Original Study Article

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Transitional Lumbosacral Vertebrae in Children With Pelvic Fractures: Frequency of Diagnosis and Distribution of Types and Subtypes

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ABSTRACT

BACKGROUND: Various aspects of transitional lumbosacral vertebrae in children remain relevant due to a lack of research on several critical issues. For instance, the frequency of diagnosis and the distribution of different types and subtypes of this condition in the pediatric population remain unknown. The clinical features, particularly pain as the main symptom, have not been sufficiently studied. Furthermore, effective and pathogenetically based approaches to the treatment and prevention of low back pain associated with transitional lumbosacral vertebrae in different pediatric groups have not yet been developed.

AIM: The study aimed to determine the prevalence and structure of transitional lumbosacral vertebrae in children with pelvic fractures.

METHODS: This study included 41 children who sustained pelvic fractures between 2022 and 2024, with transitional lumbosacral vertebrae in 10 patients. The diagnostic protocol adhered to the standard for patients with pediatric trauma and included mandatory computed tomography of the lumbar spine and pelvis. Pelvic fractures were classified according to the Tile/AO classification system. Acetabular fractures were assessed using the classification criteria proposed by Judet et al. Transitional lumbosacral vertebrae types and subtypes were categorized based on the Castellvi classification.

RESULTS: The diagnostic frequency of transitional lumbosacral vertebrae was found to be 24.4% ± 6.7% of clinical cases. Subtype IIa was the most common, accounting for 50.0% ± 15.8% of cases, followed by subtype IIIb, which occurred in 30.0% ± 14.5% of patients. Subtypes Ia and IIb each represented 10.0% ± 9.4% of the observed cases. The study revealed that, unlike in adult patients, a distinguishing feature of the condition in children was the absence of the main symptom, namely, pain in the lumbosacral junction.

CONCLUSION: The high diagnostic frequency of this condition, which often remains latent for some time, highlights the importance of targeted radiological assessment of the lumbosacral junction. Once transitional lumbosacral vertebrae are identified, patients should be informed of their presence to support the joint development of individualized strategies for preventing lumbosacral pain.

Keywords: children; transitional lumbosacral vertebrae; frequency of diagnosis; distribution of disease types; pelvic fractures.

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Оригинальное исследование

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Переходные пояснично-крестцовые позвонки у детей, получивших переломы костей таза: частота диагностики, структура типов и подтипов заболевания

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АННОТАЦИЯ

Обоснование. Различные аспекты переходных пояснично-крестцовых позвонков у детей сохраняют свою актуальность по причине неизученности многих важнейших вопросов. Так, например, неизвестна частота диагностики и структура различных типов и подтипов этого заболевания среди детей. Не изучены особенности клинической симптоматики, прежде всего основного ее симптома — боли. Не разработаны эффективные и патогенетически обоснованные методы лечения и профилактики поясничной боли, связанной с переходными позвонками среди различных групп детского населения.

Цель — установить частоту и структуру переходных пояснично-крестцовых позвонков среди детей, получивших переломы костей таза.

Материалы и методы. В группе из 41 ребенка, получивших переломы костей таза в 2022–2024 гг., у 10 пациентов диагностировали переходные пояснично-крестцовые позвонки. Объем проведенного исследования был стандартным для больных травматологического профиля и в обязательном порядке включал проведение компьютерной томографии поясничного отдела позвоночника и таза. Для установления типа полученных детьми повреждений костей таза использовали классификацию Tile/AO. При оценке переломов вертлужной впадины использовали критерии классификации R. Judet и соавт. Переходные пояснично-крестцовые позвонки распределяли на типы и подтипы в соответствии с классификацией A.E. Castellvi и соавт.

Результаты. В ходе исследования установлена частота диагностики переходных позвонков: 24,4±6,7% клинических наблюдений. В структуре патологии преобладал подтип IIa заболевания: 50,0±15,8% случаев. На втором ранговом месте находились пациенты с подтипом IIIb заболевания: 30,0±14,5% больных. На долю пациентов с подтипами Ia и IIb пришлось по 10,0±9,4% клинических наблюдений. В ходе исследования установлено, что отличительной особенностью течения заболевания, в сравнении с пациентами зрелого возраста, было отсутствие основного симптома — боли, локализующейся в люмбо-сакральном переходе.

Заключение. Высокий процент частоты диагностики заболевания, протекающего до определенного времени латентно, свидетельствует о том, что необходимо целенаправленно изучать лучевую картину люмбо-сакрального перехода и при выявлении переходных позвонков информировать пациентов об их наличии с целью совместной разработки индивидуальных мер профилактики пояснично-крестцовой боли.

Ключевые слова: дети; переходные пояснично-крестцовые позвонки; частота диагностики; структура заболевания; переломы костей таза.

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原创研究

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儿童骨盆骨折患者中腰骶移行椎的检出率及其类型和亚型结构分析

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摘要

论证。儿童腰骶移行椎的多个方面因诸多关键问题尚未明确而仍具有研究价值。例如，该疾病在儿童中的检出率及其各类型和亚型的构成尚属未知。尚未研究其临床症状的特点，尤其是其主要症状——疼痛。尚未建立针对不同儿童群体中与移行椎相关腰痛的有效且具有病理机制依据的治疗和预防策略。

目的：确定骨盆骨折儿童中腰骶移行椎的检出率及其类型和亚型的结构特征。

材料与方法。在2022—2024年间的41例骨盆骨折患儿组成的研究组中，10例被诊断为腰骶移行椎。所有患者均接受了腰椎与骨盆的计算机断层扫描，检查方案为创伤科常规评估流程。为明确患儿骨盆骨折的类型，采用Tile/AO分型标准。在评估髋臼骨折时，采用R. Judet等人提出的分类方法。腰骶移行椎则按照A.E. Castellvi等人的分类方法将其分为不同的类型和亚型。

结果。本研究中腰骶移行椎的检出率为24.4±6.7%。在该病变类型构成中，以IIa亚型最为常见，占比50.0±15.8%。排名第二的是IIIb亚型，占30.0±14.5%的患者。Ia型与IIb型各占10.0±9.4%的临床病例。研究发现，相较于成人患者，儿童患者的一个显著特征是在病程中缺乏典型的局限性腰骶部疼痛。

结论。此类病变在儿童中虽可长期隐匿存在，然而其检出率较高，提示在影像学评估中应有针对性地检查腰骶交界区。一旦发现腰骶移行椎，应及时向患者告知其存在，并共同制定个体化的腰骶疼痛预防措施。

关键词：儿童；腰骶移行椎；检出率；疾病分型结构；骨盆骨折。

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BACKGROUND

Current scientific data on various aspects of transitional lumbosacral vertebrae in children and adolescents are limited. As this is a congenital condition, it could most probably be diagnosed during childhood [1]. However, this is usually not the case; signs of the condition are often incidentally detected during imaging studies conducted for other reasons, most commonly for traumatic injuries to the spine or pelvis [2]. In addition, delayed transitional vertebrae diagnosis is frequently associated with numbering errors [3] or decreased attention from medical personnel when interpreting imaging results [4]. The relevance of this issue is further emphasized by the fact that the prevalence of this condition across pediatric populations remains unknown [5]. Clinical symptoms observed in adults are often mechanically extrapolated to growing patients without considering the anatomical and physiological characteristics of the developing spine [6]. Moreover, there is no standardized approach to effective treatment, especially for adequate pain management for L_5 radiculopathy [7].

These challenges are critical from a research perspective and in improving the quality of life for children with transitional lumbosacral vertebrae, who were unaware of their congenital lumbosacral anomaly before sustaining pelvic bones injuries [8].

The work aimed to determine the prevalence and distribution of transitional lumbosacral vertebrae in children with pelvic fractures.

METHODS

This study included longitudinal observations of 41 children aged 5–18 years who sustained pelvic fractures between 2022 and 2024. As part of a comprehensive diagnostic workup, including computed tomography (CT), transitional lumbosacral vertebrae were found in 10 of the 41 patients (24.4% ± 6.7%). These 10 children formed the study's focus group. The mean age of the patients was 13.6 ± 2.8 years. The cohort included four boys (40.0% ± 15.5%) and six girls (60.0% ± 15.5%). The scope of the investigation was standard for trauma patients: recording of complaints and medical history, clinical examination conducted by relevant specialists, and comprehensive radiological assessment, with mandatory pelvic CT.

Pelvic fractures were classified using the Tile/AO system [9]. The classification by Judet et al. was used to assess acetabular fractures [10]. Transitional lumbosacral vertebrae were categorized into types and subtypes based on the classification by Castellvi et al. [11].

Statistical analysis involved calculating the relative value of each indicator as a percentage (*P*) and the standard error of representativeness (±*m*).

RESULTS

Clinical and radiological assessment of the injured children allowed for identifying the nature of the pelvic injuries. The pelvic trauma in eight clinical cases (80.0% ± 6.2%) was classified as type "a" according to accepted classification systems. In two patients (20.0% ± 6.2%), the fractures—specifically, acetabular fractures—were classified as type "b" injuries.

In evaluating pelvic imaging findings, particularly 3D CT scans, special attention was given to assessing the lumbosacral junction and sacrum for the presence of transitional lumbosacral vertebrae. When such vertebrae were detected, the type and subtype of the anomaly were determined using axial CT slices (scans). Table 1 presents the results of the CT analysis of the lumbosacral junction in 10 injured patients with diagnosed transitional vertebrae.

The data in Table 1 indicates that in half of the clinical cases (50.0% ± 15.8%), the diagnosed condition of the lumbosacral junction corresponded to type II, subtype a, according to the Castellvi classification (Fig. 1).

The subtype IIa presented in Fig. 1 is characterized by an enlarged transverse process (either left, as in this case, or right) of the vertebra above the sacrum, which articulates with the sacral ala via a pseudoarticulation [11].

The second most common subtype of the diagnosed transitional vertebrae was subtype IIIb, which was observed in 30.0% ± 14.5% of the clinical cases (Fig. 2).

Analysis of the CT scans shown in Fig. 2 focused on the sacrum, which exhibits five pairs of sacral foramina. Normally, five sacral vertebrae fuse by the age of 22–24 years to form the sacrum (*os sacrum*), which has four pairs of sacral foramina [12]. A sacrum with five pairs of sacral foramina, as revealed by 3D reconstruction, is an indicator of transitional vertebrae type III or IV [11].

Subtypes Ia and IIb each accounted for 10.0% of the clinical cases. The radiological characteristics of these subtypes were typical: hypertrophy of one of the transverse processes of the vertebra above the sacrum (in subtype Ia) and bilateral

Table 1. Frequency of diagnosed types and subtypes of transitional vertebrae in children with pelvic fractures

Type and subtype of the condition		Number of cases	
		n	%
I	a	1	10.0 ± 9.4
	b	–	–
II	a	5	50.0 ± 15.8
	b	1	10.0 ± 9.4
III	a	–	–
	b	3	30.0 ± 14.5
IV		–	–
Total		10	100.0

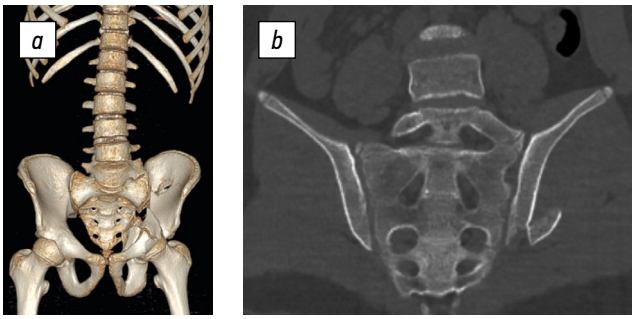

Fig. 1. Three-dimensional reconstruction (*a*) and CT scan (*b*) of the lower thoracic and lumbar spine, pelvic bones, and hip joints of a 16-year-old female patient. Subtype IIIb injury of the left side of the pelvis (acetabular and iliac wing fractures). Transitional lumbosacral vertebra, subtype IIa.

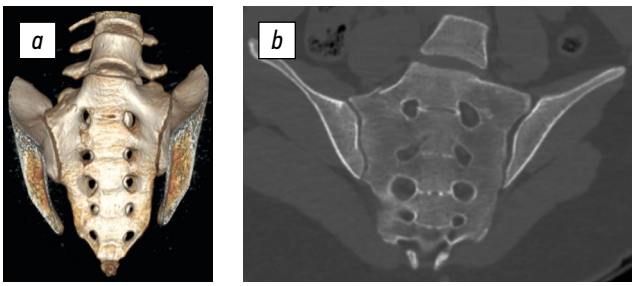

Fig. 2. Three-dimensional reconstruction (*a*) and CT scan (*b*) of the lower lumbar spine and sacrum of a 16-year-old female patient. Type a sacral injury (right iliac wing fracture). Transitional lumbosacral vertebra, type III, subtype b.

pseudoarticulations between the hypertrophied transverse processes of the lowest lumbar vertebra and sacral alae (in subtype IIb).

Avulsion fractures of the cartilaginous pelvic structures, such as the anterior superior iliac spines and anterior inferior iliac spines, are classified as pediatric-specific injuries [13]. In the study group, a 13-year-old girl sustained an avulsion fracture of the right iliac crest after falling from a horse. Comprehensive assessment confirmed the avulsion fracture and presence of a transitional lumbosacral vertebra (Fig. 3).

The presence of a transitional vertebra was first indicated by the sacrum with five pairs of sacral foramina (Fig. 3*a–c*). Further analysis of the radiological findings revealed that, unlike the clinical case shown in Fig. 2, the two cranial vertebrae were separated by pseudoarthrosis at the level of the sacral wings on the left and right sides, classifying this clinical case as subtype IIb (Fig. 3*d*).

A critical finding of the present study was none of the 10 patients diagnosed with transitional vertebrae during evaluation for pelvic injuries had reported any complaints related to the spine or sacrum prior to the trauma. This was confirmed by the parents of the injured children.

DISCUSSION

The term transitional lumbosacral vertebrae was introduced by Durr over 160 years ago. In 1860, he published an article in the German journal *Zeitschrift für rationale Medizin*, where he proposed this term to describe vertebrae that had “adopted” the shape and functions of two adjacent spinal regions. The modern interpretation of transitional lumbosacral vertebrae is reflected in the classification proposed in 1984 by a group of American orthopedic surgeons led by Castellvi, which has remained widely accepted among specialists. Fig. 4 shows a schematic representation of the classification by Castellvi et al. [11].

The Castellvi classification is based on the analysis of the size of the transverse processes of the lowest lumbar vertebra and type of contact (pseudarthrosis or synostosis) between these processes (or one of them) and the sacral wings on one or both sides. This condition originates in utero, between weeks 4 and 6 of gestation [14].

Scientific data indicate that the prevalence of transitional vertebrae in the general population greatly varies, ranging from 4% [15] to 36% [16]. According to Vaidya et al. [17], this variation is due to differences in the study populations, imaging techniques used, and interpretation of the findings.

Currently, CT is considered the most effective method for objectively diagnosing transitional vertebrae. In a scientific publication, Hanhivaara et al. [18] used the phrase “superior diagnostic efficacy” to describe the capabilities of this imaging modality.

As previously noted, in 50.0% ± 6.7% of the clinical cases in our cohort, transitional vertebrae of type II, subtype a were

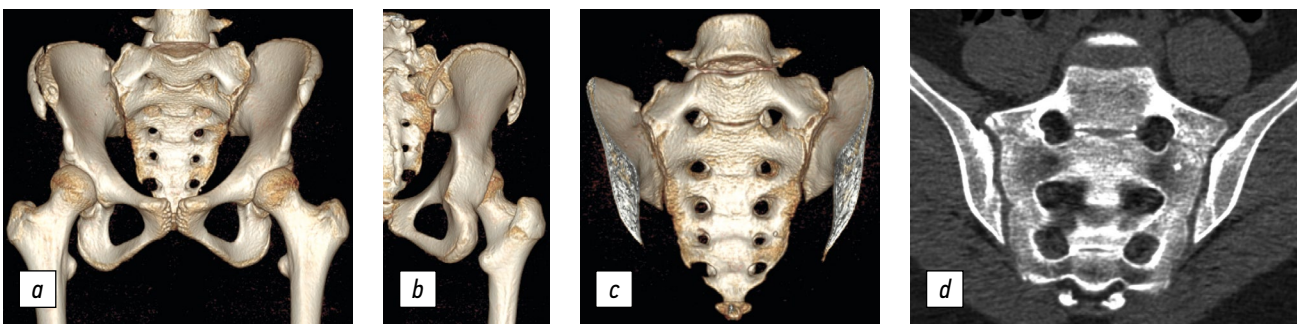

Fig. 3. Three-dimensional reconstructions (*a*, *b*, and *c*) and CT scan (*d*) of the lower lumbar spine, pelvic bones, and hip joints of a 13-year-old female patient. Avulsion fracture of the right iliac crest (*a* and *b*). Transitional lumbosacral vertebra, type II, subtype b (*a*, *c*, and *d*).

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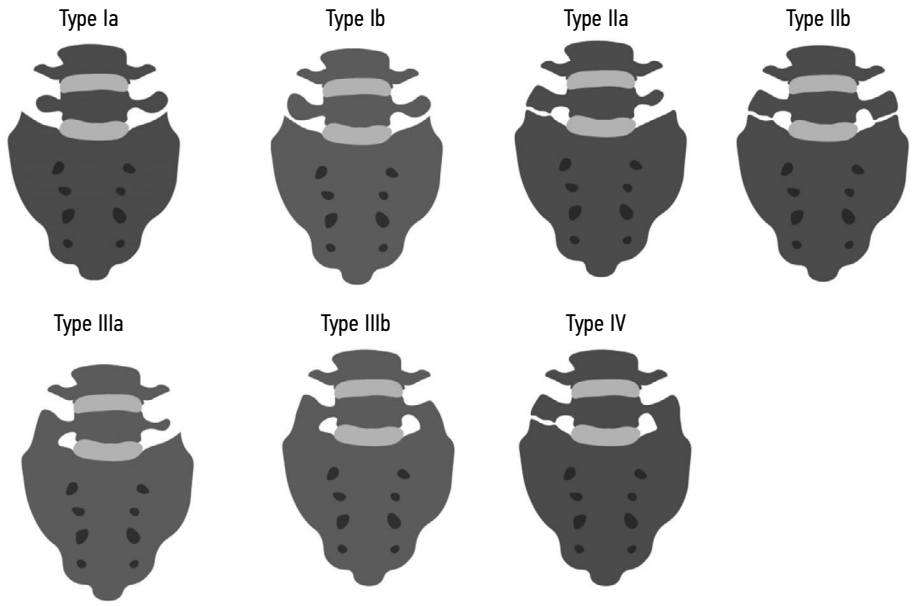

Fig. 4. Schematic representation of different types and subtypes of transitional lumbosacral vertebrae according to Castellvi.

diagnosed. These findings are consistent with the results of a previous analysis conducted by the authors, which examined the prevalence of different types and subtypes of transitional vertebrae. That analysis was based on data from 17 scientific research studies across Europe, Asia, and the Americas. Collectively, these studies analyzed the radiological data of 5090 patients of various ages with transitional lumbosacral vertebrae. Ranking of disease types and subtypes revealed that clinical cases corresponding to subtype IIa ranked first in diagnostic frequency, with 26.9% ± 0.6% of cases [5].

Scientific data reveal that subtype IIa is the most frequently associated with vertebrogenic pain localized in the lumbosacral region [19]. The average intensity of the pain syndrome typically corresponds to 6 points on the visual analog scale [20]. The main cause of pain in patients with transitional vertebrae is extraforaminal stenosis at the lumbosacral junction [21], which significantly increases the risk of L_5 and S_1 nerve root impingement [22]. In addition, García López et al. [23] noted that transitional vertebrae induce abnormal rigidity (as described in the article) in the lumbosacral junction, which negatively affects the spine's shock-absorbing function. These structural abnormalities at the lumbosacral junction progress as skeletal ossification advances during growth [24]. This may explain the absence of low back pain in 10 pediatric patients analyzed in the current study despite the presence of pathognomonic radiological signs of transitional vertebrae. Interestingly, when characterizing patients with transitional vertebrae, Tsoupras et al. [25] use the term "skeletally immature subjects."

The absence of low back pain in children and adolescents with transitional vertebrae is further confirmed by another study conducted by the authors of the present study. In 19 children with uncomplicated lumbar vertebral fractures who also exhibited reliable radiological signs of transitional vertebrae, no vertebrogenic pain was reported prior to trauma [26]. Moreover, the possibility of low back pain has been reported in pediatric patients with transitional vertebrae [27]. In some cases, the duration, intensity, frequent recurrence, and limited efficacy of conservative pain treatment may be indications for surgical intervention, as in adult patients with the same condition [28]. In adolescents, surgery generally involves pseudoarthrectomy of the hypertrophied transverse process of the lumbosacral transitional vertebra [29].

CONCLUSION

The aim of the study was successfully achieved: The frequency and distribution of lumbosacral transitional vertebrae were determined in a pediatric cohort with pelvic bone fractures. It was found that the diagnostic frequency of lumbosacral transitional vertebrae in the studied cohort was 24.4% ± 6.7% of clinical cases. Subtype IIa was the most prevalent, accounting for 50.0% ± 15.8% of cases. Subtype IIIb ranked second, being diagnosed in 30.0% ± 14.5% of patients. Subtypes Ia and IIb were each found in 10.0% ± 9.4% of cases. No cases of subtypes Ib and IIIa and type IV transitional vertebrae were identified. A key distinguishing feature of the clinical presentation in children was the absence of the primary symptom, namely, pain in the lumbosacral region, despite the fact that the radiological features of all detected subtypes were identical to those observed in adult patients.

The study results confirm that lumbosacral transitional vertebrae are a widespread condition in the general population, including in pediatric patients. The alarmingly high detection rate of this condition during imaging examinations

performed for various injuries to the axial skeleton indicates the need for focused radiological assessment of the lumbosacral junction. In cases wherein developmental anomalies of the lumbosacral region are identified, patients and their parents should be informed of the condition and counseled regarding its possible clinical manifestations in the near future. This is particularly crucial, as pain potentially caused by transitional vertebrae may be misinterpreted as a consequence of pelvic fractures, leading to diagnostic errors and hindering the selection of an appropriate treatment strategy.

ADDITIONAL INFORMATION

Author contributions: E.G. Skryabin: conceptualization, methodology, investigation, formal analysis, writing—original draft; A.Yu. Krivtsov: investigation, formal analysis, writing—original draft. All authors approved the version of the manuscript to be published and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics approval: The study was approved by the Local Ethics Committee of Tyumen State Medical University (approval protocol No. 187/06.1 dated April 2, 2025). The study and its protocol were not registered.

Consent for publication: Written informed consent was obtained from the patient for the publication of personal data in a scientific journal. The scope of the published data (results of pelvic imaging) was approved by the patients' legal representatives.

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