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Transitional lumbosacral vertebrae

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Abstract

Transitional lumbosacral vertebrae in the form of S_I lumbarization and L_V sacralization are classified as spinal anomalies. In the domestic medical literature, there are few publications devoted to these pathological conditions. In the course of a study of the available literature on the problem of transitional lumbosacral vertebrae, it was found that the frequency of cases of transitional lumbosacral vertebrae diagnosis ranges from 4 to 30% of clinical cases. The share of patients with lumbar vertebrae accounts for an average of 40% of cases, the share of patients with sacralization of the vertebrae is 60% of clinical observations. Mutations in the Hox gene are considered to be the trigger for the development of pathology, and pain is usually the leading clinical symptom. Plain radiography, computed tomography and magnetic resonance imaging are used to diagnose the pathology. Radiation imaging of the entire spine is required to eliminate errors in vertebrae counting. The type of pathology is determined using various classifications. As conservative therapeutic agents, drug blockades applying anesthetics and hormonal drugs are used. The arsenal of surgical interventions includes resection of the enlarged transverse process of the supracacral vertebra, decompression of stenotic intervertebral foramina, impulsive radiofrequency ablation, and posterior fusion. Measures for the prevention of pathology are not currently developed.

Keywords: transitional lumbosacral vertebrae, S_I lumbarization, L_V sacralization, review.

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The lumbarization of the S vertebra$_I$ and the sacralization of the L_V vertebra are referred to as developmental anomalies of lumbosacral localization, united by the general term "transitional lumbosacral vertebrae" [1]. Transitional lumbosacral vertebrae are one of the most common causes of low back pain [2]. Despite this universally recognized fact, very little medical information has been published on the various aspects of this pathology by Russian authors; if published, studies are mainly concerned with the frequency of diagnosis [3, 4].

This review aimed to analyze the main domestic and foreign publications devoted to transitional lumbosacral vertebrae. Scientific publications for writing the literature review were obtained from modern databases PubMed, eLIBRARY, and CYBERLENINKA. In total, 87 scientific articles were reviewed in detail. These articles reflect current problems and aspects of the topic.

The inclusion criteria of scientific publications were as follows: systematic reviews, meta-analyses, monocenter cohort studies, case–control studies, and clinical cases describing strategies undertaken in the treatment of patients with transitional lumbosacral vertebrae. The following keywords were used in the literature search: lumbosacral transitional vertebrae, lumbarization of the S_I vertebra, and sacralization of the L_V vertebra.

Transitional lumbosacral vertebrae are characterized by additional articulation of the transverse processes of L_V and S_I, fusion (unilateral or bilateral) of these vertebrae, and separation (partial or complete) of the two upper sacral vertebrae [5]. These pathologic conditions occur in 4%–30% of all age groups [6].

According to the definition by Ulrich et al., the term "lumbarization" should be understood as "...a disruption of the completeness (increase in the number) of the lumbar vertebrae due to the lack of blockage of the first sacral vertebra with the underlying vertebra and iliac bone (lumbarization S_I), or due to bilateral agenesis of the 12th rib (lumbarization of the Th_{XII})." The same authors define the term "sacralization" as "...a lumbosacral anomaly consisting in the acquisition by the lower lumbar vertebra of features characteristic of sacral vertebrae: uni- or bilateral synchondrosis (blocking) of the transverse process of the L_V vertebra with the wing of the iliac bone, or complete fusion of the L_V body with the S_I body" [7].

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Epidemiology

According to most researchers, the frequency of lumbarization and sacralization in the population ranges from 1% to 2% of clinical observations [8–10]. Among patients diagnosed with transitional lumbosacral vertebrae, lumbarization and sacralization account on average for a combined 39.85% and 60.15% of clinical observations, respectively [11].

While giving these percentages, we did not include the scientific article by Khashoggi et al. in the analysis of the frequency of the forms of the pathology under discussion. These authors analyzed the results of radiological examination of the kidneys and bladder in 2078 residents of Saudi Arabia. Indirect symptoms of transitional lumbosacral vertebrae were established on urograms in 158 (7.6%) of the examined patients, and 96.8% of patients were classified as having sacralization and 3.2% having lumbar vertebrae [12].

Sex differences in the frequency of cases of anomalous vertebrae in the lumbosacral region, judging from the literature, are not clearly traceable. Some authors indicate that this pathology predominates in women [6]. Some scientists hold the opposite opinion [13, 14], and according to Griffith et al., who published their study in April 2022, the disease is two times more common in men than in women [15]. They also provided information that transitional vertebrae visualization does not have sex differences [16].

Pathogenesis

Modern genetic studies have established that mutations of the Hox genes (*Hox-10* and *Hox-11*) can cause disorders in the formation, migration, differentiation, and segmentation of the somite sclerotomes predominantly on week four of embryonic development [5]. After birth, as the child grows and matures, clinical symptoms of pathology appear at different age periods due to changes in the normal anatomy and biomechanics of the vertebral and motor segments, always characteristic of lumbarization and sacralization [10].

Clinical symptomatology and relationship with other nosologic forms of vertebrogenic pathology

Lumbar and sacral pain is the leading clinical symptom of transitional vertebrae [17]. Many authors recognize that naming the cause of the algic syndrome in each case is not possible, so they suggest that pain is most likely caused by the degeneration of the intervertebral disks and arch joints adjacent to the anomalous segment [18, 19].

Hong Kong scientists published interesting research results in the spring of 2022. Griffith et al. reported that patients with transitional lumbosacral vertebrae have a larger cross-sectional area of vertebral bodies throughout the lumbar region than healthy volunteers–by 9.8% in men and 4.5% in women. According to scientists, this fact contributes to a more rapid degeneration of intervertebral disks and arch joints in the lumbar spine [15].

Degenerative and dystrophic processes of various severity, including protrusions and herniated disks among patients with lumbar lumbarization of the S_I vertebra, are diagnosed in >90% of clinical observations, with pathology detected at the L_V–L_{VI} level in 70% of cases and at the L_{VI}–S_{II} level in 18% [8]. Belgian researchers obtained similar results. Vergauwen et al. reported that in patients with transitional lumbosacral vertebrae, intervertebral disk protrusions and extrusions at the levels above the abnormal segment are found in 45% of cases, whereas in patients without anomalies, they are found in 30% of clinical observations. The authors registered the same trend with regard to the degeneration of the arch joints (60% and 42% of cases, respectively) and stenosis of spinal nerve root canals (53% and 28% of clinical observations, respectively) [20]. Other authors also confirm the more frequent development of intervertebral disk degeneration at the cranial levels [21–23].

The degenerative stenosis of the spinal canal is very often diagnosed in patients with lumbar disk herniations in up to 45% of cases [8, 24]. When herniated bulges develop in the presence of the background of transitional lumbosacral vertebrae, the incidence of lumbar stenosis exceeds its detection rate in the general population [25, 26]. The same pattern was observed in patients with fixed spinal cord syndrome: transitional lumbosacral vertebrae were identified in 63% of patients during radial imaging [27].

Patients suffering from scoliotic deformities have radial symptoms of lumbarization and sacralization in an average of 12%–18% of clinical observations, which aggravates the clinical picture of spinal curvatures and requires careful planning of surgical treatment schemes [28–30].

Contradictory data are presented in the literature regarding the mutually aggravating course of the lumbarization of the S_I vertebra with severe vertebrogenic pathology such as spondylolisthesis of the lower lumbar vertebrae. Most authors point out that patients with spondylolysis spondylolisthesis are often diagnosed with both forms of transitional lumbosacral vertebrae [6, 31, 32]. Thus, Moreau et al. specified that comorbidity occurs in 60% of cases [33]. According to domestic authors, lumbarization of the S_I vertebra was diagnosed in 17.5% and sacralization of the L_V vertebra in 6.34%

of clinical observations in children and adolescents with high-grade spondylolisthesis [34]. Moreover, Smorqick et al. did not consider transitional lumbosacral vertebrae as a background condition on which the degenerative form of spondylolisthesis forms and progresses [35].

Among developmental anomalies of lumbosacral localization, the lumbarization of the S_1 vertebra most often occurs with *spina bifida posterior* [36, 37]. Often, the mutually aggravating effect of these two pathological conditions is clinically manifested not only by pain syndrome but also by neurological symptoms of varying severity [38].

The frequency of comorbidity in patients with transitional lumbosacral vertebrae is high, and they often have concomitant pathology of the hip joints [39]. Thus, Sun et al. diagnosed various types of transitional vertebrae in patients with hip pain syndrome with a frequency of 39%–43% of clinical observations, with IIIb predominating among the known forms (up to 63% of cases). Interestingly, these authors diagnose spinal anomalies based on the study of hip joint radiographs [40]. Heaps et al. utilized the same approach to the diagnosis of sacralization and lumbarization in patients with acetabular impingement [41].

In the analysis of literature sources devoted to the topic under study, very few publications devoted to the study of frontal and sagittal balance in patients, while this topic has been studied in detail in patients with varying severity of torsional scoliosis and spondylolisthesis [34]. The few publications that cover these issues often have contradicting conclusions. For example, Benlidayi et al. studied 96 radiographs of patients and concluded that in the presence of transitional lumbosacral vertebrae, the angle of the *sacrum is* smaller than that of the control group, i.e., the *sacrum is* verticalized, which implies smoothing of the lumbar lordosis [42]. At nearly the same time, Price et al. stated that lumbar lordosis is always increased in patients with lumbarization [43].

Imaging

Radiological examination of the spine and sacrum is the leading method in the objective diagnosis of the lumbarization of the S vertebra$_1$ [1]. Review radiography [22, 44], computed tomography [45, 46], and magnetic resonance imaging [47, 48] are used in patient examination. These radiation diagnostic methods are used both in isolation and combination to choose an approach to the planned therapy, including indications for surgical treatment [49].

Overview radiography of the spine and sacrum is employed to obtain overview information about the condition of this anatomical region, and standard anteroposterior radiographs do not always provide information about the type of lumbarization of the S vertebra$_1$ [48, 50]. In these cases, radiography of the lumbosacral spine in the anteroposterior projection at a cranial angle of 30° is preferred (Fergusson projection) [1, 17].

The results of multispiral computed tomography are more obvious, and they are usually used to conclude about the type of transitional vertebrae, including those in the thoracolumbar region [32, 50, 51]. Tatar et al. revaled that axial scans illustrate morphologic features of the existing pathology, whereas sagittal images provide information about the lumbosacral anatomy [52]. The use of magnetic resonance imaging for diagnosis provides reliable information about the presence and severity of extraforaminal stenosis, impingement, and swelling of the spinal nerve roots L_4, L_5, and S_1 [53–55].

Foreign authors also reported the use of positron emission tomography and scintigraphy to diagnose transitional lumbosacral vertebrae [56]. Lumbarization and sacralization cases diagnosed using radial imaging methods are classified according to the recommendations of Castellvi et al. These American authors developed a classification system. Thus, based on the degree and nature of the concrescence of the transverse process (processes) of the suprascapular vertebra with the iliac wing (uni- or bilateral) or sacral wing, seven types of pathology are distinguished: types I, II, and III are subdivided into subtypes A and B, and type IV is not subdivided [57].

In the lumbarization of the S vertebra$_1$, the classification of O'Driscoll et al. can be applied, who proposed to distinguish four types of pathology based on magnetic resonance criteria for the presence or absence of a disk between the upper sacral vertebra and the lower sacrum. According to these English authors, type I pathology (absence of a disk) accounts for 30% of cases, type II (disk rudiment), 42%; type III (formed disk), 16%; type IV (disk is identified throughout the anteroposterior length of the sacrum), 12% of clinical observations. The authors suggest that types III and IV should be referred to as cases of lumbarization [58].

When discussing the types of transitional lumbosacral vertebrae in patients, we should emphasize the scientific work of Mahato, who presented information on the modification of the classification by Castellvi et al. in his article published in (2013). The author proposes to distinguish not 7 but 19 pathological subtypes characterizing various variants of changes in the anatomy and biomechanics of the sacroiliac joints in patients with transitional lumbosacral vertebrae [59]. However, as the analysis of literature sources on the prob-

Table 1. Proportion of different types of transitional lumbosacral vertebrae reported in the analyzed scientific publications

№	Authors, serial number in the reference list	Number of patients	Types, %				Total
			I	II	III	IV	
1	Nardo L. et al. [14].	841	41,3	41,6	11,7	5,4	100,0
2	Tang M. et al. [62].	928	44,8	43,2	7,2	4,8	100,0
3	Illeez O.G. et al. [19].	700	30,0	57,7	5,4	6,9	100,0
4	Yao X. et al. [60].	37	—	45,9	54,1	—	100,0
5	Hanhivaara J. et al. [46].	1101	68,0	16,0	13,0	3,0	100,0
6	Kanematsu R. et al. [61].	22	68,2	31,8	—	—	100,0
7	Karandeeva A.M. et al. [10]	24	33,4	20,8	45,8	—	100,0
8	Total patients, average frequency of diagnosis of each type	3653	40,81	36,71	19,6	2,88	100,0

lem shows, this modified classification has not been widely used in practice in subsequent years [6, 16, 17, 21, 28, 31, 41].

Literature sources provide different frequencies of transitional vertebral types [9, 13]. Table 1 presents the results of studies whose authors reported the frequency of diagnosing all four types of pathology in their scientific publications.

The results of the analysis of data presented in Table 1 show that, in total, types I and II occupy the first and second rank places in the structure of transitional lumbosacral vertebrae, accounting for 40.81% and 36.71% of clinical observations, respectively. Type III was recorded two times less frequently (19.6%). Type IV was most rarely documented (2.88%).

Published information revealed that subtypes Ia, IIa, and IIIa, i.e., cases of unilateral sacralization and lumbarization, are fraught with more pronounced clinical symptoms [14]. Type IV lumbarization is characterized by more severe degenerative changes in the cranial intervertebral disks with corresponding clinical symptoms [60-63].

The analysis of radiation study findings shows that pseudarthroses and concrescences are more often localized on the left side [13]. Thus, McGrath et al. reported that left-sided forms of transitional lumbosacral vertebrae are found in 48.03% of cases, right-sided in 23.54%, and bilateral in 28.43% [45]. Dzupa et al. reported similar results. The analysis of 150 cases of transitional lumbosacral vertebral diagnostics showed that left-sided forms of pathology were diagnosed in 56.66% of patients, right-sided in 32.6%, and bilateral in 10.68% [64].

The relevance of the problem under study is supported by an important problem, i.e., errors made when making a clinical diagnosis, and they are mainly associated with incorrect vertebral numbering [45, 65, 66]. Reinberg, the author of the fundamental two-volume Russian manual on clinical radiology, recommended that the situation when two full-fledged lumbar vertebrae are identified on a radiograph in the anteroposterior projection under the horizontal line connecting the crests of the iliac bones should be considered a reliable reference point for lumbarization [67].

Some authors use the coccyx, iliac wing, iliac–lumbar ligament, right renal artery, superior mesenteric artery, aortic bifurcation, and cerebral cone as landmarks [37, 68]. However, most of the listed anatomical formations have anatomophysiologic peculiarities of development and are subject to individual variability, which can lead to frequent diagnostic and then therapeutic errors [29]. In clinical practice, such errors occur with a frequency ranging from 33% [45] to 54% [69].

For example, American scientists Josiah et al. found that in patients with transitional lumbosacral vertebrae, the crests of the iliac bones are on average 12 mm higher, the bifurcation of the iliac artery is 23 mm higher, and the site of fusion of the right and left iliac veins into the inferior vena cava is 8 mm higher than the intervertebral disk L_{IV}–L_{V} in people without anomalies of lumbosacral localization. Ignoring these anatomical and physiological features during minimally invasive surgical interventions is fraught not only with technical difficulties in providing access to the vertebrae but also with iatrogenic damage to vital neurovascular bundles [70]. According to. Smith et al., a lumbarized sacrum is a contraindication for performing lateral transolumbar interbody spondylodesis at the L_{V}–L_{VI} level [71].

Scientists who study transitional lumbosacral vertebrae revealed there is no reliable way of counting the number of vertebrae without analyzing the results of high-quality radial imaging of the entire vertebral column, starting from the level of the

C vertebra$_{II}$ and caudally up to and including the coccyx [66, 68]. With this most reliable method of vertebral counting, determining the type of transitional lumbosacral vertebrae and developing optimal treatment tactics are possible [72, 73].

Against this background, the results of the study by French et al. (Australian researchers) published in *Global Spine* are in dissonance with the conventional wisdom. The authors argue that only anteroposterior and lateral radiographs of the lumbosacral spine are sufficient to diagnose the disease, which will identify the disease type according to the classification by Castellvi et al. [74].

The fallacy of these judgments may be indicated by the publication of an international group of authors from New Zealand, Japan, and France, who reported that when studying only the lumbar spine and sacrum in 268 patients, 7 were diagnosed with transitional lumbosacral vertebrae. In the same group of 268 patients, the same symptoms were diagnosed in 4 additional patients, i.e., a total of 11 patients [75].

Treatment

Patients with established diagnoses of sacralization and lumbarization who experience pain need treatment [9]. Anti-inflammatory drugs and analgesics are considered the first-line medications [75]. Drug blockade in the projection of the "false joint," in the area between the transverse process of the transitional vertebra and the sacral wing (or wings in the case of bilateral lesions and in types Ib, IIb, IIIb, and IV), enhances the therapeutic effect [76]. Thus, according to the results of Glemarec et al., blockades with analgesic (lidocaine) in combination with glucocorticoid (cortivazole) allowed us to obtain persistent pain syndrome relief for 12 weeks in patients with transitional lumbosacral vertebrae. In the control group of patients who received injections of the same analgesics and isotonic sodium chloride solution, the therapeutic effect lasted for 4 weeks [77].

South Korean authors Son et al. consider the performance of transforaminal epidural blockade with glucocorticoids pathogenetically reasonable [78]. The results of the conducted conservative therapy are evaluated using a visual analog scale: a 50% decrease in scores from the initial ones or a score of <3 after the injections are considered a good result of pain relief [49]. In some cases, the positive effect of local anesthesia is considered a criterion for surgical intervention at the level of transitional lumbosacral vertebrae [79].

In clinical practice, including adolescent patients, pseudarthrectomy, i.e., resection of the enlarged transverse process (or both transverse processes) of the supraspinous vertebra from a posterior [80] or anterior [81] access, is widely used among surgical techniques. According to McGrath et al., this technique leads to a significant improvement in the quality of life of patients who underwent surgery, as evidenced by the results of testing according to the criteria of the PROMIS-GH Mental and Physical Health therapy outcome assessment information system [82].

Minimally invasive surgery revealed the application in the management of pain in patients with transitional lumbosacral vertebrae [83, 84]. With these surgeries, endoscopic equipment and intraoperative 3D navigation allow the decompression of the stenosed intervertebral foramen with good therapeutic effect, eliminating impingement of the spinal nerve roots L_4, L_5, and S_1 [53, 75, 80].

Pulsed radiofrequency ablation of the "false joint" in the lumbosacral junction is considered a promising method of minimally invasive surgery in patients with pain syndrome [61].

Posterior spondylodesis is also used as a surgical intervention in patients with lumbarization and sacralization [85]. Literature articles discuss, first of all, the issue of the extent of the spondylodesis zone to preserve the maximum possible movements in the lumbar spine [73]. Interestingly, an interesting report on this topic is given by a group of Chinese surgeons who obtained, in their opinion, a "type IIa to type IIIa transformation" after a 60-year-old man underwent posterior interbody spondylosis at the L_{IV}–S_I level. A control computed tomography study performed 1 year after the surgery allowed us to state that the patient had a complete bone block between the right transverse process of the suprascapular vertebra and the sacral wing on the right side, with complete absence of pain syndrome in this area [86].

According to Byvaltsev et al., heterogeneous strategies of the surgical treatment of patients with transitional lumbosacral vertebrae lead to contradictory data on the outcomes of these operations are recorded. The authors, having studied the long-term results of surgical treatment of 314 patients with transitional lumbosacral vertebrae, recorded unfavorable clinical outcomes in 42 (13.37%) clinical observations. The correlation analysis performed by the operating surgeons revealed that in patients with sacralization of the L vertebra$_V$, unfavorable results were obtained during percutaneous accesses for anomalies of types Ib and IIIb and during decompression-stabilizing surgeries for type Ia and IIIa pathologies. In patients with lumbarization of the S vertebra$_I$, unsatisfactory results were recorded during decompressive interventions for anomalies of types IIa, IIb, and IV [87].

Conclusion

Literature analysis shows that the clinically important aspects of significant interest to practical health care have not been developed to date. Thus, none of the analyzed scientific articles provide information about hereditary predisposition and familial forms of these pathological conditions. No information is presented on whether sacralization and lumbarization are caused by disorders of the biomechanics of the lumbosacral spine that affect the condition of pregnant women, and if so, how.

Knowing whether disturbed anatomy in the lumbosacral spine in athletes affects their performance in various sports is of definite interest. The prevention of vertebrogenic pain syndrome in patients diagnosed with lower lumbar and sacral anomalies is a critical issue. The proposal to perform "prophylactic radiologic examination of the lumbosacral spine in children and adolescent," which was put forward by a team of domestic authors [2], requires balanced study and discussion by interested specialists. The above questions lie "on the surface," and this allows us to hope that the transitional lumbosacral vertebrae will be studied in the future, and the results of these studies will be available to interested readers on the pages of medical publications.

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