



Review article

Treatment of cerebrospinal fluid leak after spine surgery

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ABSTRACT

Owing to the complexity of spinal surgery, there is a great prevalence of dural tear causing cerebrospinal fluid (CSF) leakage. Many studies focused on suture repair for dural tear to stop CSF leak. Now some new treatment strategies have shown a promising effect that is listed as follows: 1) creating watertight dural closure to stop CSF leak with the help of dural substitute material; and 2) retarding CSF leak by changing pressure difference, including reducing the subarachnoid fluid pressure, increasing the epidural space pressure and both. In fact several methods mentioned above are usually combined to treat CSF leak. However, no update review summarized the relevant studies implemented in recent years. In this review, the authors would compare the effects of different dural closure techniques, and introduce the latest treatment methods and mechanisms.

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The incidence of durotomy-induced CSF leak varied with different spinal procedures. If handled improperly, it may lead to a number of adverse sequelae, such as CSF fistulas (persistent leak through the incision), meningitis, brain abscess, intracranial hemorrhage, hematoma, and neurological deficits.^{1–4} Literature review was conducted from the databases of PubMed, Ovid, and Elsevier. Papers associated with treatment options as well as outcome analysis were eligible for evaluation. Quantitative data on successful rate in complete closure, complications, as well as advantages and shortcomings were analyzed.

Prevention

The most important aspect of treating CSF leak is prevention, including preoperative risk factor evaluation and intraoperative meticulous manipulation. Residual bone spikes may puncture the dural sac. Instrumentation may lead to more dead space and paraspinal muscles tamponade is essential to effectively prevent small dural tear. In some cases, a dural tear will not rupture the arachnoid membrane and CSF leak will not occur. But because of the thin, delicate nature of the arachnoid, any procedure that increases intraabdominal pressure, such as violent awakening from

anesthesia, coughing, constipation and urinary retention, would induce dural tear. For revision surgery, it is recommended to begin dissection in areas of unscarred tissue and proceed toward the potentially scarred regions.^{5–8}

Treatment strategies

Although direct suture repair for dural tear has been widely used, it still has a failure rate of 5%–9%. A new treatment strategy has been proposed recently, which is to change the pressure difference to retard CSF leak. In this review, all treatment approaches were classified into two groups based on a fluid flow mechanics: 1) stopping CSF leak by direct suture or augmented closure with dural substitute material^{8–15}; 2) retarding CSF leak by reducing the subarachnoid fluid pressure and/or increasing the epidural space pressure.^{16–24}

Direct suture or augmented closure

Suture repair skills are summarized as follows: 1) direct suture being suitable for dural tear or small dural defect; 2) continuous suture or 8-figure suture with 4.0–6.0 thread; 3) the GORE-TEX suture material only left a very small suture hole; 4) <3 mm of the distance between two sutures with each suture apart 1 mm from the margin.⁸ For minimal invasive spine surgery, it is impossible to suture by traditional thread. Many surgeons now preferred direct suture with adjuvant dural closure material. Polyethylene

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Glycol (PEG) is preferred to use as a hydrogel sealant.⁹ Kim compared the efficacy of PEG hydrogel sealant and fibrin glue as an adjuvant repair. It was found that the successful rate in watertight closure is 91.2%: 63.6%.¹⁰ But there is a warning of potential expansion up to 50% of its size. Two cases of cervical cord compression by hydrogel were reported.¹¹ In the year of 2016, a low-swell PEG hydrogel as a modified form was developed. It showed a significantly higher rate of watertight closure than fibrin glue (98.6% vs. 79.2%).¹² There still need more studies to assess its safety.

Augmented closure by means of fat, muscle tissue or fascial graft is indicated when the dural defect is too large to be directly repaired. Joseph reported 144 patients with ossified posterior longitudinal ligament (OPLL) injury undergoing cervical corpectomy, of which 6.3% of dural defect were repaired with an onlay graft of crushed muscle/fascia. All patients were successfully repaired without reoperation.¹³ Song established a Sprague–Dawley rat model of dural tear and autologous fascia graft repair. The result demonstrated that dural tear could cause a series of inflammatory reaction in the spinal cord and further impair its sensory conduction function. Repair with autologous fascia could attenuate neuro-inflammation and help to maintain normal sensory conduction function.¹⁴ In Shahrokh's study, the successful rate of watertight closure was 87.5%.¹⁵ Autologous fat graft as an excellent water sealant is a good alternative for muscle graft. It could revascularize, prevent scar formation, and does not adhere to the neural elements.

CSF pressure adjustment according to the fluid flow mechanics

It is reported that unrecognized durotomy during surgery is 6.8% and the rate of spontaneous CSF leak cessation is 80%–95%. The flow of CSF in the subarachnoid space is based on the difference in CSF pressures between 2 communicating points.^{16,22–24} Therefore, CSF leak can be retarded by decreasing the difference between the two pressures, including reducing the subarachnoid fluid pressure and increasing the epidural space pressure.

Reducing the subarachnoid fluid pressure

The methods to reduce subarachnoid fluid pressure include inhibiting the formation of CSF, adjusting patient's position, and CSF shunting by subarachnoid catheter. In a randomized clinical trial, acetazolamide was administered in the first 48 h with the dose of 25 mg/kg/day. After treatment, the CSF leak stopped in all of 28 patients.¹⁷ For patients with CSF leak, the most challenge is the unrecognized site of the fistula after surgery. For such cases, diversion of CSF with closed subarachnoid catheter was widely used. The successful rate reported by the literature is 85%–94%.^{18,19} But the overall complication rate is up to 44.4% and the most severe complications are over-drain, pneumocephalus and meningitis. 17% of the patients complained of the root irritation pain by catheter placement and headache due to over-drain.²⁰

As the fluid dynamics of Bernoulli's law demonstrated, the value of $(P + \rho gh)$ is constant. In this condition, the pressure is lower at higher position. So increasing the height of the dural tear site could decrease the subarachnoid pressure and further reduce the site of CSF leak. In cases of lumbar or thoracic CSF leak, patient should be kept in Trendelenburg or prone position; while in cases of cervical CSF leak, opposite of the Trendelenburg position is required.^{3,5,6} To examine the relation between subarachnoid CSF pressure and varying body positions in the cervical and lumbar spine, Gregory set up a dog model, in which two 22-gauge angiocatheters attached to pressure transducers were inserted into the subarachnoid space through laminectomies in the third cervical (C3) and fourth lumbar (L4) regions. As inclination increased from 0° (supine position) to

90° (upright), cervical CSF pressure decreased by 29%. The mean lumbar subarachnoid pressure increased by 52%. When durotomy was used to simulate lumbar subarachnoid drainage, lumbar durotomy plus reposition of the animal to 90°, cervical CSF subarachnoid pressure would be reduced by 46%.²¹

Increasing the epidural fluid pressure

An epidural CSF pool may be developed secondary to durotomy, which is wrapped up by the incision tissue. When the CSF outflow is beyond the strength of sutured tissue, it will lead to a persistent CSF communication between the intra-dural and outside of the wound. So a tight fascial closure technique is required to avoid CSF leak. A tight fascial closure can increase the epidural fluid pressure, retard CSF flow and facilitate the dural flaps to adhere. In the meantime, subfascial drain and discharging excessive CSF will eliminate the dead space.²² There exists a dispute about the time of subfascial drainage.^{6,22,23} Our previous study supported the drain duration of more than 7 days. Samuel found this time to be about 10–17 days postoperatively when the wound closure is well healed.²³ Another study supported drain placement for an average of 2.1 days after suture of durotomy and 86.3% of CSF leak was stopped. Cho et al designed a volume-controlled chest tube drain for CSF leak after anterior thoracic OPLL surgery. It can produce a profitable result without the need of additional subarachnoid drainage.¹⁶ However in the cases of anterior cervical surgery, there are not enough muscles for coverage of cervical vertebrae, swallowing and coughing can cause CSF pressure fluctuation. So the effect is poor in anterior cervical region.^{16,24}

Some scholars paid their attention to the epidural blood patch (EBP) in treating CSF leak. The EBP can not only seal the CSF leak, but also increase the epidural fluid pressure to reverse the CSF blood gradient along the entire spinal cord.^{3,5,6,25} For patients with an uncertain site of CSF leak, lumbar EBP should be used. Real-time US guidance can allow accurate positioning of a Tuohy needle and deposition of an epidural blood patch in the setting of a surgically removed ligamentum flavum where loss of resistance and fluoroscopically guided techniques are not possible.²⁶ Some scholars concerned that an EBP may result in an increase in intracranial pressure (ICP) by a shift of CSF from the spinal to the intracranial compartment, but the concern was denied by another study.²⁷

Other treatment methods

Sean Grannum's study suggested that dural tear after lumbar decompressive surgery could be maintained well without suture repair. These patients were simply laid on a flat bed until related symptom was settled. The mean duration of bed rest was 2.6 days (range 2–4 days).²⁸ In addition, poor healing of dural tear may be caused by certain conditions, such as large dural defect, poor overlying soft tissue coverage, infection, nutritional deficits, steroid agents, and elevated CSF pressure. These mentioned clinical problems should not be overlooked.

Summary

Even direct suture repair still has a failure rate of 5%–9%, because the pin hole created by passage of the suture needle may convert a low pressure dural defect to a high pressure defect resulting in persistent leakage. Clinical surgeons usually choose several treatment methods together to create a 'watertight' dural closure condition. Although some new treatment methods are provided, most of them belong to a small sample study or case report. In the future, a large sample of study or an evidence-based medicine study is needed to compare these treatment effects.

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