Authors

Choi, Elliot H
Chan, Alvin Y
Brown, Nolan J
et al.

Publication Date

2021-05-01

DOI

10.1016/j.wneu.2021.02.079

Peer reviewed

HHS Public Access

Author manuscript

World Neurosurg. Author manuscript; available in PMC 2022 May 01.

Published in final edited form as:

World Neurosurg. 2021 May ; 149: 140–147. doi:10.1016/j.wneu.2021.02.079.

Effectiveness of Repair Techniques for Spinal Dural Tears: A Systematic Review

Elliot H. Choi, MS[1,2], **Alvin Y. Chan, MD**[1], **Nolan J. Brown, BS**[1], **Brian V. Lien, MS**[1], **Ronald Sahyouni, MD, PhD**[3], **Andrew K. Chan, MD**[4], **John Roufail, MD**[1], **Michael Y. Oh, MD**[1]

[1]Department of Neurological Surgery, University of California, Irvine, CA 92686

[2]Medical Scientist Training Program, School of Medicine, Case Western Reserve University, Cleveland, OH 44106

[3]Department of Neurological Surgery, University of California, San Diego, CA 92093

[4]Department of Neurological Surgery, University of California, San Francisco, CA 94143

Abstract

Background: Incidental or intentional durotomy in spine surgery is associated with a risk of cerebrospinal fluid (CSF) leakage and reoperation. Several strategies have been introduced but the incomplete closure is still relatively frequent and troublesome. In this study, we review current evidence on spinal dural repair strategies and evaluate their efficacy.

Methods: PubMed, Web of Science and Scopus were used to search primary studies about the repair of the spinal dura with different techniques. Of 265 articles found, 11 studies, which specified repair techniques and post-operative outcomes, were included for qualitative and quantitative analysis. The primary outcomes were CSF leakage and post-operative infection.

Results: The outcomes of different dural repair techniques were available in 776 cases. Pooled analysis of 11 studies demonstrated that the most commonly used technique was a combination of primary closure, patch or graft and sealant (22.7%, 176/776). A combination of primary closure and patch or graft resulted in the lowest rate of CSF leakage (5.5%, 7/128). In this study, sealants as an adjunct to primary closure (13.7%, 18/131) did not significantly reduce the rate of CSF leakage compared to primary closure alone (17.6%, 18/102). The rates of infection and postoperative neurological deficit were similar regardless of the repair techniques.

Conclusions: Although the use of sealants has become prevalent, available sealants as an adjunct to primary closure did not reduce the rate of CSF leakage compared to primary closure. The combination of primary closure and patches or grafts could be effective in decreasing postoperative CSF leakage.

Correspondence: Michael Y. Oh, MD, Professor and Vice Chair, Director, Spine Services, Department of Neurological Surgery, University of California, Irvine, ohm2@hs.uci.edu, Phone: 714-456-3402.

Keywords

dural repair; durotomy; primary closure; sealants; spine surgery; neurosurgery

Introduction

Dural tears are not uncommon complications in spine surgery, with an incidence varying from 1.6% to 10%[1–6]. Although primary repair of a dural tear is generally satisfactory, persistent CSF leakage resulting from incomplete closure can lead to complications such as postural headache, nausea, vomiting, dural cutaneous fistula formation, meningitis and even intracranial hemorrhage[7–9]. Moreover, treating these complications often requires prolonged bed rest, which is associated with subsequent complications including pneumonia, deep venous thrombosis and pulmonary embolism. Therefore, it is imperative to repair the durotomy during the initial surgery.

Many investigators have developed dural repair techniques to achieve watertight dural closure. The repair techniques have been described from simple sutures and sealants to different types of patches and grafts. Typically, sutures have been used to close simple dural tears. However, the application of sutures has limitations depending on the anatomical location and condition of the damaged dura. Over the past decades, various surgical sealants that address these limitations have been developed[10–13] and have become an alternative solution for neurosurgeons. In addition, muscle, fascia, fat and synthetic materials have long been used to repair moderate-sized dural tears[14, 15].

Although various strategies have been introduced for dural repair, studies that assess the efficacy of each strategy are scarce. We therefore aim to review current literature on the efficacy and safety of the available techniques. The primary outcome including post-operative CSF leakage and infection were examined. Also, adverse events resulting from the sealants, synthetic patches and biological grafts were discussed.

Methods

Search Strategy

A PubMed literature search was performed using the terms "(dural AND (repair OR closure) AND (spine OR spinal)) AND ((autologous OR allogenic OR synthetic) OR (seal OR glue) OR (suture OR clip))." The search retrieved 265 studies from September 1976 to April 2020. Case reports, technical reports, cadaveric studies, animal studies, non-surgical studies and non-English articles were excluded. Also, studies with fewer than 15 subjects were excluded. Studies that stated the specific repair techniques and their corresponding CSF leakage rate were included. This literature review was designed and performed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Figure 1)[16]. Ultimately, 11 studies met these exclusion and inclusion criteria for this systematic review. Then, a second literature search using Web of Science or Scopus was performed to include missing articles from the PubMed literature search. References of review articles were also examined for potential additional studies. Later, several case reports were included as examples for the discussion. Quality assessment of the included studies was conducted using the Levels of Evidence categorization system from Oxford Centre for Evidence-based Medicine. The scale ranges from 1 (highest level of evidence) to 5 (lowest level of evidence).

Extraction and Analysis of the Data

The following data were extracted from the included studies: year of publication, number of patients in each study, number of patients included for the analysis, mean age, sex, indication for surgery, involved location, use of drainage, repair technique, follow-up duration after dural repair, rate of post-operative CSF leakage, rate of post-operative surgical site infection and rate of post-operative neurological deficit. Dural repair technique was categorized as primary closure (suturing and/or clipping), sealant and patch or graft. Post-operative CSF leakage was defined as continuous CSF drainage through a conventional wound drain or direct wound leakage in two studies[17, 18], whereas it was defined as dural leakage that requires revision surgery or conservative treatment in the remaining studies[19–27]. World Health Organization criteria for surgical-site infection was used to define surgical-site infection[28]. Surgical-site infection can be superficial infections involving the skin or more severe infections involving tissues under the skin, organs or implanted material[28]. Post-operative neurological deficit was defined as a reduction of two grade or more on manual muscle testing or post-operative sensory disturbance[17]. A direct comparison between studies was not possible due to heterogeneity. Thus, a pooled analysis was performed to measure rates of CSF leakage, infection or neurological deficit. The rates were calculated without adjustment for the surgeries, indication for surgeries or patient demographics.

Results

The initial search resulted in 265 studies. After the screening and assessment, a total of 11 studies fulfilled the inclusion criteria[17–27]. The type of study and level of evidence were summarized in Table 1. The level of evidence ranged from 2 to 4. Of the 11 studies, 6 studies were level of 4 evidence, 1 study was level of 3 evidence, and 4 studies were level of 2 evidence. A total of 776 cases (incidental durotomy: 628 cases, intentional durotomy: 148 cases) were included in this systematic review after excluding the cases that lost follow-up or did not receive dural repair (Table 1). The mean collective sample size study was 79. The mean collective age was 57.6 years. The collective ratio of male to female study participants was 1 to 1.1.

The dural repair techniques were categorized as outlined in Table 2. Of the 776 cases, the most common technique was a combination of primary closure, patch or graft and sealant (22.7%, 176/776) followed by a combination of primary closure and sealant (16.9%, 131/776), a combination of primary closure and patch or graft (16.5%, 128/776), patch or graft (14.8%, 115/776), primary closure (13.1%, 102/776), sealant (9.9%, 77/776) and a combination of patch or graft and sealant (6.1%, 47/776). Primary closure was used as the basis for repairing all 148 intentional durotomies (Table 2). The studies involving these intentional durotomies were mostly metastatic and primary spinal tumor cases.

The involved location, use of drainage, follow-up duration after dural repair, repair technique and outcome were summarized in Table 3. Of the 11 studies, 10 studies reported the involved locations. The most commonly involved location was lumbar (77.8%, 548/704) followed by thoracic (16.8%, 118/704), cervical (2.3%, 16/704), lumbo-sacral (1.4%, 10/704), cervico-thoracic (0.7%, 5/704), thoraco-lumbar (0.7%, 5/704) and sacral (0.3%, 2/704) (Table 3).

A direct comparison between studies was not possible due to heterogeneity. Thus, the rates of post-operative CSF leakage were combined based on the repair techniques (Table 4). The pooled rates of CSF leakage ranged from 5.5% (a combination of primary closure and patch or graft) to 55.7% (patch or graft) depending on the types of repair technique. A combination of primary closure and patch or graft resulted in the lowest rate of CSF leakage (5.5%, 7/128) followed by a combination of primary closure, patch or graft and sealant (13.6%, 24/176), a combination of primary closure and sealant (13.7%, 18/131), primary closure (17.6%, 18/102), sealant (22.1%, 17/77), a combination of patch or graft and sealant (31.9%, 15/47) and patch or graft (55.7%, 64/115). The pooled rates of post-operative infection and neurological deficit were analyzed in the same manner (Table 4). The pooled rates of infection ranged from 0.0% to 6.4% depending on the types of repair technique, but there was no significant difference between the groups. The pooled rates of neurological deficit ranged from 0.0% to 5.7% depending on the types of repair technique. In line with the pooled rates of infection, no significant difference in the pooled rates of neurological deficit between the groups was observed.

Discussion

Dural tears are common complications encountered by spine surgeons. Primary dural repair remains the treatment of choice, but recent literature has reported different repair techniques and adjuncts. This systematic review assesses the outcomes of spinal dural repairs with different repair techniques. We reviewed 776 cases from 11 studies for qualitative and quantitative analysis.

Dural Repair Techniques

Traditionally, sutures have been considered the gold standard for dural tear repair. Braided nylon suture, monofilament polypropylene suture and Gore-Tex suture have been routinely used and demonstrated their hydrostatic strengths[29–31]. Two different repair techniques including interrupted and running locked suture techniques have been commonly used[10, 31]. Two studies have reported no significant differences in CSF leakage between interrupted and running locked suture techniques[10, 31]. Although few studies suggested that dural tear repair could be achieved without sutures[21, 24, 32, 33], this option is reasonable only in certain circumstances (e.g. the dural tear is located anteriorly or inaccessible). Indeed, only 1% and 5% of survey respondents preferred suturing to manage anterior dural tears and nerve root tears, respectively[34]. Suturing could also be challenging if the procedure is minimally invasive[35, 36]. As an alternative technique, nonpenetrating titanium clips have been used to achieve primary closure. The advantages of this technique include ease and speed of use, tighter closure and less need for extended dissection in confined spaces[37, 38].

Various sealants have been introduced to augment sutures or clips. In general, there are two different types of sealants: the synthetic absorbable sealant containing PEG (polyethylene glycol) and the biologically absorbable sealant containing fibrinogen and thrombin. It has been known that these sealants polymerize on the dura and covers it. Although these sealants can improve the strength of sutured repair in calf spine model[31], several lines of evidence have suggested that currently available sealants do not reduce the rate of CSF leakage in spine (sealant: 9.1% vs. control: 13.8%) and cranial surgery (sealant: 8.2% vs control: 8.4%)[39, 40]. These findings were consistent with other studies demonstrating fibrin (fibrin sealant: 8.3% vs. no fibrin sealant: 9.4%) and PEG (PEG sealant: 6.6% vs. control: 6.5%) do not significantly reduce the number of CSF leakage[13, 41]. In our study, a combination of primary closure and sealant did not significantly reduce the rate of CSF leakage compared to primary closure alone.

Closure of dural tears with grafts or patches has been another option. Autologous fat, muscle and fascia have been available options for the repair of dural tears. More recently, synthetic and absorbable patches including collagen matrix, gelatin sponge, polyglycolic acid sheet and collagen patch coated with fibrin have received Food and Drug Administration approval. These products have the advantage of ready availability and can be cut to shape. Also, the use of grafts or patches is advantageous when dural tears are relatively large[23]. Several lines of evidence suggested that collagen matrix can have a chemotactic interaction with dural fibroblasts and behave like a scaffold for the dural fibroblasts[42, 43]. On the other hand, grafts could release growth factors such as basic fibroblast growth factor, epidermal growth factor or transforming growth factor beta and promote the proliferation of dural fibroblasts, deposition of collagen and sutural fusion[44–46]. Although underlying molecular mechanisms enhancing dural repair are different, compelling evidence has demonstrated that grafts or patches could be an effective option. These data also partially explain that the combination of primary closure and patches or grafts could be effective in decreasing postoperative CSF leakage, as shown in our study.

Adverse Effects and Drawbacks of Dural Repair Techniques

Although primary durotomy repair is frequently implemented, it comes with the disadvantage that watertight closure is difficult to achieve in some circumstances[29]. Complications related to CSF leakage include pseudomeningoceles, wound infections, CSF fistulas and intracranial hypotension syndrome, which often require revision surgery[47]. A variety of suturing techniques can be implemented to help prevent CSF leakage, but the failure to form watertight closures has resulted in the development of nonpenetrating titanium clips[37, 47]. These clips may come with the advantages of reduced CSF leakage, dural exposure, scarring, and intradural adhesions as well as improved efficiency and ease of application as compared to traditional suturing[29, 37]. Although a concern with titanium clips has been the risk of causing metallic artifacts during post-operative imaging[37], several studies have suggested that the clips are small enough that they do not have significant impact on the quality of post-operative imaging[29, 37, 48, 49]. Nonetheless, several disadvantages associated with non-penetrating clips have been reported: dural laceration, dislodgement, the inability to reposition or re-use clips once they have left the applier, greater cost, and even a high rate of CSF leaks as reported by Timothy and colleagues in

2007[49]. Overall, nonpenetrating titanium clips appear to better reduce CSF leakage as compared to standard suturing, although further studies are needed to confirm the efficacy[29, 37].

While fibrin sealant for dural repair may offer advantages as an adjunct to traditional suturing, including reduced CSF leakage, these biological systems can carry a risk of viral and prion infection as well as allergic responses[50, 51]. For these reasons, autologous fibrin tissue adhesives have been devised and have demonstrated efficacy in reducing CSF leakage in neurosurgical operations[52, 53]. However, they require a long production time (3 days) and are difficult to handle[54]. PEG has emerged as a hydrogel spinal sealant that may be superior to both traditional sutures and fibrin sealants in its ability to achieve watertight dural closure[11]. However, its negative effects are well-profiled, as it has demonstrated a tendency to swell postoperatively often leading to stenosis and nerve root compression[55–59].

Furthermore, a collagen patch coated with fibrin has emerged as an alternative fibrin sealant that contains human blood components and may increase the risk of blood-borne disease transmission[60]. An additional logistical drawback is that this patch is not always large enough to completely cover dural injuries; as such, severable pieces may be required for dural reconstruction[60]. Finally, the high cost associated with this collagen patch may preclude its use at most centers[60]. Other grafts include autologous dural substitutes such as fascia lata, fat, muscle, skin, and pericranium[61]. Notably, autologous grafts do not come with a risk for infection or immunogenic reactions[20]. However, they can increase surgical time and risk for additional morbidity as a result of the intraoperative grafting process.

Limitations

The current systematic review has some limitations. First, more than half of the studies were retrospective case series. Thus, the average evidence level is relatively low. Moreover, it is common that a repair technique is determined by a surgeon in case series studies rather than predetermined by a protocol. Therefore, the selection bias of a repair technique is inevitable. Second, the included studies lack details about the size of dural tears and anatomical location. Although the included studies, except one study, reported the involved vertebral locations, they did not describe the exact location and size. Third, there were various types of patches or grafts, which were categorized to “patch or graft.” For example, patches could be subcategorized into collagen matrix, dural substitute, gelatin sponge, polyglycolic acid sheet and collagen patch coated with fibrin. Grafts could be subcategorized into autologous fat, muscle and fascia. The efficacy of each patch or graft was not evaluated in this study. Fourth, there was heterogeneity among the studies in terms of duration of bed rest and the use of subfascial or subarachnoid drainage. Seven studies described the use of drainage, whereas four studies did not. It is conceivable that the post-operative outcomes cannot be solely attributed to the specific repair technique. In addition, further information about the reoperation or treatment to manage CSF leakages following the initial repair would be interesting to note. However, only three studies reported the reoperation or treatment technique, and four studies reported that reoperation was not performed due to no CSF leakage. However, five studies did not mention about reoperation or treatment technique. Lastly, 45.6% (354/776 cases) of the data was extracted from one study[17]. Thus, the pooled analysis could be influenced by this study. These limitations should be considered when drawing conclusions from this systematic review.

Conclusion

In this systematic review, we analyzed the efficacy of different dural repair techniques in preventing post-operative CSF leakage, infection and neurological deficit. Primary closure resulted in a lower rate of CSF leakage than sealant, patch, or graft, suggesting that primary closure should be used as the basis for repairing durotomies if possible. A sealant as an adjunct to primary closure did not significantly reduce the rate of CSF leakage. Compared to other repair techniques, a combination of patch or graft and primary closure could be more effective for preventing post-operative CSF leakage. Regardless of the repair techniques, the rates of post-operative infection and neurological deficit were similar.

Dural tears are relatively common complications in spine surgery. However, further studies will be required to evaluate the efficacy of each repair method. Heterogeneity among the primary studies and various reporting methods preclude definitive message.

Conflict of interest and funding disclosure:

The authors report no conflicts of interest. Elliot H. Choi is supported by NIH MSTP funding (T32GM007250). Dr. Andrew K. Chan receives research support for a non-related study from Orthofix Medical, Inc.

Glossary

CSF	Cerebrospinal fluid
PEG	Polyethylene glycol
PRISMA	Preferred reporting items for systematic reviews and meta-analyses

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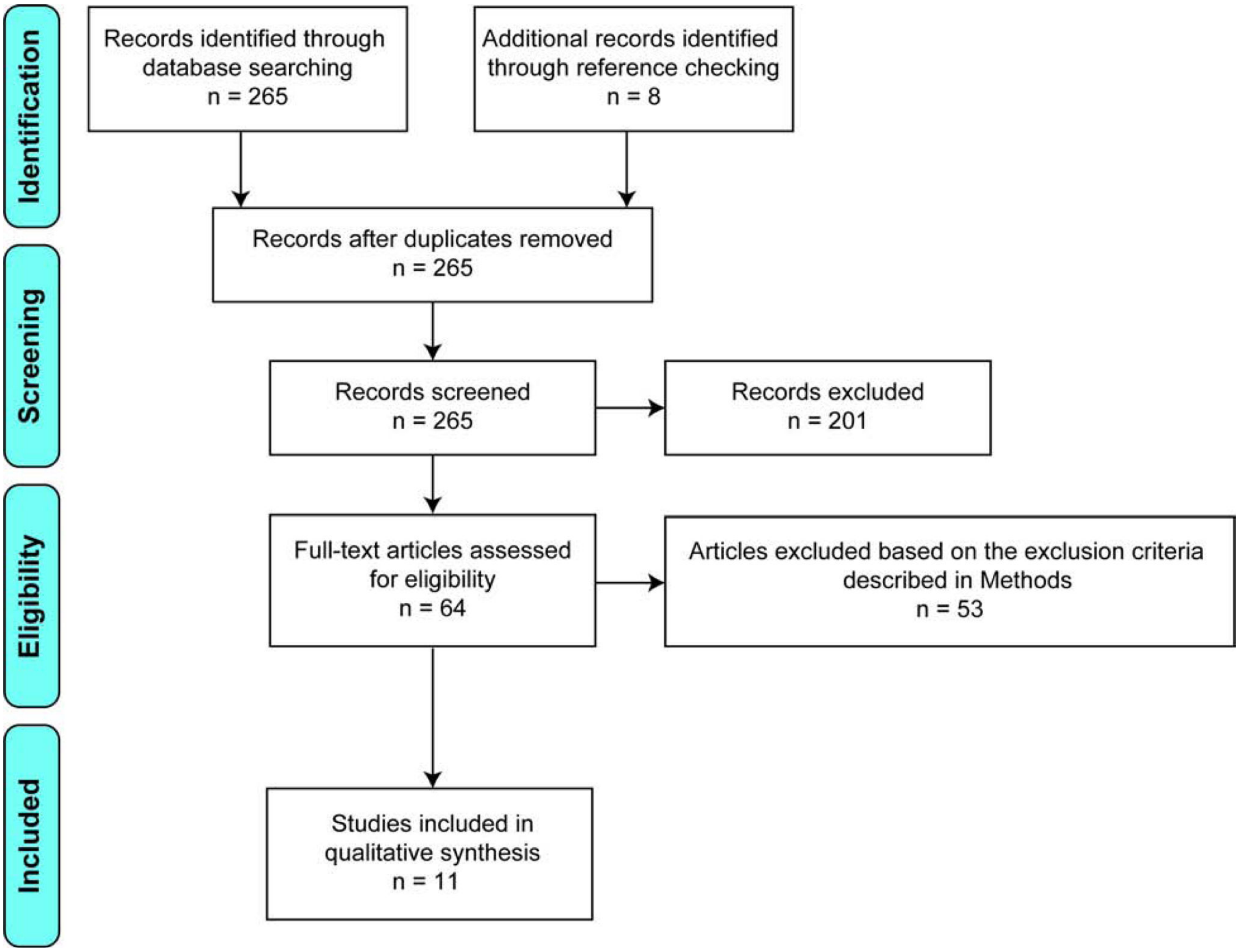

Figure 1.

PRISMA diagram. Process of exclusion and inclusion of studies for the systematic review.

Table 1.

Characteristics of the included studies and patient demographics

Study, year	Study type	Level of evidence	Number of total subjects (Incidental/ Intentional)	Number of subjects included in the systematic review (Incidental/ Intentional)	Mean age (years)	Sex (M/F)	Indication for surgery
Takenaka et al, 2019[17]	Retrospective cohort	2	429 (429/0)	354 (354/0)	69.7 ± 12.7	206/223	Disk herniation, Scoliosis, Spinal canal stenosis, Spondylolisthesis
Montano et al, 2018[18]	Prospective cohort	2	35 (0/35)	35 (0/35)	58.1 ± 15.6	14/21	Ependymoma, Ganglioglioma, Hemangioma, Hemangioblastoma Meningioma, Schwannoma
Arnautovic et al, 2016[19]	Case series	4	40 (0/40)	37 (0/37)	57.4 ± 17.3	11/29	Astrocytoma, Breast metastasis, Ependymoma, Hemangioblastoma, Meningioma, Myxopapillary, Schwannoma
Kamenova et al, 2016[20]	Retrospective cohort	2	69 (69/0)	69 (69/0)	72.2 ± 12.8	35/34	Disk herniation, Spinal canal stenosis
Masuda et al, 2016[21]	Case series	4	75 (22/53)	75 (22/53)	57.1	34/41	Epidural tumor, Intradural extramedullary tumor, Spinal canal stenosis, Metastatic spinal tumor, Ossification of ligamentum flavum, Spinal cord hernia, Spinal deformity, Spondylolisthesis, Spondylotic myelopathy, Subarachnoid cyst
Jo et al, 2015[22]	Case series	4	15 (15/0)	15 (15/0)	42.2 ± 8.6	12/3	Ankylosing spondylitis
Grannum et al, 2014[23]	Case control	3	28 (28/0)	13 (13/0)	50.8	14/14	Spinal canal stenosis
Tan et al, 2014[24]	Case series	4	23 (0/23)	23 (0/23)	54.4 ±12.6	8/15	Congenital fatty filum, Congenital meningocele, Ependymoma, Lymphoma, Meningioma, Schwannoma, Spinal dural arteriovenous fistula, Tarlov cyst
Anderson et al, 2013[25]	Case series	4	50 (50/0)	50 (50/0)	58.9	28/22	Adjacent segment degeneration, Cauda equina syndrome, Herniated disk, Scoliosis, Spinal canal stenosis, Spondylolisthesis
Sun et al, 2012[26]	Retrospective cohort	2	85 (85/0)	85 (85/0)	54.3	44/41	Ossification of ligamentum flavum
Hodges et al, 1999[27]	Case series	4	20 (20/0)	20 (20/0)	58.1 ± 15.9	7/13	NA
Total			869 (718/151)	776 (628/148)		869 (413/456)	

NA: not available

Table 2.

Characteristics of the repair techniques included in this study

Repair technique	Number (%)	Incidental/Intentional
Primary closure (suturing and/or clipping)	102 (13.1)	102/0
Sealant	77 (9.9)	77/0
Primary closure + Sealant	131 (16.9)	108/23
Patch or graft	115 (14.8)	115/0
Primary closure + Patch or graft	128 (16.5)	93/35
Patch or graft + Sealant	47 (6.1)	47/0
Primary closure + Patch or graft + Sealant	176 (22.7)	86/90
Total	776	628/148

Table 3.

Outcomes of the dural repairs in the included studies

Study	Involved location	Drainage	Follow-up after dural repair (months)	Technique	CSF leakage	Post-operative infection	Post-operative neurological deficit	Revision technique for CSF leakage
Takenaka et al, 2019[17]	Lumbar (354/354)	Subfascial*	NA	Primary closure	17/80	2/80	5/80	NA
				Sealant	17/77	2/77	1/77	
				Primary closure + Sealant	17/88	0/88	6/88	
				Patch + Sealant	13/45	2/45	1/45	
				Primary closure + Patch + Sealant	22/64	1/64	3/64	
Montano et al, 2018[18]	Cervical (3/35) Cervico-thoracic (2/35) Thoracic (13/35) Thoraco-lumbar (3/35) Lumbar (14/35)	NA	23	Primary closure + Patch	1/35	0/35	0/35	Needle aspiration + Bed rest
Arnautovic et al, 2016[19]	Cervical (11/40) Cervico-thoracic (3/40) Thoracic (11/40) Thoraco-lumbar (2/40) Lumbar (12/40) Sacral (1/40)	NA	45	Primary closure + Patch + Sealant	1/37	1/37	1/37	Autologous fat + Lumbar drainage
Kamenova et al, 2016[20]	Lumbar (69/69)	Subarachnoid (2/69) Subfascial (60/69) Not available (7/69)	NA	Primary closure	1/13	0/13	NA	NA
				Patch	4/22	4/22	NA	
				Primary closure + Patch	3/34	0/34	NA	
Masuda et al, 2016[21]	NA	Subarachnoid (75/75)	28	Primary closure + Patch + Sealant	1/75	1/75	0/75	Patch + Sealant
Jo et al, 2015[22]	Lumbar (15/15)	Subarachnoid (6/15) Subfascial (1/15)	17	Primary closure	0/9	0/9	0/9	No reoperation
				Primary closure + Patch	0/6	0/6	0/6	
Grannum et al, 2014[23]	Lumbar (13/13)	NA	60	Patch	0/13	0/13	0/13	No reoperation
Tan et al, 2014[24]	Cervical (2/23) Thoracic (9/23) Lumbar (11/23) Sacral (1/23)	Subarachnoid (0/23) Subfascial (0/23)	20	Primary closure + Sealant	0/23	NA	0/23	No reoperation
Anderson et al, 2013[25]	Lumbar (50/50)	Subfascial#	NA	Primary closure + Patch	0/50	0/50	0/50	No reoperation

Study	Involved location	Drainage	Follow-up after dural repair (months)	Technique	CSF leakage	Post-operative infection	Post-operative neurological deficit	Revision technique for CSF leakage
Sun et al, 2012[26]	Thoracic (85/85)	Subfascial (84/85) Subfascial and subarachnoid (1/85)	NA	Primary closure + Patch	3/3	0/3	0/3	NA
				Patch	60/80	1/80	0/80	
				Patch + Sealant	2/2	1/2	0/2	
Hodges et al, 1999[27]	Lumbar (10/20) Lumbo-Sacral (10/20)	NA	>10	Primary closure + Sealant	1/20	0/20	0/20	NA

NA: not available;

* exact number is not available but no patient underwent subarachnoid drainage;

only used for multilevel laminectomy or fusion cases

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Table 4.

Pooled rates of CSF leakage, post-operative infection, and post-operative neurological deficit after dural repairs

Repair technique	CSF leakage, number (%)	Post-operative infection, number (%)	Post-operative neurological deficit, number (%)
Primary closure	18/102 (17.6)	2/102 (2.0)	5/ 89 (5.6)
Sealant	17/77 (22.1)	2/77 (2.6)	1/77 (1.3)
Primary closure + Sealant	18/131 (13.7)	0/108 (0.0)	6/131 (4.6)
Patch or graft	64/115 (55.7)	5/115 (4.3)	0/93 (0.0)
Primary closure + Patch or graft	7/128 (5.5)	0/128 (0.0)	0/94 (0.0)
Patch or graft + Sealant	15/47 (31.9)	3/47 (6.4)	1/47 (2.1)
Primary closure + Patch or graft + Sealant	24/176 (13.6)	3/176 (1.7)	4/176 (2.3)
Total	163/776 (21.0)	15/753 (2.0)	17/707 (2.4)