Treatment and prevention of tethered and retethered spinal cord using a Gore-Tex surgical membrane

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The incidence of the tethered cord syndrome after repair of spinal dysraphism is not insignificant. A re-tethered spinal cord may also develop after an untethering operation. In order to treat and/or prevent the tethered and retethered spinal cord, the authors developed and successfully used a new method in 12 cases. After complete release and reconstruction of the spinal cord, a Gore-Tex surgical membrane was placed over the cord and fixed to the lateral dural surface with stay sutures. During a postoperative follow-up period ranging from 23 months to 7 years, no further neurological deterioration was observed in the 12 patients and magnetic resonance imaging studies showed no adhesion of the spinal cord to the operative site. It is concluded that this simple new method is effective for the treatment and prevention of tethering and/or retethering of the spinal cord, although a longer follow-up study is required.

Key Words • tethered spinal cord • spinal dysraphism • operative technique • Gore-Tex surgical membrane

Late neurological deterioration due to tethering of the spinal cord, termed “tethered cord syndrome,” is widely recognized in patients with spinal dysraphism. Recently, retethering of the spinal cord has been shown in patients with lipomyelomeningocele after initial repair. The causal mechanism of tethered cord syndrome is somewhat complicated, especially in patients with surgical repair of spinal dysraphism. Neuroradiological examinations have shown evidence of tethering not only in patients with the syndrome but in those without neurological deterioration as well.

The surgical procedure for the treatment of tethered cord is release of the spinal cord. This is usually sufficient for treating a tight filum terminale; however, the cord may become retethered after repair of a lipomyelomeningocele or myelomeningocele. Prevention of this problem should be considered at the time of primary cord release in cases of lipomyelomeningocele or myelomeningocele.

We have developed a simple new method of treating the tethered spinal cord and preventing its recurrence, and have successfully applied it in 12 patients. The operative technique and follow-up study are described in this report.

Clinical Material and Methods

Patient Population

Between July, 1986, and September, 1991, 12 patients underwent surgery for release and/or prevention of a tethered cord. The diagnosis of tethered cord was made via neuroradiological examination, including magnetic resonance (MR) imaging, obtained after the patients suffered neurological deterioration. Surgery to prevent tethering of the cord was performed in all patients, including eight patients after an initial repair for spinal dysraphism. After surgery, all patients were followed regularly for a period ranging from 23 to 85 months (mean 45.2 months). Follow-up evaluation included careful neurological examinations and T1- and T2-weighted MR imaging studies.

Operative Technique

After microsurgical untethering of the spinal cord (Fig. 1A and B), as much lipomatous and/or scar tissue as possible was carefully removed. All spinal roots in the affected area were exposed and identified at the exit zone of the vertebral foramen from the rostral normal roots to the caudal filum terminale. After spinal reconstruction or conus reconstruction was performed (Fig. 2A), a surgical membrane constructed of expanded polytetrafluoroethylene (Gore-Tex) and trimmed to the proper size was placed over the reconstructed spinal cord and attached to the lateral dural surface with stay sutures to prevent slipping (Figs. 1C and 2B). When the dura mater was insufficient for a primary dural closure, paravertebral fascia was used for the dural plasty. The area of laminar defects was covered and reinforced with paravertebral muscle (Fig. 1D).
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FIG. 1. Schematic representation of the operative procedure. A and B: Untethering of the spinal cord. The arachnoid may be preserved in cases of myelomeningocele, but not in most cases of lipomyelomeningocele. Complete untethering is important, although total removal of lipomatous tissue is not necessary when the risk of causing neurological deficits is possible. SA = subarachnoid space. C: The surgical Gore-Tex membrane (GTx) is placed over the reconstructed spinal cord and fixed with stay sutures to the lateral dural surface. D: Dural closure should be completely watertight, especially in cases with arachnoid deficits. As the surgical membrane does not adhere to the surrounding tissues, cerebrospinal fluid leakage should be prevented by primary suture closure. Paravertebral fascia is used for the dural plasty if the dura mater is insufficient. M = paravertebral muscle.

FIG. 2. Intraoperative photographs showing the procedure for prevention of tethered cord. A: All spinal roots in the affected area are exposed and conus reconstruction is performed. B: The Gore-Tex surgical membrane is placed over the reconstructed spinal cord and attached to the dura mater with stay sutures.

Results

Treatment of Tethered and Retethered Spinal Cord

Four patients in our series showed late neurological deterioration after initial repair of spinal dysraphism (Table 1). One patient (Case 3) showed repeat tethered cord syndrome after initial untethering and repair of a myelomeningocele. The presentation of the recurrent syndrome was the same as the initial presentation. Neuroradiological studies of the four patients revealed scoliosis in one patient and tethering of the spinal cord in four. The tethering was accompanied by a tight stretching of the spinal cord, a low conus medullaris, and a dorsal attachment of the spinal cord to the dysraphic operative site (Fig. 3A and B).

All four patients had dense adhesions between the dorsal surface of the spinal cord and the overlying dura and scar tissue, although two had undergone conus reconstruction at initial operation. After complete untethering, three patients (Cases 1, 3, and 4) showed rostral relocation of the conus medullaris. In the remaining patient (Case 2), the conus remained in the same position; the spinal roots were tight and seemed to anchor the spinal cord in this patient. Surgery to prevent retethering of the cord was performed using the technique described above in all four cases.

The postoperative clinical course is summarized in Table 1. One patient (Case 3) showed improvement of the syndrome identical to that noted during the postoperative course of the initial repair. The other three patients suffered no further neurological deterioration. No complications except one transient bladder dysfunction (in Case 1) were observed after the procedure. Postoperative neuroradiological studies revealed no adhesions of the cord to the operative site. Although the conus medullaris remained low in all four patients, rostral relocation of the cord was observed in three patients on MR imaging. Follow-up studies for up to 7 years showed no adhesions of the spinal cord to the repair site (Fig. 3C and D).

Prevention of Tethered Cord at Initial Repair

Eight patients with spinal dysraphism underwent operation by this method for prevention of postoperative tethered cord (Table 2). Four had cerebrospinal fluid (CSF) leakage due to a myelomeningocele or myeloschisis and an emergency operation was performed for the initial repair. The other four had lipomatous lesions and underwent the procedure for untethering of the spinal cord. Preoperative MR imaging was performed in three patients with lipomatous lesions. A low conus medullaris and adhesion of the spinal cord to the lipomatous lesions were observed in all three patients (Fig. 4A and B). Tethering of the spinal cord was not tighter than in those with tethered cord syndrome as described previously.

In four patients with a myelomeningocele or myeloschisis, the spinal cord moved ventrally but not rostrally after reconstruction. Even in the cases of lipomatous lesions, rostral relocation of the cord was not observed after complete untethering. However, the spinal roots were not tight after reconstruction in these
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### TABLE 1

Clinical summary for four patients with tethered cord syndrome after repair of spinal dysraphism

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Age at 1st Op</th>
<th>Type of Dysraphism*</th>
<th>Interval Between Ops (mos)</th>
<th>Outcome</th>
<th>Follow-Up Period (mos)</th>
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<tr>
<td>1</td>
<td>2, F</td>
<td>lipomyelomeningocele</td>
<td>26</td>
<td>unchanged</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>4, F</td>
<td>myelocele</td>
<td>50</td>
<td>unchanged</td>
<td>84</td>
</tr>
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<td>3</td>
<td>40, F</td>
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<td>52</td>
<td>improved</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>7, M</td>
<td>lipomyelomeningocele</td>
<td>44</td>
<td>unchanged</td>
<td>37</td>
</tr>
</tbody>
</table>

* Classification according to Inoue, et al.*

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Eight patients. In one patient (Case 10), the lipomatous lesion was located lateral to the spinal cord, and a Gore-Tex surgical membrane was placed laterally for prevention of cord adhesion.

The postoperative clinical course of the eight patients is summarized in Table 2. No complications were observed in any of the patients. No neurological deterioration was found 23 to 55 months after surgery. Postoperative and follow-up MR imaging studies showed a low conus medullaris in all eight patients; however, there were no cases of adhesion of the spinal cord.

### TABLE 2

Clinical summary for eight patients who underwent prevention of spinal cord tethering at the initial repair for dysraphism

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age, Sex</th>
<th>Type of Dysraphism*</th>
<th>Outcome</th>
<th>Follow-Up Period (mos)</th>
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<tr>
<td>5</td>
<td>1 day, F</td>
<td>myelocele</td>
<td>unchanged</td>
<td>55</td>
</tr>
<tr>
<td>6</td>
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<td>unchanged</td>
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<td>7</td>
<td>6 days, F</td>
<td>lipomyelomeningocele</td>
<td>unchanged</td>
<td>43</td>
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<tr>
<td>8</td>
<td>1 mo, M</td>
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<td>unchanged</td>
<td>40</td>
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<td>9</td>
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<td>unchanged</td>
<td>34</td>
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<td>10</td>
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<td>unchanged</td>
<td>32</td>
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<tr>
<td>11</td>
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<td>unchanged</td>
<td>26</td>
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<tr>
<td>12</td>
<td>3 wks, F</td>
<td>lipomyelomeningocele</td>
<td>unchanged</td>
<td>23</td>
</tr>
</tbody>
</table>

* Classification according to Inoue, et al.*
to the repair site (Fig. 4C). Partial contact of the spinal cord to the lipomatous lesion at the upper level of the repair site was observed in one patient.

Discussion

Tethered and Retethered Spinal Cord

This series includes four cases of tethered cord syndrome that developed after initial repair of spinal dysraphism. Magnetic resonance images of these patients showed tethering and tight stretching of the spinal cord. The actual existence of tethered cord at the time of initial repair was not obvious in three patients because preoperative MR studies at the initial evaluation had not been performed. However, in one patient, typical tethered cord was evident on both initial and follow-up MR studies prior to surgery. Actual retethered spinal cord was recognized with repeat tethered cord syndrome in this patient. This indicates that a procedure to prevent cord retethering is necessary at the time of the initial untethering operation. Moreover, we propose a limited use of the term "retethered spinal cord" for verified cases, because tethering of the spinal cord with a low conus is not always present at the time of initial repair.

Treatment of Tethered Cord and Prevention of Retethered Cord

We treated three patients with tethered cord syndrome by the usual technique without applying a surgical membrane. One suffered recurrence of tethered spinal cord syndrome 4 years postoperatively, with the same symptoms and findings on MR imaging. This patient underwent reoperation to release the spinal cord and to prevent repeat tethering as described in this report. The four patients in our series were successfully treated with this new method.

Prevention of Tethered Cord at Initial Repair for Spinal Dysraphism

The exact incidence of tethered cord syndrome after repair of spinal dysraphism has not been determined, because other overlapping factors contribute to the clinical spectrum. However, as the reported percentage is not insignificant, we believe that prevention of tethering should be performed at the time of initial repair. A total of six cases of tethered cord syndrome after initial repair by the usual technique were found. Although the postoperative monitoring period for our series is of intermediate length, follow-up MR images have shown no adhesion of the spinal cord to the repair site after application of this new technique. Our method is simple, nonradical, and useful for patients with a shallow and widely bifid spinal canal, a condition that makes it difficult to relocate the spinal cord anteriorly. This also means that complete removal of a lipomatous lesion is not necessary in patients with lipomyelomeningocele who have a shallow spinal canal. The surgical risk may be decreased by this procedure.

Operative Procedure and Surgical Membrane

The usual spinal cord or conus reconstruction method prevents tethered cord after repair of spinal dysraphism in some patients, but may not be preventative in others. Interruption of contact between the reconstructed spinal cord and the dural sac prevents tethering of the cord when a material is used that will not adhere to the surrounding tissue. The Gore-Tex surgical membrane was developed for cardiovascular surgery to prevent tissue adhesions, which has been documented after long-term follow-up monitoring in this field. Our results also show no adhesions on MR imaging studies to date; however, long-term follow-up monitoring will be required. The Gore-Tex membrane is also useful as artificial dura mater in preventing the adhesion of brain tissue to the repair site. The efficacy of the membrane for a period of at least 15 months has been reported in a series of reoperated patients. In an experimental study on repair of spinal dural defects, Keller et al., have reported that neural tissues showed adhesion to silicone-coated Dacron but not to a polyester fiber mesh. It is possible that a polyester fiber mesh may also prevent the adhesion of the spinal cord to the operative site in patients with tethered or retethered spinal cord.

Conclusions

In order to prevent spinal cord becoming retethered after earlier release and to prevent tethered cord at initial repair of spinal dysraphism, we developed a simple new procedure using a Gore-Tex surgical membrane. Clinical and MR imaging studies reveal the effectiveness of this technique for periods of up to 7 years after the operation. Although long-term follow-up study is required, application of this technique will decrease the incidence of tethered cord syndrome after repair.

References

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