



Review Article: Perspective

Perspective: Early diagnosis and treatment of postoperative recurrent cerebrospinal fluid fistulas/ dural tears to avoid adhesive arachnoiditis

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ABSTRACT

Background: Intraoperative traumatic cerebrospinal fluid (CSF) fistulas/dural tears (DT) occur in up to 8.7–9.5% of primary lumbar surgical procedures. Further, they recur secondarily in between 8.1% and 17% of cases. It is critical to diagnose and treat these recurrent lumbar DT early (i.e. within 3–4 weeks of the index surgery) to avoid the evolution of adhesive arachnoiditis (AA), and its' permanent neurological sequelae.

Methods: Postoperative lumbar CSF fistulas/DT should be diagnosed on postoperative MR scans, and confirmed on Myelo-CT studies if needed. They should be definitively treated/occluded early on (e.g. within 3–4 postoperative weeks) to avoid the evolution of AA which can be readily diagnosed on MR studies, and corroborated, if warranted, on Myelo-CT examinations. The most prominent MR/Myelo-CT findings include; nerve roots aggregated in the central thecal sac, nerve roots peripherally scarred/adherent to the surrounding meningeal wall ("empty thecal sac sign"), soft tissue masses in the subarachnoid space, and/or multiple loculated/scarred compartments.

Results: Percutaneous interventional procedures (i.e. epidural blood patches, injection of fibrin glue (FG)/fibrin sealants (FS)) are rarely effective for treating postoperative recurrent lumbar CSF fistulas. Rather, direct surgical occlusion is frequently warranted including the use of; an operating microscope, adequate surgical exposure, 7-0 Gore-Tex sutures, muscle/dural patch grafts or suture anchors, followed by the application of microfibrillar collagen, and fibrin sealant/glue.

Conclusion: Lumbar AA most commonly results from the early failure to diagnose and treat recurrent postoperative CSF fistulas. Since the clinical course of lumbar AA is typically one of progressive neurological deterioration, avoiding its' initial onset is key.

Keywords: Adhesive arachnoiditis, Cerebrospinal fluid fistula, Dural tear, Lumbar surgery, MR, Myelo-CT, Neurological deficits, Postoperative recurrent, Primary, Secondary

INTRODUCTION

Lumbar spine surgery results in up to a 8.7–9.5% incidence of intraoperative cerebrospinal fluid (CSF) fistulas/dural tears (DT) occurring during index procedures. Further, up to 8.1–17% of patients with primary lumbar DT experience recurrent postoperative CSF leaks/DT [Table 1].^[7,11,16] Of interest, the frequency of intraoperative DT including all spinal levels is a lower 1.8%. It is especially critical to diagnose and treat (i.e. occlude/resolve) these recurrent

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Table 1: Literature summary AA.

Author REF Year	Population	Study design	Diagnostic studies	Findings	Outcomes
Johnston <i>et al.</i> ^[8] 1978 Spine Dolan ^[3] 1993 Surg Neurol Ribeiro and Reis ^[14] 1998 Acta Med Port	28 Lumbar Surg-LT Results AA 1966–1970 41 Cases AA	Surg-Micro Lysis Adhesion F/O 1976 Surg Lumbar Disc	Causes AA Spinal Surg, Myelo, TR	Surg-Straightforward Surgical Exercise Contraindicated Reduce AA with Iohexal Contrast for Myelo-CT MR Find	Surg-Does Not Prevent Scar/Recurrent Symptoms With Surg Majority Improved MR Find III: Soft Tissue Mass in SA Space
Hughes <i>et al.</i> ^[7] 2006 Surg Neurol	184 3 year Lumbar IF Fusions 16 (8.7%) DT Prolonged JP SFD	8 DT Rx SFD Discharge Home Antibiotic	Drains Removed Outpatient 10-17 Days Later SFD/Discharge for DT: No>Complications or Leaks 45 yo M Spinal AA	SFD/Discharge DT: Helped Early Diagnosis Postop Lumbar CSF Leak	Recommended Rx: Primary Closure DT SOC Select Cases Prolonged JP for SFD Useful
Koerts <i>et al.</i> ^[10] 2008 Clin Neurol Neurosurg Hayashi <i>et al.</i> ^[6] 2014 J Neurosurg Spine	Case Report; Postop Spinal AA 64 yo F Severe Sacral Pain After Perc FG Injected Into Sacral MC TSGF+A Placed on Sutured Dural Repair to Avoid Persistent CSF Leak	Correlate HC and CC STAT MR: FG Migrated to L4 In SA Space From Sacral Cyst	MR 2 mos Later Cystic Lesion Peridural Space S2-S4 with T2 Compression Cauda Equina/Roots	Surg: Total Cyst Excision Filled with CSF/FG Gelatinous Material	Cause: Multiple Back Surgeries FG Caused AA Must 1st Show No Opening Between Cyst and SA Space Before Using It For Injection Reduce Cost and Frequency Early Postop Recurrent CSF Leak Decrease LOS Fewer Long-Term Complications 10 More Surg “Most had Only Brief Clinical Improvement”
Moussa and Aboul-Enein ^[11] 2016 Neurosurg Rev	Group A TSFG+A versus Group B SubFDBR	1371 Patients Lumbar Surg 131 DT (9.5%) Group A: 62 Pts Group B: 69 Pts	Postop Day 14 CSF Leak Recurrent Group A: 8.1% Group B: 17% Lower LOS Group A versus Group B	Decrease LOS Fewer Long-Term Complications 10 More Surg “Most had Only Brief Clinical Improvement”	
Anderson <i>et al.</i> ^[2] 2017 AJR	Clinical and MR CAA 29 cases Age 23-96 11F, 18 M	18 years 1995–2013 Studies 29 MR 7 Myelo-CT	Summary Findings 23 Loc CSF 15 NRCED 12 CS/HT2 11 AracS, 6 CA, 5 Syrinx, 3 IC MR Evidence AA No Change in Neuro Status	Causes 10 TR 9 Prior Surg 9 NTR SAH 3 Inf, 1 Myelo, 1 GB, 1 AS, 1U MR Finding of AA May Be Incidental Without Clinical Deficits	LESI TFESI Clinical and MR Findings May Not Correlate 2/3 Lumbar EBP Resolved CSF Leak 1 Cervical Not Effective
Eisenberg <i>et al.</i> ^[4] 2019 J Pain Res	LESI Manage LBP/Rad AA Rare	2 TFESI at L5S1 2 L34 Interlam ESI	4 Pts 1 Cervical 1 Redo L5S1 Fusion 2 Lumbar Decompressions	MR Documented CSF Leak Sites EBP 5–14 ml Autologous Blood 3 Lumbar 2 Cervical	LESI TFESI Clinical and MR Findings May Not Correlate 2/3 Lumbar EBP Resolved CSF Leak 1 Cervical Not Effective
Wong <i>et al.</i> ^[16] 2019 J Pain Res	Targeted EBP DT Postop Spine Surg 4 Patients 2F 2M Ages 44–73	1.8% Postop Surg Dural CSF Leak	4 Pts 1 Cervical 1 Redo L5S1 Fusion 2 Lumbar Decompressions	MR Documented CSF Leak Sites EBP 5–14 ml Autologous Blood 3 Lumbar 2 Cervical	LESI TFESI Clinical and MR Findings May Not Correlate 2/3 Lumbar EBP Resolved CSF Leak 1 Cervical Not Effective

(Contd...)

Table 1: (Continued)

Author REF Year	Population	Study design	Diagnostic studies	Findings	Outcomes
Peng and Conermann ^[13] 2020 StatPearls	AA Persistent Inflammation SA Space	Causes AA Spinal Surgery Inf, SAH, L-ESI, Myelo	Pathology AA Membrane Thickening Dural Adhesions Scar/ Clumped Roots	Progression Scar Roots<<CSF Flow Result CAAA with Calcification Arachnoid	Clinical Result Progressive Neural Disability Cord Swelling Syrinx
Tsuchida <i>et al.</i> ^[15] 2020 Pain Pract	Use Supine+Prone MR Diagnose AA	17 Pts High Risk AA versus 18 Controls LBP	MR AA Assess Root Mobility 11 Axial Images L2-L5S1-Calculcate: Low Intensity Dorsal Half/Entire Dural Sac	Some AA pts: Larger Low Intensity Dorsal Sac with AA versus Controls	High Risk AA: Roots Lose Potential to Migrate Ventrally with Prone Position
Parenti <i>et al.</i> ^[12] 2020 Clin Neurol Neurosurg	AA in 28 Pts After Lumbar Surgery on MR versus Clinical	Cause: Prior Surg Or Inf 2012–2018	MR Imaging Cauda equina Nerve Root Contour/ Thickening+Adhesion Location Enhancement	Abnormal Nerve Root Contour Associated with Motor/Sensory Symptoms	MR Findings not Correlate with Clinical Features Lumbar AA
Agulnick <i>et al.</i> ^[1] 2020 Surg Neurol Int	Spine Surgeons Complex CSF Leaks/DT	Use of bone Suture Anchor Technique	No residual Dural Margin/Remnant	Mini-Micro Bone Suture Anchors Facilitate Repair Complex DT	Substitute for: Fascia, Periosteal, Muscle Grafts Follow with Microfibrillar Collagen and FS
Jurga <i>et al.</i> ^[9] 2021 Acta Neurol Belg	AA; 3 Pts Inflamed Pia-Cord-Roots	Disability Wheel-Chair Paretic	Causes Spine Surg Epidural Anesthesia Myelo Tumors	3 Pts 1M, 2F Paraparesis MR Most Sensitive Most Specific AA	Conservative Rx PT Remained Paraparetic- Non-Ambulatory

AA: Adhesive arachnoiditis, C: Chronic, Surg: Surgery, TR: Trauma, NTR: Non-traumatic subarachnoid hemorrhage, Inf: Infection, Myelo: Myelogram (Iophendylate Contrast), GB: Guillaume Barre syndrome, AS: Ankylosing spondylitis, U: Unknown, Loc: Loculated, CSF: Cerebrospinal fluid, NRC: Nerve root clumping, E: Enhancement, D: Displacement, CS: Cord swelling, HT2: High/increased t2 signal, ArachS: Arachnoid septations, CA: Cord atrophy, IC: Intrathecal calcifications, Postop: Postoperative, Pts: Patients, Surg: Surgery, Int: Intrathecal, St: Steroids, TS: Thecal Sac, SA: Subarachnoid, LBP: Low back pain, L-ESI: Lumbar epidural steroid injections, Epi: Epidural, Anes: Anesthesia, M: Male, F: Female, Rx: Treatment, PT: Physical therapy, LESI: Lumbar epidural steroid injections, Rad: Radiculopathy, Interlam: Interlaminar, TFESI: Transforaminal ESI, Present: Presentation, Perc: Percutaneous, FG: Fibrin Glue, FS: Fibrin sealant, mos: Months, MC: Meningeal cyst, Proc: Procedure, Imp: Improvement, Micro: Microscopic, HC: Hydrocephalus, CC: Cauda equina syndrome, EBP: Epidural blood patch, IDur: Incidental durotomy, TSGF+A: Thrombin-soaked gel foam+autologous blood, SFDBR: Subfascial drain-bed rest, Intraop: Intraoperative, DT: Dural tear, SFD: Sub fascial drain, IF: Instrumented fusions, SOC: Standard of care, IH: Intracranial hypotension, MicroDisc: Microdiscectomy, MIS: Minimally invasive, LT: Long term, F/O: Follow-up, Inflamm: Inflammation

CSF leaks/DT early in the postoperative clinical course (i.e. within the 1st 3–4 postoperative weeks) to avoid the evolution of lumbar adhesive arachnoiditis (AA) with its typical progressive unrelenting course of neurological deterioration.

MATERIALS AND METHODS

Frequency of primary and recurrent postoperative CSF fistulas/DT

The frequency of CSF fistulas/DT occurring during primary lumbar procedures ranges from 8.7% to 9.5% [Table 1].^[7,11,16] Recurrent postoperative lumbar CSF leaks/DT occur in

between 8.1% and 17% of cases. Notably, this frequency declines to 1.8% when all spinal levels are considered.^[11,16]

Postoperative CSF fistula/DT predominant cause of AA

AA develops secondary to an inflammatory response occurring within the 3 meningeal layers, particularly impacting the subarachnoid space [Table 1].^[13,14] Prior surgery, particularly involving an intraoperative CSF leak at the index procedure, is the major contributor to postoperative lumbar AA. This is particularly true where there is a recurrent postoperative CSF leak/DT that is not diagnosed and/or treated early in the clinical course (i.e. within <3–4 postoperative weeks).

Other etiologies of lumbar AA

Other etiologies of lumbar AA include; lumbar epidural or intrathecal particulate steroid injections, myelography (oil and water soluble contrast), trauma, infection, and subarachnoid hemorrhage amongst others [Table 1].^[3,8,9,12,13,14] Anderson *et al.* (2017) specifically enumerated the various etiologies of chronic AA occurring at any spinal level in 29 patients; these included trauma (10 patients), prior surgery (9 patients), non-traumatic subarachnoid hemorrhage (9 patients), infection (3 patients), prior myelography (1 patient), Guillaume Barre Syndrome (1 patient), ankylosing spondylitis (1 patient), and unknown (1 patient).^[2]

Symptoms/signs of persistent postoperative lumbar CSF leaks/DT leading to increased neurological deficits, intracranial hypotension (IH), and AA

Major clinical disability is often associated with lumbar AA characterized on MR by; nerve root clumping, enhancement/displacement, cord swelling/atrophy, and/or syrinx formation [Table 1].^[2,9,13] Peng and Conermann (2020) emphasized that AA is a persistent inflammatory process in the subarachnoid space that typically leads to unrelenting, progressive neurological deterioration.^[13] All 3 patients treated by Jurga *et al.* with lumbar AA (2021) went on to become paraparetic.^[9] Other “spinal” neurological sequelae of AA have included; increasingly severe chronic back/leg pain, lower extremity weakness, cauda equina syndromes, progressive paraparesis, dissociated sensory loss/painful dysesthesias, and/or varying degrees of sphincter dysfunction.^[9,13] Those with AA attributed to persistent postoperative lumbar CSF fistulas/DT not recognized or treated early in the clinical course (i.e. within 3-4 postoperative weeks) may go on to develop intracranial hypotension (IH). The symptoms/signs of IH include; postural/positional headaches, upper back/shoulder pain, nausea/vomiting, blurred vision, cochlear-vestibular dysfunction/hearing loss, photophobia, amongst other findings.

Neurodiagnostic studies for lumbar AA

MR diagnosis of lumbar AA

Ribeiro and Reis defined the 3 Types of classical MR findings for patients with lumbar AA [Table 1].^[14] Type I lumbar AA was characterized by adherent/clumped nerve roots located peripherally within the thecal sac. Type II lumbar AA had roots peripherally adherent to the meninges (“Empty Thecal Sac Syndrome”). Type III lumbar AA resulted in soft tissue masses variously distributed within the subarachnoid space.^[14] Other classical MR findings of AA included; a lack of ventral root mobility with prone MR positioning, diffuse membrane/dural thickening, arachnoidal calcification, and multiple loculated compartments within the subarachnoid space.^[2,4,10,12,13,14] When,

Tsuchida *et al.* (2020) utilized both supine and prone MR studies in 17 patients considered “high risk” for AA versus 18 controls (i.e. with low back pain without AA), those with AA exhibited large, low density, non-mobile, dorsally clumped roots that failed to migrate ventrally [Table 1].^[15]

Myelo-CT diagnosis of lumbar AA

Ribeiro and Reis defined the 2 Types of classical Myelo-CT findings of lumbar AA [Table 1].^[14] Type I included the empty thecal sac sign (i.e. nerve roots adherent to the peripheral dura). Type II demonstrated local or diffuse filling defects throughout the thecal sac [Table 1]. Myelo-CT studies for patients with lumbar AA could also identify the specific sites of the CSF leak/DT. This was of particular interest to interventional radiologists planning percutaneous epidural blood patches, or attempts at percutaneously injecting FS/FG. However, it was even more important for spinal surgeons who were intent on direct open surgical occlusion of these CSF fistulous/DT sites.

Both MR and Myelo-CT studies document lumbar AA in one clinical series

Anderson *et al.* (2017) documented chronic AA in 29 patients utilizing MR (all 29 patients), and selective Myelo-CT studies (7 patients) [Table 1].^[2] Both studies documented; loculated CSF collections (23 patients), nerve root clumping/nerve root enhancement/displacement (15 patients), cord swelling with an increased intrinsic cord signal (12 patients), arachnoidal septations (11 patients), cord atrophy (6 patients), syrinx formation (5 patients), and intrathecal calcifications (3 patients).

Brain MR documentation of IH in patients with untreated persistent postoperative lumbar CSF fistula/DT

Brain MR is the study of choice to document IH, particularly in patients with persistent, untreated or inadequately treated/recurrent postoperative lumbar CSF fistulas/DT. Here, the classical Brain MR findings with/without contrast include; dural enhancement, subdural hematomas, cerebellar/tonsillar herniation (i.e. “brain sagging”), and intracranial venous distension.

Surgical techniques for treating intraoperative and postoperative recurrent lumbar CSF fistulas/DT

Basic surgical techniques for repair of primary and/or recurrent postoperative lumbar DT

The management of initial and/or recurrent postoperative lumbar CSF fistulas/DT includes; an operating microscope (i.e. to maximize visualization), adequate surgical exposure (i.e. to maneuver dural sutures/safely retract neural tissues), and to use of 7-0 Gore-Tex sutures (i.e. 7-0 Gore-Tex should be used due to the small size and maneuverability of the needle

that is smaller than the suture thus enabling the suture itself to occlude dural holes made by the needle). For these repairs, 4-0 Nurolon should not be employed as first, the needle is too large to adequately maneuver in small spaces, and second, the suture is smaller than the needle allowing for more leakage through the dural puncture sites. More complex repairs may also warrant muscle/dural patch grafts, and/or suture anchors.^[1] Mini/micro bone suture anchors can be tapped directly into the bone surrounding a lumbar decompression/fistula site where there is no residual dural edge for suturing; with these suture anchors, a spine surgeon can attain a water-tight dural closure, and avoid lumbar drains and/or lumbo-peritoneal shunts [Table 1].^[1] In almost all cases, the closure or primary and secondary lumbar CSF fistula/DT repairs should be routinely supplemented by the application of microfibrillar collagen, and a fibrin sealant/fibrin glue (FS/FG). The latter FS/FG substantially increases the strength of the repair. Failure to adequately diagnose and treat these recurrent lumbar postoperative CSF fistulas/DT markedly increases the risk of lumbar AA, and its attendant neurological sequelae.

Treating primary intraoperative lumbar DT with prolonged postoperative jackson pratt drainage

In Hughes *et al.* series, 16 (8.7%) of 184 patients developed intraoperative DT during index lumbar instrumented fusions; all patients underwent adequate, according to the authors, primary dural closure [Table 1].^[7] Further, 8 patients were additionally treated with prolonged postoperative Subfascial Jackson Pratt Drainage (SJPD) versus 8 control patients who did not receive such drains. Of interest, those with drains were sent home on antibiotic therapy, and drains were removed in these out-patients 10-17 days later. They observed that the long-term drains did not increase the postoperative complication rate (i.e. no increased infections, or persistent postoperative CSF fistulas), and also had the advantage of leading to the early diagnosis and treatment of postoperative recurrent CSF fistulas/DT. Nevertheless, a major shortcoming of this series was their sweeping conclusion, based on only 8 patients, that postoperative, outpatient, long-term (i.e. 10–17 days) use of SJPD for patients with CSF fistulas/DT was both safe and effective. Certainly, such out-patient management of CSF drains would significantly increase the risk (i.e., in larger “significantly powered” series) for subdural hematomas, meningitis/infection, intracranial hypotension/brain sagging etc. that could go unrecognized with significant complications in unmonitored settings.

Efficacy of managing index lumbar CSF fistulas/DT using thrombin soaked gelfoam + autologous blood (TSGF+A) versus subfascial drain + bed rest (SubFDBR)

In 131 (9.5%) of 1371 patients, Moussa *et al.* (2011) tested the relative efficacy of applying thrombin soaked Gelfoam plus

autologous blood (TSGF+A: Group A-62 patients) versus subdural drains + bed rest (SubFDBR: Group B-69 patients) for occluding primary intraoperative lumbar CSF fistulas/DT [Table 1].^[11] On postoperative day 14, recurrent CSF leaks were observed in 8.1% of Group A (TSGF+A) versus 17% for Group B (SubFDBR) patients. They concluded that TSGF+A applied at index lumbar procedures involving a CSF fistula/DT provided better protection against a recurrent postoperative DT versus SubFDBR. Nevertheless, as the package insert itself indicates, applying Gelfoam in a confined spinal space is contraindicated due to swelling; it should not be left in place following surgery, and should, therefore not be used as described here. (Insert Gelfoam Warning: “Whenever possible, it (Gelfoam) should be removed after use in laminectomy procedures and from foramina in bone, once hemostasis is achieved. This is because GELFOAM may swell to its original size on absorbing fluids, and produce nerve damage by pressure within confined bony spaces”).

Utility of duragen/durgen plus and FS/FG for repair of lumbar CSF fistulas/DT

Microfibrillar collagen products, including Duragen and Duragen Plus (Microfibrillar Collagen, Integra LifeSciences Corporation, Plainsboro, New Jersey, USA) are excellent adjuncts to increase the strength/durability of intraoperative CSF fistulas/DT repairs. The package insert states; “it is a dura substitute for the repair of dura mater.” Duragen can be used as an en-lay graft. However, Duragen Plus is thicker and also suturable. With Duragen Plus you should apply circumferential 7-0 Gore-Tex sutures (i.e., or suture anchors if no dural edge is available) to secure it in place, and prevent it from migrating away from the repair site. When used appropriately, it effectively further reduces the risk of a recurrent postoperative CSF fistula/DT. When used, Duragen Plus should overlap the residual dural edges, including that of the underlying Duragen layer, by 1 cm. As noted above, it can also be placed dorsal to repairs performed with suture anchors.^[1] Further, as the packaging insert states: “FG may be used to augment repair especially if used in skull base procedures or intradural spinal surgery.” Additionally the insert states: “Closed suction wound drainage is recommended for 1–3 days postoperatively.”

Pros and cons of FG for repair of lumbar CSF fistulas/DT

Limited efficacy of lumbar FG percutaneous application by interventional radiology

There are various studies in which interventional radiologists utilized different FS/FG to percutaneously occlude persistent postoperative CSF fistulas/DT (e.g. reports with DuraSeal, Integra LifeSciences, and others). However, these procedures are effective in a very small subset of patients. Further, “mass effect” from the FS/FG itself may lead to new focal neurological deficits. Rather, these recurrent CSF fistulas/

DT typically require direct surgical repair (i.e., open surgical closure of recurrent CSF fistulas/DT).

Contraindication for interventional radiologists percutaneously treating a sacral meningeal cyst with FG

Hayashi *et al.* in 2014 (i.e. interventional radiologists) percutaneously injected FG into a sacral meningeal cyst (S2-S4) in a 64-year-old female complaining of persistent sacral pain.^[6] The STAT post-procedure MR documented cephalad migration of the FG from the sacral level of the injection (S2-S4) up to L4. Two months later, the repeat T2 MR documented enlargement of the cystic S2-S4 lesion that now contributed to significant cauda equina compression. At this point, due to marked mass effect, the cyst had to be removed. Pathological evaluation revealed the cyst was filled with FG and CSF. Here, the authors concluded that before injecting FG into a spinal “cyst” in the future, they should ensure there is no residual communication with the subarachnoid space.

Failure of postoperative percutaneous techniques (epidural steroid injections (ESI), epidural blood patches (EBP)) to address recurrent lumbar CSF fistulas/DT

Contraindication for treating postoperative pain due to persistent CSF fistulas/DT with lumbar epidural steroid injections as they contribute to AA

The administration of epidural spinal injections (ESI) in patients with known or suspected recurrent/residual postoperative CSF fistulas/DT is contraindicated [Table 1].^[4] First, the particulate steroid in the ESI directly contributes to AA; under these circumstances, the ESI is typically being injected into a wound in which there is free communication between the injection site and the subarachnoid space. Second, the 17-Gauge Tuohy needle used to perform the ESI is large and may create additional holes in the dura, further contributing to the recurrent postoperative CSF fistulas. Third, ESI have no documented long-term efficacy. Eisenberg *et al.* in 2019 attempted to manage pain attributed to AA utilizing lumbar transforaminal ESI; 2 were TFESI at the L5S1 level, and 2 were L3-L4 interlaminar ESI.^[4] They concluded that patients did not exhibit any improvement in neurological status with these injections.

Use of targeted lumbar EBP to treat postoperative recurrent lumbar CSF fistulas/DT

Interventional radiologists perform EBPs, despite a significant lack of success, to treat postoperative residual/recurrent lumbar CSF fistulas/DT [Table 1].^[5,16] In Wong *et al.* (2019), they observed a 1.8% frequency of postoperative dural fistulas following all-level spinal surgery.^[16] They specifically treated 4 patients (i.e. with 5–14 ml of autogenous blood) with recurrent MR-documented postoperative CSF fistulas/DT; i.e. 1 cervical, 1 a repeat L5S1 fusion, and 2 lumbar

decompressive procedures. One cervical and 1 lumbar injection were considered “effective”. Notably, only the occasional early performance of EBP’s may “close” very small recurrent postoperative CSF fistulas/DT defects. Therefore, the vast majority of these DT require direct “early” (i.e. within 3-4 postoperative weeks) repair by spinal surgeons. Waiting longer, risks the the evolution of postoperative, permanent AA, and its’ irreversible and progressive neurological sequelae. Notably, EBP using the cited volumes of 5–14 ml of autologous blood may also lead to direct epidural spinal compression, and thus precipitate new neurological deficits. Faltings *et al.* discussed the early successful utilization of postoperative EBP to treat IH occurring due to failed CSF fistula/DT repairs (e.g. using tissue grafts/dural sealants) occurring during index microdissectomies treated with tissue grafts/dural sealant.^[5]

Lack of efficacy of secondary lumbar surgery to reverse neurological sequelae of AA

The majority of clinical studies acknowledge that postoperative lumbar AA is not a surgically-remediable lesion [Table 1].^[2,3,8,9] In 1978, Johnston and Matheny observed that secondary surgery for lysis of adhesions addressing AA did not effectively prevent recurrent scar formation, or relieve AA symptoms.^[8] Anderson *et al.* experience (2017) similarly revealed that repeat surgery for 10 of the 29 patients with chronic AA resulted in just “brief clinical improvement,” and therefore, did not recommend reoperations.^[2] The 3 patients with lumbar AA in Jurga *et al.* (2021) series were all managed without secondary lumbar spinal surgery as they correctly determined based on prior literature, that it had been proven ineffective; all 3 remained wheel-chair bound/paraparetic.^[9] Very few studies, like the 1993 series of 41 patients with AA evaluated by Dolan *et al.* recommended secondary surgery for lumbar AA.^[3]

Unanticipated complication of lumbar AA – hydrocephalus

In 2008, Koerts *et al.* reported a single case in which a 45 year-old-male following multiple back operations developed spinal/lumbar AA, that additionally contributed to hydrocephalus [Table 1].^[10]

CONCLUSION

Following lumbar surgery, CSF fistulas/DT can recur postoperatively in up to 17% of cases. Early recognition and repair of such persistent postoperative recurrent CSF fistulas/DT are essential to avoid the evolution of AA with its permanent and progressive neurological sequelae.

Declaration of patient consent

Patient’s consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

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