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TREATMENT STRATEGY FOR PATIENTS WITH THORACIC AND LUMBAR SPINE FRACTURES WITH DURA MATER TEAR

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Background. The dura mater tear are quite common in patients with thoracic and lumbar fractures. Prevention of cerebrospinal fluid leakage and sealing of the dura mater suture is an important stage in the treatment of such patients.
Objective: to find an optimal surgical tactics for patients with fractures of the thoracic and lumbar spine and dura mater tear.
Materials and methods. This study included 167 patients operated on for fractures of the thoracic and lumbar spine with concomitant traumatic spinal canal stenosis. We analyzed their clinical data and results of instrumental examination. All patients underwent laminectomy at the level of their fractures and transpedicular fixation. The main group included 55 patients with dura mater tear, whereas the control group comprised 112 patients without dura mater tear.
Results. Dura mater tear was found in 32.9 % of patients with fractures of the thoracic and lumbar spine. Of them, 21.8 % had compression of the spinal cord or nerve roots at the sites of dura mater tear. This fact should be taken into account when performing decompression and the reduction maneuver to prevent additional injuries to the neural structures.
Thirty-three (60.0 %) patients underwent direct suturing aimed to restore the dura mater integrity. Their mean size of the dura mater tear was 13.2 ± 7.4 mm². Thirteen patients (23.6 %) with larger dural tear (27.5 ± 6.3 mm²) underwent their repair using either a fragment of dura mater from a deceased donor ($n = 2$), Reperen implants ($n = 5$), or Durepair patches ($n = 6$). In 9 patients (16.4 %), the integrity of dura mater was restored without suturing (the "sandwich"-sealing method) (mean size of the dura mater defect 5.0 ± 2.6 mm²). Twenty-one patients had additional sealing of dura mater suture using bioglue.
Postoperative wound cerebrospinal fluid leakage was registered in 5 out of 55 patients from the main group. Cerebrospinal fluid leakage was most common in patients who had undergone dura mater repair with implants (23.1 %), while those who had undergone direct dura mater suturing were less likely to develop it (6.1 %). No cerebrospinal fluid leakage was observed in patients with small defects (≤3 mm²) and in those whose dural tears were located at the nerve root cuffs. Patients with postoperative cerebrospinal fluid leakage had no additional sealing of dura mater suture using bioglue.
Postoperative wound infection was registered in 4 (7.3 %) patients from the main group and 6 (5.4 %) patients from the control group.
Conclusion. Sealing of dura mater sutures with glue compositions is an effective method to prevent postoperative cerebrospinal fluid leakage. Sealing of dura mater sutures with a collagen sponge does not prevent wound cerebrospinal fluid leakage.

Key words: spinal cord injury, dura mater, cerebrospinal fluid leakage, vertebral motor segment

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BACKGROUND

Surgical treatment of spinal cord injury (SCI) always aims to ensure complete decompression of the neurovascular structures of the spine. In case of tear to the dura mater (DM), it also aims to restore its integrity and preserve the subdural space to normalize cerebrospinal fluid (CSF) circulation. All surgeries include mandatory reclination and reposition of the injured spinal segments to achieve normal anatomical and physiological parameters of the spinal canal and normal spinal fusion. Decompression is important to preserve the spinal cord and spinal nerves, as well as to create conditions for their recovery [1–4]. According to different authors, between 7.7 and 64.0 % of patients with injuries of the thoracic and lumbar spine also have DM tear, which is usually diagnosed at laminectomy [5–10]. Among patients with injuries of the thoracic and lumbar spine, DM tears are most frequently observed in case of combination fractures of the vertebral body and its lamina and displacement of the fragments [7, 9, 11–15]. In such patients, laminectomy is associated with an increased risk of intraoperative damage to the DM, spinal cord, and spinal nerves. Early diagnosis of DM tear is crucial to choose an optimal surgical strategy. Preoperative identification of risk factors for DM tear is extremely important. They include [7, 9, 12–14]:

- less than 50 % narrowing of the spinal canal at the level of fracture;
- increased interpedicular distance of the fractured vertebra;
- presence of laminar fractures;
- the maximal separation distances of the edges in laminar fractures;
- fractures at several levels;
- severity of concomitant injuries;
- severity of neurological disorders.

Very few publications describe the methods of DM restoration and their effectiveness [7, 8, 11–14]. The choice of an optimal surgical technique for DM tear repair integrity and its impermeability is still challenging.

MATERIALS AND METHODS

A total of 350 patients with thoracic (n = 124) and lumbar (n = 226) fractures underwent surgeries at the Department of Emergency Neurosurgery, N.V. Sklifosovsky Research Institute for Emergency Medicine between 01.01.2014 and 12.31.2018. Seventy-three of them had transpedicular fixation of the affected spinal segments and postural reduction of the spine without laminectomy. In 84 of them, the supportability of the spinal motion segment was restored by anterior spinal fusion, while 26 patients had vertebroplasty. a total of 167 individuals underwent posterior decompression at the level of fracture with laminectomy and transpedicular fixation of the affected spinal segments. The level of fracture varied between Th3 and L5, but most of the patients had fractures at the level of Th12–L3. Posterior spinal decompression was performed from 3 hours to 23 days after the trauma.

This was a retrospective study. Its participants were divided into two groups. The main group included 55 (32.9 %) patients who had DM tear caused by fragments of vertebral fracture. The control group consisted of 112 patients without DM tear.

The AO Spine Thoracolumbar Spine Injury Classification System (AOSpine), 2013 was used to assess the type of injury [16]. Neurological disorders were evaluated using the American Spinal Injury Association (ASIA) scale [17].

The indications for decompression surgery via the posterior approach using laminectomy and transpedicular fixation of the affected spinal segments include:

- unstable spinal fracture with a high risk of secondary damage to the spinal cord or Cauda equina;
- clinical signs of spinal cord and/or Cauda equina compression.

All patients underwent extended laminectomy and transpedicular fixation of the affected spinal segments. In case of destruction of the anterior column of a broken vertebra, the surgery was divided into two stages. In 78 (46.7 %) patients, the second stage included anterior spinal fusion within a period of 2–6 weeks.

All patients received intraoperative antibiotics. If the operation lasted more than 6 hours or the blood loss was more than 1000 mL, the antibiotic dose was 1 g.

The choice of surgical tactics was based on the type of injuries of the spine and neural structures assessed by CT and/or MRI. Extended laminectomy was done at the level of the fractured vertebra, also partially involving the vertebra located above the fractured one. In case of fracture dislocations, laminectomy was done at the level of dislocated vertebra and the vertebra located below and using a high-speed electric drill and Kerrison rongeur. We performed decompression of the neural structures located between the fragments of the broken vertebra. Then we removed bone and disc fragments and all substrates causing compression of the dural sac, nerve roots, and the spinal cord. Ventral decompression of the dural contents was performed via the posterior approach without a pronounced lateral traction during the manipulation.

During the decompression, 19 patients were found to have neural structures between the fragments of the broken vertebra. In 12 patients of them, the spinal cord or spinal roots were prolapsed and strangulated at the sites of DM tear (Fig. 1).

We performed revision of the subdural space to assess the condition of the spinal cord and/or its roots. The next stage included restoration of DM integrity and patency of subdural space. After matching the edges of the damaged area of the DM, we carefully sutured the DM and/or performed its repair using interrupted or continuous sutures with nonresorbable polypropylene threads (Prolene 5/0 or 6/0).

Titanium transpedicular and/or laminar systems were used for spinal fusion. Their installation was controlled by an electron-optical converter. Following complete decompression of neural structures and restoration of DM integrity or confirmation that it was intact, we performed reposition, restored normal positions of the vertebrae and normal spinal axis, eliminated deformations and installation transpedicular fixation.

Data processing and analysis was performed using the SPSS Statistics 22.0 for Windows. The Pearson χ^2-test was used to estimate differences between the groups.

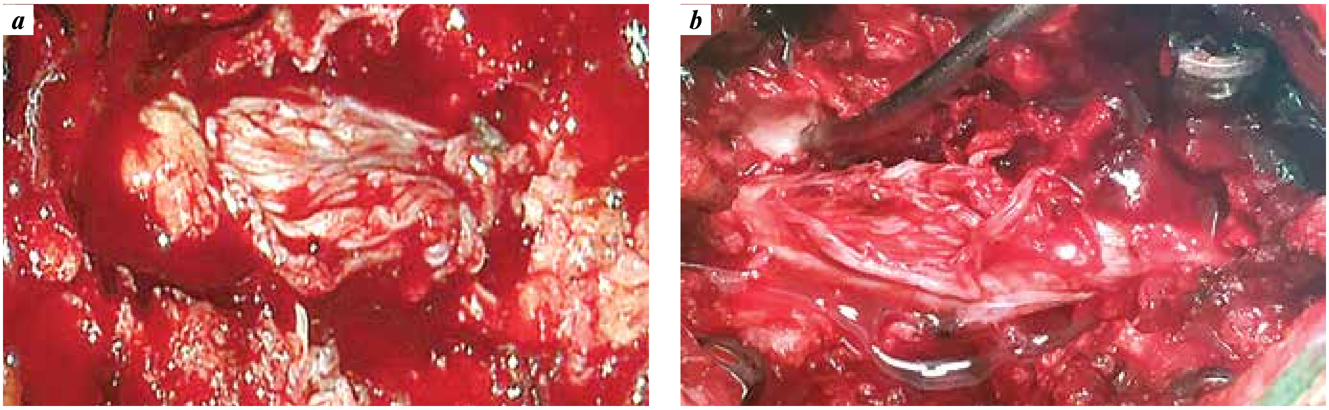

Fig. 1. *Intraoperative pictures: a — nerve roots prolapse through the injured dura mater; b — nerve roots injured by bone fragments*

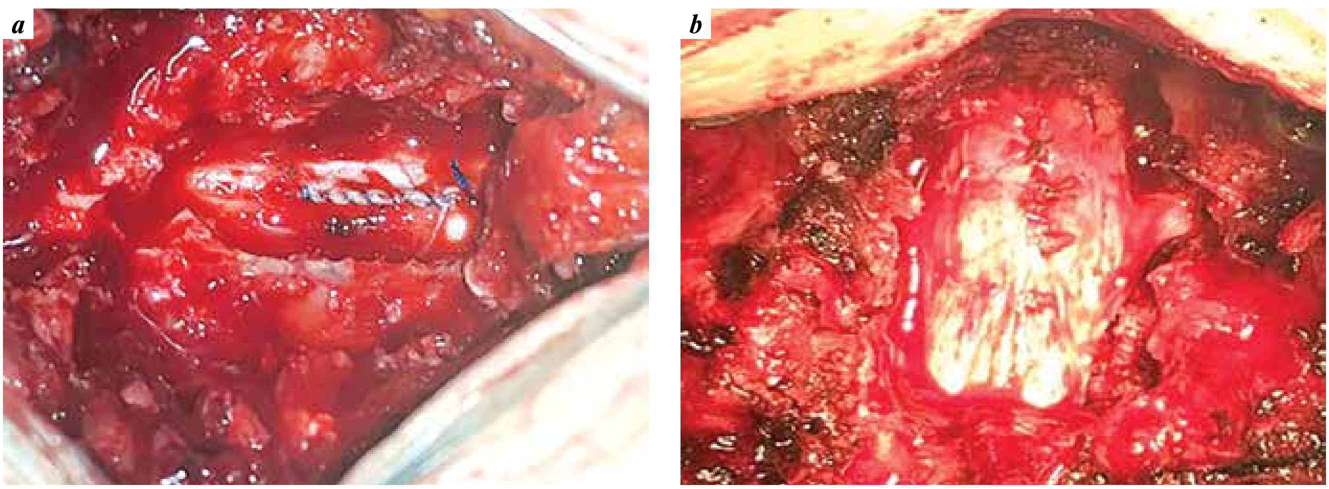

Fig. 2. *Dura mater repair (intraoperative pictures): a — using continuous suture; b — using interrupted suture*

RESULTS

Mean patient age was 38 years (range 17–80 years, $n = 167$). The sampled population included 101 (60.5 %) males and 66 (39.5 %) females. All patients underwent preoperative CT of the spine; 43 patients additionally had MRI. All patients were diagnosed with posttraumatic spinal canal stenosis between 23 and 100 %.

DM tear was found on the posterior and/or posteriolateral surface of the dural sac in all cases. The area of DM tear varied between 2 and 38 mm^2 (mean 15.2 ± 9.9 mm^2). The choice of surgical tactics for restoring the integrity of the DM depended on the location, size of the dural tear, and the presence of disintegration of the DM wall.

Methods of restoring DM integrity

1. DM suturing. Thirty-three out of 55 (60.0 %) patients underwent direct DM suturing without an expanding plastic. Mean size of the affected DM tear was 13.2 ± 7.4 mm^2 (range: 3.0–28.0 mm^2) (Fig. 2).

In 25 patients, we used the TachoComb® sponge (Takeda Austria GmbH, Austria) to ensure additional sealing of the suture. The sponge was placed by a single block to overlap the edge of the DM suture by 1–1.5 cm (Fig. 3 *a*). In 8 patients, sutures were additionally sealed by glue (Fig. 3 *b*).

2. DM repair by expanding plastic surgery. Thirteen out of 55 (23.6 %) patients underwent DM repair with expanding plastic, because large size of the defect and loss of DM fragments did not allow us to suture without narrowing of the dural sac. Mean size of the affected DM tear in these patients was 27.5 ± 6.3 mm^2 (range: 18.0–38.0 mm^2). Two patients had their DM repaired using fragments of cadaverous lyophilized DM, whereas the remaining 11 patients had their DM repaired using synthetic material: Reperen implants ($n = 5$), or Durepair patches ($n = 6$). The implant of the appropriate size was attached to the edges of the DM tear using a continuous suture, creating an additional space of the dural sac. In 5 patients, TachoComb® sponge was placed by a single block to overlap the edge of the DM suture by 1–1.5 cm to seal it. In the remaining 8 patients, the DM suture was reinforced by glue (Fig. 4).

3. Without DM suturing. In 9 (16.4 %) patients, the DM integrity was restored without suturing (the "sandwich"-sealing method). Their mean size of the DM tear was 5.0 ± 2.6 mm^2 (range: 2.0–10.0 mm^2). Five patients had their DM defects located at the nerve root cuffs (mean size

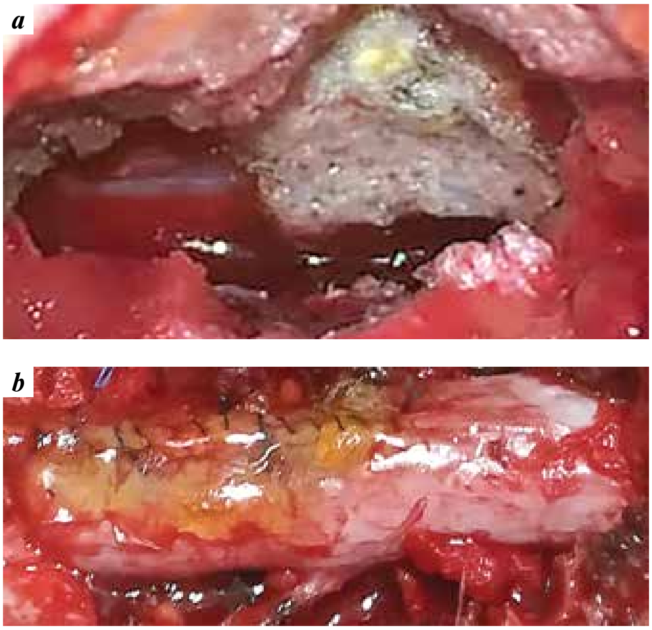

Fig. 3. *Sealing the dura mater suture (intraoperative pictures): a – using TachoComb (Takeda Austria GmbH, Austria); b – using BioGlue (CryoLife, Inc., USA)*

Fig. 4. *Repair of the dura mater defect by inserting and suturing an artificial implant (intraoperative picture)*

6.6 ± 2.3 mm²). These patients underwent no DM suturing due to the high risk of dural sac stenosis and root compression. Small DM tears (<3 mm²) were identified in 4 patients, including 2 with single, and 2 with multiple tears. These patients also had no DM suturing; their defects were covered by the fragment of fat/muscle tissue and collagen material (the "sandwich"-sealing method). In 5 patients, DM sutures were additionally sealed with bioglue placed directly on the DM using (the "sandwich"-sealing method). In total, 21 patients had their DM sutures sealed with biological adhesive (glue) compositions, including 8 patients from the group of DM suturing, 8 patients from the group of DM repair with expanding plastic, and 5 patients from the no suturing group using the "sandwich"-sealing method.

The Queckenstedt test was used for intraoperative control of CSF leakage after DM integrity restoration by one of the abovementioned methods. Repeated sealing was performed in case of CSF leakage.

Redon drainage (up to 0.5 cm in diameter) was placed in the epidural space for passive liquid outflow. In patients with DM defects, especially in case of large DM tears, the drainage was left for 2–5 days to prevent postoperative CSF leakage. Different methods of DM integrity restoration are shown in the Table.

Patient distribution by the method of dura mater (DM) integrity restoration

Method of DM integrity restoration	Mean size of the DM defect, mm²	Number of cases	
		abs.	%
DM suturing	13.2 ± 7.4	33	60.0
DM repair (plastic surgery)	27.5 ± 6.3	13	23.6
Without DM suturing (the "sandwich"-sealing method)	5.0 ± 2.6	9	16.4
Total	*15.2 ± 9.9*	*55*	*100*

CSF leakage in the early postoperative period was registered in 5 (9.1 %) patients with DM tear. It was diagnosed on average after 4.6 ± 2.1 days postoperatively (min on day 2, max on day 7, *n* = 5). Patients with small DM tears (≤3 mm²) or tears located at the nerve root cuffs had no postoperative CSF leakage. Among 33 patients who underwent conventional DM suturing, 2 (6.1 %) patients developed CSF leakage. Three out of 13 patients from the group of DM repair with expanding plastic (23.1 %) had CSF leakage. Postoperative wound CSF leakage developed only in patients who additionally had a collagen sponge (TachoComb®) placed on the suture line, while DM suture sealing with glue prevented wound CSF leakage in all of the patients.

All 5 patients with postoperative CSF leakage underwent revision of the surgical wound. CSF leakage through the DM suture was detected using the Queckenstedt test. The DM area (with CSF leakage) was tamponed with either a free fragment of muscle (*n* = 3) or fat tissue (*n* = 2). All patients with wound CSF leakage underwent additional DM sealing using a biological two-component glue. The postoperative wound in all 5 patients was sutured in layers. The drainage tube was installed through a contraincision in the subfascial space and was left for 3–5 days. All patients underwent lumbar punctures in the postoperative period with the removal of 30–50 mL CSF for 3–5 days. None of the patients had recurrent cerebrospinal cyst (pseudomeningocele) of soft tissues, according to ultrasound, or CSF leakage.

Ten out of 167 (5.9 %) patients developed postoperative wound infection. Complications were detected on an average of 7.4 ± 2.2 days (range: 4–11 days, *n* = 10) postoperatively. Postoperative wound infection was registered in 4 out of 55 patients with DM tear (7.3 %) and 6 out of 112 patients without DM tear (5.4 %). There was no significant difference in the incidence of postoperative wound infection between the groups (χ^2 = 0.24, P = 0.624). All patients with postoperative wound infection underwent wound revision, its debridement, and drainage tube installation. The tube was removed after 3–5 days. Wound healing in this group of patients was observed after 21.8 ± 2.4 days on average (min – on day 18, max – on day 26, *n* = 10). Two patients with severe concomitant injuries died on days 10 and 13 due to complications not related to surgery.

DISCUSSION

Unstable spinal fractures are characterized by deformation of the spinal canal and compression of the dural sac contents, which might cause neurological disorders [18, 19]. Decompression of the neurovascular structures of the spine is required to preserve neural structures and create conditions for their recovery. Patients with unstable spinal fractures in combination with a fracture of the posterior structures are at risk of hernial protrusion of neural structures between the fragments of the broken vertebra. Therefore, all patients first undergo decompression of neural structures via the posterior approach using extended laminectomy, without attempting postural reduction and spine distraction. It allows decompression of the neural structures located between broken vertebral fragments. Patients with DM tear require restoration of its integrity, otherwise they are at risk of compression of the neural structures located between the fragments of the broken vertebra during spinal reduction, which may cause new tears to the DM, spine, and spinal nerves. The reduction maneuver can be performed only after complete decompression of the neural structures [7–10, 13]. In our study, DM tears were identified in 55 (32.9 %) patients. Nineteen individuals were found to have their neural structures located between the fragments of a broken vertebra at the decompression stage. Twelve patients out of 55 with DM tear (21.8 %) were diagnosed with compression of the spinal cord or its roots at the sites of DM tear.

At the stage of laminectomy, surgeons often observed CSF leakage from the damaged DM area, usually at the level of the affected vertebra [6, 20]. Nevertheless, pseudomeningocele after DM tear is quite rare in patients with vertebral fractures (unlike in patients with iatrogenic DM damage), which is associated with active inflammation and hematoma development in the injured area [21, 22]. Only one case of pseudomeningocele in a patient with lumbar spine fracture and DM tear has been reported so far [22]. Sealing of the teared DM area in SCI patients is needed to prevent postoperative infections that can (compromise) significantly worsen treatment outcomes [23]. We observed no significant differences in the incidence of postoperative wound infection between the groups ($p = 0.624$). Four (7.3 %) patients in the main group and 6 (5.4 %) patients in the control group developed postoperative wound infection. The is a lack of data on the incidence of surgical wound infections in SCI patients with DM tears.

Restoration of DM integrity is more difficult in patients with SCI than in patients with iatrogenic damage [21], because the affected area often has an irregular shape and might have DM disintegration. No "gold standard" for DM restoration in SCI patients has been developed so far because of the significant variability of tear shapes and difficulties associated with DM repair with implants and sealing [7, 8, 11–14].

Many surgeons prefer to restore DM integrity by its direct suturing if the tear is located on the posterior surface [9, 13, 24]. However, in case of large dural tear or DM disintegration, it is recommended to perform DM repair using different materials. In our study, 33 (60.0 %) patients underwent direct DM suturing. Thirteen patients had their DM tears repaired using either a fragment of dura mater from a deceased donor (*n* = 2), Reperen implants (*n* = 5), and Durepair patches (*n* = 6). In 9 patients (16.4 %) with small dural tears and tears located at the nerve root cuffs, the DM integrity was restored without suturing (the "sandwich"-sealing method).

DM tear sealing without its direct suturing (the "sandwich"-sealing method) was effective in all patients: with small DM tears (≤3 mm^2) and tears located at the nerve root cuffs. CSF leakage was most common (23.1 %) among patients with large DM defects that could not be directly sutured and required repair with implants. Only 2 out of 33 (6.1 %) patients developed CSF leakage after direct DM suturing. Additional sealing with glue prevented CSF leakage in 100 % of cases regardless of the method used for DM integrity restoration (direct suturing or repair with implants).

CONCLUSION

DM tears were observed in 32.9 % of patients with thoracic and lumbar vertebral fractures. Every 5th (21.8 %) patient had compression of the spinal cord or its roots at the sites of DM tear. This fact should be taken into account when performing decompression and the vertebral reduction maneuver to prevent additional injuries to the neural structures.

DM tear sealing without its direct suturing (the "sandwich"-sealing method) can be effective to prevent CSF leakage in patients with small DM tears (≤3 mm^2), including those located at the nerve root cuffs. Suture sealing with a collagen sponge does not prevent CSF leakage in patients with DM tears. The presence of DM tears had no impact on the incidence of postoperative wound infection: it was observed in 7.3 % of patients with DM tears and 5.4 % of patients without DM tears.

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Authors' contributions

A.G. Martikyan: literature review, article writing;
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A.E. Talypov: research design of the study, scientific editing of the article;
A.Yu. Kordonskiy: research design of the study, data analysis;
I.S. Lvov: data analysis, literature review;
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