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REVIEW

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Does early tethered cord release in occult spinal dysraphism improve urological outcomes? A systematic review

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Abstract

Introduction: Occult spinal dysraphism involves a wide range of congenital anomalies, e.g., lipoma, Lipomeningomyelocele, congenital dermal sinus, etc. Occult spinal dysraphism also may present with a wide spectrum of clinical manifestations and radiological findings, i.e., it ranges from asymptomatic patients that are accidentally discovered to low lying conus with neurological, skeletal and urological manifestations. Even though neurosurgeons are well-aware of neurological presentations that indicate surgical intervention in children with occult spinal dysraphism, urological symptoms may present some controversy in management. This review aims to discuss urological outcomes of detethering as regarding time of intervention, improvement of the urological symptoms after detethering, and the role of urodynamics preoperatively and during follow-up.

Methodology: An online search of the literature was done including studies in English language from 1990 to January 2022. Included studies were analytical with well conducted descriptive nature of acceptable quality (at least level 3 evidence). Patient characteristics included both male and female children and adolescents, up to 19 years old who presented with clinical and/or radiological evidence of tethering of the spinal cord. Most studies that were included had availability of urodynamics. A total of 15 studies were included involving 633 patients. Meningomyelocele (MMC) and other spina bifida operta cases are excluded.

Results: Results of all studies were collected and mean age of studies was gathered and plotted on a chart in relation to urological outcome and urodynamic improvement. Most results favored early detethering; however, many factors were found to affect the inverse proportion curve of age with clinical improvement or urodynamics. For example, studies that included secondary tethered cord showed poorer results than results that included primary tethered cord only, preoperative severity of urological symptoms (more severe symptoms were associated with irreversible poor outcomes), and preoperative urodynamic parameters.

Conclusion: The management of tethered cord syndrome and occult spinal dysraphism remains controversial. There is lack of class 1 evidence regarding tethered cord release surgery in occult spinal dysraphism. Heterogenicity of pathology, symptomatology and radiology make the randomization of such sample size difficult. The outcomes of surgical detethering are therefore multifactorial. A large sample of prospective randomized controlled studies addressing each factor, e.g., age, severity of symptoms, preoperative urodynamic parameters, is recommended in order to evaluate the impact of each factor on outcome.

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Keywords: Tethered cord syndrome, Occult spinal dysraphism, Filum terminale, Tethered cord release, Spinal cord detethering, Spinal cord untethering, Detethering, Untethering, Urinary incontinence

Background

Spinal dysraphism refers to congenital midline abnormalities of the back, from skin to the vertebral column. It includes all malformations that are the consequence of incomplete formation of midline structures of the dorsum. It can be classified as open form (operta) or closed form (occulta) [1].

Occult spinal dysraphism (OSD) is a subtype of spinal dysraphism in which the overlying skin is intact with no exposed neural tissue, but the spinal cord is attached to different structures deep to the skin. The exact incidence of OSD in the general population remains not entirely clear, because many lesions sometimes remain undiscovered and persist without being manifested. Yet a percentage of 5–30% was a reported debatable rate with a significant female preponderance [2–4].

Intraspinal anomalies that are commonly referred to as OSD include the split cord syndrome, fatty filum terminale, terminal syrinx, meningocele manqué, dermal sinus tract, lipo-myelomeningocele, Neurenteric cyst and myelocystocele [5].

Most manifestations of OSD are related to cord tethering, i.e., traction of conus medullaris by anchoring bands. Prognosis of this syndrome is usually dependent on the degree of cord traction and stretch [6–8]. Tethered cord syndrome mainly presents during childhood, but rarely may present during adulthood [9].

It is important to note that a wide spectrum of symptomatology exists for tethered cord syndrome. The patient may be asymptomatic with radiological evidence of spinal cord tethering up to a classic clinical picture with an anatomically normal radiological picture with no low lying conus (occult tethered cord) [10]. Yamada et al. have proposed that symptoms appear after hypoxic damage within the conus medullaris of patients with tethered cord syndrome (TCS) [9].

Individuals with TCS may present with one or more combinations of myriad of symptoms and signs that include neurological, orthopedic and urological manifestations. Neurological presentations, which are due to disruption of motor and sensory pathways to the lower extremities, include gait disturbance, muscular atrophy, hyper-/hyporeflexia, spasticity, and sensory deficits [10]. Additionally, orthopedic abnormalities, including foot deformities, limb length discrepancies, scoliosis, and vertebral anomalies, such as bifid vertebrae, hemivertebra, and sacral agenesis, are usually found in 90% of OSD cases. Urologic symptoms range from incontinence, urgency, frequency, and recurrent UTIs to subtle changes observed on urodynamic studies (UDS).

Early diagnosis of OSD in children is essential to attain better prognosis, so pediatric care providers must be aware of the disease [11]. When we encounter cases with neurological symptoms, decision for surgery in tethered cord is usually straightforward. However, when we are faced with cases with urological symptoms decisions might be debatable. Current controversies with respect to the TCS management include two points: (1) the early untethering of the spinal cord in asymptomatic patients; and (2) the proposed neurogenic hyper-reflexic bladder resulting from a tethered spinal cord with a normally positioned conus medullaris. A majority of authors in literature recommend early untethering procedure for the asymptomatic patient with TCS as early intervention might be an effective prophylaxis against progressive neurological and sphincteric decline, which may occur precipitously [12, 13].

This review will discuss the urological outcomes of surgery in occult spinal dysraphism. We aim to address information in the literature regarding preoperative work up (specifically urodynamic studies), appropriate timing of intervention, and expectations after surgery. Given the controversies in management of occult spinal dysraphism and paucity of evidence addressing the topic, we think an up-to-date reviewing and pooling of available data will summarize the current state of knowledge on the effect of early spinal cord untethering on urological outcomes.

Methodology

Protocol, information sources, study selection

We performed a systematic literature review via Pub Med, Cochrane library, EMBASE. Search was performed using the keywords “tethered cord syndrome,” "occult spinal dysraphism," "filum terminale," “tethered cord release,” "spinal cord detethering," "spinal cord untethering," "detethering," "untethering," “urinary incontinence,” "incontinence," "enuresis," "bedwetting," "urgency," "precipitancy," "urodynamic," “tight filum terminale,” “fatty filum,” “Lipomeningomyelocele,” “Split cord malformation,” “Congenital dermal sinus,” “Myelocystocele,” “Neurenteric cyst” from 1990 to 2022. We followed Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines.

Study selection, eligibility criteria, exclusion criteria

Included studies were analytical with well conducted descriptive nature of acceptable quality (at least level 3 evidence), e.g., randomized controlled trials, cohort, case–control series, and reviews. Studies will be eligible if they contain the target keywords in title or abstract, addressing the age group up to 18 years with clinical or radiological evidence of spinal cord tethering. Studies with less than 10 patients, case reports, letters to the author were omitted. Records reporting results in languages other than English as well as those discussing open spinal dysraphism, secondary tethered cord (secondary causes of tethering including postoperative fibrosis, e.g., postmeningomyelocele repair, neoplasms, infections, etc.), and adult patients were excluded. Likewise, records that did not report preoperative or postoperative urological symptoms or UDS were excluded.

Locating data and selecting data

Criteria for inclusion and exclusion of studies in accordance with the study populations:

- **Population**: Male and female children and adolescents, up to 19 years old who presented with clinical or radiological evidence of tethering of the spinal cord. Meningomyelocele and other spina bifida operta cases are excluded.
- **Intervention**: Early (before the age of 6 years old, our median age) surgical detethering of the spinal cord in cases with clinical and/or radiological diagnosis of tethered cord syndrome due to occult spinal dysraphism.
- **Control**: Delayed (after the age of 6 years old, our median age) surgical detethering of the spinal cord in cases with clinical and radiological diagnosis of tethered cord syndrome due to occult spinal dysraphism.
- **Outcome**: Primary outcome: The urological clinical outcome after surgical detethering of the spinal cord. Retention can be assessed in all ages through the need for CIC. Incontinence, however, was assessed in children who are at toilet training age > 5 years with > 4-h dry interval considered continent. Children younger than the toilet training age were assessed during follow-up for incontinence. Follow-up period varied among different studies with some studies recorded follow-up for minimum of 5 years duration at 6-month intervals. Secondary outcome: urodynamic outcomes including immediate postoperative and at 6 months interval for variable durations according to each study. Reliability of UDS as a diagnostic and prognostic method to measure surgical outcome (Preoperative and postoperative urodynamic studies should be available for the cases).

Data extraction

The full text of the articles was reviewed to exclude full texts not fulfilling the criteria or deviating from the initial impression taken from the title/abstract reviewing. References/bibliography of the selected articles was examined to evaluate potential for further research and possible inclusion in the analysis. Studies that fit the inclusion criteria were manually reviewed and data were analyzed. The following information was obtained from each study: number of patients studied, types of spinal dysraphism lesions, age at presentation and at intervention, length of post-operative follow-up, cutaneous presenting signs, preoperative neurological examination, postoperative neurological examination, preoperative urological symptoms, postoperative urological symptoms, preoperative urodynamic data, and postoperative urodynamic data. For each study, the pre- and postoperative data (neurological examination, urological symptoms, and urodynamic data) were compared to obtain a number and percentage of patients that were unchanged, improved, or worsened. These data elements were collected and summarized in a table format.

Statistical considerations

The data synthesis was performed through methods recommended by the working group of the Cochrane collaboration on the systematic reviews of diagnostic test accuracy. RevMan software was used for statistical analysis and data pooling.

Evidence of publication bias

Bias was assessed according to the recommendations of Hayden et al. [14]. The following biases were assessed for each study: study participation, study attrition, prognostic factor measurement, outcome measurement, confounding measurement and account, and analysis. Any study with high risk for bias in any category was excluded from the review.

Results

Total of 615 citations were retrieved according to our search strategy and review of bibliographies that addressed occult spinal dysraphism topic and spinal cord untethering. One-hundred and forty-four of these studies discussed urinary incontinence in children and adolescents. Thirty-one of these studies involved urodynamic results. Fifteen of these studies met the inclusion criteria and were included in the analysis. Thirteen were obtained from Medline via PubMed and 2 were obtained

Table 1 List of include studies in this review

Serial	Author	*N*	Mean age in years	Primary outcome	Secondary outcome
1	Anthony et al. [16], 1992	35	0.25/10	Infant vs. Children 81.8% vs. 16.6% percent improvement	Out of 29 children 11 had abnormal Urodynamics, 9 improved and 2 remained the same
2	Meyrat et al. [17], 2003	15	5	Only UDS improvement no clinical data	Gradual improvement of UD score at 12 months
3	Guerra et al. [18], 2006	24	6	All urological symptoms improved	7 out of 21 patients with abnormal UDS improved
4	Khoury et al. [19], 1990	31	8.6	8/29 72% improvement	16/27 improved in DO (59%)
5	Hsieh et al. [20], 2006	162	17	2 cases of urological symptoms improved postoperatively (but incontinent case was retained, i.e., complicated)	Of the 17 children who underwent TCR 10 had abnormal UDS and 7 normal UDS, 5 of the 10 improved postop. All 7 normal were normal postop as preop
6	Macejko et al. [21], 2007	79	0.8	Out of 79 patients 49 had no postop urological problems, 20 had minor, 10 had major. The 2 presented with urological problems preoperatively improved	8/30 (27%) UDS improvement. 10/36 (28%) deterioration of normal UDS No clinical correlation
7	Ailawadhi et al. [22], 2013	11	9.6	16/24 improved 8/24 the same. None were worse	In 24 patients. UDS low compliance 3 out of 11 improved, involuntary contractions of bladder 5 out of 18 improved, dyssynergia 7 out of 19 improved
8	Yener et al. [23], 2015	40	7.2	All improved. 13 patients in group 1 (preop + symptoms, postop -ve), 11 in group 2 (pre and postop + ve), 3 in group 3 (-ve pre, + ve post), 13 in group 4 (pre and post -ve)	improvement was seen throughout groups of postop UDS findings
9	Alsowayan et al. [15], 2016	22	0.1	8 asymp + 14 symp (9 urological) 9/9 improved in symptomatic	UC improved 7/15 DSD improved 5/7
10	Kumar et al. [24] 2017	15	7.6	7 improved 1 worsened the rest?	Improved in 6/15, 3/15 worsened, 6/15 unchanged
11	Rendeli et al [25], 2007	64	3	No clinical only urodynamic	64 patients classified by age: < 12 months best urodynamic results 65% improved, 12–36 m 33%, > 36 m 28%
12	Broderick et al [26], 2015	27	3	27 patients asymptomatic 26/27 the same 1 complication	15 had UDS FU postop, 13/14 improved
13	Metcalfe et al. [27], 2006	36	2	Urinary improvement in 26/36 patients (72%)	UDS improved in 57% of cases
14	Frainey et al. [28], 2014	59	5	59 patients 20 asymptomatic 19 were continent post-TCR 39 were symptomatic: 28 continent pre TCR remained continent post-TCR 11 incontinent pre TCCR 5 gained continence post-TCR	Assessment of urodynamic data revealed that neither pre- nor post-TCR urodynamics predicted continence status
15	Noguiera et al. [29], 2004	13	9	13 patients; Postoperative improvement in 7 (54%) but 5 remained on anticholinergics	Postoperative UDS resolution of hyperreflexia in 5 (45%) patients and areflexia in the patient with incontinence (50%)

from manual search and review of bibliographies. These studies were retrieved and reviewed. This review includes 15 studies the sum of the population in all the studies is 633 patients. See Table 1. The total number of patients in this review is 633. Age ranges from 1 month in Alsowayan et al. [15] to 19 years in Anthony et al. [16]. Older ages were excluded from this review to avoid confounding bias from age discrepancy. The studies were collected and listed in ascending order of age. The time of intervention of spinal cord untethering (SCU) was taken into consideration and was plotted versus the percent clinical improvement and percent UDS improvement in separate charts, see Figs. 1 and 2. Figure 1 shows a trend toward an inverse proportion with increasing age from 100% improvement (defined as resolution of symptoms present before SCU) at age 1 month to 50% improvement at age 17 years. Surprisingly, this trend was not followed for UDS outcomes. There seems to be little correspondence with age and the trend of % UDS improvement slightly rises with age with 27% at age 9.6 months and 70.5% at age 17 years. This could be attributed to more reliability of urodynamic studies with increasing age. Finally, the median age of the total number of patients in the studies was calculated to be 6 years. The mean improvement of clinical and UDS outcomes was calculated and is plotted in Fig. 3. The chart illustrates that children operated before the age of 6 had better clinical outcomes than those operated after the age of 6. It also highlights the paradoxical improvement of UDS results of those operated after 6 years when compared to those before the age of 6 years (%).

Discussion

Most studies support early neurosurgical intervention examples include Anthony et al. [16], Guerra et al. [18], Yener et al. [23], Rendeli et al. [25], Noguiera et al. [29], Kumar et al. [24] and Khoury et al. [19]. Some studies showed that urological symptoms yielded disappointing results such as Kang et al. [30] and Ailawadhi et al. [22]. A key age of 3 years for detethering was proposed in a

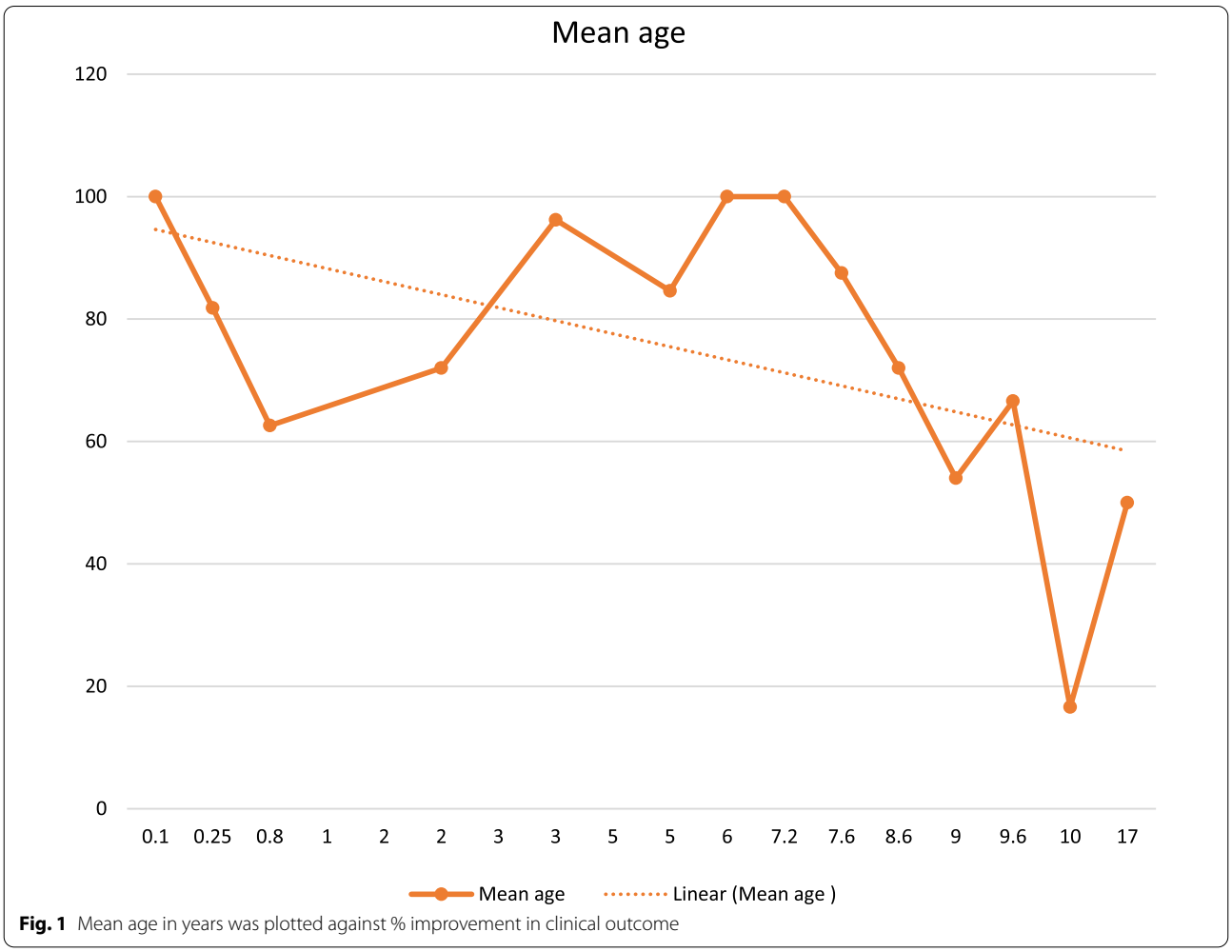

Fig. 1 Mean age in years was plotted against % improvement in clinical outcome

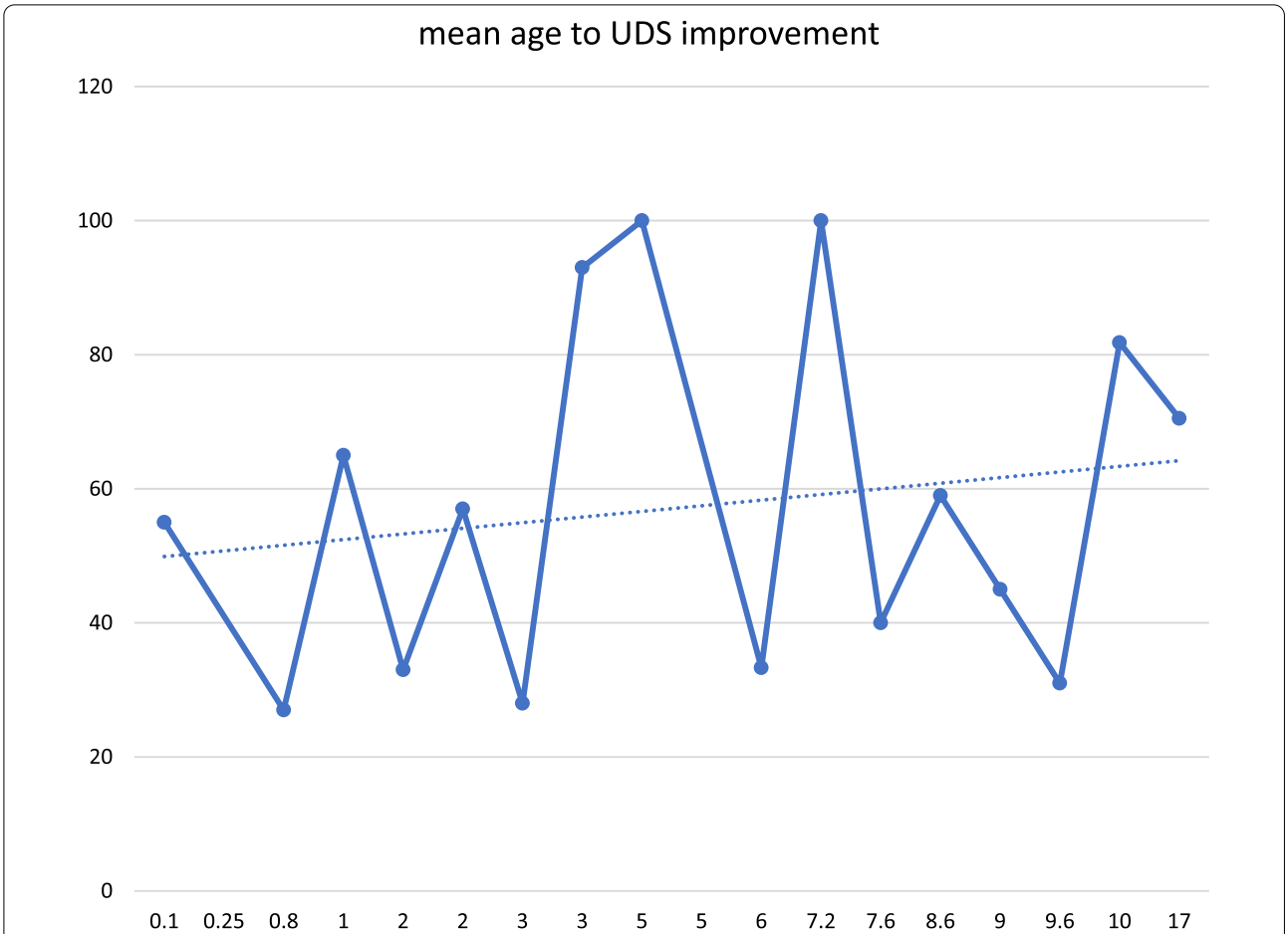

Fig. 2 Mean age in years was plotted against % improvement in UDS parameters

study by Meyrat et al. [17] after which cases may clinically deteriorate. In Nogueira et al., a correlation between neuro-orthopedic symptoms and improvement after detethering can be seen. It was concluded that clinical improvement is less likely when patients present with neuro-orthopedic symptoms than in those who present primarily with urological symptoms and urodynamic abnormalities [29], which implies that early detethering before progression of neuro-orthopedic manifestations is recommended. Khoury et al. (a controversial study performed on children with urinary incontinence without neurological or radiological evidence of tethering) have observed that early detethering before neurogenic deficit will yield better results [19]. Stool soiling was included in Guerra et al. [18] and shows improvement after detethering.

Yener et al. shows that the most dramatic positive results were in group 4 (those who presented without urinary symptoms and underwent prophylactic detethering) and thus study favors detethering in asymptomatic patients [23]. Alsowayan et al. reported improvement 86% of urologically symptomatic patients and 100% of asymptomatic patients remained asymptomatic, also in favor of asymptomatic detethering [18].

Kang et al. [31] (not included in our review for lack of UDS outcomes) concluded that the presence of preoperative urologic symptoms was an important factor in determining urological symptom improvement after surgery, in addition it concluded that pain is most common symptom and the most reversible and that bladder symptoms are disappointing once occurs and so detethering before symptoms is recommended [31].

This idea promotes that more investigations need to be done in asymptomatic patients, even if the literature reports a postoperative risk of neurogenic bladder of 10% [32]. It supports prophylactic surgery in asymptomatic patients. It also highlights the entity "occult tethered cord" and calls for a more sensitive modality such as urodynamics to screen for clinically occult patients to prevent irreversible symptoms from occurring, which was recently published as a systematic review [33].

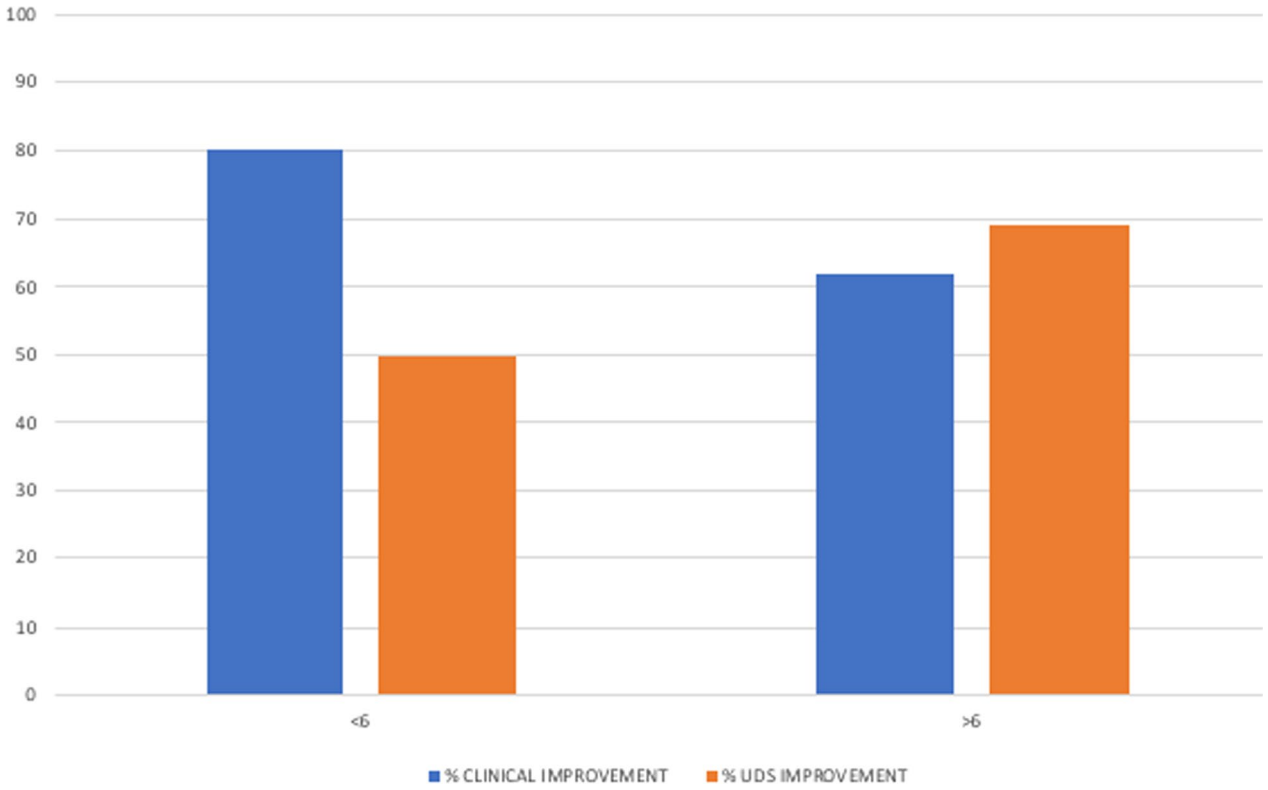

Fig. 3 Chart illustrates % clinical and UDS improvement in relation to median age

Randeli supports early detethering at younger age and illustrates that bladder capacity and mean detrusor leak pressure improved in all groups at younger patients. At the latest follow-up 65% of patients in the youngest group (less than 12 months) had improved urodynamic parameters vs 33% of those 12 to 36 months old and 28% of those older than 36 months, the youngest showed the best UDS improvement [25].

In Broderick et al. detethering in asymptomatic showed no correlation with preoperative UDS parameters [26]. The secondary outcomes of this review include the urological outcome of early surgery in patients with UDS outcomes.

Another point that was tackled in a study by Meyrat et al. was that many of the asymptomatic patients had abnormal UDS findings highlighting the importance of UDS in not only early diagnosis of tethering but also for early detection of retethering. What is unique about this study is the inclusion of an overall urodynamic score that is highlighted in Table 2 [17].

Table 2 Grading of the urodynamic study parameters by Meyrat et al. [17]. The 4 parameters that were included were: 1. Bladder volume 2. Compliance 3. Detrusor activity 4. Vesico-sphincteric synergy/Detrusor sphincter dyssynergia (DSD). Classification of UDS is as follows: 0 to 4 is normal, 5 and 6 raises question of neuro-urological disorder and needs to be repeated, more than 6 is abnormal

Grade	Parameters			
	Bladder volume	**Compliance**	**Detruser activity**	**Vesico-sphincteric synergy**
0	> 100	> 25	Normal	Synergy
1	80–99	20–24	Frequent contractions in all phases	Lack of relaxation
2	60–79	20–24	Systole end phase 2	Intermittent dyssynergy
3	40–59	15–19	1 + 2	Continuous dyssynergy
4	20–39	10–14	Few systoles in all phases	
5	< 20	< 10	Frequent systoles in all phases	

Even though many individual studies recommended urodynamic reliability. The 15 studies collectively did not yield a correspondence of early surgery to better urodynamic outcomes. However, this does contradict neither the usefulness of UDS nor the value of early detethering. We believe there is a variety of important reasons why this is the case:

- Most studies were not randomized
- Heterogenicity of the pathology of occult spinal dysraphism, e.g., LMMC, FF, etc.
- Variation in clinical status of the sample, i.e., ranging from asymptomatic in some studies, mild urological symptoms to severe urological symptoms.
- Reliability of urodynamic parameters with age.
- Variability of each urodynamic parameter

In Guerra et al. [18] the results were consistent that early detethering is recommended. The study discussed conus position and its correlation with urodynamic studies (UDS) finding. It concluded that better outcomes can be yielded in normal position conus, which is promoting early detethering.

Frainey et al. concluded there is no correlation between preoperative conus position on imaging or preoperative UDS to outcomes post-TCR [28]. On the contrary in Metcalfe et al. a normal appearing filum (occult tethered cord) was untethered in symptomatic children with refractory urinary and fecal symptoms yielded clinical and urodynamic improvement (57% of the cases) they strongly reinforced that urodynamic studies are mandatory for diagnosing an occult tethered cord [27].

Conclusions

The management of Tethered cord syndrome and occult spinal dysraphism remains controversial. There is lack of class 1 evidence regarding tethered cord release surgery in occult spinal dysraphism. Further confusion is caused by lack of classification of the variety of pathologies of occult spinal dysraphism (OSD). It is recommended that Van Leeuwen classification be used when stratifying data. It is important to consider intervening early and there is rationale for prophylactic surgery in asymptomatic children. The role of UDS is unclear and is conflicting. Our results are paradoxical with better results at older ages; however, many studies consider it reliable for preoperative workup and postoperative follow-up. More evidence-based high-quality randomized controlled trials (RCTs) with larger population samples need to be developed. Specifically, there is justification for developing more studies that discuss prophylactic detethering before development of symptoms. It can be deduced from our literature review that since the Cochrane review of 2015 not much attention has been drawn to start a well-designed, randomized multicenter prospective study in order to provide confirmative data. Future studies will require prospective analysis of outcomes.

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