THERAPEUTIC AND DIAGNOSTIC VALUE OF TRANSFORAMINAL EPIDURAL INJECTIONS IN PATIENTS WITH HERNIATED DISC AND RADICULAR PAIN: ANALYTICAL LITERATURE REVIEW

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The aim of the study is to analyze comprehensive information on the use of epidural injections in the treatment and diagnosis of patients with herniated intervertebral discs. Epidemiology and modern concepts of the pathogenesis of pain syndrome formation in patients with herniated intervertebral discs, algorithms and methods of conservative and surgical treatment of such patients are highlighted. Information on the methods and features of various routes of epidural injections used for these drugs is presented, as well as a comparative assessment of their effectiveness and safety. The diagnostic and prognostic significance of transforaminal epidural block is discussed separately.
Key Words: selective nerve root block, transforaminal epidural injection, disc herniation, sciatica, radiculopathy, radicular pain, diagnostic injection.

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It has been 86 years since the publication of the classic study by Mixter and Barr, which established the involvement of disc herniation in the pathophysiological mechanisms of sciatica. However, treatment of this disease still causes a lot of controversy in the medical community.

Periodic pain in the lumbosacral spine occurs in 60–80 % of the world's adult population [1]. In the United States, low back pain ranks 5th in the frequency of medical visits, with 30 to 50 billion health care US dollars being spent on its treatment annually [2].

Radicular pain syndrome comprises a significant subgroup of patients with degenerative spinal diseases [3, 4]. Depending on the time period studied, the prevalence of radicular pain throughout life varies from 12.2 % to 43.0 % in different groups [5]. The annual incidence of an episode of radicular pain ranges from 1 to 5 % [6]. Radhakrishnan et al. [7] found that the annual incidence of cervical radiculopathy is 107.3 and 63.5 cases per 100,000 for men and women, respectively.

The modern concept of radicular pain syndrome as a complex disease involves the interaction of various factors: inflammatory, immunological, and compressive ones [8–11].

In the majority of patients, invasive procedures can be avoided, and pain syndrome can be relieved by using various methods of conservative treatment [12–15]. Along with physiotherapy, conservative treatment using various combinations of non-steroidal anti-inflammatory drugs (NSAIDs), opioid analgesics, muscle relaxants, antidepressants, systemic corticosteroids, and anticonvulsants is the first line of treatment for patients with radicular pain syndrome due to disc herniation [16–17].

Discectomy with or without stabilization is a proven and popular technique in cases when drug therapy in these patients has been unsuccessful. A significant number of patients who have underwent this treatment somehow require reoperation, with some of them not receiving the expected effect from surgery, which significantly increases healthcare costs [18–23]. According to the literature [24–29], epidural injections at the preoperative stage can provide significant advantages in the treatment of patients with disc herniation and radicular pain syndrome and even help avoiding surgery in some cases.

The aim of the study was to analyze the data on the use of epidural injections in the treatment and diagnosis of patients with herniated intervertebral discs and radicular pain.

Surgical Techniques

According to the Russian clinical guidelines, patients with intervertebral disc herniation of the lumbosacral spine in the presence of radiculopathy and the absence of the effect of conservative treatment for four weeks are recommended to have surgery [30].

To date, a large number of methods of surgical intervention for a herniated disc have been developed. All of them can be divided into three types: microsurgical,

microendoscopic, and endoscopic techniques [31].

Discectomy is the most common neurosurgical procedure in the United States; more than 480,000 procedures are performed there annually [32, 33]. Microsurgical discectomy has been considered one of the most effective and popular techniques for quite a long time [34].

Comparison of microdiscectomy with tubular and endoscopic discectomy showed the best short-term results for the latter two techniques, while assessment of long-term results after one month, six months, and one year did not reveal a significant difference in the outcomes between the techniques [35–36].

The method of percutaneous decompression includes several different techniques, which are aimed at eliminating the compression of nerve structures, reducing the size of the protrusion and restoring the function of the affected disc. These techniques are classified into mechanical, thermal, and chemical decompression, as well as biomaterial implantation [37]. Among these, the most common technique is nucleoplasty, which is considered an alternative to open surgery. It uses bipolar radio frequency energy to reduce the intradiscal pressure [38]. It has been established in the above-mentioned review article that this technique allows reducing the intensity of pain syndrome by 66 %. In addition, a 50 % decrease in the degree of disability was noted by the end of the first month after the procedure.

Patients who had underwent surgical treatment for disc herniation of the lumbar spine experienced a rapid improvement in their condition after three months (the average VAS score was 15.3; the mean Oswestry score was 15.5); however, the patients still complained for pain and mild-to-moderate functional disorders after a five-year follow-up (the average VAS score was 21.0; the mean Oswestry score was 13.1) [36].

Despite the growing experience of surgical interventions and the improvement of surgical technologies, pain recurrence in individuals who have undergone surgery on intervertebral disc occurs with a frequency of 4 % to 67 % [18]. Up to 42 % of lawsuits filed by neurosurgical patients are related to spinal surgery [19]. From 10 % to 40 % of patients who had underwent spinal fusion had the failed back surgery syndrome [20]. In a review article with a meta-analysis, Chen et al. [23] investigated the incidence of complications after various surgical techniques for resection of a herniated disc. For the techniques considered, complications were observed in 5.8–25.8 % of the operated patients. Up to 50 % of unsatisfactory results were obtained in patients who had underwent discectomy for protrusions and hernias of lumbar intervertebral discs [22].

The average additional annual cost of any reoperation on the lumbar spine is about $ 11,161 [21].

Despite all of the above, it is important to note that discectomy using a microscope or an endoscope remains an effective and proven technique. Meanwhile, it is necessary to optimize the diagnostic algorithms, methods of providing medical care, as well as the strategy for selecting the candidates for surgery.

Epidural Injections

One of the most frequently discussed aspects of treating patients with pain in the cervical and lumbar spine accompanied by radicular pain syndrome is epidural injections.

Taking into account the inflammatory component in the pathophysiology of radicular pain, it seems reasonable to use epidural steroid injections as one of the strategies for treating this disease [39].

A local anesthetic solution was initially used for these purposes. The first injection of corticosteroids was performed and described in 1952 [40].

Currently, there are a number of injection approaches that allow epidural drug administration of drugs: caudal epidural injection, interlaminar epidural injection, and transforaminal epidural injection [41–43].

Due to the fact that modern scientific literature describes significant differences both in the technical features of epidural injections via different approaches and in the effectiveness and outcomes for various pathologies, they are usually considered as independent techniques [44].

All procedures are recommended to be performed under X-ray or ultrasound control [45–48].

A caudal epidural injection is performed by advancing the needle through the sacral canal into the sacral epidural space [45, 49]. Kim et al. [50] showed that 10 ml of injection solution is sufficient for reaching the L3–L4 segment. The authors also found that, after the initial injection of 10 ml, the subsequent 30 ml of the solution reach only the L2–L3 level, i.e., they spread one segment cranially.

In interlaminar epidural injection, a needle is inserted into the epidural interlaminar space [46, 51].

The options for patient positioning for transforaminal epidural injection, as well as radiographic landmarks determining the site of needle insertion, can vary depending on the level of pathology [45, 47]. This is due to the anatomical features of osseous and neural structures, as well as blood flow path typical of various regions of the spinal column [52].

The spread of the contrast along the nerve root confirms the correct needle positioning, after which drug solutions are injected slowly [48].

Comparative Effectiveness of Epidural Injections

A study by Manchikanti et al. [53] describes the use of epidural injections for the relief of radicular pain and low back pain in patients with lumbar disc herniation. The results of three large studies, which included 120 patients each, revealed no significant advantages of either caudal, transforaminal, or interlaminar approaches after a two-year follow-up [53]. The results of the six-month follow-up and assessment of improvement in the functional status after one year showed that lumbar interlaminar epidural injections had a potentially greater efficacy in managing pain relief. There were no significant differences in the effectiveness of the techniques depending on the level of pathology in the lumbar spine [54–56].

A study by Singh et al. [57] established the advantage of caudal epidural steroid injections compared to transforaminal epidural steroid injections based on the results of a one-year follow-up. In addition, the authors demonstrated a higher efficacy of pain relief: pain intensity was decreased by 58.2 % in the group receiving caudal epidural steroid injections and by 46.8 % in the group with transforaminal epidural block [57]. Sighnificantly higher regression of functional impairment according to the Oswestry scale was also noted (27.0 % and 41.7 % in caudal epidural injections and transforaminal epidural injections, respectively) [57].

Pandey et al. [58] performed a comparative assessment of the efficacy of caudal epidural injections in patients with radicular pain syndrome and low back pain. The results of a one-year follow-up revealed a significant advantage in the group with the transforaminal approach, in which only 10.0 % of patients were treated ineffectively [58]. The same parameter for the groups with caudal and interlaminar routes of injection reached 25.6 % and 22.2 %, respectively [58].

Kamble et al. [59] compared the effectiveness of the above-mentioned techniques. Despite the fact that the results of short-term relief of pain intensity were comparable across the groups, patients of the transforaminal group had an advantage: the absence of a significant increase in pain intensity according to the results of one-month and six-month follow-up, as well as a more pronounced decrease in functional impairment [59]. However, it is worth noting that long-term efficacy was not evaluated in this study.

The work by Adilay et al. [60] indicates the high efficiency of the transforaminal technique in patients with lumbar radicular pain syndrome.

Makkar et al. [61] studied the efficacy of a modified interlaminar technique using the lateral parasagittal approach in comparison with conventional interlaminar and transforaminal epidural injections. The results of a six-month follow-up demonstrated that the most effective pain relief was noted for modified interlaminar epidural injections (80 %) and transforaminal epidural injections (75 %), without a statistically significant difference between the groups.

In 2018, Lee et al. [62] conducted a systematic literature review with a meta-analysis. The authors compared the efficacy of caudal epidural injections and transforaminal epidural injections in patients with lumbar disc herniation. Of the 6,711 studies, six were selected that matched the criteria and subject of the review. Four studies supported the superiority of the transforaminal technique; one study demonstrated the advantage of the caudal approach; and one article showed no significant difference between the effectiveness of transforaminal and caudal epidural injections. The authors concluded that transforaminal epidural injections provide better clinical benefit than caudal injections and, despite the low level of evidence in the meta-analysis, may be considered as the preferred method of epidural steroid administration.

Bensler et al. [63] found no statistically significant difference in the efficacy of interlaminar and transforaminal epidural injections in patients with lumbar disc herniation. However, they noted a trend towards slightly better results in case of interlaminar injections. It is worth noting that the study was limited to a one-month follow-up period and did not assess the long-term efficacy.

A review by Smith et al. [64] provides an analysis of the studies on the transforaminal technique. The efficacy of transforaminal epidural injections was found to be higher in patients with a shorter duration of radicular pain, an early positive response to injection, and radiculopathy confirmed by electromyography. In addition, a number of publications indicate a greater efficacy of transforaminal epidural injections in patients with a low degree of nerve root compression evidenced by MRI than in patients with a high degree of compression [65, 66].

The duration of the analgesic effect of injections varies. In most studies, one injection was sufficient to achieve a successful outcome. In case of recurrence of pain after the first successful relief, it is possible to use the transforaminal epidural injection again. However, the potential systemic side effects of epidural corticosteroid administration are well known. For this reason, the dosage of the administered drug and the frequency of such injections should be limited to the minimum effective amount and frequency with appropriate time intervals between the procedures. Most of the studies discussed in this review favored the 3–6-month treatment (and some even the 1–2-year treatment) option after transforaminal epidural injections. A reasonable explanation for such a long-term effect is most likely the favorable natural history of lumbar radicular pain in some patients rather than one-year or two-year effect, which is directly related to corticosteroid administration [64].

In 2006, Lin et al. [24] retrospectively analyzed the outcomes of 70 candidates with disc herniation subjected to surgical intervention for cervical radicular syndrome who had transforaminal epidural injections due to the ineffectiveness of conservative treatment. Follow-up examination (the average follow-up period, 13 months) showed that 63 % of the patients managed to avoid surgery.

Costandi et al. [25] conducted a retrospective analysis of the outcomes of 64 patients with cervical disc herniation and radicular pain receiving transforaminal epidural injections of 10 mg of dexamethasone and 1 ml of 0.5 % bupivacaine solution. The previous conservative treatment and physiotherapy for eight weeks had not resulted in any improvement in the condition of all patients. After three years, 70.3 % of patients (95 % CI1/4, 57.6–81.0 %) managed to avoid surgery. The difference in the mean VAS scores before and after the procedure was 4.4 (95 % CI1/4, 3.75–5.10). The mean reduction in pain intensity was 66 % [25].

In 2018, Kesikburun et al. [26] performed a retrospective study of 64 patients with pain syndrome associated with disc herniation of the cervical spine. All patients had transforaminal epidural block. Based on the data obtained, a significant decrease in the average pain intensity from the score of 8.6 ± 1.4 at baseline to 3.2 ± 2.5 was achieved at the control visit two weeks after the injec-

tion. In order to achieve the therapeutic effect, patients received one to three injections. More than 80 % of patients noted an over 50 % reduction in pain intensity compared to the baseline. The average duration of the therapeutic effect of a transforaminal epidural injection was 13.3 ± 9.44 months.

It was also found that a higher baseline VAS score correlated with a more pronounced analgesic and a longer therapeutic effects ($p = 0.042$ and 0.011, respectively). The authors concluded that the study results indicated that transforaminal epidural injections are an effective method for treating neck pain radiating to the arm in patients with cervical disc herniation.

A systematic literature review with a meta-analysis by Conger et al. [67] conducted in 2019 revealed no studies of the technique of transforaminal epidural injections in patients with cervical disc herniation that would meet the inclusion and exclusion criteria, since all the studies lacked the comparison group.

The proponents of a more aggressive surgical strategy often argue that, despite the high efficiency of epidural injections in the first months after block, patients with intervertebral disc herniation require surgery in the long-term period.

This position can be challenged, since there are studies demonstrating a significant decrease in the size of a hernial bulging over several years up to its complete disappearance [68–71].

In general, the use of epidural injections allows achieving a good clinical effect in more than half of patients (Table 1).

Diagnostic and Prognostic Value of Transforaminal Epidural Injections

Neurologists and neurosurgeons often meet patients with a clinical picture that does not correspond to the data of instrumental examination, which can lead to an erroneous interpretation of the data obtained. For instance, a number of studies indicate a low correlation between the MRI data of facet joints, spinal stenosis, and the integrity of the posterior longitudinal ligament with the intraoperative data [72–74].

The possibility of the point injection of a drug solution to the nerve roots during transforaminal epidural block makes this technique a fundamentally unique diagnostic tool in the treatment of patients with intervertebral disc herniation [27]. This feature can also be useful in multilevel lesions of adjacent intervertebral discs and when predicting the success of the subsequent surgery at this level.

In 1992, Derby et al. [28] established a correlation between the efficacy of transforaminal epidural block and the outcome of the subsequent surgery. Among patients with more than one-year duration of radicular pain syndrome, a positive outcome of surgery was noted in 85 % of cases in the group with effective injections, while poor outcome was observed in 95 % in the group with ineffective injections [28].

Leung et al. [29] highly appreciated the diagnostic value of transforaminal epidural injections performed in 186 patients, since an immediate response to the administration of a local anesthetic and a steroid drug was obtained in 80.2 % of cases.

In their review, Datta et al. [75] indicate that the diagnostic value of transforaminal epidural injections at the preoperative stage has not been proven, although further study of this issue is of interest to researchers.

A study of cervical transforaminal epidural injections performed by Costandi et al. [25] confirmed the predictive value of the technique by showing that all patients with a good outcome after surgery noted a significant pain reduction after the injection. Patients in whom surgery was ineffective, on the contrary, achieved less than 50 % relief of radicular pain after transforaminal epidural injection. In general, despite the lack of a consolidated opinion in the medical community and a sufficient evidence base regarding the diagnostic value of transforaminal epidural injections, the authors note that many experienced doctors consider this technique a useful tool.

Solutions for Epidural Injections

To date, the most common groups of drugs for epidural injections are steroid solutions and solutions of local anesthetics, which can be used both individually and in combination.

The division of steroid drugs into particulate and non-particulate substances is based on the chemical properties of solubility of synthetic corticosteroids in water and their aggregation characteristics. Particulate steroids are usually poorly soluble in water; they can precipitate and crystallize in a hydrophilic environment. For this reason, steroids with a larger particle size were suggested to impose a greater risk of small artery occlusion as a result of their iatrogenic intravascular administration via epidural steroid injection and lead to brainstem, cerebellar, or spinal cord infarction [76].

In this regard, Derby et al. [77] conducted a microscopic examination of the solutions of dexamethasone sodium phosphate (a non-particulate steroid), triamcinolone acetonide, betamethasone sodium phosphate, betamethasone acetate, and methylprednisolone acetate (particulate steroids). The largest particles of triamcinolone acetonide were 12 times the average size of the erythrocyte. The particles of triamcinolone and betamethasone are tightly packed and form large aggregates of up to 100 μm in size. Particles and aggregates of methylprednisolone individually and mixed with a local anesthetic (1 % lidocaine hydrochloride) and iodinated contrast medium (240 mg/ml iohexol) turned out to be smaller than an erythrocyte. However, they are tightly packed and can form emboli. Dexamethasone particles, alone and mixed with a local anesthetic and a contrast agent, were 10 times smaller than the average size of an erythrocyte and did not show a tendency to aggregation [77].

El-Yahchouchi et al. [78] showed that the use of triamcinolone improved the outcomes in patients after epidural steroid injections only insignificantly and noted no significant difference in the efficacy in comparison with dexamethasone and betamethasone.

Zheng et al. [79] concluded that the risk of adverse intravascular outcomes in epidural steroid injections can be reduced by using particulate steroids and avoiding mixing hormones with anesthetics that can cause precipitation. In particular, a mixture of dexamethasone and ropivacaine, which do not form solid particles alone, may crystallize under certain acidic/basic conditions.

Feeley et al. [31] performed a meta-analysis comparing particulate and non-particulate steroid use in epidural steroid injections. No significant benefit was shown for the use of particulate steroids for pain relief. At the same time, the authors specify that, until that moment, no specific cause of paraplegia has been established in certain patients after epidural steroid injections, while the hypothesis on embolization by steroid particles has not been confirmed, since the correlation is not the establishment of a causal relationship.

In a literature review, Mehta et al. [81] compared the efficacy of particulate and non-particulate steroids for epidural injections. The obtained data did not reveal the advantages of certain steroids in relieving radicular pain. However, taking into account the risk of possible severe complications, which were noted in the use of particulate steroids, the use of non-particulate steroids was recommended as a first-line drug.

Bensler et al. [63] compared the effects of triamcinolone and dexamethasone in patients with lumbar disc herniation in transforaminal epidural injections and noted a significantly greater efficacy of particulate steroids. According to the results of one-month follow-up, improvement was noted in 44.3 % of cases in the triamcinolone group and in 33.1 % of patients of the dexamethasone group.

Comparison of Safety and the Risk of Complications after Epidural Injections

Lee et al. [82] studied complications after epidural injections that required hospitalization in patients after 52,935 manipulations using both triamcinolone acetonide (32,805 injections) and dexamethasone (20,130 injections). Transforaminal, caudal, and interlaminar approaches were used for drug administration. The total number of complications was 244 (0.46 %), 56 (0.11 %) of which were directly related to the effect of the administered drug (Table 2).

In the Closed Claims Database of the American Society of Anesthesiologists, complaints related to cervical epidural steroid injections represent 22 % of all complaints related to chronic pain management and reported in the period of 2005–2008. When conducting epidural steroid injections, embolization of glucocorticoid suspensions with large particles of the drug into the brain and spinal cord is possible. Taking into account that the cervical epidural space is located just a few millimeters from the cervical spinal cord, direct needle injury is more common during an interlaminar epidural injection [83].

Engel et al. [84] described a number of serious complications associated with epidural steroid injections in the cervical spine. An incorrectly performed injection was shown to cause such pathological conditions as spinal cord infarction, epidural hematoma, tetraplegia, vertebral artery occlusion, cerebellar infarction, or Horner's syndrome.

Meanwhile, a study by Kesikburun et al. [26] did not register any serious complications after transforaminal epidural injections in the cervical spine, with the exception of short-term vasovagal syncope in several patients with a maximum duration of no more than two minutes.

No cases of serious complications were observed after cervical transforaminal epidural injections in 17 papers selected for the review article by Conger et al. [67]. Only mild side effects were reported: syncope and transient vertigo, headache or facial flushing [85–88], transient dizziness or nystagmus [89], increased pain in the arm or neck [90], and transient Horner's syndrome [91].

Costandi et al. [25] did not find a single case of complications during the procedure in 64 patients subjected to cervical transforaminal epidural injections.

Bush et al. [92] conducted a total of 1,047 procedures and evaluated the safety of transforaminal epidural injections in the cervical spine in 527 patients. Complications were noted only in six cases; they resolved on their own without any intervention and were considered insignificant.

Zini et al. [93] observed serious complications after epidural injections in different levels of the spine in less than 0.05 % of cases.

Arachnoiditis is more common during interlaminar epidural injections and can occur due to inadvertent injection of glucocorticoid suspensions containing large drug particles into the intrathecal space [94–96].

Rapid administration of large amounts of the drug for caudal epidural block followed by an increase in retinal venous pressure caused blindness in some cases [97].

Racoosin et al. [98] note that, in order to avoid the development of secondary lipodystrophy, the maximum number of repeated injections at the same level should not exceed four procedures per year.

Infectious complications after epidural steroid injections, in particular meningitis and epidural abscess, are quite rare and mainly associated with a fungal infection, the development of which can be avoided by sterilizing the surgical site [95, 97, 99].

Unusual transient post-procedure complications are known after transforaminal epidural injections in the lumbar spine, including hiccups, oculomotor nerve palsy, and perineal pruritus [100–102]. A number of publications [103–108] describe technical problems associated with dural puncture and inadvertent injection of a drug into a vein or disc. However, none of the above cases led to the development of irreversible impairments.

There is a report on the formation of a secondary epidural hematoma caused by bleeding from a periarticular cyst after a transforaminal epidural injection in a patient after cessation of clopidogrel and aspirin one week before the procedure [109]. The most common compli-

cations after lumbar transforaminal epidural injections are associated with cerebrospinal infarction: 14 such cases have been reported [110–115]. Moreover, in all cases, with the exception of one [110], a suspension of glucocorticoids containing large drug particles was used. It was initially considered that the main cause of complications during cervical transfo-

Table 1
Results of the studies on the efficacy of epidural injections

Study	Technique (number of patients)	Total number of patients, n	Follow-up period, months	Affected region	Results
Manchikanti et al. [53]	IEI (120) TEI (120) CEI (120)	360	24	Lumbar spine	A significant decrease (> 50 %) in VAS and Oswestry scores was observed in 63.0 %, 65.0 %, and 61.0 % of cases for CEI, IEI, and TEI, respectively (all patients). Among patients responding to treatment (improvement within at least 3 weeks in response to no more than 2 treatments), a significant improvement (a > 50 % decrease in VAS and Oswestry scores) was observed in 76.0 %, 72.0 %, and 77.0 % for CEI, IEI, and TEI, respectively
Singh et al. [57]	TEI (40) CEI (40)	80	12	Lumbar spine	The average decrease in the patient's VAS score was 46.8 % in the TEI group and 58.2 % in the CEI group. The average decrease in the Oswestry score was 46.7 % in TEI patients and 65.4 % in CEI patients
Pandey et al. [58]	CEI (82) TEI (40) IEI (18)	140	12	Lumbar spine	According to the Japanese Orthopedic Association (JOA score), effective pain relief was noted in 90.0 %, 77.7 %, and 74.3 % in the TEI, IEI, and CEI groups, respectively
Kamble et al. [59]	CEI (30) TEI (30) IEI (30)	90	6	Lumbar spine	The decrease in the average VAS score was 73.4 % for TEI, 51.5 % for IEI, and 51.4 % for CEI
Adilay et al. [60]	TEI (1097)	1097	4	Lumbar spine (L4–L5, L5–S1)	The decrease in the average VAS score was 75.0 % for TEI at L4–L5 and 55.8 % for TEI at L5–S1
Smith et al. (review article) [64]	TEI	30 studies	1–24	Lumbar spine	Among the studies included in the review, a significant decrease in the VAS score (> 50 %) was observed in 64.0 % of patients (57–71 %) after a 12-month follow-up
Rados et al. [65]	TEI (32) IEI (32)	64	6	Lumbar spine	A significant decrease (> 50 %) in the VAS score was noted in 5.0 % in the IEI group and in 63.0 % in the TEI group; a decrease in the Oswestry score by more than 10 points was found in 50.0 % and 66.0 % of the patients in the IEI and TEI groups, respectively
Makkar et al. [61]	Lateral IEI (20) IEI (21) TEI (20)	61	6	Lumbar spine	A significant decrease (> 50 %) in VAS was noted in 80.0 % of the modified IEB group (16/20) and in 75.0 % of the TEI group (15/20). In the IEI group, this score was 42.9 %
Lee et al. (review article) [62]	IEI CEI	6 studies	1–6	Lumbar spine	Four studies supported the superiority of TEI, one paper favored CEI, and another article showed no significant difference between the effectiveness of TEI and CEI
Lin et al. [24]	TEI (70)	70	36	Cervical spine	A significant reduction in the severity of symptoms according to the outcome scale after cervical spine surgery (Odom scale) was observed in 63.0 % of patients
Costandi et al. [25]	TEI (64)	64	36	Cervical spine	Complete regression of symptoms was observed in 70.3 % of patients; no surgical treatment was required
Kesikburun et al. [26]	TEI (64)	64	21,4 ± 9,4	Cervical spine	A significant decrease (> 50 %) in the VAS scores was noted in 81.2 % of patients
Bensler et al. [63]	IEI (99) TEI (99)	198	1	Lumbar spine	No significant difference in the effectiveness of the techniques was found using the PGIC scale, according to which, 53.3 % and 43.9 % of patients with IEI and TEI, respectively, experienced an improvement. The average decrease in theVAS score was 33.7 % and 28.7 % for IEI and TEI groups

IEI – interlaminar epidural injection, CEI – caudal epidural injection, TEI – transforaminal epidural injection.

Table 2

Types of complications in admitted or applying to admission department patients who had epidural injections, according to Lee et al. [83]

Complications directly related to the procedure (n = 14)	Complications related to the effect of the drug (n = 56)	Complication of unknown cause (n = 174)

Post-injection hypotension (n = 8);
spinal infection/sepsis (n = 3);
spinal hematoma (n = 2);
septic shock of unknown origin (n = 1)
	Various gastrointestinal disorders (n = 17);
	psychological disorders (n = 14);
	dizziness (n = 9);
	increased blood glucose (n = 8);
	uncontrolled hypertension (n = 5);
	increased heart failure (n = 2);
	menstrual irregularities (n = 1)
		Deterioration of the existing neurological symptoms (n = 156);
		urinary infection (n = 10);
		ischemic stroke (n = 8)

raminal approach is direct injury to the vessel leading to vascular spasm or dissection. However, over time and with the deepening of scientific knowledge about vascular anatomy and the properties of steroid drugs obtained in animal studies, the embolic mechanism of complications in intravascular administration of large-particle steroids has been established as the most likely one [116].

Cases of subdural injection of the drug for transforaminal epidural block have been described [117]. However, the incidence of this complication is extremely low and, according to a large multicenter study [118] of the results of 16,638 epidural injections, equals 0.04 % for transforaminal route and 0.20 % for interlaminar route of injection.

In a review article, Smith et al. [64] note that the published data on the risks of transforaminal epidural injections is mainly based on case reports, and therefore the evidence is of very low quality. Taking into account a significant number of procedures (more than 14,000) that did not reveal any neurological, hemorrhagic, or infectious complications, the authors confidently state that, although the complications can be catastrophic, their prevalence is extremely low [64].

Conclusion

Analysis of the literature data allows us to conclude that, despite the widespread use of epidural injections in back pain, there is no clear algorithm and method of drug administration for treating patients with intervertebral disc herniation and radicular pain.

It should be noted that performing transforaminal epidural injection in accordance with methodological guidance and algorithms, using fluoroscopic control, a contrast agent, and adequate solutions for the injection can significantly reduce the risk of complications for a technique with a sufficiently high safety profile.

The literature analysis performed suggests that transforaminal epidural injections present a potentially effective technique for relieving pain, which in some cases makes it possible to stabilize the patient's condition without the need for surgery. Furthermore, the diagnostic modality of transforaminal epidural injections can be useful in determining the extent of the subsequent surgery. The degree of effectiveness and the significance of transforaminal epidural injections in the treatment of patients with intervertebral disc herniation and radicular pain syndrome require a further study.

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