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ORIGINAL ARTICLE

Increased complications without neurological benefit are associated with prophylactic spinal cord untethering prior to scoliosis surgery in children with myelomeningocele

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Abstract

Purpose Children with myelomeningocele (MMC) are at increased risk of developing neuromuscular scoliosis and spinal cord re-tethering (Childs Nerv Syst 12:748-754, 1996; Neurosurg Focus 16:2, 2004; Neurosurg Focus 29:1, 2010). Some centers perform prophylactic untethering on asymptomatic MMC patients prior to scoliosis surgery because of concern that additional traction on the cord may place the patient at greater risk of neurologic deterioration peri-operatively. However, prophylactic untethering may not be justified if it carries increased surgical risks. The purpose of this study was to determine if prophylactic untethering is necessary in asymptomatic children with MMC undergoing scoliosis surgery.

Methods A multidisciplinary, retrospective cohort study from seven children's hospitals was performed including asymptomatic children with MMC < 21 years old, managed with or without prophylactic untethering prior to scoliosis surgery. Patients were divided into three groups for analysis: (1) untethering at the time of scoliosis surgery (concomitant untethering), (2) untethering within 3 months of scoliosis surgery (prior untethering), and (3) no prophylactic untethering. Baseline data, intra-operative reports, and 90-day post-operative outcomes were analyzed to assess for differences in neurologic outcomes, surgical complications, and overall length of stay.

Results A total of 208 patients were included for analysis (mean age 9.4 years, 52% girls). No patient in any of the groups exhibited worsened motor or sensory function at 90 days post-operatively. However, comparing the prophylactic untethering groups with the group that was not untethered, there was an increased risk of surgical site infection (SSI) (31.3% concomitant,

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28.6% prior untethering vs. 12.3% no untethering; $p = 0.0104$), return to the OR (43.8% concomitant, 23.8% prior untethering vs. 17.4% no untethering; $p = 0.0047$), need for blood transfusion (51.6% concomitant, 57.1% prior untethering vs. 33.8% no untethering; $p = 0.04$), and increased mean length of stay (LOS) (13.4 days concomitant, 10.6 days prior untethering vs. 6.8 days no untethering; $p < 0.0001$). In multivariable logistic regression analysis, prophylactic untethering was independently associated with increased adjusted relative risks of surgical site infection (aRR = 2.65, 95% CI 1.17–5.02), unplanned re-operation (aRR = 2.17, 95% CI 1.02–4.65), and any complication (aRR = 2.25, 95% CI 1.07–4.74).

Conclusion In this study, asymptomatic children with myelomeningocele who underwent scoliosis surgery developed no neurologic injuries regardless of prophylactic untethering. However, those who underwent prophylactic untethering were more likely to experience SSIs, return to the OR, need a blood transfusion, and have increased LOS than children not undergoing untethering. Based on these data, prophylactic untethering in asymptomatic MMC patients prior to scoliosis surgery does not provide any neurological benefit and is associated with increased surgical risks.

Keywords Myelomeningocele · Scoliosis · Tethered cord release · Prophylactic untethering

Introduction

Myelomeningocele (MMC), an open neural tube defect resulting from incomplete closure of the neural tube during primary neurulation, occurs in approximately 1–2 per 1000 live births globally, and 0.6 per 1000 live births in regions of folate fortification [1]. Despite untethering of the spinal cord at the time of initial closure of the MMC, up to one-third of patients will experience symptomatic cord re-tethering during their lifetime [2–4]. Clinical re-tethering may present with progressive or worsening sensory loss; motor weakness; bowel or bladder dysfunction; orthopedic deformities, including worsening or new-onset scoliosis; or a combination of any of the above. Radiographically, the vast majority of MMC patients appear to have a low-lying conus, consistent with radiographic spinal cord tethering. In symptomatic children, additional surgery for untethering often leads to clinical improvement, but the benefit of prophylactic untethering in asymptomatic children is much less clear [3, 5–7].

In addition to re-tethering, children born with MMC are at an increased risk of developing neuromuscular scoliosis, which has a reported prevalence of 23–88% among MMC patients [8, 9]. Scoliosis can compromise ambulation, sitting stability, pulmonary function, and cause pain. While simple tethered cord release (TCR) may halt curve progression in mild cases, [6, 10, 11] many MMC patients will develop progressive scoliosis and require corrective surgery during childhood or adolescence.

Given the high prevalence of radiographic cord tethering among MMC patients, some surgeons believe that the spinal column lengthening that may occur during scoliosis corrective surgery can exert additional traction on the spinal cord and place the patient at increased risk of neurologic deterioration in the peri-operative period. For this reason, some centers perform prophylactic untethering in MMC patients undergoing scoliosis surgery regardless of clinical symptoms of re-tethering.

The purpose of this study was to determine if prophylactic untethering is necessary in asymptomatic children with MMC undergoing scoliosis surgery. We sought to quantify and compare the incidence of neurological deficits and complications between patients with and without prophylactic untethering with the aim of providing recommendations for best practices going forward. As the incidence of MMC patients undergoing scoliosis surgery is relatively low, we performed a multi-institutional, multidisciplinary study in order to achieve sufficient statistical power and generalizability.

Methods

After acquiring IRB approval from each institution, de-identified data were collected from pediatric neurosurgeons and orthopedic surgeons at seven children's hospitals across the country. Inclusion criteria were any patient < 21 years old with a history of myelomeningocele repair who underwent scoliosis surgery between 1994 and 2018, with at least 90 days of follow-up. Patients who had any clinical symptoms of re-tethering (except progressive scoliosis) were excluded.

Baseline clinical data collected included age at the time of scoliosis surgery, gender, presence of a ventriculo-peritoneal shunt (VPS), baseline motor and sensory level, baseline urologic function, and pre-operative scoliosis measurements including coronal deformity (measured by Cobb angle) and sagittal deformity (measured by sagittal vertical axis (SVA). Intra-operative data collected included the type of scoliosis surgery (e.g., the use of a 3-column osteotomy or growth-friendly construct), spinal levels instrumented, changes in intra-operative neuromonitoring potentials, presence of a dural tear, use of a spinal drain, and need for blood transfusions. Ninety-day post-operative variables assessed included any change in motor, sensory, or urologic function, cerebrospinal fluid (CSF) leaks, surgical site infections (SSIs), other wound complications, VPS malfunctions, return to OR, overall hospital length of stay (LOS), and post-operative scoliosis measurements. All data were collected by independent teams at each participating center and compiled centrally, with clarification as needed.

Patients were split into three groups for analysis: (1) concomitant untethering was defined as a patient who underwent prophylactic TCR at the same time as the scoliosis surgery; (2) prior untethering was defined as a patient who underwent prophylactic untethering within 3 months prior to, but not at the same time as, the scoliosis surgery; and (3) no prophylactic untethering was defined as a patient who underwent only scoliosis surgery without prophylactic untethering.

The primary outcome was defined as neurologic deterioration from baseline at 90 days post-operatively, including any motor, sensory, or urologic function loss. Secondary outcomes included SSIs, unplanned re-operation, mean LOS, or any other complication. Only the post-scoliosis surgery hospitalization was included for analysis. For the patients in the prior untethering group, any complications incurred during their untethering hospitalization were not included.

Statistical analysis

Baseline characteristics and outcomes were compared between groups using Student's *t*, Chi-square, ANOVA, and Fisher's exact tests. For LOS analysis, outliers were excluded, defined as patients who had LOS longer than two standard deviations above the mean. Univariate and multivariate logistic regression models were constructed to assess the adjusted relative risks (aRR) of the interventions after adjustment for potential confounding by clinically important variables and disparate baseline characteristics. Multivariate regression analysis was performed factoring in any variable with at least trend level significance ($p < 0.2$) on univariate analysis. Subgroup analysis included analysis of only the study centers that performed all 3 types of interventions, in order to better assess whether there was an effect of surgeon or center on the results. Data analysis and graphs were generated with SAS software, v9.4 (SAS Institute Inc., Cary, NC). Two-tailed hypotheses were used with a statistical significance level set at $p < 0.05$.

Results

Three hundred fifty scoliosis surgeries from seven different centers were initially included in the study. One hundred forty-two of these were subsequently excluded because they were rod-lengthening procedures only; none of these had prophylactic untethering prior to surgery as prophylactic untethering prior to a rod-lengthening procedure would not be considered within the realm of routine clinical practice. This resulted in 208 patients in total: 32(15%) underwent concomitant untethering, 21(10%) underwent untethering within 3 months, and 155(75%) did not undergo any prophylactic untethering. Complete pre- and post-operative scoliosis measurements by Cobb angle and/or SVA were only available for 23 of the patients in total, so radiographic measurements were excluded from analysis.

Baseline characteristics

Baseline characteristics of the entire cohort, as well as for each group, are outlined in Table 1. The mean age at time of scoliosis surgery was 9.4 years (range 1–17 years), with the average age of the prior untethering group (13 years, range 8–15 years) slightly older than the concomitant group (9 year, range 2–16 years) and the no untethering group (9.3 years, range 1–17 years; $p = 0.0265$). Other than age, there were no statistically significant differences in baseline characteristics among the three groups. Furthermore, the decision of whether to prophylactically untether an asymptomatic patient prior to scoliosis surgery was practice-dependent rather than based on clinical findings (personal communication, RCA). All groups had a close to even gender split (52% girls overall). The vast majority of patients (84%) had a VPS, and overall, patients were evenly split between thoracic myelomeningoceles (32%), upper lumbar (L1–3) myelomeningoceles (34%), and lower lumbar/sacral (L4-S1) myelomeningoceles (34%). The higher proportion of thoracic myelomeningoceles seen in this study likely reflects the increased risk of developing scoliosis in children with thoracic myelomeningoceles.

Surgical characteristics

Intra-operative variables are outlined in Table 2. Over one-third of patients (39%) received a blood transfusion, with significantly more in both the concomitant untethering group (52%) and the prior untethering group (57%) compared with the no untethering group (34%) ($p = 0.02$). There were no statistically significant differences in any of the other intra-operative variables measured (for complete data, see Table 2). Intra-operative neuromonitoring changes were seen in 5/205 (2.4%) patients, all of who were in the no prophylactic untethering group. Centers did not report if the neuromonitoring changes seen returned to baseline during the case; however, none of these patients woke up with a change in their neurologic function.

Post-operative outcomes

Post-operative outcomes are outlined in Table 3. No patient experienced a clinically significant change in motor or sensory function at 90 days post-operatively. Only two patients overall, both in the concomitant prophylactic untethering group, had improved urologic function ($p = 0.03$), with most patients requiring straight catheterization at baseline. CSF leaks were

Table 1 Baseline characteristics

Patient characteristics	All patients undergoing scoliosis corrective surgery ($N = 208$)	Concomitant prophylactic untethering ($N = 32$)	Prophylactic untethering within 3 months prior ($N = 21$)	No prophylactic untethering ($N = 155$)	p value
Age					0.0265
	Mean: 9.4 years Range: 1–17 years	Mean: 9 years Range: 2–16 years	Mean: 13 years Range: 8–15 years	Mean: 9.3 years Range: 1–17 years	
Gender					0.8761
Boys	99 (47.6%)	16 (50%)	9 (42.9%)	74 (47.7%)	
Girls	109 (52.4%)	16 (50%)	12 (57.1%)	81 (52.3%)	
Presence of VPS					0.2140
	174 (83.7%)	30 (93.8%)	18 (85.7%)	126 (81.3%)	
Level of myelomeningocele					> 0.05
Thoracic	68 (32.7%)	16 (50%)	5 (23.8%)	47 (30.3%)	
L1-L3	70 (33.7%)	6 (18.8%)	10 (47.6%)	54 (34.8%)	
L4-S1	70 (33.7%)	10 (31.30%)	6 (28.6%)	54 (34.8%)	

seen in 3/208 (1.4%) patients and VPS malfunctions were seen in 7/174 (4.0%) patients, with no significant differences among the groups.

SSIs were seen in 35/208 (17%) of patients overall: 10/32 (31%) undergoing concomitant untethering, 6/21 (29%) undergoing prior untethering, and 19/155 (12%) without untethering ($p = 0.01$). Compared with the group without untethering, there was an increased aRR of SSI of 2.48 ($p = 0.06$) in the concomitant untethering group, 2.95 ($p = 0.06$) in the prior untethering group, and 2.65 (95% CI 1.17–5.02, $p = 0.02$) when combining both prophylactic untethering groups compared with no untethering patients (Table 4).

Return to the OR within 90 days was seen in 46/208 (22%) of patients overall: 14/32 (44%) undergoing concomitant untethering, 5/21 (24%) of patients undergoing prior untethering, and 27/155 (17%) of patients without untethering ($p = 0.005$). Compared with the group without untethering, there was an increased aRR of return to the OR within 90 days of 2.73 ($p = 0.03$) in the concomitant untethering group, 1.78 ($p = 0.3$) in the prior untethering group, and 2.17 (95% CI 1.02–4.65, $p = 0.045$) with both prophylactic untethering groups combined (Table 4). While the majority of patients returned to the OR for a wound washout to treat an SSI, additional cases were

Table 2 Intra-operative variables

Patient characteristics	All patients undergoing scoliosis corrective surgery ($N = 208$)	Concomitant prophylactic untethering ($N = 32$)	Prophylactic untethering within 3 months prior ($N = 21$)	No prophylactic untethering ($N = 155$)	p value
Number of levels involved in the scoliosis surgery					0.6589
>5 levels	195 (93.8%)	32 (100%)	20 (95.2%)	143 (92.3%)	
Growth-friendly construct used					0.2463
	87 (41.8%)	10 (31.2%)	7 (33.3%)	70 (45.2%)	
3 column osteotomy					0.3805
	28 (13.5%)	6 (18.8%)	1 (4.8%)	21 (13.5%)	
Change in neuromonitoring					0.7605
	5 (2.4%)	0 (0%)	0 (0%)	5 (3.2%)	
Dural tear					0.5005
	11 (5.3%)	2 (6.3%)	2 (9.5%)	7 (4.5%)	
Use of spinal drain					N/A
	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
Blood transfusion					0.0182
Yes (% of known)	74 (39.4%)	16 (51.6%)	12 (57.1%)	46 (33.8%)	0.0392
Unknown (% of total)	20 (9.6%)	1 (3.1%)	0	19 (12.3%)	0.0808

Table 3 Post-operative outcomes

Patient characteristics	All patients undergoing scoliosis corrective surgery ($N = 208$)	Concomitant prophylactic untethering ($N = 32$)	Prophylactic untethering within 3 months prior ($N = 21$)	No prophylactic untethering ($N = 155$)	p value
Change in motor/sensory function					N/A
	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
Urologic changes					0.0328
	2 (1.0%)	2 (6.3%)	0 (0%)	0 (0%)	
CSF leak					0.5882
	3 (1.4%)	1 (3.1%)	0 (0%)	2 (1.3%)	
SSI					0.0104
	35 (16.8%)	10 (31.3%)	6 (28.6%)	19 (12.3%)	
Other wound complications					0.2531
	26 (12.5%)	7 (21.9%)	2 (9.5%)	17 (11.0%)	
VPS malfunction	$N = 174$	$N = 30$	$N = 18$	$N = 126$	0.1941
	7 (4.0%)	3 (10%)	0 (0%)	4 (3.2%)	
Return to OR					0.0047
	46 (22.1%)	14 (43.8%)	5 (23.8%)	27 (17.4%)	
LOS					< 0.0001
(mean no. of days)	8.2	13.4	10.6	6.8	

related to other wound issues such as dehiscence and CSF leak without evidence of infection.

The composite outcome of any complication was seen in 49/208 (24%) of patients overall: 14/32 (44%) undergoing concomitant untethering, 6/21 (29%) undergoing prior untethering, and 29/155 (12%) without untethering ($p = 0.008$). With both prophylactic untethering groups combined, there was an increased aRR of 2.25 (95% CI 1.07–4.74, $p = 0.045$) compared with no untethering patients (Table 4, Fig. 2).

Hospital LOS was also significantly variable among groups. The overall mean LOS was 8.2 days: 13.4 days for patients undergoing concomitant untethering, 10.6 days for patients undergoing prior untethering, and 6.8 days for patients without untethering ($p < 0.0001$) (Figs. 1 and 2).

In order to control for inter-site differences and practice patterns, subgroup analyses were performed examining only the four centers that had patients in all three cohorts. Similar results were seen across all variables, supporting the findings that outcomes are associated with the intervention group, and not the hospital or surgeon.

Discussion

In this multicenter, multidisciplinary, retrospective report, we have demonstrated that asymptomatic children with myelomeningocele who underwent scoliosis surgery had no motor or sensory neurologic changes regardless of prophylactic untethering. However, those who underwent prophylactic untethering either at the time of or within 3 months prior to scoliosis surgery were not only more likely to experience SSIs and return to the OR than children not undergoing prophylactic untethering, but also had higher rates of blood transfusions and longer hospital stays than children not undergoing prophylactic untethering. To our knowledge, this is the first study directly comparing the outcomes of prophylactic

Table 4 Multivariate regression analysis, with no prophylactic untethering as the referent group

	Concomitant prophylactic untethering ($N = 32$)		Prophylactic untethering within 3 months prior ($N = 21$)		Prophylactic untethering at any time ($N = 53$)	
	aRR (95% CI)	p value	aRR (95% CI)	p value	aRR (95% CI)	p value
SSI	2.48 (0.95–6.49)	0.0630	2.95 (0.94–9.21)	0.0627	2.65 (1.17–5.02)	0.0196
Return to OR	2.73 (1.19–6.73)	0.0256	1.44 (0.47–4.82)	0.5407	2.17 (1.02–4.65)	0.0453
Any complication	2.59 (1.08–6.19)	0.0329	1.78 (0.60–5.32)	0.2999	2.25 (1.07–4.74)	0.0325

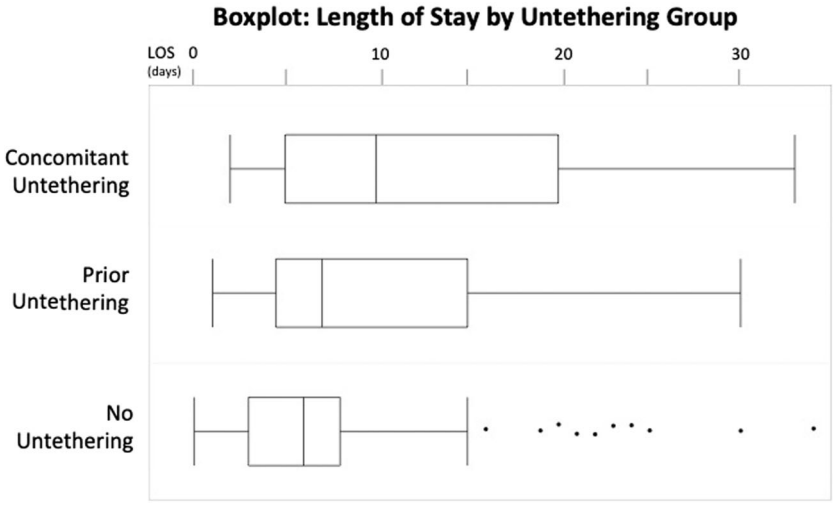

Fig. 1 Hospital length of stay by untethering group

untethering in children with MMC at different time points before scoliosis surgery.

Scoliosis surgery in myelomeningocele patients is known to have some of the highest complication rates [8, 12–21]. The reasons for this are likely multifactorial and related to neurosegmental level, baseline ambulatory status, bowel and bladder incontinence, age at surgery, and other non-modifiable risk factors. Previous studies have also shown increased operative time and increased intra-operative blood loss to be associated with a higher risk of complications [4, 16, 17, 20–22]. Beyond the standard risks associated with neuromuscular scoliosis surgery, patients with MMC are thought by some surgeons to be at an increased risk of neurologic deterioration post-operatively due to the potential additional traction placed on a possibly already tethered spinal cord [13, 14, 23]. This perceived risk has resulted in some centers performing prophylactic untethering prior to deformity correction, regardless of clinical symptoms of re-tethering. This was traditionally done as a two-stage procedure, with untethering followed by scoliosis surgery approximately 1 to 2 months later. However, given the continued curve progression during the intervening interval, some surgeons have reported decreased morbidity with a single-stage operation involving concurrent untethering and deformity correction [5, 13–15, 23].

On the other hand, surgical untethering of the spinal cord, which involves opening of the dura and direct neural manipulation, is not without inherent risks including CSF leak, meningitis, additional post-operative immobilization, and neurologic injury, as well as increased healthcare resource utilization. These issues have led some centers to argue that prophylactic surgery for untethering in asymptomatic patients is unnecessary [4]. Current evidence exists in the literature both for [14, 15, 23], and against prophylactic untethering, [4] but these are small single-center series and case reports. To date, little data exists on the relative risks or merits of either approach, and current practice is largely based on single-center experience.

Primary outcome

In an attempt to provide a higher level of evidence either for or against prophylactic untethering at different time points in asymptomatic children with MMC undergoing scoliosis

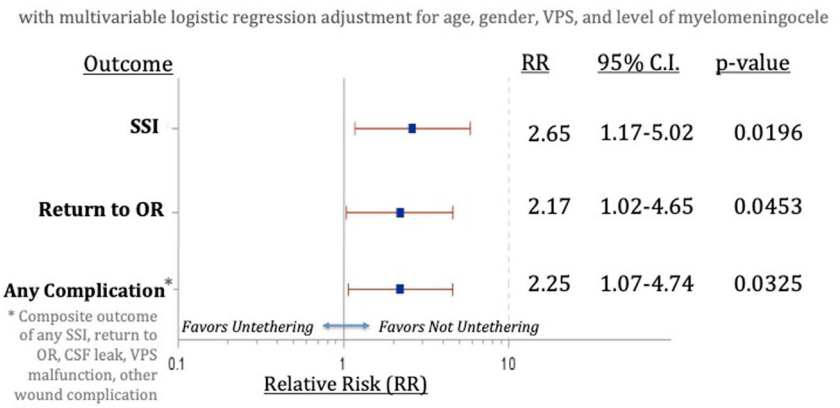

Fig. 2 Relative risk of post-operative complications associated with prophylactic untethering

surgery, we collected data from seven centers and separated patients into three analysis groups: concomitant untethering, prior untethering (within 3 months), and no prophylactic untethering. We chose neurologic function at 90 days post-operatively as our primary outcome due to the perceived benefit of reduction of neurological risk with prophylactic untethering. Furthermore, a 90-day post-operative time point allows for recovery from transient neurologic symptoms due to cord manipulation that may not impact long-term function. In this study, at 90 days post-operatively, not a single patient in any of the analysis groups experienced a clinically significant change in motor or sensory function, or worsening in urologic function. This overall positive neurologic outcome may be partially due to our choice of outcome measures at 90 days post-operatively, which allows time for transient deficits to improve and the expertise available at the high-volume centers included in the study, as well as the reporter bias, as outcomes were assessed by the surgical team post-operatively. However, as the reporter bias would hold true for all of the groups assessed, it should not affect the validity of the comparison. Two patients in the concomitant detethering group were reported to have improved urological outcome; however, the clinical significance of this in children requiring intermittent catheterization is unclear. Overall, these data suggest that there is no increased risk of neurological injury in MMC patients undergoing scoliosis surgery without prophylactic untethering compared with those that have untethering concomitantly or within 3 months prior.

Secondary outcomes

Our secondary outcome measures included both intra-operative and post-operative variables. We found no statistically significant differences among the groups regarding number of levels instrumented, growth-friendly constructs, 3-column osteotomies, changes in neuromonitoring, dural tears, spinal drains, CSF leaks, or VPS malfunctions. Compared with children without prophylactic untethering, children undergoing untethering had an increased risk of SSI (aRR = 2.65, $p = 0.02$), return to the OR (aRR = 2.17, $p = 0.045$), and any complication (aRR = 2.25, $p = 0.03$), after adjustment for confounding in multivariable logistic regression analysis. Children undergoing untethering also had an increased mean LOS ($p < 0.0001$) and increased rate of blood transfusion ($p = 0.04$).

Of the intra-operative variables assessed, the only one that showed a statistically significant difference was the need for blood transfusion, with 52% of the concomitant untethering patients receiving a blood transfusion, 57% of the prior untethering group, and only 34% of the no prophylactic untethering patients ($p = 0.04$). This likely reflects longer operative times and increased blood loss in the prophylactic untethering groups, both of which have been associated with increased complication rates following scoliosis surgery [4, 16, 17, 20–22].

The significantly higher rate of SSI in children undergoing prophylactic untethering (aRR 2.48–2.95) may be due to difficulty with watertight wound closure in the area around the myelomeningocele or repeated opening and closing of the incision in the prior untethering group. Similarly, patients undergoing prophylactic untethering had an increased risk of returning to the OR within 90 days (aRR 1.44–2.73).

Given the higher complication rates in the groups undergoing prophylactic untethering, it is not surprising that patients in both prophylactic untethering groups had statistically significantly longer LOS compared with the group without untethering ($p < 0.0001$). Patients who did not undergo prophylactic untethering stayed in the hospital, on average, 6.8 days following their scoliosis surgery, as compared with 10.6 days for patients who underwent prior untethering and 13.4 days for patients who underwent concomitant untethering. Most pediatric neurosurgeons order bed rest for 48–72 h post-operatively following intradural surgery for untethering. For a patient undergoing concomitant untethering, not only does this add an additional 2–3 days of hospital time, but also by delaying post-operative physical therapy and early mobility, it may slow down recovery from scoliosis surgery even further, and possibly contribute to the increased infection and complication rate.

There are several important limitations to this study:

1. While to our knowledge this study represents the largest cohort of myleomeningocele patients undergoing scoliosis surgery reported to date, it is still a limited total number of patients, and as such, may not be sufficiently powered to detect a worsening in neurological function post-operatively. An a priori power analysis could not be conducted, as the expected incidence of neurologic deterioration following scoliosis surgery in patients with myleomeningocele is not known. Prior reports have also reported a neurologic deterioration rate of zero [4, 14, 24]; however, this may reflect a publication bias.
2. The number of patients among the three groups was skewed significantly toward no prophylactic untethering (75% of the total cohort), likely reflecting an already shifting practice pattern away from prophylactic untethering. We therefore performed a multivariate regression analysis in an attempt to control for confounders.
3. Though the decision of whether to prophylactically untether an asymptomatic patient prior to scoliosis surgery was practice-dependent rather than based on clinical findings (personal communication, RCA), it is possible that there was some selection bias in group assignment.
4. We are unable to explain the older skew of patients in the prior untethering group; however, the multivariate regression analysis took this difference into account.

5. We were not able to collect pre- and post-operative Cobb angles and SVA measurements to quantify the degree of scoliosis correction among the groups. Although it is possible that these differed among the groups and confounded the results, we think this is unlikely due to the similar number of instrumented levels, growth-friendly constructs, 3-column osteotomies, and neuromonitoring changes seen among the groups.
6. The retrospective nature of this study has inherent limitations including recall bias.

Despite the limitations, to our knowledge, this is the first large multicenter, multidisciplinary study directly comparing the outcomes of prophylactic untethering in asymptomatic children with MMC at different time points before scoliosis surgery. Looking at composite outcomes, we found an increased aRR of SSI (aRR = 2.65, $p = 0.02$), return to OR (aRR = 2.17, $p = 0.045$), and any complication (aRR = 2.25, $p = 0.03$) associated with prophylactic untethering. Based on these data, prophylactic untethering in asymptomatic MMC patients prior to scoliosis surgery does not provide any neurological benefit but is associated with significantly increased surgical risks.

Compliance with ethical standards

Conflict of interest The authors have no relevant disclosures to report.

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