ISOLATED AND COMBINED DEGENERATIVE TANDEM CERVICAL AND LUMBAR SPINAL STENOSES: LITERATURE REVIEW

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The paper presents detailed definitions, anatomical features and analytical data on the epidemiology and etiopathogenesis of isolated lumbar and cervical spinal stenoses and their combinations (tandem stenoses). Most widely used classifications of stenosing processes of the spine, modern X-ray imaging methods for diagnosis of spinal stenosis and approaches to surgical treatment are described.
Key Words: spinal canal stenosis, isolated stenosis, tandem stenosis, degenerative diseases of the spine, diagnosis, surgical treatment.

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Spinal stenosis is a clinical and morphological concept, involving narrowing of the vertebral canal, resulting in the compression of its content and development of neurological disorders [22, 23, 26]. It can be limited to one spinal motion segment (two adjacent vertebrae, intervertebral disc, facet joints, ligaments) or affect two or more spinal motion segments [1, 3, 4].

It has been shown that many clinical manifestations of degenerative diseases of the spinal column are caused by deformities of the spinal canal [12]. Portal [107] established the connection between the deformity of the spinal canal and the spinal cord compression. Clinical symptoms of spinal stenosis were described by Von Bechterew [128], Sachs and Frankel [112]. The practical features of spinal stenosis was demonstrated by Eisberg [59] and Verbiest [127].

The cervical spine is one of the most frequently affected sections in spine diseases [16, 90] that is dominated not by the supporting function, but by ensuring the mobility of the head and the organs of perception that determines the variety of clinical manifestations of the disease at this level [15, 46]. Mobility of the cervical spine has certain unique anatomical and physiological organizational features for preservation of the spinal canal contents, but these features are compressing factors in the degeneration processes at the same time [46].

Cervical spinal stenosis is accompanied by cervical myelopathy syndrome, and the decrease in saggital diameter of the spinal canal between levels C1 and C2 from 14 to 13 mm and below C2 level to 12 mm as a norm combined with an average 10-mm thickness of the dural sac at this level objectively defines the risk of the spinal cord compression [2]. Almost 12 % of compression syndromes at the cervical spine level are accompanied by vertebral artery syndrome [6], which differs in etiopathogenesis from vertebrobasilar insufficiency induced by intravasal changes. It has been demonstrated that traumatic injuries, deformities, bone overgrowths and various developmental abnormalities in the cervical segments contribute to the vertebral artery compression and irritation of its perivascular sympathetic plexus [10, 21]. In the cervical spine, facet joints are located close to outgoing segmental nerves and form the enclosed bony canal for both the nerve roots and vertebral artery [114]; the size and the area of the intervertebral foramen decrease with severity of degenerative process, mainly due to the decrease in the area of the lower facet joints. It was shown that a 1-mm disc height decrease causes a 25–30 % decrease in the intervertebral foramen and a 3-mm decrease causes a 50 % decrease in the intervertebral foramen area [6].

Epstein et al. demonstrated [60] that 2% of spinal stenosis cases occur at the level of C3–C4, 17 % – at the level of C4–C5, 27 % – at the level of C5–C6, 17 % –

at the level of C6–C7, and 5 % – at the level of C7–T1.

It has been shown that a 2–5-mm thickening of the posterior longitudinal ligament reduces the anteroposterior size of the spinal canal by 3–7 mm [124]. It is known that the incidence of cervical myelopathy syndrome due to ossification of the posterior longitudinal ligament (OPLL, Tsukimoto disease) is almost 1000 times higher in the Southeast Asians than in the Europeans [14, 15]. Ossification of the posterior longitudinal ligament often occurs in the hypermobile segment as a way of dynamic compensation of translation (anteroposterior displacement) of vertebra and over the area of compressed annulus fibrosus. Surgical biopsy from the posterior longitudinal ligament of patients with cervical spinal stenosis displays morphological signs of chondrofication, calcification and ossification [71, 72].

Lumbar spinal stenosis is defined as a long chronic process either congenital (constitutional or dysontogenetical) and/or acquired (due to the presence of osteophytes, ossified ligaments and ossified disc herniation, as well as hypertrophy of intervertebral joints, leading to a narrowing of central and/or lateral spinal canal). It results in disparity between the size of osteo-fibrous sheath of the spine and the neurovascular elements and is accompanied by disruption of blood and cerebrospinal fluid flow, as well as by mechanical impact on the spinal roots, which clinically manifest as typical symptoms: claudicatio intermittens and other less specific and vertebral vertebrogenic symptoms [23, 24, 54, 99].

The first lumbar stenosis national studies were provided by D.R. Stulman et al. [34] and D.K. Bogorodinsky et al. [5].

Verbiest [125, 126] published a series of works on idiopathic lumbar stenosis and revealed a pattern of anatomical changes of the vertebral canal with a representative clinical manifestation of cauda equina roots injury, defining it as claudicatio intermittens.

In recent years, the problem of different etiologies of lumbar spinal stenosis has attracted the attention of many researchers [3, 20, 23, 25, 29, 86, 100, 109, 115]. According to the definition by Arnoldi et al. [39], lumbar spinal stenosis corresponds to any type of narrowing of the spinal canal or intervertebral foramen. Yu.A. Orlov et al. [18] defines stenosis as long-term chronic process, contributing to a narrowing of the spinal canal, where the capacity of bone and fibrous sheath of the spine does not correspond to vascular and neural structures therein [88].

Later, a concept of dynamic stenosis was developed as significant increase in anteroposterior dimensions and cross-sectional area of the spinal canal during flexion and decrease in these values by 30–67 % in extension [30, 84, 106] Besides the important role of claudicatio intermittens, intracanal venous stasis [132] and transient ischemic spinal roots [103] in semiotics of radicular syndromes was established.

Anatomical studies have found that the intervertebral foramen stenosis of the lumbar spine was characterized by a decrease in its vertical dimension [53, 77] and intraforaminal opening, which in 41.7 % of cases may contain intraforaminal ligaments involved in the compression of the content of intervertebral canals [27]. Post-mortem studies also confirmed these hypotheses [120].

It has been shown that reduction of the intervertebral disc height results in intervertebral joints overloading and formation of marginal bone overgrowths protruding posteriorly into the spinal canal and the thickening of the yellow ligament. It contributes to narrowing of the spinal canal with the spinal roots and the spinal cord compressions [132]. In degenerative process, the yellow ligament, the anterior longitudinal ligament and the capsule of the facet joints mainly contribute to the development of degenerative spinal canal stenosis [61], that is important in the development of the lateral recess stenosis. The ossification of the posterior longitudinal ligament at the lumbar level occurs rarely [61]. The central, lateral or foraminal spinal stenosis develops with (or is exacerbated by) spondylolisthesis [47, 61]. It is known that the incidence of L4 vertebra degenerative spondylolisthesis is about 6 times higher than that of other vertebrae [83, 111]. Features of lumbar stenosis development are also related with peculiarities of its embryogenesis [126]. According to A.I. Prodan et al. [23] and Borenstein et al. [48], the facet joints changes cannot occur without damage to the intervertebral disc. It was found that overloading of articular processes, related with degeneration process of the intervertebral disc, directly affects its multiple microfractures development with an associated increased risk of vertebra slipping and the development of spondylolisthesis, mainly at the L4–L5 level [111]. It has been noted that in degenerative spondylosis the facet joints are disoriented by 50 % and loose the resistance force [62]. Degenerative changes also lead to adjacent vertebrae ankylosis , which causes spinal stenosis in the presence of osteophytes [8]. Multiple injuries of discs, joints and ligaments in case of primary osteoarthritis in the elderly lead to polysegmental stenosis [33, 36]. A damage occurring on several levels with normal spinal canal sections between them results in intermittent stenosis. Lumbar stenosis is most common at the level of L2–L4 [21, 23, 49].

Lumbar stenosis is a common spinal disease in the population [40, 47], which is identified in 2/3 of patients with long-term degenerative processes in the lumbar spine. This type of stenosis is currently estimated as one of final steps of degenerative processes. It has been shown that incidence of the central stenosis occures in 21.0 % of cases, lateral in 26.8 %, combined in 52.2 %, and multilevel in 21.0 % of cases [29, 89, 134]. Patients with stenosis represent up to 6 % of patients operated on for lumbar vertebral syndromes [18, 24].

Currently it is known that the development of lumbar stenosis in the majority of patients with degenerative spine lesions is associated with segmental degenerative instability [6, 42, 46, 56].

Intervertebral disc degeneration is directly associated with the instability of the spinal motion segment [31]. More than 50 % compression of spinal cauda equina by is considered critical and characterized by reflex impairment, morphological changes of nerve tissue and neu-

rological deficits [7, 123]. Another important prognostic factor is the development of both preoperative and postoperative depressions, which directly influence treatment outcomes [98].

Tandem (combined, simultaneous, concomitant, concurrent) stenosis is defined as a spinal stenosis, occurring at the same time in the cervical and lumbar spine [51, 56, 66, 91, 133]. The figure presents MRI data of a patient with tandem stenosis of the cervical and lumbar spine. Tandem stenosis of the cervical and lumbar spine occurs in 5–25 % of patients with dominating clinical symptoms of compression in one of the spinal segments [41, 81, 89, 97]. It should be emphasized that tandem stenosis often occurs without obvious clinical symptoms, as has been pointed out by Ghobrial et al. [66] who analyzed PubMed electronic database (1966–2013). Lee et al. [92] retrospectively studied ninety three 70-year-old patients with the main symptoms of neurogenic claudicatio intermittens and established that in 23 % of cases the cervical spine stenosis was asymptomatic. Based on a retrospective analysis of 66 patients with neurogenic claudication at the age of 50, Bednarik et al. [45] have shown that the progression of myelopathy in case of asymptomatic stenosis of the cervical spine increases the risk of full-scale tandem stenosis by 5 % every year. After a retrospective study of 19 patients aged 68 with mixed symptoms of neurogenic claudication and neurological symptoms in the upper limbs, Dagi et al. [58] reported that it is an objective criterion for the development of tandem stenosis of the cervical and lumbar spine. Kim et al. [82], who retrospectively analyzed the data of 100 patients at the age of 71 with neurogenic intermittent claudication, showed that clinical manifestation of the lumbar stenosis is associated with cervical stenosis in 76 % of cases t and with thoracic stenosis in 30 %. Krishnan et al. [87] retrospectively studied 53 patients aged 60 years with symptoms of myelopathy previously operated on for tandem stenosis of the lumbar and cervical spine and established that it is preferable to carry out a phased decompressive surgery in patients older than 60 years.

The nature of tandem stenosis usually involves a spondylotic degeneration [41, 94, 100, 116–118, 129, 130, 131], clinical symptoms of which are represented by the triad of intermittent neurogenic claudication, progressive gait disturbance, myelopathy and polyradiculopathy of both upper and lower limbs [60, 66, 75, 91, 93, 135]. It was shown that in case of identification of spinal canal stenosis in one department of the spine and the presence of neurological clinical manifestation the probability of tandem stenosis is increased by 15.3 %, and over time by 32.4 % [91].

The incidence of concurrent tandem stenosis of the lumbar and thoracic spine [44, 64], as well as cervical and thoracic one is low and occurs in about 1 % of cases [43]. Inter-regional (multi-regional) spinal stenosis at three levels of the spine at the same time (cervical, thoracic and lumbar) is an extremely rare observation [74].

Verbiest proposed the first classification of spinal stenosis [125, 127]. He proposed concepts of "absolute and relative stenoses" which differ in the sagittal size of the spinal canal, wherein absolute stenosis causes compression of the cauda equina roots, while relative one contributed to mutual exacerbation of compressing factors. The size of the spinal canal of 12 mm is considered as a sign of relative stenosis, and less than 10 mm – as a sign of absolute or mixed one. Mixed stenosis is a combination of relative and absolute ones at various levels of the spinal canal. Papp et al. [105] proposed an etiological classification, according to which the lumbar stenosis was divided into primary (congenital and acquired forms) and the secondary when the stenosis is associated with other diseases. Arnoldi et al. [39] published a pathogenetic classification of vertebral stenosis, which identified the following types of spinal stenosis: a congenital or developmental stenosis (idiopathic or achondroplastic); acquired – degenerative (central, peripheral section of the spinal canal, lateral recess or nerve root canal), degenerative spondylolisthesis and combined, which is presented by different combinations of congenital stenosis, developmental stenosis, degenerative stenosis and nucleus pulposus herniation.

For clinical practice it is advisable to use classifications that combine classification of stenosis based on anatomical characteristics and contributing etiological factors [9, 20, 26, 76, 123]. Based on anatomical criteria, stenoses are divided into central stenosis, a decrease in the distance between the posterior surface of the vertebral body and the nearest opposite point on the arch at the base of the spinous process (up to 12 mm, a relative stenosis, less than 10 mm, an absolute one); lateral stenosis, a narrowing of the radicular canal and intervertebral foramen to 4 mm or less; combined stenosis. Based on etiology, stenoses are divided into congenital or idiopathic stenosis [102], achondroplasia [68, 119], acquired stenosis [78], combined stenosis, which corresponds to any combination of congenital and acquired stenosis. It is the most common form of stenosis [28]. V.F. Kuznetsov [13] proposed to take into account the extent of stenosis along the spinal axis (monosegmental, polysegmental, intermittent and total), as well as its stages: dynamic and fixed. The spinal canal stenosis is also classified according to its clinical manifestations [12, 22, 25]: without clinical symptoms, functional stenosis, stenosis with myelopathy and (or) radiculopathy symptoms. Acute myeloradiculoischemia (radiculoischemia) [35] and chronic myeloradiculoipathy (radiculopathy) [19] are distinguished on the pace of development of neurological manifestations. Neurological manifestations of stenosis may be transient, moderate and severe, and they can be accompanied by disruption of the spinal cord conduction or cauda equine roots.

Verification of clinical diagnosis of stenotic process in the spinal canal is conducted using available X-ray imaging and electrophysiological methods [1, 11, 63, 70, 97]. The following algorithm of examination of patients is used: neurological examination, spondylography in two projections, functional spondylography, spondylography in 3/4 projection, MRI, MRI myelography, CT, myelography,

Fig.
Clinical example of a patient B., 49 years old, with tandem spinal canal stenosis of the cervical and lumbar spine with clinical manifestations of radiculopathy at the level C5–C8 on the left, at the level L3–L5 on the left, cervicobrachialgia and sciatica on the left, double-sided top hyperreflexia and absence of gross manifestations of cervical myelopathy: **a** – sagittal T2-weighted image of the cervical spine reveal extended spinal stenosis at the C3–C7 level; **b** – frontal T2-weighted image of the intervertebral disc of the cervical spine at the C3–C4 level (maximum stenosis) reveal bean-shaped deformation of the spinal canal; **c** – sagittal T2-weighted image of the lumbar-sacral spine, reveal extensive spinal stenosis at the level of L1–S1; **d** – frontal T2-weighted image of the intervertebral disc in the lumbar-sacral spine at the L4–L5 level (maximum stenosis) reveals the narrowing of the spinal canal

electroneuromyography. It involves comprehensive analysis of diagnostic parameters in conjunction with the detailed clinical, morphological and physiological characteristics, which directly affects the choice of tactics and the most adequate method for surgical treatment of spinal stenosis [67, 80, 102, 113, 115, 121].

Traditional X-rays of various parts of the spine have not lost their relevance, providing an identification of spinal deformity and instability of spinal motion segments, as well as a preliminary assessment of the spinal canal size [69, 96]. In case of the spinal canal stenosis modern standardized set of examinations includes functional spondylography, CT and MRI [120], and MRI is considered to be the gold standard in the diagnosis of isolated and tandem stenosis [17, 95, 118]. Combinations of CT and myelography provides objective confirmation of the diagnosis of lumbar stenosis in 90.6 % of cases, and the specificity of the method is 96 % [110]. The combined CT and myelography data are correlated with MRI data: the boundary of the bone tissue of the spinal canal is preferably identified by CT and myelography, and the soft tissue is preferably identified by MRI, which is particularly important in determining the foraminal stenosis [73, 104]. Functional myelography and epidurography are necessary for the diagnosis of dynamic stenosis [108]. Currently, vertical MRI scanners allow functional examinations, which is especially important for verification of dynamic lumbar spinal stenosis and instability of the spinal motion segments [50].

In the diagnosis of lumbar spinal stenosis, the data of electromyographic muscle mapping have 100 % specificity and 30 % sensitivity, confirming the necessity for additional use of electrophysiological methods of examination [25].

Surgical treatment of patients with stenotic processes of various portions of the spinal canal is preferable, but the choice of technique is individualized based on the analysis of data of comprehensive examination [24, 37, 40].

The main indications for surgical treatment of spinal stenosis are severe pain, that cannot be managed by medication and conservative methods, progressive claudicatio intermittens syndrome, disorders of pelvic organs [1, 3, 80]. Surgical tactics and volume of operations are based on complex data on the clinical neurological picture and cross-referenced with neuroimaging and neurophysiological data [3, 25]. Depending on the type of stenosis it can involve decompression of the spinal or radicular canals [57, 65]. Extensive decompressive laminectomy at the level of two or three segments is considered in case of polysegmental lumbar spinal canal stenosis, whereas monosegmental stenosis is treated using facetectomy and laminectomy at the level of the affected segment [32, 52, 79, 85, 107]. Patients with unilateral neurologic manifestations undergo mandatory gentle decompression with resection of medial facet joints and removal of additional soft tissue compressing components. Lateral stenosis and related radicular syndromes are treated by facetectomy, foraminotomy [1, 3].

There is currently no standard approach to surgical treatment of patients with tandem spinal stenosis. It

associated with necessity for detailed differention from other diseases, corresponding to the level of degenerative lesions, and identification of the dominant clinical picture, which directly defines the subsequent tactics and volume of surgical intervention, in the plethora of overlapping neurological symptoms [58, 89, 94, 101].

Many studies have confirmed the need for staged approach to surgical procedures. Some authors consider appropriateness of the surgical inbetventions at clinically relevant levels of the spinal canal [94, 117], while others prefer initial decompression in the cervical spine [89, 110]. Some spinal surgeons reported positive outcomes of one-stage surgical treatment of the spine in both affected departments [58, 101].

Difficulties in elaborating surgical approach for patients with tandem stenosis are associated with the fact that even in the presence of instrumental data on compression of neurovascular structures in the lumbar spine, neurological symptoms in the lower limbs in cervical spinal stenosis may be caused by spinal cord compression in the cervical region. Therefore, the initial spinal decompression can eliminate radicular symptoms in lower limbs and thus eliminate the need for the second stage of surgical treatment [58, 101]. At the same time, due to a long and relatively non-physiological position of a patient, a surgical intervention at the lumbar spine level can contribute to exacerbation of neurological symptoms caused by compression of the cervical spinal cord [51, 122].

Decompression of clinically significant stenotic segments of the spine contributes to positive clinical outcomes [38, 134]. However, multilevel degenerative stenosis requires extensive decompression, which is associated with significant blood loss, iatrogenic injury to musculoligamentous apparatus and its risk for older patients [38, 55]. Minimally invasive surgery [3, 7, 22] has become widely used in spinal surgery as a way to prevent development of postoperative complications, reduce damage to surrounding soft tissues in surgical approach and severity of postoperative pain syndrome. It allows performing surgical procedures at all clinically significant levels with minimal risk of intra- and postoperative complications and with faster rehabilitation.

In modern literature vast number of studies are retrospective [41, 74, 81, 101], and therefore there is a need for multicenter prospective studies of the outcomes of surgical interventions in treatment of patients with tandem spinal stenosis of the cervical and lumbar spine.

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