Original Article

Current Research in MRI
Curr Res MRI 2025;4(3):67-74

MRI-Based Neuraxial Spectrum and Multimodal Assessment of Pediatric Tethered Cord Syndrome: Delineating Associated Spinal and Cranial Anomalies with Gender-Specific Urological Risks

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Cite this article as: Özkan E, Yılmaz Ş, Bayram Ilıkan G, Yakut Hİ. MRI-based neuraxial spectrum and multimodal assessment of pediatric tethered cord syndrome: delineating associated spinal and cranial anomalies with gender-specific urological risks. *Curr Res MRI*. 2025;4(3):67-74

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Received: February 05, 2026 **Revision Requested:** February 11, 2026 **Last Revision Received:** February 16, 2026
Accepted: February 18, 2026 **Publication Date:** February 25, 2026

DOI: 10.4274/CurrResMRI.2026.26135

Abstract

Objective: To characterize the radiological spectrum of pediatric tethered cord syndrome (TCS) and evaluate the correlation between imaging findings and gender-specific urological risks in a large clinical cohort.

Methods: 131 pediatric patients diagnosed with TCS between 2014 and 2019 were retrospectively analyzed. Inclusion required radiologic confirmation that the conus medullaris terminated below the L2-L3 intervertebral disc level on lumbar magnetic resonance imaging (MRI). The Evaluation included lumbar and brain MRI, spinal and urinary ultrasonography, and voiding cystourethrography (VCUG), all analyzed using modality-specific available-case denominators. Statistical associations were evaluated using chi-square and Fisher's exact tests. $P < 0.05$ was considered statistically significant.

Results: The cohort (mean age, 54 months; 63.4% female) most frequently showed conus terminations at L4 (29.0%) and L5 (26.7%),while a borderline termination at L3 was identified in 13.7% of cases. Prevalent MRI findings were spina bifida (44.3%), filum terminale lipoma (37.4%), diastematomyelia (34.4%), and syringomyelia (32.8%). Among patients with cranial imaging, 26.1% exhibited Chiari II malformation. Neurogenic bladder-compatible findings in 15.5% via ultrasound and 42.9% via VCUG. Male gender was significantly associated with the presence of neurogenic bladder (16.7% in males vs. 4.8% in females; P=0.031). Other spinal anomalies showed no significant gender-based disparities.

Conclusion: TCS frequently involves complex, concurrent spinal and cranial anomalies, necessitating comprehensive neuraxial MRI. While radiological findings are similar across genders, male patients have a significantly higher risk of neurogenic bladder and therefore require vigilant urological surveillance even when asymptomatic. Borderline L3 levels underscore the importance of a multimodal diagnostic approach to identify occult cases.

Keywords: Tethered cord syndrome, magnetic resonance imaging, neurogenic bladder, spinal dysraphism, Chiari malformation

INTRODUCTION

Tethered cord syndrome (TCS) represents a diverse constellation of neurological, urological, and orthopedic dysfunctions resulting from the abnormal fixation of the distal spinal cord to inelastic surrounding structures. While the conus medullaris typically ascends to the adult level at the first and second lumbar (L1-L2) vertebrae during normal embryological and early postnatal development, reaching this position by the second month of postnatal life, errors in secondary neurulation or retrogressive differentiation can impede this process.[1,2] Pathologies such as a thickened filum terminale, lipomyelomeningocele, diastematomyelia, or dermal sinus tracts anchor the caudal cord, subjecting it to repetitive mechanical traction during spinal flexion and extension.[3,4]

The pathophysiology of TCS extends beyond simple mechanical stretching. According to the "ischemic hypothesis" proposed by Yamada et al.,[5] chronic traction impairs oxidative metabolism within the lumbosacral cord, leading to mitochondrial dysfunction and a decrease in cytochrome a3 reduction/oxidation ratios. This metabolic failure precipitates ischemic neuronal injury, which, if left untreated, progresses from reversible physiological impairment to irreversible structural damage involving the neuronal perikarya and axons.[5,6] Consequently, the clinical presentation is often progressive and insidious. While cutaneous stigmata such as hypertrichosis, subcutaneous lipomas, or dermal dimples are present in up to 80% of pediatric cases and often serve as the initial sentinel signs, the absence of these markers does not exclude the diagnosis.[7]

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Clinically, TCS is characterized by a triad of symptoms: motor and sensory deficits, musculoskeletal deformities (e.g., scoliosis, pes cavus), and sphincter dysfunction.[8] Among these, neurogenic bladder and bowel dysfunction—often presenting as constipation—are particularly critical, as they significantly impair quality of life and are the least reversible symptoms after delayed intervention.[9,10] Although magnetic resonance imaging (MRI), which demonstrates a low-lying conus (below L2) or a thickened filum terminale (>2 mm), is the gold standard for diagnosis, a subset of patients presents with occult TCS. In these challenging cases, the conus resides at a normal anatomical level, yet the filum terminale has lost its viscoelastic properties, necessitating reliance on clinical symptoms and dynamic imaging modalities, such as prone MRI or ultrasound elastography, for surgical decision-making.[2,11,12]

A significant gap in the current literature involves the influence of patient demographics, specifically gender, on the clinical phenotype and prognosis of TCS. While spinal dysraphisms have historically shown a slight female predominance, recent large-scale epidemiological analyses have suggested distinct risk profiles. For instance, male patients are reported to have a higher burden of preoperative comorbidities, whereas female patients may exhibit higher rates of postoperative complications, such as urinary tract infections.[13] However, the specific correlation between gender and the severity of urological presentation at diagnosis remains under-investigated in single-center cohorts.

Furthermore, the management of TCS—particularly the timing of surgery in asymptomatic or "radiologically borderline" patients—remains a subject of intense debate. While some authors advocate for prophylactic untethering to prevent the onset of irreversible ischemic injury, especially before 34 months of age,[14] others argue for a conservative approach due to the risks of retethering and surgical complications.[9,15]

In this study, we present a comprehensive retrospective analysis of 131 pediatric patients diagnosed with TCS at a single tertiary center. We aim to delineate the clinical and radiological spectrum of the disease, evaluate the prevalence of associated spinal and urogenital anomalies, and specifically investigate the impact of gender on the development of neurogenic bladder dysfunction. By correlating demographic data with clinical outcomes, this study seeks to refine risk stratification protocols and contribute evidence-based insights into the surgical management of pediatric TCS.

MATERIAL AND METHODS

Study Design, Setting, and Ethics Approval

This retrospective, archive-based study was conducted using de-identified data obtained from our institutional Hospital Information System (HIS) and Picture Archiving and Communication System (PACS). The study protocol was approved by the Ankara Bilkent City Hospital Local Ethics Committee (approval no: E1/1071/2020, date: September 16, 2020), and the study was conducted in accordance with the principles of the Declaration of Helsinki and relevant institutional regulations. Given the retrospective design and use of anonymized data, the ethics committee waived the requirement for written informed consent.

Case Identification and Data Sources

Pediatric patients evaluated between 1 January 2014 and 1 January 2019 were screened in the HIS and PACS databases using search terms consistent with a preliminary clinical and/or radiologic suspicion of TCS. Eligible patients were those aged 0-18 years with radiologic confirmation of TCS on lumbar MRI, defined as termination of the conus medullaris below the L2-L3 intervertebral disc level. Patients were excluded if imaging data were technically insufficient for diagnostic assessment, if key clinical or radiologic records were incomplete, or if there was a history of spinal surgery. To ensure the evaluation of the native anatomical spectrum, the analysis was based on initial diagnostic MRI examinations obtained prior to any surgical intervention (e.g., myelomeningocele repair or tethered cord release). For each included patient, demographic data (age and gender) and all available radiologic examinations performed as part of the TCS evaluation were recorded, primarily to provide descriptive characterization of the cohort.

Imaging Examinations and Radiologic Variables

The imaging modalities assessed (when available in the archive) included lumbar spine MRI, brain MRI, spinal ultrasonography (US), urinary tract US, and voiding cystourethrography (VCUG). Lumbar MRI was obtained for all included patients as part of diagnostic confirmation of TCS, whereas brain MRI, spinal US, urinary tract US, and VCUG were performed in selected cases based on clinical indication and analyzed using modality-specific available-case denominators.

Lumbar MRI, brain MRI, and VCUG examinations were retrospectively re-evaluated by the investigators using archived images stored in the PACS to ensure diagnostic consistency. In contrast, ultrasound findings were extracted from official radiology reports, given the real-time nature of sonographic assessment. The presence or absence of associated lumbosacral anomalies were recorded using predefined binary variables, including diastematomyelia, syrinx/syringomyelia, filum terminale lipoma, spina bifida, dermal sinus tract, meningocele, myelomeningocele, vertebral fusion/segmentation anomalies, butterfly vertebra, bifid vertebra, scoliosis/rotoscoliosis, Tarlov cyst, terminal ventricle, bony spur, and sacral/coccygeal agenesis, based on retrievable documentation. In this study, "spina bifida" was defined as bony defects of the posterior vertebral elements, distinct from open neural tube defects. The termination level of the conus medullaris was recorded as a categorical vertebral level (e.g., L3, L4, L5, S1, S2) based on the level assignment in the radiology documentation.

Urinary tract US findings were classified as normal or abnormal; specific abnormalities were recorded when present (e.g., findings compatible with neurogenic bladder, hydronephrosis, horseshoe kidney, renal agenesis, ectopic kidney, collecting system anomalies, bifid pelvis, multicystic dysplastic kidney, and double bladder). VCUG examinations were recorded as performed or not performed; when available, results were classified as normal or abnormal, neurogenic bladder-compatible findings were noted, and vesicoureteral reflux (VUR) grades were extracted. Spinal US variables (e.g., diastematomyelia, syringomyelia, spina

MAIN POINTS

- Male gender is a significant predictor of neurogenic bladder dysfunction in pediatric tethered cord syndrome patients (P=0.031).
- A borderline conus medullaris level at L3 represents a diagnostic challenge in 13.7% of patients.
- Spina bifida (44.3%) and filum terminale lipoma (37.4%) are the most prevalent associated spinal anomalies.
- High rates of concomitant Chiari II malformation (26.1%) underscore the need for comprehensive neuraxial screening.
- Multidisciplinary assessment is essential, as neurogenic bladder may present without overt neurological deficits.

bifida, filum terminale lipoma, dermal sinus, and meningomyelocele) were similarly extracted when reported. Brain MRI examinations were classified as normal or abnormal, and associated cranial findings potentially relevant to TCS and neural tube-related comorbidities were recorded, including Chiari type II malformation, hydrocephalus, corpus callosum agenesis or dysgenesis, septal agenesis, demyelinating plaques, hypoxic-ischemic encephalopathy or postoperative changes, and cranial meningocele, as documented in the reports.

For combined urogenital involvement, "neurogenic bladder" was operationally defined as the presence of neurogenic bladder-compatible findings on urinary tract US and/or VCUG.

Statistical Analysis

Analyses were performed using the statistical software IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Categorical variables are presented as counts and percentages. For modalities not performed in all patients (urinary US, VCUG, spinal US, and brain MRI), percentages were calculated using an available-case approach, restricting denominators to patients who underwent the respective examination.

In addition to descriptive analyses, selected exploratory associations were evaluated using cross-tabulations. The chi-square test was used when expected cell counts were adequate; otherwise, Fisher's exact test was applied. Two-sided *P*-values <0.05 were considered statistically significant.

RESULTS

Demographics and Conus Medullaris Level

A total of 131 pediatric patients with a confirmed diagnosis of TCS were included in the study, all of whom underwent lumbar MRI. Additionally, cranial MRI was available for 69 patients (52.6%), urinary US was performed in 97 patients (74.0%), and VCUG was performed in a targeted subset of 14 patients (10.7%), based on clinical indications. The cohort exhibited a female predominance, comprising 83 females (63.4%) and 48 males (36.6%). The mean age at evaluation was 54 months (range, 5 days to 17 years). When stratified by gender, the mean ages were 63 months (range: 5 days to 16 years) for males and 49 months (range: 1 month to 17 years) for females. The analysis of lumbar MRI findings revealed that the conus medullaris terminated most frequently at the L4 (29.0%; n=38) and L5 (26.7%; n=35) vertebral levels (Table 1, Figure 1). A distinct subset of patients (13.7%; n=18) presented with a conus level at L3, representing a borderline group; this subgroup included those with clinical signs or symptoms suggestive of TCS, supporting the diagnosis despite the higher conus level. More caudal terminations were observed at S1 (21.4%), at S2 (6.1%), and, rarely, at S3-S4 levels (1.5% each).

Associated Spinal and Cranial Anomalies

Multiple spinal anomalies frequently co-occurred on lumbar MRI scans. The most common associated malformation was spina bifida (44.3%) (Figure 2), followed by filum terminale lipoma (37.4%) (Figure 3), diastematomyelia (34.4%) (Figure 4), and syrinx/syringomyelia (32.8%) (Figure 5 and Table 2). Myelomeningocele was observed in 16.0% of patients (Figure 6), while scoliosis/rotoscoliosis and vertebral fusion anomalies were identified in 13.0% and 12.2% of patients, respectively.

Table 1. Demographic Characteristics and Conus Medullaris Termination Levels (n=131)

Characteristic	n	%	Mean Age (Range)
Gender			
Female	83	63.4	49 months (1 mo - 17 years)
Male	48	36.6	63 months (5 days - 16 years)
Total cohort			54 months (5 days - 17 years)
Conus Level			
L3	18	13.7	
L4	38	29.0	
L5	35	26.7	
S1	28	21.4	
S2	8	6.1	
S3 - S4	4	3.1	
Total cohort	131	100	

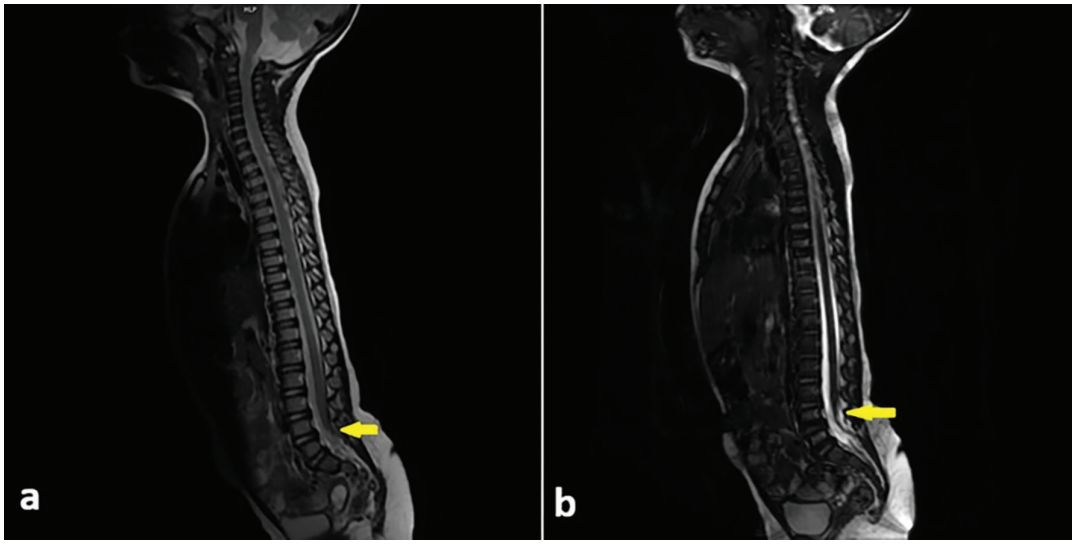


Figure 1. Sagittal lumbar MRI of a male patient with tethered cord syndrome. (a) T1-weighted and (b) T2-weighted images demonstrate a low-lying conus medullaris terminating at the L5 vertebral level (yellow arrows).

MRI, magnetic resonance imaging.

Dermal sinus tract (10.7%), Tarlov cyst (6.9%), and other anomalies were observed less frequently. Brain MRI examinations were available for 69 patients; Chiari type II malformation was the most common intracranial finding (26.1%) (Figure 7), followed by hydrocephalus (5.8%) and corpus callosum agenesis/dysgenesis (4.3%) (Table 3). Among patients with Chiari type II malformation, 50.0% (9/18) had concomitant spina bifida.

Urogenital Assessment and Gender Correlations

Urinary tract US was performed in 58 patients (44.3%). Among those examined, the most prevalent abnormalities were findings compatible with neurogenic bladder (15.5%), followed by hydronephrosis (6.9%) and renal agenesis (5.2%) (Table 3). VCUG was performed in a targeted subset (n=14); neurogenic bladder-compatible findings were present in 6 patients (42.9%), and VUR was identified in 3 patients (21.4%). No abnormalities were detected on VCUG examination in 6 patients (Table 3).

Statistical Analysis of Gender and Comorbidities

Statistical analysis revealed that male gender was significantly associated with the presence of neurogenic bladder (16.7% in males vs 4.8% in females; Fisher's exact test, P=0.031). Apart from this urological risk, no statistically significant associations were found between gender and the prevalence of spina bifida (P=0.411), filum terminale lipoma (P=0.129), diastematomyelia (P=0.570), syrinx/syringomyelia (P=0.925), or Chiari type II malformation (P=0.205). Similarly, the association between spina bifida and Chiari type II malformation did not reach statistical significance in this cohort (P=0.599). Detailed findings are summarized in Table 4.

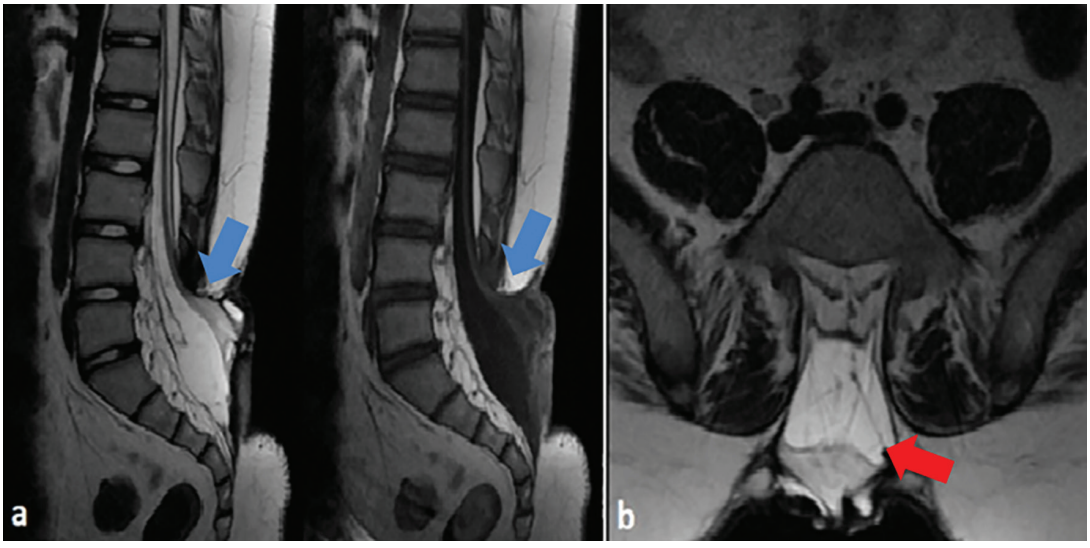


Figure 2. MRI findings of spinal dysraphism. (a) Sagittal image demonstrates a low-lying conus medullaris consistent with tethered cord syndrome, accompanied by a posterior vertebral defect (blue arrows). (b) The coronal image clearly depicts the spina bifida anomaly at the lumbosacral junction (red arrow).

MRI, magnetic resonance imaging.

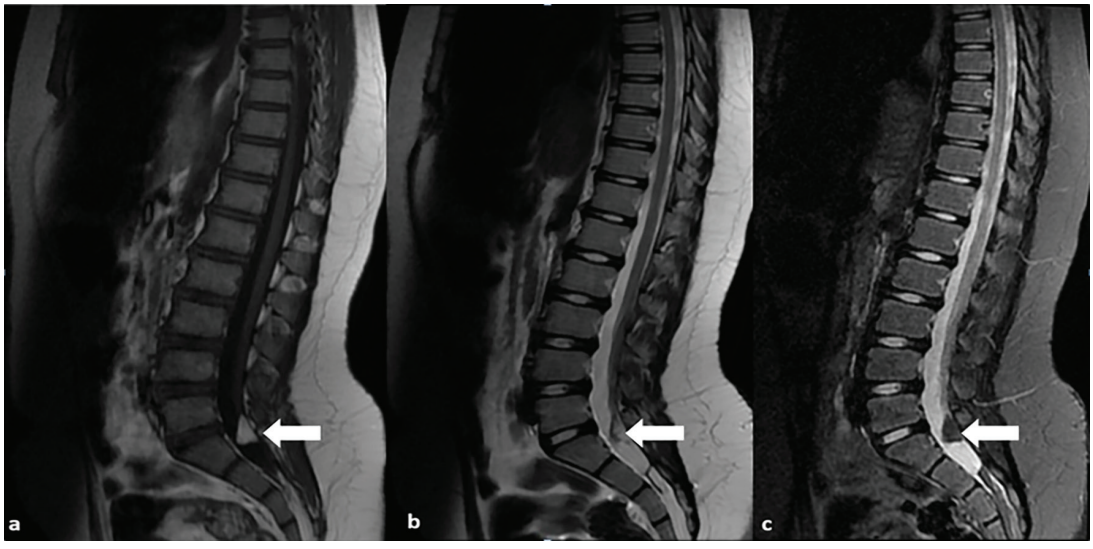


Figure 3. MRI characteristics of a filum terminale lipoma in a patient with tethered cord syndrome. The lesion (white arrows) is isointense to subcutaneous fat on all sequences. (a) Sagittal T1-weighted and (b) sagittal T2-weighted images show high signal intensity, whereas (c) the sagittal STIR sequence demonstrates signal suppression, confirming the fatty nature of the lesion.

MRI, magnetic resonance imaging; STIR, short tau inversion recovery.

DISCUSSION

This study provides a comprehensive analysis of 131 pediatric TCS cases, highlighting a distinct gender-specific risk profile for urological dysfunction despite a female-dominant prevalence in the overall cohort. Our results underscore the complexity of TCS management, necessitating a nuanced approach to diagnosis and surgical timing.

Gender Disparities in Tethered Cord Syndrome Presentation

Our finding of a 63.4% female prevalence is consistent with historical data indicating a female predisposition in spinal dysraphisms.[4,13] However, the novel and critical finding of this study is the statistically significant association between male gender and neurogenic bladder (P=0.031). This observation adds a new dimension to the findings of Bhimani et al.,[13] who analyzed the American College of Surgeons National Surgical Quality Improvement Program Pediatric database and reported that males had a higher burden of preoperative comorbidities, including developmental delays, and that females were more prone to postoperative urinary tract infections. Our data suggest that the "male phenotype" of TCS might be associated with a more aggressive disruption of sacral autonomic pathways or with a higher susceptibility to early ischemic injury, as proposed by the Yamada hypothesis.[6] This warrants intensive urodynamic surveillance of male infants with TCS, even in the absence of overt symptoms. However, it should be noted that this association was identified through univariate analysis. Although statistically significant, the limited number of events precluded multivariate adjustment for potential confounding co-anomalies.

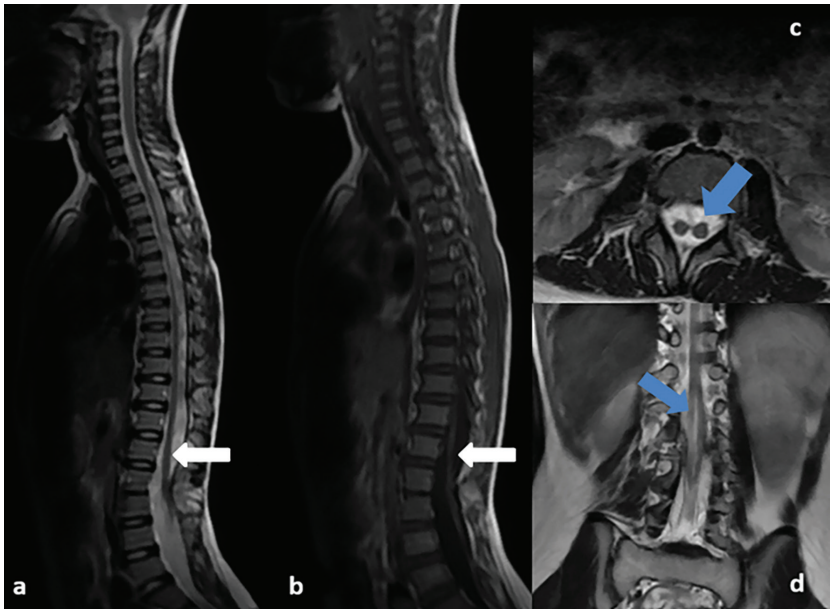


Figure 4. Multiplanar MRI evaluation of a patient with tethered cord syndrome and diastematomyelia. (a, b) Sagittal images demonstrate the low-lying distal termination of the conus medullaris (white arrows). (c) Axial and (d) coronal views clearly reveal the longitudinal splitting of the spinal cord into two hemicords (blue arrows) (diastematomyelia).

MRI, magnetic resonance imaging.

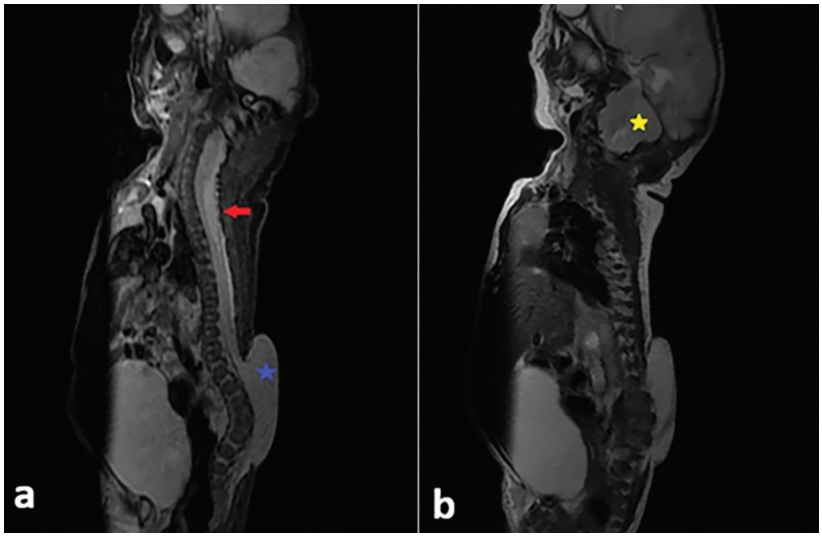


Figure 5. Associated neuraxial anomalies in a patient with tethered cord syndrome. (a) Sagittal spinal MRI reveals a syrinx cavity (red arrow) and a myelomeningocele sac (blue star). (b) Sagittal cranial MRI demonstrates a downward displacement of the cerebellar tonsils, consistent with Chiari type II malformation (yellow star).

MRI, magnetic resonance imaging.

The Diagnostic Dilemma: "Occult" Tethered Cord Syndrome and the Conus Level

Radiologically, the conus medullaris typically terminates at the level of L1-L2 in infancy.[2] In our series, the majority of patients had frank tethering at L4-L5. However, 13.7% of patients presented with a conus at L3. This "borderline" group presents a diagnostic challenge, often referred to as Occult TCS. Raghavan et al.[2] emphasized that tethering can occur with a normal conus level, particularly when associated with a thickened filum terminale (>2 mm). In such equivocal cases, recent literature advocates for dynamic imaging. Stamates et al.[11] demonstrated that prone MRI is a highly sensitive tool; a lack of ventral motion of the conus indicates tethering. Furthermore, novel techniques such as US elastography have shown promise in quantifying spinal cord tension intraoperatively.[12] Although our study relied on standard supine MRI, the presence of clinical symptoms in our L3 subgroup supports the concept that traction injury can occur without gross anatomical descent, necessitating a lower threshold for surgical exploration in symptomatic borderline cases.

Table 2. Prevalence of Associated Spinal Anomalies Detected on Lumbar MRI (n=131)

Spinal Anomaly	n	%
Spina bifida	58	44.3
Filum terminale lipoma	49	37.4
Diastematomyelia	45	34.4
Syringomyelia	43	32.8
Meningomyelocele	21	16.0
Scoliosis/rotoscoliosis	17	13.0
Fusion anomalies (e.g., block vertebra)	16	12.2
Dermal sinus tract	13	9.9
Lipomyelomeningocele	13	9.9
Sacral agenesis/caudal regression	9	6.9
Hemivertebra	8	6.1
Tarlov cyst	2	1.5
Butterfly vertebra	1	0.8

Patients may have more than one anomaly; percentages do not total 100.
MRI, magnetic resonance imaging.



Figure 6. Open spinal dysraphism in a patient with tethered cord syndrome. Sagittal MRI demonstrates a myelomeningocele, characterized by the posterior extension of the spinal cord into the subcutaneous soft tissues (red arrow).
MRI, magnetic resonance imaging.

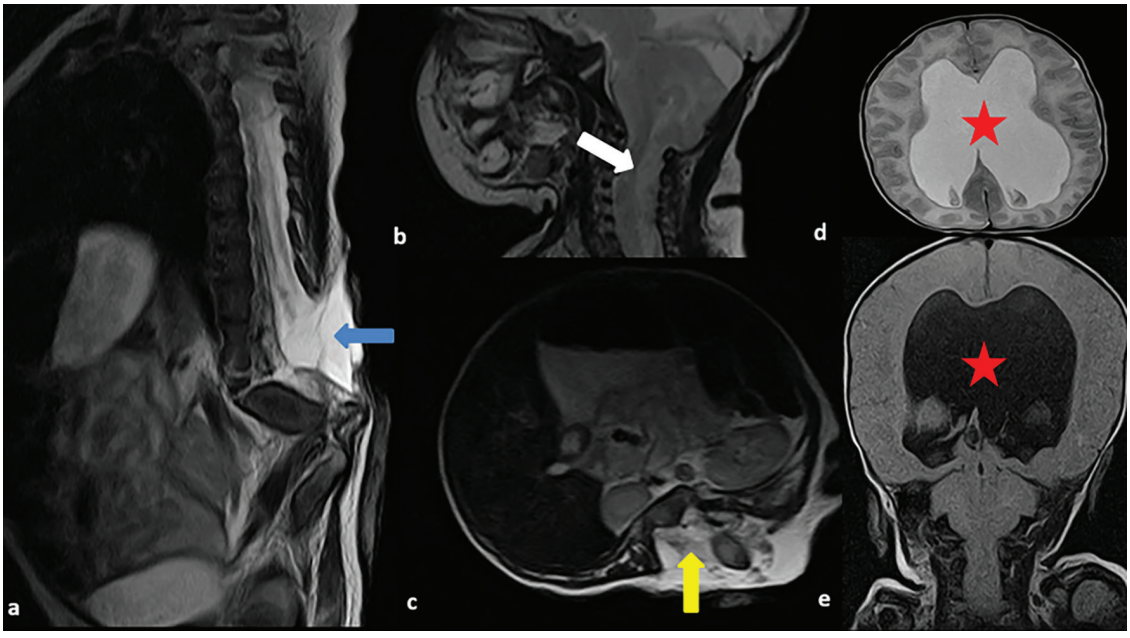


Figure 7. Complex neuraxial malformations in a patient with tethered cord syndrome. (a) Sagittal spinal MRI reveals severe scoliotic deformity and spina bifida (blue arrow), both of which are associated with a tethered cord. (b) Sagittal cranial MRI demonstrates tonsillar herniation (white arrow) consistent with Chiari type II malformation. (c) An axial spinal image highlights the posterior vertebral defect (spina bifida) (yellow arrow). (d, e) Axial cranial images show significant ventricular dilation, indicative of associated hydrocephalus (red stars).
MRI, magnetic resonance imaging.

Associated Anomalies and Systemic Screening

The high prevalence of spina bifida (44.3%) and lipomas (37.4%) in our cohort underscores the importance of comprehensive spinal assessment in patients with TCS. These findings align with existing literature reporting frequent co-occurrence of spinal dysraphism and fatty filum terminale abnormalities in pediatric TCS.[2,16] The observed frequency of Chiari type II malformation (26.1% among those who underwent brain MRI) further emphasizes the need to evaluate patients for associated intracranial anomalies when clinically indicated. Previous studies have highlighted the potential association between spinal dysraphism, hindbrain herniation, and hydrocephalus, particularly in myelomeningocele patients. Additionally, urinary tract US and VCUG findings revealed that neurogenic bladder-compatible changes and VUR were present in a subset of patients, supporting a multidisciplinary diagnostic approach that includes renal, potentially, echocardiographic evaluation.[17]

Surgical Timing and Prognosis

The timing of intervention remains a pivotal discussion point. While symptomatic patients clearly benefit from detethering to arrest neurological decline, the management of asymptomatic patients is controversial. Seki et al.[14] reported that prophylactic surgery in asymptomatic children, particularly before 34 months of age, yields significantly better long-term neurological prognoses compared to conservative follow-up. Similarly, Shang et al.[16] found that symptom duration was an independent predictor of surgical outcome, with early intervention leading to better recovery rates. Conversely, Hsieh et al.,[9] in a systematic review, noted that while surgery generally stabilizes function, the evidence for prophylactic surgery must be weighed against surgical risks such as CSF leakage and retethering. Given that 15.5% of our cohort already had neurogenic bladder at presentation, and considering the limited reversibility of established bladder dysfunction,[10] our findings suggest that male patients warrant increased urological vigilance and potentially earlier evaluation, given the observed higher association with neurogenic bladder findings.

Table 3. Cranial and Urological Findings Detected in Screened Patient Subgroups

Imaging Modality and Findings	Screened (n)	Detected (n)	%
Cranial MRI Findings	69		
Normal cranial MRI		46	66.7
Abnormal findings (total)		23	33.3
- Chiari II malformation		18	26.1
- Hydrocephalus		4	5.8
- Corpus callosum anomalies		3	4.3
- Other (arachnoid cyst, etc.)		3	4.3
Urinary US Findings	58		
Normal urinary US		46	79.3
Abnormal findings (total)		12	20.7
- Neurogenic bladder (wall thickening/ trabeculation)		9	15.5
- Hydronephrosis/pelvicalyceal ectasia		5	8.6
- Other (renal agenesis, ectopia)		3	5.2
VCUG Findings	14		
Normal VCUG		6	42.9
Abnormal findings (total)		8	57.1
- Neurogenic bladder dysfunction		6	42.9
- Vesicoureteral reflux		3	21.4

Patients may have more than one anomaly; percentages do not total 100. Percentages for cranial anomalies were calculated based on the subset of patients with cranial MRI (n=69).
MRI, magnetic resonance imaging; US, ultrasound; VCUG, voiding cystourethrography.

Table 4. Statistical Analysis of Associations Between Gender, Conus Level, and Major Anomalies

Parameter	Comparison Group 1	Comparison Group 2	*P*-value*
Gender vs. Anomalies	**Female (n=83)**	**Male (n=48)**	
Neurogenic bladder**	4 (4.8%)	8 (16.7%)	**0.036**
Spina bifida	39 (47.0%)	19 (39.6%)	0.411
Filum terminale lipoma	27 (32.5%)	22 (45.8%)	0.129
Diastematomyelia	30 (36.1%)	15 (31.3%)	0.570
Syrinx/syringomyelia	27 (32.5%)	16 (33.3%)	0.925
Chiari II malformation***	9/44 (20.5%)	9/25 (36.0%)	0.158
Conus Level vs. Anomalies	**Lumbar (L3-L5) (n=91)**	**Sacral (S1-S4) (n=40)**	
Filum terminale lipoma	37 (40.7%)	12 (30.0%)	0.246
Diastematomyelia	34 (37.4%)	11 (27.5%)	0.306
Chiari II malformation***	13/50 (26.0%)	5/17 (29.4%)	0.784
Associations Between Anomalies	**Spina Bifida (+)**	**Spina Bifida (-)**	
Chiari II malformation***	9/28 (32.1%)	9/41 (22.0%)	0.354

**P*-value: Calculated using Fisher's exact test.
**Neurogenic bladder: Indicates the presence of bladder dysfunction identified via either urinary ultrasonography or voiding cystourethrography.
***Chiari II malformation: Prevalence rates and statistical associations for Chiari II malformation were calculated based on the sub-cohort of patients who underwent cranial MRI screening (n=69; 44 females, 25 males), rather than the total study population. Conus level grouping: For statistical comparison, conus termination levels were categorized into Lumbar (L3, L4, L5) and Sacral (S1, S2, S3-S4) segments.
MRI, magnetic resonance imaging.

Study Limitations

The present study has certain limitations. First, its retrospective, single-center design may limit the generalizability of the findings to the broader population. Second, the inclusion criterion of a low-lying conus (below L2-L3) inherently focuses on the anatomical spectrum of TCS, potentially excluding "occult" cases with a normal conus level. Third, not all patients underwent cranial or urinary imaging, which may have introduced a selection bias regarding the prevalence of associated anomalies. Fourth, the relatively low number of neurogenic bladder events precluded multivariate analysis. Finally, as this is an imaging-based study, long-term post-operative clinical outcomes were not included in the analysis.

CONCLUSION

TCS in the pediatric population is a multifaceted disorder with significant gender-based variations in clinical presentation. Our study identifies male sex as a significant risk factor for neurogenic bladder dysfunction, challenging clinicians to adopt lower thresholds for urodynamic investigation in male infants. Furthermore, the presence of borderline conus levels (L3) in a subset of patients underscores the importance of multiparametric evaluation, potentially incorporating prone MRI or US elastography, to identify "occult" tethering. Future management strategies should prioritize early detethering, especially in high-risk groups, to prevent irreversible ischemic injury and optimize long-term quality of life.

Declaration of AI and AI-Assisted Technologies in the Writing Process

The authors used AI-assisted technologies only for language polishing and grammatical refinement during the writing process. The scientific content and data integrity were verified by the authors, who maintain full responsibility for the publication.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Committee Approval: This study was approved by the Ankara Bilkent City Hospital Local Ethics Committee (approval no: E1/1071/2020, date: September 16, 2020).

Informed Consent: Given the retrospective design and use of anonymized data, the ethics committee waived the requirement for written informed consent.

Footnotes

Author Contributions: Concept – E.Ö., Ş.Y., G.B.I., H.İ.Y.; Design – E.Ö., G.B.I., H.İ.Y.; Data Collection or Processing – E.Ö., Ş.Y., H.İ.Y.; Analysis or Interpretation – E.Ö., G.B.I.; Literature Search – E.Ö., Ş.Y., G.B.I., H.İ.Y.; Writing – E.Ö.

Declaration of Interests: The authors declare that there is no conflict of interest

Funding: The authors declare that this study did not receive any financial support.

REFERENCES

1. Barson AJ. The vertebral level of termination of the spinal cord during normal and abnormal development. *J Anat.* 1970;106(Pt 3):489-497. [CrossRef]
2. Raghavan N, Barkovich AJ, Edwards M, Norman D. MR imaging in the tethered spinal cord syndrome. *AJR Am J Roentgenol.* 1989;152(4):843-852. [CrossRef]
3. Kına H, Baydın S, Canaz H, Baydın SŞ, Demirci H, Alataş İ. Tethered cord sendromu ve cerrahi yaklaşım. *Sinir Sistemi Cerrahisi Derg.* 2014;4(2):78-81. [CrossRef]
4. Agarwalla PK, Dunn IF, Scott RM, Smith ER. Tethered cord syndrome. *Neurosurg Clin N Am.* 2007;18(3):531-547. [CrossRef]
5. Yamada S, Won DJ, Yamada SM. Pathophysiology of tethered cord syndrome: correlation with symptomatology. *Neurosurg Focus.* 2004;16(2):E6. [CrossRef]
6. Yamada S, Zinke DE, Sanders D. Pathophysiology of "tethered cord syndrome". *J Neurosurg.* 1981;54(4):494-503. [CrossRef]
7. Yelikbayev GM, Tutayeva AA. Clinical manifestation of a tethered cord syndrome at children and research methods for early diagnosis of disease. *Biomedical and Pharmacology Journal*. 2015;8(2):597-601. [CrossRef]
8. Lew SM, Kothbauer KF. Tethered cord syndrome: an updated review. *Pediatr Neurosurg.* 2007;43(3):236-248. [CrossRef]
9. Hsieh P, Apaydin E, Briggs RG, et al. Diagnosis and treatment of tethered spinal cord: a systematic review. Pediatrics. 2024;154(5):e2024068270. [CrossRef]
10. Habib A, Idrees M, Shivananda DB, et al. Tethered cord syndrome (TCS) and constipation in children: a multifaceted approach (literature review). *Ann Med Surg (Lond).* 2025;87(3):1529-1542. [CrossRef]
11. Stamates MM, Frim DM, Yang CW, Katzman GL, Ali S. Magnetic resonance imaging in the prone position and the diagnosis of tethered spinal cord. *J Neurosurg Pediatr.* 2018;21(1):4-10. [CrossRef]
12. Kerensky MJ, Paul A, Routkevitch D, et al. Tethered spinal cord tension assessed via ultrasound elastography in computational and intraoperative human studies. *Commun Med (Lond).* 2024;4(1):4. [CrossRef]
13. Bhimani AD, Selner AN, Patel JB, et al. Pediatric tethered cord release: an epidemiological and postoperative complication analysis. *J Spine Surg.* 2019;5(3):337-350. [CrossRef]
14. Seki T, Hida K, Yano S, et al. Surgical outcome of children and adolescents with tethered cord syndrome. *Asian Spine J.* 2016;10(5):940-944. [CrossRef]
15. Vepakomma D, Kumar N, Alladi A. Tethered cord syndrome-role of early surgery. *J Indian Assoc Pediatr Surg.* 2019;24(2):124-128. [CrossRef]
16. Shang AJ, Yang CH, Cheng C, et al. Microsurgical efficacy in 326 children with tethered cord syndrome: a retrospective analysis. *Neural Regen Res.* 2019;14(1):149-155. [CrossRef]
17. Prasad N, Gupta M, Singh R, et al. Tethered cord syndrome and its association with cardiovascular and other anomalies: insights from a prospective observational cohort of 60 cases. *Cureus.* 2025;17(9):e92644. [CrossRef]