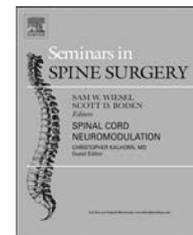


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## Dural tears

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### ABSTRACT

Dural tears are a known complication of cervical, thoracic, and lumbar spine surgery. We present a brief overview of the anatomy of dural tears, diagnostic techniques, and a review of treatment options. Incidence of tearing and treatment varies by location and size, and post-operative management is controversial. The most well evidenced treatment techniques and management protocols have been reviewed and summarized.

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### 1. Anatomy

Cerebrospinal fluid (CSF) is primarily produced in choroid plexus in the third and fourth ventricles of the brain. This fluid flows from the third and fourth ventricles into the subarachnoid space through three small foramina, then surround the brain and spinal cord in the subarachnoid space. The meninges are composed of pia, arachnoid, and dura mater. The dura mater provides a barrier and an outer encapsulating layer, allowing the fluid to bathe and protect the brain and spinal cord.<sup>1</sup> This fluid transfers nutrients to and waste from the neural tissues. The volume of CSF in adults at any time is between 125 and 150 mL,<sup>2</sup> and over 500 mL is produced and reabsorbed per day.<sup>3</sup> CSF submerges the brain, reducing the effective weight of the brain from 1500 gs to 50 gs and works as a “shock absorber” to prevent mechanical brain injury.<sup>2</sup>

Change in CSF pressure gradient within the central nervous system can cause neural tissue (brain, spinal cord, nerve roots) to move out of its position and herniate, i.e., uncal herniation, nerve root herniation.<sup>4</sup> Areas of high pressure push fluid to low pressure sometimes with devastating consequences; this can occur after surgery, trauma, and lumbar puncture. Patients may evolve to myelocutaneous fistulas, pseudomeningoceles, abscesses, and meningitis. Durotomies

after lumbar puncture or myelograms differ from traumatic or surgical defects by having normal anatomy to contains the CSF.<sup>5</sup> Surgical and traumatic durotomies have altered surrounding anatomy with dead space and decompressed tissue, a lower pressure area for CSF to fill.

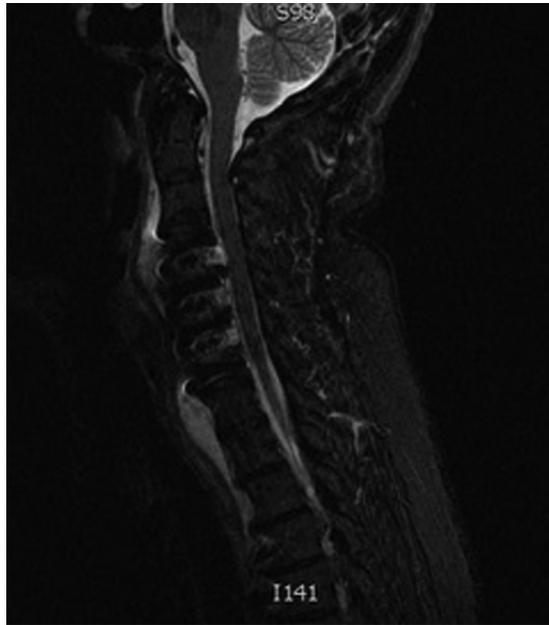
### 2. Diagnosis

The diagnosis of a dural tear in the operating room or in the clinic are imperative to prompt management. Meticulous surgical technique aids in prevention of dural tears, watching for bone spike and hardware penetration, which can range from a pinhole to laceration multiple centimeters in length (Figs. 1–3).

Intraoperative detection allows for primary watertight repair, but sometimes tears can occur and not be visible. Dural laceration without arachnoid mater penetration and no fluid must be treated primarily.<sup>6</sup> The inevitable post-operative increase in CSF pressure will rupture the arachnoid mater and a leak postoperatively will occur. A pulsatile swirl of fluid in a bloody field or repeat bleeding in an area of prior hemostasis should raise the index of suspicion for tear.<sup>5</sup> This is a result of a decrease in thecal sac hydrostatic pressure, thus decreasing the tamponade of the local epidural veins.

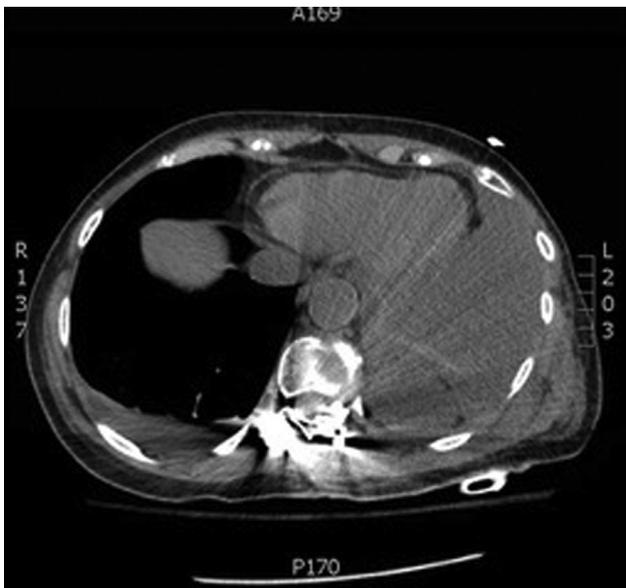
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**Fig. 1** – Large prevertebral CSF collection, spanning from C2 to T3. Patient presented with increasing dysphagia after 3-level ACDF. Patient was taken to operating room, dural repair successfully treated with a fat graft and a fibrin sealant.

A large National Surgical Quality Improvement Program dataset with over 86,000 patients found that late presenting dural tears occur in 0.2% of patients. Those at risk were patients who underwent lumbar procedures, decompression procedures, and procedures longer than 250 min. Those with



**Fig. 2** – Large pleural effusion after sustaining a tear via a lateral retroperitoneal approach for a T12 corpectomy. Patient underwent a successful repair with collagen matrix and a fibrin sealant.



**Fig. 3** – Large pleural effusion after sustaining a tear via a lateral retroperitoneal approach for a T12 corpectomy. Patient underwent a successful repair with collagen matrix and a fibrin sealant.

tears had higher likelihood of surgical site infection, sepsis, pneumonia, UTI, wound dehiscence, thromboembolism, and acute kidney injury.<sup>8</sup> Late presenting tears are diagnosed with the combination of clinical and radiographic findings. In draining wounds or fluid collection, CSF leaks must be on the differential along with infection, seroma, and liquefied hematoma. Late presenting spine dural tears can present with nausea, vomiting, dizziness, VI cranial nerve palsies,<sup>9</sup> masses, respiratory issues, and severe headaches. Cervical spine tears are often smaller and symptoms may not be as obvious.

The most common clinical manifestation is orthostatic headache, which may take minutes or longer to present.<sup>16</sup> These headaches are described as a pressure sensation that can range from dull to throbbing. The headaches are a result of the stretching of meninges resulting from loss of buoyancy and caudal displacement of neural structures.<sup>10</sup> Often the headaches are either frontal or retroorbital, but can be in any region. Postural headaches with worsening or new sciatica may be suggestive of pseudomeningocele, attributed to nerve root entrapment.<sup>11</sup> Other presenting symptoms may include neck or interscapular pain, cochleovestibular manifestations, nausea, diplopia, facial numbness, galactorrhea, radicular upper extremity symptoms, ataxia and cognitive difficulties.<sup>16</sup>

If in the clinical setting a fluid collection is suspicious for dural tear, beta-2-transferrin immunofixation electrophoresis can be done. This protein is only found in the CSF and perilymph secondary to its production by cerebral neuraminidase,<sup>12</sup> with sensitivity and specificity approaching 100%.<sup>13</sup> The sample only necessitates a few milliliters of fluid on any absorbing material (cotton swab, gauze, etc.) and the lab will be able to isolate it.<sup>14,15</sup>

MRI is the primary imaging modality when identifying a CSF leak, with a 1996 study citing 100% sensitivity.<sup>17</sup>

Computed tomography head scans can identify subdural fluid collections suggestive of hematoma or herniations, and high resolution CT scans may help identify fluid collection against bony lesions.<sup>18</sup> Myelography assists in diagnosing CSF leaks, equivocal whether it be CT or heavily T2 weighted MR,<sup>16,19</sup> but individual protocols are better at identifying either low flow and high flow CSF leaks. Myelography has the advantage of being able to quantitate CSF opening pressures, providing additional diagnostic information in low CSF states. Another modality with higher sensitivity and less radiation is the radionuclide cisternography imaging test.<sup>20,21</sup> This technique allows for visualization of extravasation without contrast, although not perfect with 84% sensitivity and 98% specificity.<sup>20</sup>

### 3. Location

#### 3.1. Cervical spine

Incidental dural tears after surgery are seldom reported but occur roughly 0.45–1% of the time,<sup>63–65</sup> and up to 13% after cervical spine trauma alone.<sup>66</sup> When managed appropriately, there are no long-term sequelae.<sup>64,67</sup> Older age, rheumatoid arthritis, ossification of the posterior longitudinal ligament (PLL), deformity, operative time, more levels, worse preoperative neurological status, revision, and corpectomy are all risk factors for durotomy. An ossified PLL raised the probability of a dural tear 13–20 times,<sup>64,67</sup> and extra care must be taken when resecting with a Kerrison rongeur or power burr. In the algorithm proposed by Hannallah et al.,<sup>64</sup> all accessible dural tears should be repaired primarily. If not accessible, either observation or CSF shunt should be placed. 60% of patients had resolution of symptoms within three days, and all resolved by four-month follow-up. One patient developed a pseudomeningocele that resolved and there were no long-term sequelae at 5 years. In a set of 18,463 patients, 93% with successful treatment have no further sequelae.<sup>63</sup> 57% were primarily treated with a sealant/patch, 16% used suture, and 15% used a combination of the two. 12% of these patients required further intervention, and the retrospective nature of the study did not provide a treatment algorithm or a consensus of action on further failure of intervention.

#### 3.2. Thoracic spine

Thoracic dural tear literature is sparse and limited to papers regarding thoracic decompression and ossified PLL. The highest rates of CSF leaks occur in the thoracic spine, incidence ranging from 22 to 50% in large patient studies.<sup>68–71</sup> 4% rates have been quoted when using a strict posterior approach, speculating that anterior approaches are limited by visualization, difficulty maneuvering in a small space, and ossified adhesions between the ligament and the dural sac.<sup>72</sup> Suture success rates in the thoracic spine are low, around 30%, because of the irregular shaped dural tears.<sup>68–72</sup> and despite adjunct patching, sealing, and dural substitutes, operative results are poor. Conservative measures are reasonable for first line treatment of CSF leakage; successful care in 91% of patients in a large Chinese series used a myriad of treatments

including prone positioning, continuous pressure by sandbag, ultrasound guided puncture, and aspiration.<sup>69</sup>

#### 3.3. Lumbar spine

Incidental durotomies during lumbar surgeries have an occur in approximately 3% of primary surgery and 15% of revisions.<sup>73</sup> According to the Spine Patient Outcomes research Trial, lumbar discectomy had a 4% rate, lumbar stenosis decompression had a 8% rate, and those undergoing fusion had a 11%,<sup>74–76</sup> but did not affect the long term outcomes.<sup>77</sup> Age, diabetes, central stenosis, posterior approach, revision surgery, minimally invasive surgery, and obesity have been shown to be risk factors.<sup>78–80</sup> Increased length of stay drive in-hospital costs by over \$4000 in those with an incidental durotomy.<sup>81</sup>

### 4. Treatment techniques

Prompt treatment of a tear with a watertight seal is imperative for successful outcomes. In 1981, Eismont et al. described the principles of repair.<sup>22</sup> His early paper emphasized keeping proper visualization (keeping field dry, magnified), primary repair with suture, augment as necessary with other agents, testing the repair using intrathecal pressure maneuvers, suture the wound closed in layers, and allow for bed rest post-operatively until symptoms subside. The entire extent of the tear must be identified, probed with a Penfield 4 dissector,<sup>7</sup> sometimes necessitating further bone removal and magnification for better visualization. Eismont et al. also recommended avoiding subfascial drains to prevent spinocutaneous fistulas,<sup>22</sup> but more recent literature refutes that notion concluding a drain is safe in the presence of a dural tear.<sup>23</sup>

Primary repair has been reported using a variety of suture, achieving watertight repair and return of pulsatile inflated dura. No single technique has been shown to be superior, with a failure rate of 5–10%.<sup>39</sup> Locking technique with 4–0 silk suture in 338 patients resulted in 98% of patients mobilizing postoperatively with no further intervention.<sup>24</sup> 5–0 Gore-tex has been used and recommended in a widely cited paper, but without clinical results.<sup>7</sup> A 2017 study out of Thomas Jefferson University tested various sized Nurolon and Gore-Tex suture with various techniques, and found the Gore-Tex had higher peak pressure to failure than Nurolon in all interrupted, running, and locked techniques.<sup>25</sup> Persistent leaks after repair are surmised to come from the needle puncture sites and not the original tear, and Epstein<sup>26</sup> recommends using a 7–0 Gore-Tex secondary to the suture being bigger than the needle (although he further augmented with microdural staples and fibrin glue).

If a watertight repair is unattainable after a valsalva testing maneuver by anesthesia,<sup>22</sup> supplementation of the repair is necessary. Fat grafts have been used secondary to its harvesting potential, impermeability to water, and lack of adherence to neural tissue. This can be placed either as a fat plug (into the dural defect) or as an onlay. The plug is passed through a separate incision next to the defect, sutured into the dura, and then the secondary incision is closed with suture.<sup>27</sup> An onlay technique provides the fat graft covering the exposed

dura, tucked under the bone and sutured into the dura. If the tear is anterior, this only technique can be further used to fill the disc space, although it is described with further augmentation with either fibrin glue, absorbable hemostat wrap, or hemostatic gelatin powder.<sup>28</sup> Fat grafts have greater than 90% success rates,<sup>29</sup> although there are reports of migration causing cord compression.<sup>30,31</sup> Fibrin glues and polyethylene glycol sealant have been used as an adjunct to decrease leaks but have not been shown to decrease repair failure.<sup>32,43</sup> Recent animal and human Japanese studies looking at fibrin glue or spray with polyglactin supplementation could be viable treatment options, but not fibrin glue alone.<sup>33–35</sup> Other onlay options include collagen matrices, with a 95% success rate.<sup>39</sup> Collagen matrices obviate the need for suture fixation, replaced by natural collagen in 2–3 months, and are effective in closing the dura without increase in infection.<sup>36–39</sup> Sutureless repairs may grow favor and more research with the increase in minimally invasive techniques.

Dural substitutes are used when primary closure is not possible. In mice, repairing a dural tear with autologous fascia decreased neuroinflammation and prevented conduction disturbances when compared to those without repair.<sup>42</sup> Harvesting autologous fascial tissues are optimal in avoiding disease transmission risk, although it leads to increased operative times, blood loss, exposure and may be of inadequate amount when in the pediatric population. Dural replacement with xenografts have been studied with tissue from the bovine and porcine species but must more research is needed.<sup>40,41</sup>

Treatments aimed at decreasing intracranial pressure or shunting CSF via subarachnoid drainage is an option for primary or adjunct treatment of dural tear. Novel treatment of using acetazolamide to decrease pressure and production of CSF has been shown to be effective in otolaryngology and spine literature.<sup>44–47</sup> Shunting drainage through a catheter instead of the tear helps decrease tension on the repair. Patients treated with a catheter have an increased risk of infection despite antibiotics and a silicon catheter is preferred due to lower incidence of occlusion.<sup>48,49</sup>

The treatment pendulum of late presenting dural tears has swung towards initial non-operative treatment to avoid the risks of reoperation. Late presentation can occur more than a week after the index procedure,<sup>50,51</sup> after physical exertion and coitus.<sup>52</sup> Treatment options include bed rest, subarachnoid drains, and focal compression with abdominal binders.<sup>5</sup> If the problem is surgical, it has been shown to have no difference in outcomes in those without a late presenting dural tear.<sup>53</sup> Myelocutaneous fistulas when treated with watertight closures, CSF diversion, bed rest have been reported to lead to complete resolution of symptoms.<sup>49</sup> Epidural blood patches can help with fistulas and pseudomeningoceles, with case reports of success after 20 month post-procedure presentation.<sup>54</sup> Percutaneous treatments have been shown to work with various modalities: hydrogel sealant, polyethylene glycol, blood patches, and drains.<sup>55–58</sup>

column, the lumbar spine has the greatest amount of pressure when sitting upright and is lower when supine, which is opposite of the cervical spine; Carlson et al. confirmed this in a 2003 in-vivo canine model.<sup>52</sup> Canine models have also shown fibroblastic bridging of dural defects at day 6 and full healing on postoperative day 10. Two British studies with over 100 patients total found no difference in early mobilization and complication rates.<sup>59,60</sup> Radcliff et al. found patients immobilized for greater than 24 h had no more neurological complications but were associated with higher incidence of medical complications.<sup>61</sup> Duration of bed rest is highly variable and there is limited supporting literature on the topic.

## Disclosures

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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