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Case Report

Intracranial Hypotension for Anesthesiologists: What We Should Know

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The common denominator of spontaneous intracranial hypotension (SIH), postsurgical cerebral spinal fluid (CSF) leaks, and postpuncture headache (PPH) is a decrease in CSF volume. The typical presentation is orthostatic headaches, but atypical headaches can be difficult to diagnose and challenging to treat. Management is based on clinical suspicion and characterization of the headache, followed by imaging (noninvasive or invasive). Treatment ranges from conservative to different modalities of epidural blood patches, fibrin glue injections, or surgical exploration and repair.

We report 5 cases with great variation in clinical and radiological presentations. Two cases of SIH involved difficult diagnosis and treatment, 2 others featured postsurgical high-flow CSF leaks, and one case presented with a low-flow CSF leak that needed closer evaluation in relation to hardware manipulation.

In all cases, recommendations for diagnosis and management of intracranial hypotension were followed, even though in 3 cases the mechanism of trauma was not related to spontaneous hypotension. All cases of headache were resolved.

The actual recommendations for SIH are very effective for PPH and postsurgical CSF leaks. With this case series, we illustrate how anatomical and clinical considerations are paramount in choosing appropriate imaging modalities and clinical management.

Key words: CSF leak, epidural blood patch, intracranial hypotension, postural headaches, subdural hematomas

"Headaches attributed to CSF leak" (1) is the common denominator in the presentation of spontaneous intracranial hypotension (SIH), postsurgical cerebral spinal fluid (CSF) leak, and postlumbar puncture headache. The typical presentation is an orthostatic headache that occurs within seconds to minutes of taking the upright position or is delayed by hours, improves or resolves within 30 minutes of lying down, and can be described as holocephalic and diffuse or asymmetric and localized in one region. Atypical presentations are exertional headaches, headaches at the end of the day, or even paradoxical headaches (improves in upright position and worsens on recumbency) (1).

The core pathologic factor is decreased CSF volume rather than pressure. The anatomy of the tear might be complex; for SIH, preexisting dural weakness, usually in connection with an abnormality of the connective tissue matrix, sometimes along with trivial traumas, may play an etiologic role (2). For postsurgical and postpuncture CSF leaks, the original location of the lesion can be more evident, but the extension of the injury might be more compromising and challenging.

Traumatic CSF leaks are characterized by definite trauma, either postsurgical or postdural puncture; spontaneous CSF leaks are often idiopathic, but may relate to trivial trauma, connective tissue disorders, meningeal diverticulae, or spondylitic dural tears.

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Table 1. Recommendations for the diagnosis and treatment of SIH.

For patients with typical symptoms:	For patients with atypical symptoms:
1. Conservative and symptomatic treatment for up to 2 weeks is indicated before attempting and EBP. 2. First choice image modality should be noninvasive, Gadolinium enhanced MRI (head and spine), if not available CT scan can be used to rule out other pathology. 3. With or without brain MRI confirmation, up to 3 nondirected EBP at least 5 days apart can be considered, before tests to localize the leak are done. 4. If no response after 2 nondirected EBPs, investigations to demonstrate the CSF leak should be pursued. 5. Nondirected blood patches should be as high volume as tolerated by the patient. 6. As most spontaneous CSF leaks are at the lower cervical and upper thoracic level patients should be kept in the Trendelenburg position for at least 2 hours, after the EBP and kept recumbent on their back of 2 more hours if possible. Bed rest for as much as possible over next 24 hours and avoid strenuous activity for 1 week.	1. With head and Spine MRI normal, the site of the leak should be located before performing an EBP. 2. The first investigation of choice, to locate the source of the CSF leak is noninvasive MRM (niMRM). If this cannot locate the source of the CSF leak or is not available, MRM with intrathecal gadolinium or radionucleotide cisternogram should be considered. 3. If the CSF leak cannot be located with any of the previous tests, and the symptoms of the patient are highly suggestive of SIH, a CT myelogram can be considered. 4. When the CSF leak is located a directed EBP should be performed 5. If 2 or more directed EBP have failed, one or more patches using fibrin glue should be considered 6. If the directed patches with fibrin glue have been unsuccessful neurosurgical closure of the CSF leak should be considered.

Traumatic and spontaneous CSF leaks can either be slow- or fast-flowing depending on the situation. An epidural blood patch (EBP) is the treatment of choice when conservative measures have failed. However, there is considerable variability in the response to EBPs; in SIH they are substantially less efficient than in postsurgical and postpuncture leaks (2).

Amoozegar et al (2013) published several recommendations for the diagnosis and treatment of SIH, which we propose are also appropriate for traumatic CSF leaks; we present an edited version in Table 1.

We report 5 cases in which the recommendations were applied, but there were additional challenges.

METHOD AND RESULTS: CASE SERIES

Case 1: Delayed intracraneal hypotension (IH) presented 10 days after percutaneous removal of spinal cord stimulator leads

A 62-year-old man, non-insuline dependent diabetes (NIDD) with a history of failed back surgery syndrome and bilateral stump pain had a spinal cord stimulator (SCS) with a surgical paddle lead implanted in 1990; it was replaced in 2009 with 2 percutaneous leads and a new SCS. The paddle lead was left undisturbed in the epidural space.

In 2016, the SCS leads were removed uneventfully via percutaneous approach.

Ten days later, the patient reported sudden onset of "severe headache," postural in nature, worsening when sitting and coughing and improving when lying down, and "echoing in his ears." Conservative and symptomatic treatment began, and computed tomography (CT) of the spine indicated extensive postoperative changes in the thoracic and lumbar spine with the blind end paddle lead at T9; no CSF leak was located.

A surgical consult was ordered due to the presence of hardware (paddle lead) in the epidural space, but no procedure was granted. Fourteen days after the conservative treatment started, the headache completely subsided.

Case 2: SIH treated successfully after 3 years with EBP

A 42-year-old, 60-kg woman presented postural headaches after a trivial fall and remained undiagnosed for 3 years. Worsening of the headaches prompted gadolinium-enhanced head magnetic resonance imaging (MRI), which showed classic signs of IH (Fig. 1). No CSF leak was identified with the spine MRI. Physical examination of the spine determined tenderness and trophic changes with palpable temperature change (cold) at the level of T12-L1, indicating the possible level of injury.

A fluoroscopically guided EBP at the level of L1-L2 (Fig. 2) was performed. The volume was injected until

Fig. 1. Magnetic resonance imaging before epidural blood patch (Nov 2012) with signs of intracranial hypotension, sagging of the brain, pachymeningeal enhancement, flattening of the pons.

the patient reported a sensation of pressure; a total of 21 mL was used.

Complete resolution of the headache was achieved. The MRI indicated signs of improved intracranial hypotension (Fig. 3).

Case 3: SIH worsened by postpuncture headache resulting in bilateral subdural hematomas.

A 43-year-old, 70-kg woman presented 24 hours after tripping on uneven ground with pain in the neck and occipital region; the pain radiated bilaterally to the temporal region and was postural in nature. Three days later, a noncontrast head CT and CT angiography of the Circle of Willis were reported normal. Afterwards, on the same day, a lumbar puncture was performed to rule out bacterial meningitis; this was reported to be unsuccessful as a dry tap.

Seven days after the patient's fall, worsening symptoms prompted a brain MRI, which showed small bilateral subacute vs chronic subdural hematomas (Fig. 4). A spine MRI did not identify the site of the CSF leak. The patient's headache was now present in the supine position and becoming intolerable with postural changes.

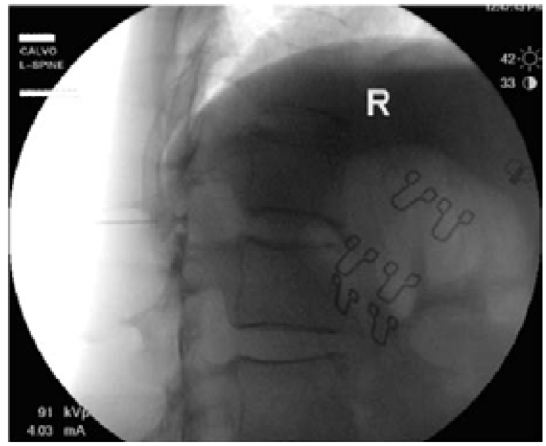

Fig. 2. Fluoroscopically guided epidural blood patch, L1-L2 interlaminar level. Lateral view.

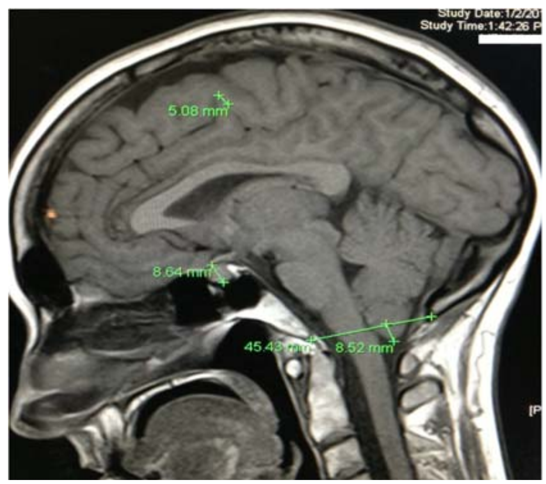

Fig. 3. Magnetic resonance imaging after epidural blood patch (Feb 2013) shows improved image of pons and brain.

We rehydrated the patient intravenously with 80 cc of normal saline (NS) per hour and orally as tolerated, and ordered bed rest for 48 hours until the headache while supine was absent or tolerable. A fluoroscopically guided EBP was performed at the L3/L4 level (Fig. 5) where the dry tap was done, and 3 cc of omnipaque dye was used to verify the position of the 18-gauge Tuohy needle in the epidural space. A maximum volume of 17 mL of autologous blood was injected, as the patient complained of feeling pressure at the level of the neck. We kept the patient in a

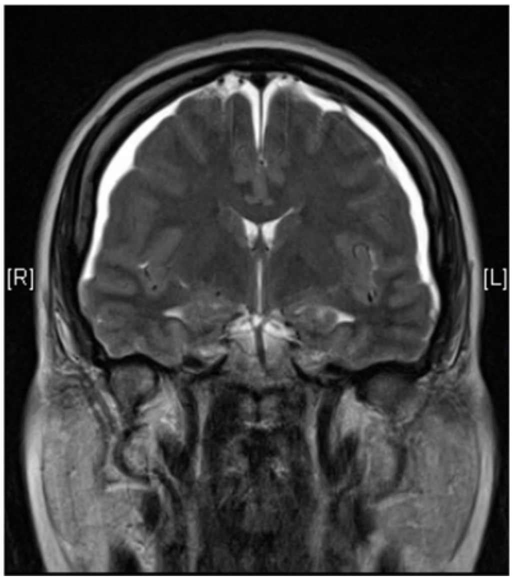

Fig. 4. Brain magnetic resonance imaging T2-weighted image of bilateral subdural hematomas.

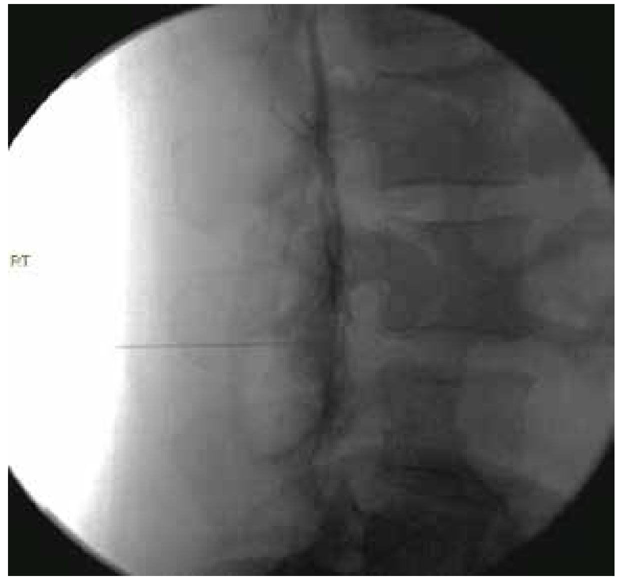

Fig. 5. Fluoroscopically guided epidural blood patch injection at L3/L4 interlaminar space. Lateral view.

supine position for the next 4 hours. No headache was reported. She was advised to abstain from Valsalva maneuvers, lifting, pushing, or pulling for the next 2 weeks, and to exercise caution when lifting heavy weights up to 4 weeks post procedure. There was no headache recurrence after 3 years.

Case 4: Post gunshot wound (GSW) with severely symptomatic postsurgical CSF leak

A 26-year-old, 57-kg man presented with a GSW to the left pelvis; CT showed a comminuted L5 spinal fracture with a small epidural hematoma at L4-L5 and moderate spinal cord stenosis. During the L5 decompression, a right-side anterolateral tear of the dural sac with a visible CSF leak and nerve root exposure was repaired surgically, and the Valsava maneuver at that time demonstrated a good seal.

POD #1 (postoperative day): Persistent left foot drop and paresthesia.

POD #7: Dizziness when sitting up and severe left-sided headache.

POD #8: Severe headaches with postural changes.

POD #9: Swelling in the lower back, with clear discharge from the incision site. Conservative management and antibiotics were started.

POD #23: The headache persisted. MRI showed a posterior dural defect at the level of S1 in keeping with a CSF leak and collection within the dorsal soft tissues between L3-L5 (Fig. 6).

POD #28: Severe headache not only with postural changes, but also while supine. Oral rehydration was initiated as tolerated along with intravenous (IV) rehydration with NS at 80 mL per hour. The patient was kept on bed rest.

POD #34: The CSF culture was negative, the headache was now mild while supine, and

an EBP was fluoroscopically guided with the patient in left lateral decubitus at L5-S1. We aspirated 15 mL of clear CSF from the paraspinal muscles and epidural space. The epidural space was verified by injection of 1 mL of omnipaque dye, followed by injection of 6 mL of autologous blood (Fig. 7). The patient reported pressure at the level of injection, but no worsening of leg paresthesia. He was kept supine

Fig. 6. Magnetic resonance imaging T1-weighted image with CSF leak at the paraspinal muscles and subcutaneous tissue.

Fig. 7. Fluoroscopically guided epidural blood patch at the L5-S1 interlaminar space. Lateral view.

for 4 hours and IV fluids were continued. No headache was reported. Afterwards, elevation of the head was allowed. The patient remained on bed rest with elevation of the head for 4 days, as he was not able to walk due to left foot drop. For the next 2 weeks, he refrained from Valsalva maneuvers, lifting, pushing, or pulling, including no self-transfer to wheelchair.

There was no recurrence of his headache at the 5-month follow up.

Case 5: Asymptomatic massive postsurgical CSF leak corrected one month after.

A 62-year-old, 75-kg woman underwent L4-L5 bilateral canal enlargement that was complicated by a dural tear. A repair was attempted surgically, but the CSF leakage persisted from the surgical site over the course of 16 days and was severe enough to wet the dressings and flow spontaneously. MRI Short T1 inversion recovery (STIR) images indicated massive fluid tracking towards the skin (Fig. 8). Conservative treatment was suggested because the patient was asymptomatic, but the CSF leakage persisted macroscopically.

One month after the surgery, a fluoroscopically guided EBP was performed at the level below the tear at L4-L5; radiopaque dye was used to verify the inferior edge of the leak and the position of the tip of the 17-gauge Tuohy needle (Fig. 9). Autologous blood was injected until the patient felt pressure, a total of 10 mL.

The site remained dry and healed 10 days later.

DISCUSSION

Intracranial hypotension remains underdiagnosed due to high variability in clinical and radiological manifestations. Postsurgical intracranial hypotension due to inadvertent CSF leaks can occur after any surgical procedure, including percutaneous (2). The occurrence of a CSF leak is not related to the magnitude of the procedure, and it can occur during a broad time period. There have been cases in which

Fig. 8. Magnetic resonance imaging STIR images with massive fluid tracking towards the skin.

Fig. 9. Fluoroscopically guided epidural blood patch at the L4-L5 interlaminar level, immediately below the defect. Lateral view.

discectomies (3) and hardware placement have produced erosion of the dura with CSF leak up to 11 years after the surgery (4). Chiropractic manipulations of the cervical spine can produce posttraumatic CSF leaks (2), and chronic degenerative disease of the spine, like thoracic disc osteophytes, can produce spontaneous CSF leaks (5).

The recommendations for diagnosis and treatment of SIH suggest that typical headaches due to CSF leak can be diagnosed clinically without the location of the leak. An MRI of the head and spine is the initial study, but in cases where this is not possible, a CT can confirm the diagnosis (1). Conservative and symptomatic treatment is the first choice for up to 2 weeks (1). Afterwards, directed or nondirected EBP should be attempted with the aid of fluoroscopy, which is ideal to confirm the location of the needle tip within the epidural space (4,12). For cases in which there is hardware involved or multiple previous surgeries, a surgical consult is in order before attempting an epidural.

More invasive studies might worsen the original pathology and may not locate the CSF leak site (6). No existing criteria take into consideration the worsening of the headache and its possible complications due to a postpuncture headache (PPH) by interventional diagnostic procedures. Invasive radiological procedures like CT myelography and radionuclide cisternography are effective in locating the CSF leak level 67% and 55% of the time, respectively, but none have showed distinct superiority in predicting a favorable clinical outcome (10), and worsening of the original pathology can happen with any interventional procedure.

EBPs have been more successful when directed at the level of the lesion (7,8), so effort must be made to locate the source of the CSF leak. The pressure dynamics of the CSF suggest that when blood is injected into the epidural space, the pressure becomes positive and compresses the dura, increasing the adjacent subarachnoid pressure, and through continuity, the intracranial pressure; therefore, high volumes of blood injected too fast or too high in the spine (cervical) can also cause complications like subdural hematomas (15).

There is no evidence regarding a specific time frame in which an EPB ceases to be beneficial for this pathology; therefore, it should be attempted when conservative treatment has failed (6-10) regardless of whether the diagnosis is delayed for several years. In chronic cases, the physical examination of the back may bring clues to determine the level of the leak, as trophic skin changes, loss of hair, and subtle changes in skin temperature can be observed (3).

There is no consensus on the volume needed, therefore the injection should be stopped at the volume at which the patient experiences pressure or discomfort. It is better to repeat an uneventful procedure than to risk complications such as paresthesia, radiculopathy, lumbosacral meningismus, or subdural hematomas (9,15).

The mechanism of the tear can help us understand the location of the anatomical lesion and it can give an idea of the volume needed. Spontaneous CSF leaks are frequently related to dural tears in the cervicothoracic or thoracolumbar transitions at the level of the nerve root sleeve. Because of this position in the anterior spinal canal, the volume of blood injected should be enough to surround the spinal canal; volumes of 10 mL or less at the cervicothoracic level (to avoid complications) and 20 mL or more at the thoracolumbar level have been reported to be successful (5,13,14).

In postpuncture CSF leaks, the lesion is in the posterior spinal canal; logically, the proximity to the epidural tear suggests that 20 mL or less would be enough for lumbar levels. However, we need to take into consideration the size of the puncture (Tuohy or spinal needle) and whether multiple punctures were performed and at what level. The same safety consideration applies to the level at which the EBP is injected.

In postsurgical CSF leaks, the flow can be fast or slow, but their response to the EBP is the same. Low-volume blood patches have been successfully reported after surgical interventions and seem to be the choice of treatment after spinal surgery (16). Due to the presence of an existing inflammatory process, the volume of blood needed for the procedure tends to be low (< 10 mL), which decreases the risk of complications such as compressive epidural hematomas or nerve injuries (11). A suggestion when dealing with postsurgical CSF leaks is to position the Tuohy needle below the tear to ensure adequate closure; this method has more benefits in fast-flowing or massive leaks.

Appropriate preprocedural care is vital to optimizing patient outcomes. In severe cases where pain is reported even in the supine position, adequate rehydration orally and intravenously should be initiated and continued until the headache is tolerable when supine; in our experience, 24 to 48 hours is an acceptable delay for this reason.

Postcare restrictions should be followed to ensure consistent success. The Tredelenburg position might not be well tolerated by highly symptomatic patients. Another option is the supine position for 4 hours, followed by head elevation for the next 4 hours. If the case is severe enough to require hospitalization, bed rest is prescribed for 48 hours.

After an EBP, the plugged hole undergoes fibroblastic remodeling within 48 hours, collagen deposition within 2 weeks, and scar formation by 3 months (5,9). For all of our cases we suggest 2 weeks of nonstrenuous activity followed by 4 weeks of normal activity with avoidance of lifting weight exceeding 20 pounds.

CONCLUSION

The actual recommendations for SIH can be used for PPH and postsurgical CSF leaks, but the mechanics of the injury should be taken into consideration when conservative treatment has failed and an EBP is the next step. The diagnostic approach to a suspected SIH should begin with obtaining an accurate history about the clinical features of the headache as they relate to the patient's posture (15). Once the mechanics of the injury and the spinal anatomy are considered, the determination of the volume required is more logical. Fluoroscopic guidance is suggested when performing an EBP, and the injection should be terminated when the patient experiences pressure or discomfort anywhere.

There is no evidence supporting a time point at which an EBP ceases to be useful, even if the diagnosis of a CSF leak has been delayed for several years. In cases where spinal hardware is present, a surgical consult should be considered before attempting an EBP, as foreign material increases the risk of infections. Highly symptomatic patients should be properly prepared before the procedure and the post-EBP restrictions should be closely followed, and if required, prolonged.

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