jin, Dong Gyu Choi

ABSTRACT
Background/aims To evaluate the surgical outcomes of two-muscle surgery for childhood intermittent exotropia comparing large angles with moderate angles.

Methods We retrospectively reviewed the medical records of 178 consecutive patients who had undergone bilateral lateral rectus recession (BLR) or unilateral recess-resect (RR) for large-angle (≥40 prism dipters (PD); group A) or moderate-angle (≥20 and <30 PD; group B) intermittent exotropia between January 2005 and December 2014 and been followed up postoperatively for 6 months or more.

Results There was a significant difference in mean angle of deviation at distance throughout the postoperative period (p<0.05). The final surgical success rate was significantly lower in group A than in group B (p<0.05). The effect/dose ratio for both BLR and unilateral RR was significantly greater in group A than in group B (p<0.05).

Conclusions The patients with childhood intermittent exotropia with large angles showed significantly higher rates of undercorrection, though they also showed greater effects of BLR or RR per millimetre (the effect/dose ratio), compared with moderate-angle exotropia.

INTRODUCTION
The choice of surgical procedure for correction of intermittent exotropia turns on the type of exotropia exodeviation angle. The success rates of surgical interventions, as reported in a number of different studies, vary widely: 42%–63% after bilateral lateral rectus recession (BLR) and 27%–83% after unilateral recess-resect (RR). 1–3 For large-angle exodeviation, selection of the best surgical procedure can be more challenging. For extra-large-angle exotropia, for example, some studies have suggested simultaneous three-muscle or four-muscle surgery. 4–9 However, other studies have demonstrated that large-angle exodeviations can be successfully managed by two-muscle surgery, with comparable surgical outcomes between BLR and unilateral RR. 10–12 In most of those studies though, the subjects were mainly adults with various types of exotropia and extremely variable angles.

The specific purpose of the present study was to compare the surgical outcomes of two-muscle surgery for childhood intermittent exotropia with large and moderate angles. Further, we evaluated the effect/dose ratio, defined as the corrected angle of deviation at postoperative 6 months divided by the sum of the amount of lateral rectus recession in each eye in BLR and by the amount of lateral rectus recession and medial rectus resection in RR, for both large angles and moderate angles.

MATERIALS AND METHODS
Study design and grouping
We retrospectively reviewed the medical records of 178 consecutive patients who had undergone surgery for large-angle (≥40 prism dipters (PD); group A) or moderate-angle (≥20 and <30 PD; group B) intermittent exotropia between January 2005 and December 2014 and been followed up postoperatively for 6 months or more.

We reviewed children with intermittent exotropia, including only those who at surgery were younger than 18 years. Patients were excluded if they had a previous history of strabismus surgery, trauma, paralytic or restrictive exotropia, sensory exotropia, other ocular diseases, or systemic abnormalities. This study’s protocol adhered to the Declaration of Helsinki and was approved by the Institutional Review Board of Hallym University Medical Center.

Preoperative examinations
We reviewed the preoperative characteristics of the patients, all of whom had undergone complete ophthalmological examinations. Those characteristics were age at onset, age at surgery, Snellen best-corrected visual acuity (BCVA), as well as accompanying strabismus including vertical deviation, inferior oblique overaction (IOOA), dissociated vertical deviation (DVD) and lateral incomitance. Vertical deviation was defined as 5 PD or more hypertropia/hypotropia at the primary position; lateral incomitance was defined as a change of 10 PD or more between the exodeviation in the lateral gaze and the primary position, and amblyopia, as a visual acuity difference of 2 lines or more between eyes. We scaled the control of exodeviation as good, fair or poor. Good control was defined as “fusion breaks only after cover testing at distance fixation and resumes rapidly without need for blinking or refixation”; fair control was defined as “subject blinks or refixates to control deviation after disruption with cover testing at distance fixation”; and poor control was defined as “subject breaks spontaneously without any form of fusion disruption or does not spontaneously regain alignment despite blinking or refixation”. 13

Clinical science
To measure the preoperative and postoperative deviation both
distance (6 m) and at near (33 cm), alternate prism cover
testing in all nine positions of gaze was performed using accom-
mmodative targets with best optical correction. For several unco-
operative patients, a modified Krimsky method was employed.
If the exodeviation at distance relative to that at near was larger
than 10 PD, one eye of the patient was patched for 1 h in order
to eliminate fusional convergence, and the alternate prism cover
test was repeated at near and at distance. Sensory status was
evaluated by Titmus Stereotest (Stereo Optical Co., Chicago,
Illinois, USA) and Worth 4-Dot test at distance in cooperative
patients. Good stereopsis was de
ed as an angle of 100 s of arc
or better on the Titmus Stereotest.

Strabismus surgery
All of the surgeries were performed under general anaesthesia
using the standard limbal approach without any hangback or
adjustable sutures by one surgeon (DGC) at the same institute.
The surgical dosages were based on the angles of distance exo-
deviation listed in table 1 (though the deviation was measured
for both distance and near). The need for surgery was deter-
mined by the state of fusional control, the angle size of devi-
ation and the age of the patient. The surgery was performed if
the patient showed exodeviation of 20–25 PD or more as well
as poor control, regardless of the state of stereopsis. The
surgery was delayed until the patient had reached at least
4 years of age, if possible. In some cases, surgery at an earlier
age was conducted if there was a rapid functional deterioration
of fusional control or if the deviation was constant. The method
of surgery was selected by the surgeon, who had no preference
for BLR or unilateral RR on non-dominant eye. In the patients
with amblyopia, non-amblyopic eye was occluded during part-
time after the correction of refractive error preoperatively.

Outcome measures
The main surgical outcome measures were postoperative align-
ment and surgical success rate. Postoperative alignment at dis-
tance and near was measured at postoperative 1 day, 1, 3 and
6 months, 1 and 2 years, and at final follow-up. Surgical success
was defined as an alignment between 10 PD of exodeviation
and 5 PD of esodeviation both at distance and at near. For com-
parison of the cumulative surgical success rate over time
between the groups and the surgical methods, a Kaplan-Meier sur-
vival analysis was performed.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Surgical dosages of unilateral recess-resect or bilateral lateral rectus recession for exotropia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prism dioptres</td>
<td>LR recession/MR resection (mm) in RR</td>
</tr>
<tr>
<td>20–24</td>
<td>5.0/4.0</td>
</tr>
<tr>
<td>25–30</td>
<td>6.0/5.0</td>
</tr>
<tr>
<td>30–34</td>
<td>6.5/5.5</td>
</tr>
<tr>
<td>35–40</td>
<td>7.0/5.5</td>
</tr>
<tr>
<td>40–44</td>
<td>7.5/6.0</td>
</tr>
<tr>
<td>45–49</td>
<td>8.0/6.0</td>
</tr>
<tr>
<td>50–54</td>
<td>8.0/6.5</td>
</tr>
<tr>
<td>55–59</td>
<td>9.0/7.0</td>
</tr>
<tr>
<td>≥60</td>
<td>9.5/7.0</td>
</tr>
</tbody>
</table>

BLR, bilateral lateral rectus muscle recession; LR, lateral rectus muscle; MR, medial rectus muscle; RR, unilateral lateral rectus muscle recession and medial rectus muscle resection.

The secondary outcome measure was the effect/dose ratio. The effect was defined as the corrected angle of exodeviation obtained by subtracting the postoperative 6-month angle of deviation from the preoperative one. The effect/dose ratio for RR was measured by dividing the effect by the sum of the amounts of lateral rectus muscle recession and medial rectus muscle resection. For BLR meanwhile, the ratio was measured by dividing the effect by the sum of the amounts of bilateral lateral rectus muscle recession.

As for the patients who underwent reoperation, their post-
operative data up to and including the final visit prior to the
secondary operation were included in the analysis.

Statistical analysis
All of the analyses were performed with SPSS for Windows
V21.0 (SPSS, Chicago, Illinois, USA). The Mann–Whitney
U test was used to compare the preoperative-characteristic data
and angles of exodeviation at distance and near between the
groups. A logistic regression analysis was performed to deter-
mine the effects of the preoperative variables on the final surgic-
'al success rate. The Pearson’s \( \chi^2 \) test was applied to compare
the surgical success rates between the groups. Kaplan-Meier sur-
vival analysis with the log-rank test was used to compare the
cumulative surgical success rate over time between the groups
and surgical methods. A p value less than 0.05 was considered
significant.

RESULTS
Of the 178 consecutive patients who had undergone either BLR
or unilateral RR for intermittent exotropia, 40 were assigned to

group A (large-angle (≥20 PD) exotropia) and 138 to group B
(moderate-angle (20–<30 PD) exotropia). Table 2 provides
the patients’ preoperative characteristics. The mean preoperative
angles at distance were 44.26±8.08 PD (range, 40–70 PD) in
group A and 26.14±3.31 PD (range, 20–30 PD) in group B.
The mean age at onset was 2.98±3.49 years (range, 0–12.25) in
group A and 3.51±2.79 years (range, 0–11.67) in group B
(p=0.033); the mean age at surgery was 5.53±4.40 years
(range, 9.96 months–16.33 years) in group A and 5.64±2.56 years
(range, 1.75–15.58) in group B (p=0.142). The mean follow-up duration was 54.50±34.45 months (range,
6–116) in group A and 56.06±27.95 months (range, 6–118) in
group B (p=0.787). There were no differences between the
groups in sex, surgery type, accompanying strabismus, amby-
lopia or BCVA (p>0.05). None of the preoperative variables
investigated was found, by logistic regression analysis, to be
significantly associated with final surgical outcome.

The mean angle of exodeviation at postoperative 1 day was
−0.67 (eso deviation)±6.39 PD in group A and −5.50±5.97 PD in
group B (p=0.000). Subsequently, there was also a significant
difference in mean angle of deviation until final follow-up day
(p<0.05): the mean angle of distance exodeviation at final
follow-up was 12.68±10.98 PD in group A and 4.71±1.27 PD in

group B (table 3). The difference in the mean angle of near
exodeviation was similar (p<0.05), except for that at post-
operative 2 years (p=0.081, table 4). Inferior oblique myectomy
for IOOA was combined with BLR in six cases in group B.
Reoperation was performed on 16 patients (40%) in large-angle
exotropia group and 30 (21.7%) in the moderate-angle exotro-
pia group during the follow-up period (p=0.020). Among the
reoperation patients, 16 (100%) in group A and 27 (90%)
in group B required reoperation for recurrence of exotropia. In

group B, two patients underwent reoperation for oblique muscle
dysfunction, and one for DVD.
The surgical success rate was significantly lower in group A than in group B throughout the postoperative period (p<0.05). The final success rates were 45% in group A and 79% in group B (p=0.000, table 3). Kaplan-Meier survival analysis showed a significant difference in the cumulative probabilities of surgical success between groups A and B (p=0.000). When patients who had undergone the same surgical method were compared by preoperative angles, for both BLR and unilateral RR, group B showed a better surgical success rate than group A (p=0.004, p=0.000, respectively). However, when the patients of the same group of preoperative angles were compared by the surgical method, there was no significant difference by surgical method (p=0.832, group A; p=0.499, group B, figure 1).

The effect/dose ratio of unilateral RR was 2.60±0.64 PD/mm in group A and 2.17±0.37 PD/mm in group B, and that of BLR was 2.37±0.48 PD/mm in group A and 2.08±0.55 PD/mm in group B; these results represent statistically significant differences between the two groups for the two surgical methods (p=0.000, p=0.025, respectively, table 6).

There was no significant adverse event, neither limitation in abduction, symptomatic diplopia at primary and lateral gaze, enophthalmos, nor palpebral fissure narrowing, in any patient during the postoperative periods.

## DISCUSSION
The surgical treatment of large-angle exotropia has been subject to significant debate. A variety of studies involving two-rectus-muscle, three-rectus-muscle, and four-rectus-muscle resections and retractions, with or without adjustable sutures, have been reported.6–9 Two-muscle surgery offers procedural simplicity, a shorter operation time and preservation of other rectus muscles for possible reoperation opportunities.10 However, abduction limitations, narrowing of the palpebral fissure or enophthalmos after extensive surgery can present problems.14 The surgical success rate of large-angle exotropia has been reported to range from 40% to 77%. Currie et al performed two-muscle, three-muscle or four-muscle surgery with adjustable sutures for primary and consecutive large-angle exotropia, 77% of their patients being within 10 PD of orthotropia. Livir-Rallatos et al conducted either BLR or unilateral RR on

### Table 2 Patients’ preoperative characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n=40)</th>
<th>Group B (n=138)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at onset (years)</td>
<td>2.98±3.49</td>
<td>3.51±2.79</td>
<td>0.033*</td>
</tr>
<tr>
<td>Age at surgery (years)</td>
<td>5.53±4.40</td>
<td>5.64±2.56</td>
<td>0.142*</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>16/24</td>
<td>59/79</td>
<td>0.756†</td>
</tr>
<tr>
<td>Preoperative mean exodeviation (PD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At distance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>44.26±8.08</td>
<td>26.14±3.31</td>
<td></td>
</tr>
<tr>
<td>At near</td>
<td>46.00±11.10</td>
<td>26.67±6.17</td>
<td></td>
</tr>
<tr>
<td>Surgery type</td>
<td></td>
<td></td>
<td>0.412†</td>
</tr>
<tr>
<td>RR (n)</td>
<td>26 (65%)</td>
<td>99 (71.7%)</td>
<td></td>
</tr>
<tr>
<td>BLR (n)</td>
<td>14 (35%)</td>
<td>39 (28.2%)</td>
<td></td>
</tr>
<tr>
<td>Accompanying strabismus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical deviation (n)</td>
<td>11 (28%)</td>
<td>32 (23%)</td>
<td>0.624†</td>
</tr>
<tr>
<td>DVD (n)</td>
<td>4 (10%)</td>
<td>11 (8%)</td>
<td>0.645†</td>
</tr>
<tr>
<td>Oblique muscle dysfunction (n)</td>
<td>12 (30%)</td>
<td>33 (24%)</td>
<td>0.376†</td>
</tr>
<tr>
<td>Lateral incomitance (n)</td>
<td>3 (8%)</td>
<td>5 (4%)</td>
<td>0.277†</td>
</tr>
<tr>
<td>Amblyopia (n)</td>
<td>6 (28%)</td>
<td>24 (18.8%)</td>
<td>0.745†</td>
</tr>
<tr>
<td>BCVA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant eye</td>
<td>0.89±0.13</td>
<td>0.87±0.15</td>
<td>0.606*</td>
</tr>
<tr>
<td>Non-dominant eye</td>
<td>0.85±0.18</td>
<td>0.83±0.18</td>
<td>0.533*</td>
</tr>
<tr>
<td>Fusion on Worth 4-dot (n)</td>
<td>2/18 (11%)</td>
<td>38/94 (40%)</td>
<td>0.033†</td>
</tr>
<tr>
<td>Good stereopsis (≤100 s)</td>
<td>10/17 (59%)</td>
<td>79/97 (81%)</td>
<td>0.038†</td>
</tr>
<tr>
<td>Follow-up duration (months)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>54.50±34.45</td>
<td>56.06±27.95</td>
<td>0.787*</td>
</tr>
</tbody>
</table>

* Mann–Whitney U test.
†Pearson’s χ² test.
BCVA, best-corrected visual acuity; BLR, bilateral lateral rectus muscle recession; DVD, dissociated vertical deviation; n, number; PD, prism dioptres; RR, unilateral lateral rectus muscle recession.

### Table 3 Angles of exodeviation at distance

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n=40)</th>
<th>Group B (n=138)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative exodeviation (PD)</td>
<td>44.26±8.08</td>
<td>26.14±3.31</td>
<td>0.000</td>
</tr>
<tr>
<td>Postoperative exodeviation (PD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>−0.67±3.39</td>
<td>−5.50±5.97</td>
<td>0.000</td>
</tr>
<tr>
<td>1 month</td>
<td>5.05±8.53</td>
<td>0.13±3.44</td>
<td>0.000</td>
</tr>
<tr>
<td>3 months</td>
<td>6.31±8.02</td>
<td>0.63±3.84</td>
<td>0.000</td>
</tr>
<tr>
<td>6 months</td>
<td>8.39±6.62</td>
<td>1.38±4.62</td>
<td>0.000</td>
</tr>
<tr>
<td>1 year</td>
<td>9.68±11.61</td>
<td>2.81±6.57</td>
<td>0.000</td>
</tr>
<tr>
<td>2 years</td>
<td>11.20±11.52</td>
<td>5.30±7.14</td>
<td>0.016</td>
</tr>
<tr>
<td>Final follow-up visit</td>
<td>12.68±10.98</td>
<td>4.71±7.27</td>
<td>0.000</td>
</tr>
</tbody>
</table>

In the angle of deviation, the minus sign indicates exodeviation, and the plus sign exodeviation.

Group A: Large-angle exotropia (>40 PD).
Group B: Moderate-angle exotropia (≥20 and <30 PD).
* Mann–Whitney U test.
n, number; PD, prism dioptres.

### Table 4 Angles of exodeviation at near

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n=40)</th>
<th>Group B (n=138)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative exodeviation (PD)</td>
<td>46.00±11.10</td>
<td>26.67±6.17</td>
<td>0.000</td>
</tr>
<tr>
<td>Postoperative exodeviation (PD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>0.78±0.70</td>
<td>−3.62±0.69</td>
<td>0.000</td>
</tr>
<tr>
<td>1 month</td>
<td>5.24±10.97</td>
<td>0.12±2.57</td>
<td>0.000</td>
</tr>
<tr>
<td>3 months</td>
<td>7.97±11.39</td>
<td>0.65±2.90</td>
<td>0.000</td>
</tr>
<tr>
<td>6 months</td>
<td>10.08±12.25</td>
<td>1.09±3.70</td>
<td>0.000</td>
</tr>
<tr>
<td>1 year</td>
<td>9.43±13.44</td>
<td>2.18±5.53</td>
<td>0.004</td>
</tr>
<tr>
<td>2 years</td>
<td>9.52±11.61</td>
<td>4.65±6.74</td>
<td>0.081</td>
</tr>
<tr>
<td>Final follow-up visit</td>
<td>11.11±11.52</td>
<td>4.05±5.76</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Group A: Large-angle exotropia (>40 PD).
Group B: Moderate-angle exotropia (≥20 and <30 PD).
* Mann–Whitney U test.
n, number; PD, prism dioptres.

### Table 5 Postoperative surgical success rates

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n=40)</th>
<th>Group B (n=138)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative 1 month</td>
<td>29 (79%)</td>
<td>132 (96%)</td>
<td>0.000</td>
</tr>
<tr>
<td>Postoperative 3 months</td>
<td>25 (63%)</td>
<td>128 (96%)</td>
<td>0.000</td>
</tr>
<tr>
<td>Postoperative 6 months</td>
<td>22 (55%)</td>
<td>126 (94%)</td>
<td>0.000</td>
</tr>
<tr>
<td>Postoperative 1 year</td>
<td>21 (53%)</td>
<td>113 (87%)</td>
<td>0.000</td>
</tr>
<tr>
<td>Postoperative 2 years</td>
<td>11 (28%)</td>
<td>89 (78%)</td>
<td>0.029</td>
</tr>
<tr>
<td>Final follow-up visit</td>
<td>18 (45%)</td>
<td>110 (79%)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Group A: Large-angle exotropia (>40 PD).
Group B: Moderate-angle exotropia (≥20 and <30 PD).
* Pearson’s χ² test.
n, number; PD, prism dioptres.
It could be somewhat inaccurate. The age at onset between the information on age at onset in most cases depended on the history of patients with exodeviation. However, RR resulted in more favourable outcomes in patients with intermittent exotropia of large exodeviation. The finding that large-angle exodeviations within 50 PD could be successfully corrected in 71% of cases. For exodeviation larger than 50 PD, however, the reported success rate of two-muscle surgery was a mere 18%. Notwithstanding, Schwartz and Calhoun reported, for cases in which there were large amounts of recession, a success rate of 77% after BLR with possible abduction limitations. Kim et al. reviewing the long-term success rate of two-muscle surgical alignment in children with primary large-angle exotropia, found that BLR and RR affected similar overall surgical outcomes, though RR resulted in more favourable outcomes in patients with exodeviation ≥45 PD.

In the preoperative characteristics, there were significant differences in terms of the age at onset and stereoaucity. The information on age at onset in most cases depended on the history taking of parents or the referral record of primary care, and so it could be somewhat inaccurate. The age at onset between the two groups showed merely a baseline correlation (p=0.033); however, the age at surgery was not significantly different (p=0.142). Sensory status was evaluated by Titmus Stereotest and Worth 4-Dot test without prism base-in to neutralise the exodeviation. There were significant differences in the rate of fusion on Worth 4-dot test as well as good stereopsis on Titmus Stereotest between the two groups, as patients with a large angle of exodeviation generally tend to have poor control or reduced stereoaucity or their combination. Furthermore, none of the preoperative variables investigated, except preoperative angle of exodeviation, was found to be significantly associated with final surgical outcome.

The present study, unlike most of the previous investigations including patients representing diverse inclusion criteria, involved only children with intermittent exotropia of large exodeviation (≥40 PD) compared with those with moderate exodeviation (20 and <30 PD).

In the results, the mean angles of postoperative exodeviation at both distance and near were significantly greater in large-angle exotropia throughout the follow-up period, except for near exodeviation at postoperative 2 years, and the surgical success rate for large-angle exotropia was significantly lower. The Kaplan-Meier survival analysis results, moreover, showed better cumulative probabilities of surgical success for moderate-angle exotropia, which distinction was significant even when patients who had undergone the same surgical method were compared by preoperative angle. Surgeons should be aware of the possibility of unsuccessful outcome when treating patients with intermittent exotropia of large exodeviation.

The effect/dose ratio in both unilateral RR and BLR was greater in large-angle than in moderate-angle exotropia. The concept of the dose–response relationship in strabismus surgery was established in 1857 by von Graefe, and the degree/mm ratio (angle reduction per millimetre of surgery) was introduced in 1906 by von Plufk. Since those times, many surgical formulas have been proposed and the surgical table for exotropia was plotted. However, angles of exodeviation larger than 40 PD are yet debated with respect to dose, with considerable disagreement among authors. In our present study, the effect/dose ratio for both two-muscle surgeries was greater in large-angle exotropia, though direct comparison between the surgical outcomes was impossible due to the different calculation methods. This finding is compatible with a previous study’s finding of a stronger response to surgery for larger preoperative deviations in exotropic patients. We assume that more further studies on large-angle exotropia will establish a consensus on surgical doses for exodeviation greater than 40 PD.

Finally, the Kaplan-Meier survival analysis results showed no significant difference between patients of the same preoperative-angle group by surgical method (p=0.832, group A; p=0.499, group B, figure 1). This indicated that either the BLR or unilateral RR procedure can be adopted without preferences for moderate-angle or large-angle exotropia. Nonetheless, Kim et al. reported higher rates of successful alignment for unilateral RR than for BLR in patients with exodeviation greater than 45 PD. Proof of this hypothesis requires additional, prospective comparative analysis.

This study has some limitations. It was a retrospective study in which the surgeon determined the method of surgery without any specific policy; thus, even though the decisions were made without any preference, minor selection bias could have occurred. The results presented in this study, therefore, should be confirmed by further, prospective study. Further, for assessment of the ability to control, we scaled the control of

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**Table 6** Effect/dose ratios (PD/mm) after surgery

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n=40)</th>
<th>Group B (n=138)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR (n)</td>
<td>26</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Effect/dose ratio</td>
<td>2.60±0.64</td>
<td>2.17±0.37</td>
<td>0.000</td>
</tr>
<tr>
<td>BLR (n)</td>
<td>14</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Effect/dose ratio</td>
<td>2.37±0.48</td>
<td>2.08±0.55</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Group A: Large-angle exotropia (≥40 PD).
Group B: Moderate-angle exotropia (≥20 and <30 PD).
Effect/dose ratio: the corrected angle of deviation at postoperative 6 months divided by the sum of the amount of lateral rectus recession in each eye in BLR and by the sum of the amount of lateral rectus recession and medial rectus recession in RR.

*Mann–Whitney U test.

BLR, bilateral lateral rectus muscle recession; n, number; PD, prism dioptres; RR, unilateral lateral rectus muscle recession and medial rectus muscle recession.
exodeviation as good, fair or poor, according to the protocol introduced by Santiago et al. Recently, Molney and Holmes introduced a novel scale for assessment of control in intermittent exotropia that can easily be performed in the office-based setting and, additionally, can provide a quantitative measure for surgical planning. However, we could not apply this scale to our study, because we retrospectively reviewed the medical records of patients who had undergone the surgery between 2005 and 2014. Future study with this quantitative method would certainly be helpful. We assumed that minor selection bias could have occurred as the patients with shorter periods of follow-up than 6 months were dropped out according to inclusion criteria because the patients showing satisfactory results were less likely to visit the clinic after the surgery, and, conversely, those showing unfavourable results were more likely to have been followed up on longer. Another drawback, however, was the dose calculation method in the cases of unilateral RR, which entailed summing the amounts of lateral rectus muscle recession and medial rectus muscle resection. This approach is problematic, because recession is more effective in reducing deviation than resection, in that recession alters the tangential point of the muscle. Strictly speaking then, summing the amounts of recession and resection is incorrect, though it could be justified for comparative purposes given that we performed the operations according to the respective surgical dosages listed in Table 1.

In conclusion, the children with large-angle intermittent exotropia showed, compared with the moderate-angle exotropia cases, significantly higher under-correction rates but also greater effects of BLR or RR per millimetre (the effect/dose ratio). For successful surgical alignment of large-angle exotropia, increased-dose two-muscle or even three-muscle surgery should be considered as a treatment option.

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