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Expert Overview

Epidural Lysis of Adhesions: What Every Interventional Pain Physician Needs to Know

Standiford Helm, MD[1], Carl Noe, MD[2], and Gabor B. Racz, MD[3]

From: [1]Department of Anesthesiology and Peri-Operative Care, University of California, Irvine, CA; [2]Department of Anesthesiology and Pain Management, UT Southwestern, Medical Center, Dallas, TX; [3]Department of Anesthesiology, Texas Tech University Health Sciences Center, Lubbock, TX

Address Correspondence:
Standiford Helm, MD
Division of Pain Medicine
Department of Anesthesiology and Peri-Operative Care
University of California
Irvine, CA
E-mail: standifh@hs.uci.edu

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Background: Epidural lysis of adhesions is an effective therapy for treating refractory axial or radicular cervical, thoracic, or lumbar pain. This therapy is an important alternative to surgical interventions. As such, epidural lysis of adhesions is a significant addition to the techniques available to pain management physicians.

Rationale for Lysis of Adhesions: The underlying rationale for epidural lysis of adhesions is that nerves can become inflamed, either by being entrapped by epidural scarring or being compressed by veins engorged by epidural scarring. Furthermore, the posterior longitudinal ligament can become adhered to the dura. The goal of adhesiolysis, therefore, is to relieve the effects of this scarring. The dural tag is a helpful technique for diagnosing the condition clinically.

Mode of Action: Epidural lysis of adhesions involves placing a spring-wound catheter into the tissue planes that entrap the nerve or vein, executing an injection protocol to expand that tissue plane, and then having the patient implement a self-directed home exercise program of neural flossing. The catheter should be placed in the ventrolateral epidural space, the site of pathology.

Technique: The injection protocol involves the use of contrast dye to confirm appropriate catheter placement. Hyaluronidase is used to enhance the flow of the medications through the tissue plane. Local anesthesia and steroids are given both for the analgesic and anti-inflammatory effects and because of corticosteroid's ability to inhibit fibroblast proliferation after the procedure. Hypertonic saline assists both with helping reduce swelling of the nerve and to provide hydrostatic force as it is diluted from 10% to 0.9% saline. Additionally, hypertonic saline causes an important, transient local anesthetic effect and a prolonged C-fiber blockade. The L5-S1 scarring triangle is an important, specific site of scarring that is now commonly treated, often in conjunction with transforaminal catheters, when performing adhesiolysis. It is imperative that patients meet appropriate discharge criteria before being discharged.

Complications: Complications are generally similar to those seen with other interventional procedures. For lysis of adhesions, the potential procedure-specific concern is the risk of subarachnoid spread of hypertonic saline. Although Hitchcock intentionally injected hypertonic saline into cancer patients intrathecally and observed limited adverse effects, epidural lysis of adhesions is specifically designed to minimize this risk by injecting a local anesthetic solution that will not cause motor weakness if injected epidurally but will cause motor weakness if it spreads to the intrathecal space. Perivenous counter spread is a rare complication that can be treated with flexion rotation procedures.

Controversies: The technique has engendered many controversies, including discussions relating to the amount of force generated. These controversies have influenced the adaptation of the procedure.

Evidence: Epidural lysis of adhesions has been studied extensively. Gerdesmeyer's randomized placebo-controlled trial with 10-year follow-up provides Level I evidence. This trial is supported by a significant number of other studies.

Conclusions: Epidural lysis of adhesions is an effective therapy for treating refractory axial or radicular pain. The technique provided is based upon experience with hundreds of thousands of patients. When performed by a trained physician, adhesiolysis is safe and effective.

Key words: Epidural lysis of adhesion, percutaneous adhesiolysis, neuroplasty, radicular pain, axial pain, lumbar pain, thoracic pain, cervical pain, hypertonic saline, neural flossing

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Epidural lysis of adhesions, also known as percutaneous adhesiolysis, or neuroplasty, can reduce pain and improve function in patients with pain refractory to more conservative treatments. The original indication was for persistent spinal pain syndrome type 2, previously known as failed back surgery syndrome. Over time, investigators have expanded the indications to include such diagnoses as stenosis. Given the wide variety of underlying etiologies for conditions that may be addressed by epidural lysis of adhesions, the current indications are broadly stated as refractory cervical, thoracic, or lumbar axial or radicular pain. Because surgical treatment of these problems is not always in the patient's best interest, epidural lysis of adhesions is an important component of the set of procedures offered by interventional pain management physicians. Although several variations of the procedure exist, certain steps are common to all of them. This paper discusses the technique of lysis of adhesions and presents the rationale for the procedure.

Rationale for Lysis of Adhesions

Kuslich, while performing lumbar decompression surgery on patients who had received local anesthetics, examined which structures reacted with pain to electrical and mechanical stimulation (1). He documented that compressed nerve roots were painful and that scar tissue could tether the nerve, making the nerve more susceptible to irritation. Additionally, Kuslich found that the richly innervated posterior longitudinal ligament (PLL) was frequently intimately connected to the annulus and the dura and that both structures could generate axial pain. Kuslich's work provides the rationale for neuroplasty by showing that entrapped nerves and scarring of the PLL and annulus can be pain generators.

Nerves can be trapped directly by scarring or indirectly by engorged veins that secondarily entrap the nerve. The scarring that traps nerves or adheres the PLL and dural need not be the dense scar formed when an incision heals. Bosscher and Heavner used epiduroscopy to demonstrate mild epidural scarring, defined as a degree of scarring through which the epiduroscope could be advanced (2). Over time, it has become clear that specific advances are needed to enhance the ability to enter tight or constrained tissue planes. Catheters need to be smaller, under 21 G, rather than larger, to get into the relatively small areas found in the epidural space. Each catheter should also have a blunt-tipped stylet that extends to its end to allow steering and minimize the risk of tissue damage. Finally, the orifices should inject the fluid laterally, rather than out the tip, to allow for the bluntness of the tip, to prevent obstruction to the injection if the tip is against scar tissue, and to facilitate the opening of the plane.

The goal of neuroplasty, therefore, is to place a catheter into the tissue planes of scar tissue to open them, thus freeing the nerves or PLL and dura and decompressing veins. This goal is consistent with the findings that the epidural space acts as a Starling resistor, in which the resistance to flow increases with the presence of epidural pathology (3,4). Thus, while the procedure is called lysis of adhesions, the mechanism should be considered the opening of tissue planes and decompression of veins rather than the breaking up of scars based on the dye spread.

Although lysis of adhesions can be repeated up to twice a year, it can also provide long-term relief. Gerdesmeyer et al have documented 10-year relief, and individual cases have been followed for 25 years, with sustained relief (5).

An important subcategory of neurolysis involves L5 and S1 nerve root entrapments. Teske has shown that the space bounded by the L5 nerve root, the S1 nerve root, and the superior aspect of the sacrum, the scarring triangle, has a volume of approximately 1 mL (6). Matsumoto developed an S1 transforaminal technique to effectively treat scarring in this area, the so called L5-S1 scarring triangle (7,8). Matsumoto's insight was that the diameter of the catheter was more important than the stiffness, with a 21 G catheter being able to enter the scarring triangle, whereas a larger one was not. Currently, 21 G steerable catheters with blunted, occluded tips, lateral dispersion, and stylets that reach to the distals of the catheters are available.

Mode of Action

Lysis of adhesions combines mechanical, pharmacological, and hydrostatic forces to achieve its goal of opening tissue planes and freeing nerve roots to move more normally.

The mechanical component involves the placement of a catheter into the tissue planes entrapping the nerve. A shear-resistant, steerable, spring-wound catheter is required to perform this task. A standard epidural catheter, which is not spring-wound, cannot be used successfully for lysis of adhesions, since the catheter is likely to kink or shear off and cannot be steered. A spring-wound catheter has the additional advantage of being easily seen on fluoroscopy (9). Further mechanical forces are applied post-procedurally, with neural flossing exercises, discussed below, used to maintain the gains made by the procedure.

Ultimately, lysis of adhesions depends not upon mechanical force but rather proper placement of the catheter. The development of thinner catheters has enhanced the ability to place catheters properly. A catheter that is improperly placed will not open tissue planes to decompress nerve roots in the ventrolateral epidural space. When placed properly, a catheter will be in the ventrolateral epidural space and open transforaminal venous runoff for long-term benefits.

Pharmacological agents used include local anesthetics, corticosteroids, hyaluronidase, and hypertonic saline (10). Hyaluronidase enhances the spread of the other agents (11). Osmosis will decrease the tonicity of 10% hypertonic saline to that of normal saline, 0.9%, increasing its volume eleven-fold in the process, thereby providing hydrostatic pressure. This process of equilibrating to the tonicity of normal saline has the additional effect of withdrawing volume from swollen, inflamed nerve roots. Hypertonic saline also has a transient local anesthetic effect, since it produces a reversable conduction blockade lasting about 30 minutes (12). More importantly, hypertonic saline can produce prolonged pain relief due to persistent C-fiber blockade (13,14). Anecdotal reports indicate that this relief can last from years to decades. Corticosteroids, in addition to the anti-inflammatory action for which they are commonly used, have been shown to inhibit fibroblast proliferation (15), thus potentially decreasing the recurrence of scarring. Scarring is thought to recur with the leakage of inflammatory material from the nucleus pulposus (16,17), which is consistent with the notion of disk degeneration, disk material leakage into the epidural space, inflammation and scar formation.

Clinically, the "dural tug" technique can performed to help identify scarring of the dura and the PLL (18). During the dural tug maneuver, the patient is seated with the legs extended and the spine flexed. The examiner then flexes the neck rapidly and asks the patient to point at the location of the pain.

Two cases involving the scarring triangle at L5-S1 are presented to illustrate the complexity of symptoms that may be related to epidural adhesions and the usefulness of the dural tag technique.

The first patient received an evaluation that included the performance of a dural tug maneuver, which reproduced the patient's pain, localized to the L5-S1 level. After this evaluation, the patient was suspected to have scarring between the dural and posterior longitudinal ligament and epidural adhesions. This patient also experienced weakness while attempting to stand on the toes of the affected leg. This weakness, or unsteadiness, while attempting to stand on the toes of the affected side is another sign associated with pathology that arises from the scarring triangle. After neuroplasty, the patient experienced improvement in both motor function and pain.

A second case involved a female patient in her fifties with a diagnosis of complex regional pain syndrome in the lower extremities. Multiple spinal cord stimulators, including sacral stimulation, failed to relieve her leg pain. Converting the sacral stimulators to monopolar stimulation relieved her leg pain, but she reported she was exhausted because of poor sleep due to nocturnal micturition, which occurred 15 times a night. The conclusion was made that the change in stimulation removed the stimulation of the bladder. She had a 3-injection protocol of neuroplasty with no change in her nocturnal micturition. The physicians recalled that urgency was always treated with bilateral bladder stimulation and repeated the neuroplasty on the contralateral side one month later. Two days after the contralateral procedure, she was able to sleep through the night. At 6-year follow-up, she continued to sleep through the night. After the neuroplasty, she was able to have her spinal cord stimulators turned off and explanted.

Some patients' pain recurs months after neuroplasty. If the workup, including advanced imaging, fails to show a reason for the recurrence at another level, the procedure should be repeated on the contralateral side.

If the pain returns after a short time, such as 3 to 4 months, the recurrence is likely either because the original side was not fully opened or that the contralateral side is becoming symptomatic. The procedure should be performed contralaterally. Doing so will open the contralateral side and will also spread to the original

side. If the pain is coming from that level, the patient should experience long-term relief. If the pain returns after 3 to 4 years, that pain is likely from the contralateral side, so that the procedure should be repeated on that side. Only if no relief results from the contralateral injection should the physician proceed with a further expensive workup.

Technique

Neurolysis is currently performed most often as a single injection procedure. The procedure can be repeated, with current standards allowing 2 procedures per year. Alternate protocols involving 2 or 3 injections, done either on one day or over 2 or 3 days, have been described and were the original method of performing neurolysis (19-21). These protocols are now employed less commonly because their use does not easily fit in with many current practice patterns.

A spring-wound, shear resistant catheter should be used to allow proper placement of the catheter. This placement includes rotating the catheter to steer it and pulling it back in the needle if needed to direct the catheter to the desired ventrolateral position without shearing. Coudé needles are recommended. The use of sharp needles is associated with complications, including catheter shearing and subdural catheter placement. The use of a catheter minimizes the risk of piercing a scar and entering the subarachnoid or subdural level.

Contrast is used during lysis of adhesions both to document proper placement of the catheter prior to injection, with flow through the foramen, and to document flow after the procedure into areas to which the initial contrast did not spread. Individual patients' epidural anatomy will vary because of adhesions, stenosis, and related factors. Part of the art of lysis of adhesions is working around these differences.

Hyaluronidase in doses of up to 300 units of the currently available recombinant formulation has been shown to be safe (22). The use of recombinant formulations has removed the previous recommendation for skin testing when using hyaluronidase from bovine or ovine sources. Anecdotally, doses much larger than 150-300 units have been reported. Studies have not determined the optimal dose of hyaluronidase. Lee reported benefits associated with hyaluronidase in most but not all studies of epidural lysis (23).

When performing lysis of adhesions, the needle will need to be rotated to direct the spring wound catheter. To minimize the risk of irritating nerve roots or of lysing the dura, a needle with a second blunt, obturating stylet that extends beyond the needle tip is suggested.

Two different CPT codes exist for the procedure. The most commonly used code is 62264, which describes complete treatment in one day. About 95% of procedures are billed using the one-day code (21).

Overall, the use of 62263 and 62263 has declined, because of the limitations of insurance coverage in contravention of scientific evidence (21).

While most procedures are done with a one-injection protocol, some experts who use the 3-injection protocol, in which the patient receives 2 injections on the first day as an outpatient and returns the next morning for the third injection, believe that the 3-injection approach is more cost-effective than the one-injection approach because they have observed fewer patients proceeding to surgery after receiving the 3 injections. The rationale for the superiority of the 3-injection protocol is the belief that with each injection, the hypertonic saline spreads more diffusely, with a wider area of persistent C-fiber blockade. If a 2- or 3-injection protocol is used, 0.25% bupivacaine or its equivalent should be used for the first injection to rule out subdural or subarachnoid injectate spread. For the subsequent injections, 0.125% bupivacaine or its equivalent should be used to minimize the risk that will persistent motor block delaying the patient's discharge.

The most fully studied approach is the use of a caudal catheter placement. When the caudal approach is used, the catheter tip's final position should be in the ventrolateral aspect of the foramen. With the caudal approach, the protocol is to begin by using 10 mL of contrast, 10 mL of hyaluronidase/saline, and 10 mL of the local anesthetic/steroid mixture. Afterward, to ensure that the injection of hypertonic saline is painless, the physician waits 2 to 3 minutes for the local anesthetic to take effect, injects 1 mL of lidocaine 1% to confirm that no subarachnoid or subdural injection has occurred, and then injects 10 mL of hypertonic saline.

Although less studied, adhesiolysis is currently most often performed using an S1 transforaminal approach to the L5-S1 scarring triangle. With this approach, the injection here is the same as for the caudal approach, with 10 mL of contrast, 10 mL of hyaluronidase, 10 mL of local anesthetic/steroid, and then 1 mL of local anesthetic followed by 10 mL of hypertonic saline.

When an S1 transforaminal approach is used, second, transforaminal, catheter is commonly placed at a more cephalad lumbar level of entrapment, often L4-5. When injecting a transforaminal catheter, the

volumes are reduced, with 5 mL of contrast, 5 mL of hyaluronidase/saline, 5 mL of local anesthetic/steroid, followed by 0.5 mL of 1% lidocaine to provide pain free hypertonic saline injection and then 5 mL of hypertonic saline.

Cervical and thoracic procedures are performed via an interlaminar approach, with the same 5 mL injections as used for transforaminal procedures.

Table 1 provides a detailed description of the protocols, including the one-injection versus 2-injection or 3-injection protocols, and the protocols for caudal and scarring triangle catheter placement and for transforaminal and for interlaminar cervical and thoracic catheter placement.

Patients should be instructed to perform neural flossing after the procedure. Neural flossing involves exercises designed to mobilize the nerve roots by sliding them in the foramen, enhancing the benefit of increased opened tissue planes. Lumbar flossing involves activities such as bringing the knees to the chest while supine. Neural flossing should be done 3 to 4 times a day for about 3 months after the procedure. More details can be found in Techniques of Neurolysis (18).

The S1 foramen is accessed by entering the skin at S2 with an 18 G Coudé needle. After the S1 dorsal foramen is entered, the stylet of the Coudé needle should be placed with a protruding obturator. If the physician is standing on the left side, the needle should be rotated clockwise; if the physician is standing on the right side, the needle should be rotated counterclockwise. The needle tip should be rotated so that it is directed cephalad and points towards the scarring triangle. A 21G spring-wound catheter is then passed in the ventral epidural space until it enters the scarring triangle about halfway along the height of the L5-S1 foramen. The physician should proceed with the injections as described.

In the rare instances when the procedure involves 2 or 3 injections, 0.125% bupivacaine or 0.1% ropivacaine should be used. These lower concentrations, made

Table 1. *Epidural lysis of adhesion protocol*.

Caudal Catheter or S1 transforaminal/L5-S1 Scarring Triangle Catheter Placement
1. Place the catheter at the ventrolateral aspect of the target foramen for the caudal placement. For the S1 transforaminal catheter, place between the lateral aspect of the ventrolateral space of L5, about halfway up the L5-S1 foramen. 2. Inject 10 mL of nonionic, low-osmolality contrast media under fluoroscopic A/P and lateral observation. Use a lateral view to rule out an intravenous or subdural injection or spread through a partial epidural tear. 3. Inject 10 mL of preservative-free (PF) normal saline with 150 units of hyaluronidase. 4. Inject 10 mL of 0.25% bupivacaine or 0.2% ropivacaine with 40 mg of triamcinolone or an equivalent steroid. Observe the patient for 20-30 minutes to rule out the delayed onset of a motor block, which would indicate subdural/subarachnoid placement. Shorter periods of observation are not recommended.
Abandon the Procedure If Motor Block Develops
5. If no motor block occurs, inject 1.5 mL of 1% lidocaine, followed 2-3 minutes later by 10 mL of 10% sodium chloride diluted with lidocaine injected in increments of 1 mL over 3-5 minutes. See below for how to dilute hypertonic saline. The small-volume, pre-hypertonic lidocaine seems to cover the periphery of the injection site, thereby minimizing pain from the hypertonic injection. Flush at the end with 1 mL of PF saline. 6. Patients must be able to walk with the same level of assistance they required before the procedure and to void prior to discharge. Discharge may occur 45-60 minutes after the procedure. If the patients are unable to walk or void, they should be observed and considered for further evaluation. 7. Instruct patients on neural flossing exercises and start these exercises in the recovery room.
Lumbar Transforaminal, or Cervical or Thoracic Interlaminar Catheter Placement
Volumes for the contrast, hyaluronidase/saline mixture, and the local anesthetic/steroid mixture are reduced to 5 mL. The pre-injection of 1% lidocaine is reduced to 0.5 mL. The volume of the hypertonic saline is reduced to 5 mL.
Modifications For a 2- or 3-Injection Protocol
The protocol may be modified to include a second injection 4 hours after the first injection. If desired, a third injection may be performed 8 hours after the first injection. Alternatively, once the patient meets the discharge criteria, they may be sent home and brought back the next day for the third injection.
When the physician is performing a 2- or 3-injection protocol, the local 0.25% bupivacaine should be diluted to 0.125%, and 0.2% ropivacaine should be diluted to 0.1% to prevent the occurrence of a sustained motor block, which would delay discharge. The 0.25% or 0.2% concentrations must be used for the first injection to rule out a subdural or subarachnoid injection.
Instructions for Preparing Hypertonic Saline
To make 10% hypertonic saline, dilute 4 mL of commercially obtainable, corrosive 23.4% hypertonic saline with 6 mL of 1% PF lidocaine. The final concentration is just under 10% saline and 0.6% lidocaine. Use one-half of these amounts to make 5 mL of hypertonic saline.

by diluting the commercially available 0.25% or 0.2% preparations, prevent the occurrence of a residual motor block after the procedure, facilitating the performance of these procedures in an outpatient setting.

For caudal procedures, 10 mL of this solution should be used. For cervical, thoracic, and transforaminal procedures, 5 mL is used. Prior to injecting the 10% saline, the physician should inject either one mL or 0.5 mL of 1% PF lidocaine, depending on whether the protocol calls for 5 or 10 mL of hypertonic saline. The physician should wait 2-3 minutes before injecting the 10% saline fairly rapidly, over a duration of 3-5 minutes The recipe for "pain-free" hypertonic saline is 4 mL of corrosive 23.4% hypertonic saline diluted with 6 mL of 1% lidocaine PF to yield a final concentration of hypertonic saline just under 10%, (9.4%) and 0.6% lidocaine.

The FDA approves of the use of 23.4% hypertonic saline as an electrolyte replenisher in parenteral fluid therapy and serves as an additive for total parenteral nutrition (TPN) and for intravenous fluids that contain carbohydrates. The substance is used off label for sclerotherapy.

If 5 mL of hypertonic saline is needed, mix 2 mL of the 23.4% saline with 3 mL of 1% lidocaine.

Percutaneous adhesiolysis may be performed under sedation, depending on the conjoint desires of the patient and the physician. As with most interventional pain procedures, it is important that the patient remains able to respond if they feel unanticipated pain. Unlike most pain procedures, it is crucial that in adhesiolysis, the patient is able to display the presence or absence of pre-procedural motor function after the injection of a local anesthetic.

Appendix 1 provides personal commentary on how hypertonic saline and hyaluronidase came to be included in the adhesiolysis protocol.

Discharge Criteria

Whether the procedure is done in the hospital or surgery center, we strongly recommend the establishment of discharge criteria. These criteria include the reduction of local anesthetic concentration if more than one injection is performed, evaluation of the patient 30-45 minutes after the last injection to ensure the patient can walk with the same level of assistance as was present prior to the procedure, and the ability to void voluntarily. Meeting the discharge criteria will prevent unreasonable costs and escalation of the level for care for the patient. Patients who are unable to meet the discharge criteria after several hours of observation should be referred for further evaluation.

Controversies

Despite the strong evidence supporting the use of lysis of adhesions, the procedure has attracted controversy. Birkenmaier examined whether lysis of adhesions could develop the biomechanical forces necessary to achieve lysis of a scar and concluded that lysis was unlikely to occur (25). These findings are correct in that the event of opening a well-healed surgical scar during lysis of adhesions is both improbable and undesirable. Birkenmeier's work has been criticized for being a nonstandardized bench study with no clinical involvement. The amount of pressure necessary to achieve clinical success in humans with epidural scarring is unknown, so the conclusion that insufficient pressures are developed cannot be supported. The success of lysis of adhesions depends not on the generation of large mechanical forces, which have the risk of injuring already susceptible nerve roots, but by proper catheter placement into the tissue planes entrapping the nerve. After Birkenmaier's study was published, a trial was performed with stiffer catheters to see if they could penetrate scars. The catheters could not, which was consistent with the need to use thinner rather than stiffer catheters. Furthermore, as shown by Bosscher and Heavner (2), multiple, less dense forms of epidural scarring can occur. This scarring can contribute to the highly pressurized veins in the epidural space that are one source of neural entrapment (26).

The use of hypertonic saline has been criticized because of concern over intrathecal spread. To mitigate this risk, the use of a local anesthetic that causes motor blockade if administered intrathecally or subdurally but not epidurally is employed when performing lysis of adhesions with hypertonic saline. Hitchcock reported a 3% incidence of transient weakness and an 8% incidence of sphincter disorders with the intrathecal use of 10-15% saline, although the assessment of sphincter disorders was difficult, since many of the patients had preexisting sphincter issues caused by their cancers (27). Accordingly, while lysis of adhesion is designed to prevent intrathecal spread, 10% saline should not be described as neurotoxic or neurolytic. Despite this focus on safety, one author has observed a pharmacist associated with a national ambulatory surgery center management firm refuse to allow the use of hypertonic saline. Attempts to discuss this refusal were not successful, so that the information used to support that determination is unknown.

Heavner, Racz, and Raj found that hypertonic saline provided better results than normal saline, with

no neurolytic side effects (28). In over 40,000 cases at Texas Tech, no long-term complications associated with hypertonic saline have been observed. The problem of pain on injection has been resolved with a small dose of lidocaine prior to the hypertonic saline injection, as described above.

Techniques to minimize intrathecal or subdural spread include not placing a caudal needle beyond S3, the terminus of the intrathecal space; using the appropriate spring-wound catheter, which is not overly stiff; advancing the catheter gently; not moving the catheter after the local anesthetic dose has shown appropriate placement; and using a Coudé needle, with a second stylet that protrudes beyond the tip of the needle. The function of the second stylet is to make the tip of the needle noncutting, thereby reducing the incidence of any injury to the nerve, a vein, or the dura. The risk of epidural, subdural, subarachnoid, or intravenous needle placement remains, whether the physician uses a blunt or sharp needle.

Supporting Evidence for Adhesiolysis

Lysis of adhesions has been investigated extensively, with strong evidence supporting its use. The most important study is the landmark randomized controlled trial conducted by Gerdesmeyer et al. The trial, which compared lysis of adhesions with a sham procedure, showed significant improvements in pain and function, with ongoing benefits at 10 years (5,29).

Gerdesmeyer's data showed that at 10 years, the treated group had less low back pain than did the placebo group (5). This information was not highlighted in the published paper.

Watanabe et al found that two-thirds of patients with stenosis who underwent lysis avoided surgery (30).

Cervical procedures have also been evaluated. In one study, Ji compared cervical neurolysis with interlaminar epidural steroid injections and found better relief with neurolysis (31).

Multiple systematic reviews have concluded that epidural lysis of adhesions is an effective and safe treatment (32-35), with level I evidence for the use of lysis of adhesions in patients who have not responded to epidural injections (36). Epidural lysis was associated with improvements in pain and disability as well as longer duration of relief.

Complications

Generally, lysis of adhesions has few complications if performed appropriately on well-selected patients. The greatest procedure-specific concern is the intrathecal spread of hypertonic saline, as discussed above.

As with all epidural procedures, the risk of epidural hematoma should be minimized by appropriate anticoagulant management. If a hematoma is suspected, an emergent MRI and spine surgeon consultation should be obtained.

Cervical and thoracic procedures carry the risk of causing direct trauma to the spinal cord. Obtaining a good lateral or contralateral oblique fluoroscopic image is critical for determining needle depth. In larger patients, it is helpful to get a lateral view first, such as a swimmer's view, to see if repositioning is needed before preparing the patient.

Perivenous counter spread is a rare but serious complication that occurs when injected fluid flows through the intravertebral epidural venous plexus to the opposite side of the spinal canal, causing compression (37). This complication should be treated with flexion rotation maneuvers to open the neural foramen and allow fluid to exit the canal via neural foramen. This maneuver can be implemented if the patient experiences pain after any spinal injection. Pain with or without motor or sensory deficit may respond to this drainage from the epidural space, decompressing the cord and allowing reperfusion of the ischemic areas.

Rarely, the spring-wound catheter can enter a vein in the ventral lateral epidural space. This complication has occurred most frequently in the cervical area. Intravenous placement can be identified by either dye spread or by the inability to steer the catheter outside the boundaries of the vein. Should intravenous cannulation occur, the catheter should be removed and the epidural space reentered at a different level. The use of a second, protruding stylet while rotating a Coudé needle will minimize the catheter's chance of reentering a vein.

It is crucial that only nonionic low osmolality contrast media be used for lysis of adhesions. One author (GBR) was involved in a case in which the facility ordered a cheaper, ionized contrast agent without informing anyone. Ionized contrast can cause twitching and potentially lead to death. This ionized contrast used in the GBR case was provided with only its unfamilar generic name on the bottle. The contrast was administered intrathecally by the author, after which the patient began to twitch. When the author consulted with a neuroradiologist who happened to be immediately present, he was instructed to, as rapidly as possible, irrigate and barbotage out the spinal fluid. Barbotage

was promptly performed, and the patient recovered. Table 2 is a list of contrast agents that may be used in neuroplasty. Table 3 is a list of contrast agents that should not be used in neuroplasty.

Table 2. *Contrast media that may be used in neuroplasty.*

Trade Name	Generic Name
Omnipaque	iohexol
Isovue-M	iopamidol

Table 3. *Contrast media that should not be used in neuroplastic.*

Trade Name	Generic Name
Ultravist	iopromide
Opitray	ioversol
Oxilan	ioxilan
Hypaque	diatrizoate
Hypaque/ Gastrografin	diatrizoate
Conray	iothalamate
Hexabrix	iothalamate

Conclusions

Epidural lysis of adhesions is a valuable procedure to treat axial and radicular pain not responsive to more conservative treatments, including persistent spinal pain syndrome type 2 and spinal stenosis. To be safe and effective, the technique must be performed according to protocol. Specific training and continuing education are needed, as is the case for any procedure.

Barriers to the use of adhesiolysis are caused by overregulation and insurance decisions inconsistent with the consistently positive data from clinical studies and clinical use.

In the future, additional refinements will be made to simplify and improve the technique and to enhance the catheters available to perform the procedure.

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Appendix 1. *Introduction to hypertonic saline and hyaluronidase.*

My introduction to hypertonic saline occurred about a year and a half into my residency and fellowship when my professor in Syracuse, New York, Willle Evers, MD, told me that he had an excellent case for me. He presented me with a patient, a 24-year-old woman who had had retinal blastoma since infancy, undergone bilateral enucleation, and been left with uncontrolled head and body pain. Dr. Evers told me of Hitchcock's use of subarachnoid 10-15% saline administration for retinal blastoma patients. After reviewing Hitchcock's Lancet article and after Dr. Evers spoke with friends in Montreal who had employed Hitchcock's technique, I applied subarachnoid iced 10-15% hypertonic saline to the patient, who was under anesthesia. The anesthetic was stormy, and when the patient appeared to settle down, we observed her overnight. The next morning, she was no longer in pain but resting happily in the company of her seeing eye dog. Although she was lost to follow-up, she made an impressive full recovery with no appreciable deficits. That outcome left a strong impression and led to many thousands of patients who received 9-10% sodium chloride with no complications from the saline. The main problem was severe burning pain that started upon injection and lasted up to 15-30 minutes. In an attempt to stop that pain, I injected 0.5 mL of 1% lidocaine into 2 cervical neuroplasty patients 2-3 minutes before injecting the hypertonic saline. Both patients received a pain-free injection of hypertonic saline. I have kept the video tape showing the second patient's pain-free second injection, since I had forgotten to inject the lidocaine prior to the hypertonic saline during the patient's first injection on the previous day. Since that time, I have never fogotten the therapeutic, pain-relieving effect of the lidocaine. While we have conducted no studies, but pure logic dictates that pain onset occurs before the onset of motor blocklade with hypertonic saline. We have conducted isolated nerve preparation studies with hypertonic saline and found that the motor block resolved in approximately 30 minutes. Increasing the amount of local anesthetic can cause a motor block, which can lead to an inability to stand up without the buckling of knees, especially in lumbosacral neuroplasties. I therefore believe it is essential to establish discharge criteria, particullarly in the surgery center when the intent is to dismiss the patient after the second injection. Additionally, in preparation for the discharge, the 0.25% second injection should be reduced to 0.125%, a concentration that will not give a protracted motor block over the observation period of 45 minutes–one hour. The discharge criteria should include being able to walk to the bathroom unaided and void.

My experience with hyaluronidase began with a trip to Oxford to see John Lloyd, MD, who was using hylauronidase to successfully treat arachnoidiitis-induced bladder and motor dysfunction. I was impressed with the ability of the hyaluronidase to spread through scar tissue. When performing adhesiolysis, I had difficulty with the viscous contrast media that spread through the scarred regions. I recalled the efficacy of the hyaluronidase in arachnoiditis and applied the enzyme successfully to adhesiolysis.