Meningomyelecele (MMC) is the most common congenital fusion defect of the neural tube and is characterized by defects of the spinal cord, vertebrae, and overlying skin. Its incidence is 1 in every 800–1000 live births.\textsuperscript{11,20} The mortality rate in the first 6 months of life is 65%–70% in untreated patients.\textsuperscript{2} It is important to close MMC defects in the early postnatal period to decrease mortality rates by providing protection for neural elements and preventing CSF leakage and related central nervous system infections.\textsuperscript{2,19} Most MMC defects can be closed primarily, but this may not be possible in all cases.\textsuperscript{22} For the reconstruction of large defects that cannot be closed primarily, skin grafts, skin flaps, fasciocutaneous flaps, muscle flaps, and musculocutaneous flaps have been used for closure of large meningomyelecele (MMC) defects that cannot be closed primarily. The V-Y rotation advancement flap technique has been used successfully for the reconstruction of defects in different areas of the body. In the present study, the authors report on their novel use of this technique in both a binary and a quadruple (butterfly) flap manner for closure of large MMC defects. They also present an algorithm that they developed for the evaluation of MMC defects.

OBJECT Skin grafts, skin flaps, fasciocutaneous flaps, muscle flaps, and musculocutaneous flaps have been used for closure of large meningomyelecele (MMC) defects that cannot be closed primarily. The V-Y rotation advancement flap technique has been used successfully for the reconstruction of defects in different areas of the body. In the present study, the authors report on their novel use of this technique in both a binary and a quadruple (butterfly) flap manner for closure of large MMC defects. They also present an algorithm that they developed for the evaluation of MMC defects.

METHODS Between January 2011 and November 2013, 17 patients (13 girls and 4 boys) with extremely large MMC defects that could not be repaired by direct primary closure underwent reconstruction of the defects with binary and quadruple V-Y rotation and advancement flaps. With the patient prone, the axillary apices, the most craniad point of the intergluteal sulcus, and the posterior axillary lines were marked, and a rectangular area on the back was designed. Edges of the rectangular area and the transverse and longitudinal diameters of the defect were measured and the presence of kyphosis was noted. These measurements and their proportions were used to develop an algorithm for patient assessment. While binary flaps were planned over the transverse diameter of the defects, quadruple flaps were planned over the bisectors of the defects, which were closed by elevating fasciocutaneous flaps.

RESULTS For patients whose defect diameter to back width ratio was between 0.30 and 0.50 and whose mean ratio of defect area to donor area was between 0.09 and 0.15, binary V-Y rotation and advancement flaps were used. When these values were in the range of 0.50–0.66 and 0.16–0.35, respectively, quadruple V-Y rotation and advancement flaps were preferred. The mean duration of postoperative follow-up was 10.4 months. With the exception of minor complications, such as partial necrosis of 0.5 × 0.5 cm in a quadruple flap, all the flaps healed uneventfully.

CONCLUSIONS With this study, closure of MMC defects with V-Y rotation and advancement flaps has been defined for the first time in the literature. The use of this technique with multiple flaps is an effective alternative to other flap options for the closure of large MMC defects. The algorithm developed in the course of this study should facilitate evaluation and reconstruction planning for patients with MMC defects.


KEY WORDS meningomyelecele; V-Y rotation and advancement flap; surgical technique; congenital
be closed primarily, skin grafts, skin flaps, fasciocutaneous flaps, muscle flaps, and musculocutaneous flaps have been used. Purse-string closure, autologous amnion graft, and closure with tissue expanders can also be used for reconstruction.7,9,24

In this paper we report on the use of the V-Y rotation advancement flap—a technique that has been successfully used for the reconstruction of defects in different areas of the body—in a binary-flap and quadruple-flap (butterfly technique) manner for the closure of large MMC defects in a consecutive series of 17 patients. V-Y rotation and advancement flap use for the reconstruction of MMC defects has not been discussed in the literature; it was used in a multiple flap manner for the first time for this indication in our case series.

We also present an algorithm that we developed for the evaluation of MMC defects during the treatment of these patients.

Methods

Seventeen patients (13 girls and 4 boys) with extremely large MMC defects that could not be closed by direct primary closure were treated at our institution between January 2011 and November 2013 and are included in this study (Tables 1 and 2). All surgery was performed with the patients in a state of general anesthesia, and the MMC repair was performed with the patients prone. Patients who had hydrocephalus had ventriculoperitoneal shunts placed by the neurosurgery team before being placed in the prone position for repair of the MMC defect. The MMC sac was incised and the nerve fibers attached to the sac were separated by microdissection under the surgical microscope. Dural leaves adherent to the surrounding tissue were elevated and then a dural sac was created by watertight saturation in a continuous fashion with 4-0 Vicryl. To strengthen the watertight closure and create an additional barrier to prevent CSF leakage, 2 ml of fibrin sealant glue (Tisseel kit, Baxter) was used over the suture line. After this stage, the plastic surgery team was included in the operation to close the defect. The axillary apices, the most cranial point of the intergluteal sulcus, and the posterior axillary lines were marked when the patient was prone with the arms placed in 90° abduction. The perimeter of a rectangular area demarcated by a line connecting the axillary apices and a line across the child’s back passing through the most cranial point of the intergluteal sulcus was considered to be the limit of the surgical procedure to be performed. The transverse and longitudinal dimensions of the rectangle were recorded. The transverse and longitudinal dimensions of the defect were also measured, and the presence of kyphosis was documented (Fig. 1A and B and Fig. 2). These measurements were used to calculate two ratios, which are used in our treatment planning algorithm: 1) transverse diameter of the defect/transverse length of the back, and 2) defect area/donor area ratio. (This second ratio was calculated by means of Digimizer image analysis software [MedCalc Software].)

After the measurements were obtained, planning of the flaps was performed: every V-Y rotation and advancement flap was planned over the horizontal axis of the defect, with the flap length set at 1.5 times half of the transverse

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Pl. Age, Sex</th>
<th>Localization</th>
<th>Status</th>
<th>Defect Transverse Diameter/Back Width</th>
<th>Amt. of Bleeding</th>
<th>Op. Time (min)</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 days, M</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>5 x 3</td>
<td>0.30</td>
<td>30</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>10 days, F</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>6 x 3</td>
<td>0.33</td>
<td>45</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>5 days, F</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>5 x 4</td>
<td>0.38</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>7 days, F</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>4 x 3.5</td>
<td>0.60</td>
<td>10</td>
<td>—</td>
</tr>
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<td>17 days, F</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>5 x 4.5</td>
<td>0.60</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>15 days, M</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>5 x 4</td>
<td>0.40</td>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>7 days, M</td>
<td>Thoracolumbar Paraplegic</td>
<td>Paraplegic Shunt + 2 V-Y rotation advancement flap</td>
<td>5 x 3.7</td>
<td>0.39</td>
<td>51</td>
<td>—</td>
</tr>
</tbody>
</table>

Mean 10 days

* Amt. amount = neurological; pt = patient.
** Back length = back length with 90° abduction.
† Duration of surgery from the time of involvement of the plastic surgery team as described in Methods.

TABLE 1. Detailed documentation of the patients and defects reconstructed with binary V-Y rotation and advancement flap

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diameter of the defect (Fig. 1C). When performing the quadruple V-Y rotation and advancement flap (butterfly) technique, every flap was planned over the bisector of the horizontal and longitudinal axes of the defect, with the flap length being 1.5 times half the length of each bisector (Fig. 1D).

During the planning of the flaps in both techniques, to obtain wider distal edges than standard V-Y rotation and advancement flaps, flap arms were drawn with a slight curve instead of a straight line exteriorly. The length of the short arms of the flaps was determined in a cut-as-go style according to the mobilization need of the flaps. Since the drawing of the quadruple flap resembles a butterfly, we call it the butterfly technique (Fig. 3A–E).

In both techniques, incisions were made up to the latissimus dorsi fascia and thoracolumbar fascia. These fascias were included in the flaps. Dissection was started from the medial side and continued until a tension-free closure was possible. In patients with kyphosis, wider dissection was performed by protecting the paraspinal perforators.

After meticulous hemostasis with bipolar cauterization, single-layer closure was accomplished with 5–0–6–0 poliglecaprone 25 (Monocryl, Ethicon). To increase the attachment of the flaps to the base, 2 ml fibrin sealant glue (Tisseel kit, Baxter) was applied to the undersurface of flaps before the final closure. Drains were not used (Figs. 4A–C, 5, and 6).

**Results**

The average size of the 11 thoracolumbar defects that were reconstructed with the quadruple-flap technique was 37.6 cm², and the average size of the 6 thoracolumbar defects reconstructed with the binary-flap technique was 14.3 cm². The demographic characteristics and neurological status of the patients, defect locations, duration of the operation after involvement of the plastic surgery team, and intraoperative blood loss are shown in Tables 1 and 2.

The mean size of the defect area, the mean ratio of defect diameter to back width, and the mean ratio of defect area/donor area were, respectively, 7.5 × 6.3 cm² (range 5 × 5 cm² to 10 × 8 cm²), 0.59 (range 0.50–0.66), and 0.24 (range 0.16–0.35) in the group treated with quadruple V-Y rotation and advancement flap (Table 2).

In the group treated with binary V-Y rotation and advancement flap, the mean size of the defect area was 5 × 3.7 cm² (range 4 × 3.5 cm² to 5 × 4.5 cm²), the mean ratio of defect diameter to back width was 0.39 (range 0.30–0.50), and the mean ratio of defect area/donor area was 0.12 (range 0.09–0.15) (Table 1).

The mean duration of follow-up was 10.4 months (range 3–12 months).

In the early postoperative period, in a patient treated with quadruple flap reconstruction, detachment occurred on the donor side of the inferior flap, which was closed with a single suture. In one other patient treated with quadruple flap reconstruction, an area of partial necrosis (0.5 × 0.5 cm) developed on the distal side of the right superior flap; this was left to secondary healing. No other complications were detected. Cerebrospinal fluid leakage was not seen in any case, and all patients healed uneventfully.
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Pt Age/Sex</th>
<th>Localization</th>
<th>Neurol Status</th>
<th>Op</th>
<th>Defect Area Size (cm)</th>
<th>Donor Area Size (cm)†</th>
<th>Defect Transverse Diameter/Back Width</th>
<th>Defect Area (cm²)</th>
<th>Donor Area (cm²)</th>
<th>Defect Area/Donor Area</th>
<th>Op Time (min)</th>
<th>Amt of Bleeding (ml)</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 days, F</td>
<td>Thoracolumbar</td>
<td>Paraplegic</td>
<td>4 V-Y rotation advancement flap</td>
<td>6 × 6.5</td>
<td>14.5 × 10</td>
<td>0.65</td>
<td>30.6</td>
<td>145</td>
<td>0.21</td>
<td>65</td>
<td>18</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>45 days, F</td>
<td>Thoracolumbar</td>
<td>Paraplegic</td>
<td>4 V-Y rotation advancement flap</td>
<td>8 × 7</td>
<td>20 × 14</td>
<td>0.50</td>
<td>44.0</td>
<td>280</td>
<td>0.16</td>
<td>70</td>
<td>18</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>7 days, M</td>
<td>Thoracolumbar</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>9 × 5.5</td>
<td>14 × 9</td>
<td>0.61</td>
<td>38.8</td>
<td>126</td>
<td>0.30</td>
<td>65</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>60 days, F</td>
<td>Thoracolumbar</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>10 × 8</td>
<td>18 × 13</td>
<td>0.61</td>
<td>62.8</td>
<td>234</td>
<td>0.27</td>
<td>75</td>
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<td>5</td>
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<td>Thoracolumbar</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>8 × 6</td>
<td>12 × 9</td>
<td>0.66</td>
<td>37.7</td>
<td>108</td>
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<td>55</td>
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<td>6</td>
<td>12 days, F</td>
<td>Thoracolumbar + kyphosis</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>8 × 6</td>
<td>13 × 9</td>
<td>0.66</td>
<td>37.7</td>
<td>117</td>
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<td>16 days, F</td>
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<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>5 × 5</td>
<td>12 × 10</td>
<td>0.50</td>
<td>19.6</td>
<td>120</td>
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<td>10</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>7 days, F</td>
<td>Thoracolumbar + kyphosis</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>7.5 × 6.5</td>
<td>14 × 11</td>
<td>0.59</td>
<td>38.3</td>
<td>154</td>
<td>0.25</td>
<td>60</td>
<td>12</td>
<td>Detachment</td>
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<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>6 × 7</td>
<td>16 × 12</td>
<td>0.58</td>
<td>33.0</td>
<td>192</td>
<td>0.17</td>
<td>70</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>3 days, M</td>
<td>Thoracolumbar + kyphosis</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>8 × 6</td>
<td>14 × 11</td>
<td>0.55</td>
<td>37.7</td>
<td>154</td>
<td>0.25</td>
<td>65</td>
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<td>Partial distal necrosis</td>
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<td>Thoracolumbar</td>
<td>Paraplegic</td>
<td>Shunt + 4 V-Y rotation advancement flap</td>
<td>7 × 6</td>
<td>15 × 11</td>
<td>0.55</td>
<td>33.0</td>
<td>165</td>
<td>0.20</td>
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<td>10</td>
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<tr>
<td>Mean</td>
<td>22 days</td>
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<td></td>
<td>7.5 × 6.3</td>
<td>14.8 × 9.9</td>
<td>0.59</td>
<td>37.6</td>
<td>163</td>
<td>0.24</td>
<td>62</td>
<td>16</td>
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</tr>
</tbody>
</table>

* Vertical × transverse.† Back length × back width.
Discussion

The aims of surgical treatment of patients with MMC in the early postnatal period are to cover exposed spinal cord, to prevent CSF leakage, and to decrease the mortality rate by protecting the patient from central nervous system infections through a combined use of neurosurgery and plastic surgery interventions. When the limited dermal circulation pattern of the newborn skin is kept in mind, the use of excessive force to achieve primary closure of large MMC defects can cause complications such as wound dehiscence, fistula, and necrosis related to wound tension and extensive skin mobilization, which may require secondary operations.

Review of the English literature showed that primary intervention is recommended for the closure of MMC defects smaller than 5 cm in diameter. Luce and Walsh have stated that they reconstructed defects with an average size of 22.7 cm² primarily. In a similar manner, in their article describing more than 10 years’ experience, Müslüman et al. stated that defects up to 24 cm² could be closed primarily. Özveren et al. separated MMC defects into 2 groups and reported that when the defect area/thoracolumbar area ratio is less than 0.08, primary closure can be performed.

Based on the retrospective analysis of our measurements, we believe that defect area or defect diameter should not be used as a criterion for decisions regarding reconstruction. We agree with Özveren et al. that the ratio of the defect area to the thoracolumbar area is important for the evaluation of the defect, but because there may be different defects with the same area related to the variability of the shape and the longitudinal and transverse diameters of the defect, we think that the ratio of the transverse diameter of the defect to the back width can be a more practical and determinative way to evaluate the defects. In addition, we want to emphasize that the presence of vertebral kyphosis can affect the decision of how to close

FIG. 3. Case 1. A–C: Intraoperative photographs showing planning of the flaps (A), elevation of the superior flaps (B), and elevation of the inferior flaps (C). D: Postoperative photograph obtained immediately after surgery. E: Photograph obtained 4 months after surgery. Figure is available in color online only.

FIG. 4. Case 2. A: Preoperative photograph; kyphosis is present. B: Postoperative photograph obtained 1 year after surgery. C: Left lateral view at 1 year after surgery showing kyphosis. Figure is available in color online only.
the defect by increasing the dimensions and complicating the problem. At this point, we believe that the algorithm we have defined by using the data obtained from this case series can be used for the evaluation of MMC defects and selection of the treatment modality (Fig. 7).

Skin grafting is a simple procedure for MMC defects that cannot be closed primarily. The incidence of graft loss, CSF leakage, and sepsis has been reported to be low, but late-term complications like Gibbus deformity, ulceration, and infection can be seen, and these can increase the need for secondary operations.

Muscle and musculocutaneous flaps have been successfully used for the reconstruction of MMC defects, and bilateral latissimus dorsi muscle flap, bipedicled thoracolumbar musculocutaneous flap, latissimus dorsi and gluteus maximus muscle advancement flaps, bilateral V-Y musculocutaneous advancement flaps, Limberg musculocutaneous flap, and reverse latissimus dorsi muscle flap have all been used. Muscle flaps have very good blood circulation in addition to their capacity to provide excellent soft tissue padding. Nevertheless, they also have disadvantages, such as longer duration of operation and increased hemorrhage due to muscle dissection. In addition, there is a risk of functional loss after use of the latissimus dorsi, and this can cause serious problems for paraplegic and wheelchair-bound patients.

Another option for the reconstruction of MMC defects is tension-free closure by means of cutaneous or fasciocutaneous flaps, including delayed flap, double rhomboid Z-plasty, V-Y advancement flap, rotation flaps, Limberg flap, and bipedicled flaps. Thomas initially described successful results with the fasciocutaneous triangular advancement flap and protection of the latissimus dorsi. Cruz and colleagues reported on their closure of medium to large defects by using random-pattern double-Z rhomboid flaps. Mutaf et al. reported successful reconstruction of large defects with unequal Z-plasties. Ulusoy et al. reported good results through use of the V-Y advancement flap with apical extensions of the V flap’s modification.

In this study, we used V-Y rotation and advancement flaps in a binary and quadruple manner for the reconstruction of MMC defects. The V-Y rotation and advancement flap was defined by Argamaso in 1974. It was subsequently used successfully for the treatment of defects in different areas of the body, including decubitus ulcers, scalp defects, pilonidal sinus defects, and fingertip amputations. In this technique, skin incisions are shorter than the classical V-Y advancement flap. In addition, while the advancement of the flap increases rotation by decreasing the tension at the pivot point of the classical rotation flap, rotation of the flap also helps to achieve tension-free closure by increasing the advancement. Thus, mobilization capacity and safety of the flap can be increased by combining the advantages of both rotation and advancement in a single procedure. For the reconstruction of a specific defect like MMC in newborns, we believe that binary and quadruple V-Y rotation and advancement flaps are good alternatives that afford increased mobilization capacity and safety. They also bring such advantages as protection of muscle function, less blood loss, shorter operative time, and ease of performance. Using multiple flaps for the reconstruction of large MMC defects instead of one single large flap provides the closure of donor area without a need for grafting by distributing the donor area in a balanced manner. Also it decreases the empty dead space and provides closure with safe flaps without jeopardizing the circulation, thus decreasing complication rates.
Conclusions

The V-Y rotation and advancement flap, with either a binary or multiple flap technique, can be used safely for MMC defects and represents a good alternative to other defined techniques. According to our experience, evaluation of MMC defects using only defect diameter or defect area is not sufficient. Using the proportion of these values to the measurements of the back region increases the chance of successful reconstruction. Also during the evaluation of MMC defects, the presence of kyphosis is a problem that directly affects the defect dimensions and repair options.

References
14. McCraw JB, Penix JO, Freeman BG, Vincent MP, Wirth FH:


Author Contributions
Conception and design: Kankaya. Analysis and interpretation of data: Oruç, Kankaya, Çolak Aslan, Ozer. Drafting the article: Ozer. Critically revising the article: Oruç, Karaaslan. Administrative/technical/material support: Karatay, Gürsoy. Study supervision: Oruç, Sungur, Ulusoy, Karaaslan, Koçer.

Supplemental Information
Previous Presentation
This study was presented as an oral presentation at the 8th BAPRAS Congress in Budva, Montenegro, on September 2013.

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