Case Report

Digital Subtraction Angiography Does Not Reliably Prevent Paraplegia Associated with Lumbar Transforaminal Epidural Steroid Injection

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Digital subtraction angiography (DSA) has been touted as a radiologic adjunct to interventional neuraxial procedures where it is imperative to identify vascular compromise during the injection. Transforaminal epidural steroid injections (TFESI) are commonly performed interventions for treating acute and chronic radicular spine pain. We present a case of instantaneous and irreversible paraplegia following lumbar TFESI wherein a local anesthetic test dose, as well as DSA, were used as adjuncts to fluoroscopy.

An 80-year-old man with severe lumbar spinal stenosis and chronic L5 radiculopathic pain was evaluated at a university pain management center seeking symptomatic pain relief. Two prior lumbar interlaminar epidural steroid injections (LESI) provided only transient pain relief, and a decision was made to perform right-sided L5-S1 TFESI. A 5-inch, 22-gauge Quincke-type spinal needle with a curved tip was used. Foraminal placement of the needle tip was confirmed with anteroposterior, oblique, and lateral views on fluoroscopy. Aspiration did not reveal any blood or cerebrospinal fluid. Digital subtraction angiography was performed twice to confirm the absence of intravascular contrast medium spread. Subsequently, a 0.5mL of 1% lidocaine test dose was performed without any changes in neurological status. Two minutes later, a mixture of one mL of 1% lidocaine with 80 mg triamcinolone acetonide was injected.

Immediately following the completion of the injection, the patient reported extreme bilateral lower extremity pain. He became diaphoretic, followed by marked weakness in his bilateral lower extremities and numbness up to his lower abdomen. The patient was transferred to the emergency department for evaluation. Magnetic resonance imaging (MRI) of the lumbar and thoracic spine was completed 5 hours postinjection. It showed a small high T2 signal focus in the thoracic spinal cord at the T7-T8 level. The patient was admitted to the critical care unit for neurological observation and treatment with intravenous methylprednisolone. Follow-up MRI revealed a hyper-intense T2 and short-tau inversion recovery signal in the central portion of the spinal cord beginning at the level of the T6 superior endplate and extending caudally to the T9-T10 level with accompanying development of mild spinal cord expansion. The patient was diagnosed with paraplegia from acute spinal cord infarction. At discharge to an acute inpatient rehabilitation program, the patient had persistent bilateral lower extremity paralysis, and incontinence of bowel and bladder functions.

In the present patient, DSA performed twice and an anesthetic test dose did not prevent a catastrophic spinal cord infarction and resulting paraplegia. DSA use is clearly not foolproof and may not be sufficient to identify potentially life-or-limb threatening consequences of lumbar TFESI. We believe that this report should open further discussion regarding adding the possibility of these catastrophic events in the informed consent process for lumbar TFESIs, as it has for cervical TFESI. Utilizing blunt needles or larger bevel needles in place of sharp, cutting needles may minimize the chances of this event occurring. Considering eliminating use of particulate steroids for TFESI should be evaluated, although the use of nonparticulate agents remains controversial due to the perception that their respective duration of action is less than that of particulate steroids.

Key words: Digital subtraction angiography, transforaminal epidural steroid injections, paraplegia, chronic low back pain.

Digital subtraction angiography (DSA) has been touted as a radiologic adjunct that might minimize complications from interventional neuraxial procedures where it is imperative to identify vascular compromise during the injection.(1,2) Indeed, Kim et al (3) showed that there is a 63.4% likelihood of entering the vascular space during cervical transforaminal steroid injections, including both venous as well as arterial injection, using standard fluoroscopy without DSA. Possibly more alarming still, the same authors identified a 10% incidence of either vascular spread of contrast medium alone, or in conjunction with nerve root spread, following injection for lumbar transforaminal steroid injections (TFESI) (3). As the number of lumbar injections worldwide is greater than the number of cervical, the possibility of having a catastrophic result develop following a vascular injection of a particulate glucocorticoid during a lumbar TFESI is clearly not insignificant.

TFESI are commonly performed interventions for treating acute and chronic spine pain and radiculopathy (4,5). The advantages of this approach are thought to be selective delivery of anti-inflammatory medication to the interface between the degenerative intervertebral disc and the exiting spinal nerve root, and greater deposition into the ventral epidural space. TFESI have shown efficacy for failed back surgery syndrome, spinal stenosis, and lumbosacral radiculopathy for up to one year or more (6). TFESI may also reduce the requirement for spinal surgical disc decompression (7), especially for sciatica symptoms less than 6 months in duration (8).

Table 1. *Complications after transforaminal epidural steroid injections. (Numbers in parenthesis indicate references, not incidences).*

Complications after Transforaminal Epidural Steroid Injections
cerebellar herniation (14)
direct spinal cord/nerve trauma
cerebellar infarction (17)
death (19)
spinal cord infarction (20)
abscess/Infection (21)
dural puncture
high block/total spinal
meningitis (22)
cortical blindness (23)
compressive hematoma (24)

Transforaminal delivery of corticosteroid or local anesthetic is generally well tolerated with a low incidence of serious complications (9,10). When serious complications arise, they typically occur during the process of placing the needle and administration of particulate steroidal medications. It appears that TFESI may be more dangerous than previously reported (11,12) and indeed, there have been cases of temporary (13) as well as permanent neurological sequelae (14-18) and death (18,19) during particulate glucocorticoid steroid (16,17) administration (Table 1).

A search is ongoing to identify the mechanisms of injury in these catastrophic outcomes. Research has stimulated various recommendations for equipment use, technique, and safety measures. Each measure has been shown to decrease the risk for inadvertent catastrophe, without absolute guarantee of safety.

We present a case of instantaneous paraplegia following lumbar TFESI of triamcinolone at L5-S1 wherein a local anesthetic test dose and DSA were used as adjuncts to fluoroscopy. To our knowledge, this is the first reported case of spinal cord infarction following lumbar TFESI wherein the combination of live fluoroscopic imaging with digital subtraction angiography, plus a local anesthetic test dose, were not successful in preventing this outcome.

Case Description

An 80-year-old man with a past medical history of hypertension, dyslipidemia, osteoarthritis, and chronic low back pain without prior surgical intervention was evaluated at a university pain management center, seeking symptomatic pain relief. He reported pain that originated in his lower back and radiated down his right leg, through his posterolateral thigh into the lateral aspect of the calf down to the ankle; the pain was worse with ambulation. Magnetic resonance imaging (MRI) revealed degenerative discs at L3-L4, L4-L5 and L5-S1, and severe right-sided L5-S1 neural-foraminal stenosis. He was diagnosed with severe lumbar spinal stenosis and L5 radiculopathic pain. Medications included valsartan, hydrochlorothiazide, diazepam, hydrocodone-acetaminophen, and pravastatin. He was not taking any nonsteroidal anti-inflammatory drugs or any type of anticoagulant or platelet inhibiting medication.

The patient's pain had been minimally controlled with oral medication, home exercise, and 2 lumbar interlaminar epidural steroid injections (LESI) using fluoroscopic guidance. An attempt had been made by one attending physician to perform a TFESI at L5-S1, but this

was not successful due to the presence of osteophytes in the neural foramen. Following the 2 LESI, the patient reported a transient 60% decrease in pain levels. For his third injection, a different supervising attending physician decided to again attempt a right-sided L5-S1 TFESI. A 5 inch, 22-gauge Quincke-type spinal needle with a curved tip was used. Foraminal placement of the needle tip was confirmed with anteroposterior, oblique, and lateral views on fluoroscopy. Aspiration did not reveal any blood or cerebrospinal fluid. Digital subtraction angiography was performed twice to confirm the absence of intravascular contrast medium spread (Fig. 1). Subsequently, a 0.5 mL of 1% lidocaine test dose was performed without any changes in neurological status. Two minutes later, a mixture of one mL of 1% lidocaine with 80 mg triamcinolone acetonide was injected. Immediately following the completion of the injection, the patient reported extreme bilateral lower extremity pain. He became diaphoretic, and reported marked weakness in both lower extremities and numbness up to his lower abdomen.

The patient was transferred for evaluation to the emergency department where he was noted to have complete motor loss of both legs (Table 2). Sensation to light touch and temperature were altered at T8 and lost below the T9 dermatome on the left, and was altered at T6 and lost below the T9 dermatome on the right side.

Reflexes were normal in his upper extremities, and absent in his lower extremities. The patient did not exhibit clonus, and had downward going toes bilaterally. Blood counts, chemistry panel, and coagulation studies were all within normal limits. Computed tomography (CT) angiography was negative for thoracic aortic dissection or aneurysm. An MRI of the lumbar and thoracic spine was completed 5 hours postinjection. It showed a small high T2 signal focus in the thoracic spinal cord at the T7-8 level (Fig. 2). In the emergency department, the patient received a 10 mg dexamethasone injection. Subsequent treatment consisted of admission to the critical care unit for neurological observation and treatment with intravenous methylprednisolone. Follow-up MRI revealed a hyper-intense T2 and short-tau inversion recovery signal in the central portion of the spinal cord beginning at the level of the T6 superior endplate and extending caudally to the T9-T10 level with accom-

Table 2. *Muscle strength exam in Emergency Department following transforaminal epidural steroid injections at L5-S1.*

	SAB	EF	EE	WE	IO	GRP	HF	HE	KF	KE	DF	PF	EHL
L	5	5	5	5	5	5	0	0	0	0	0	0	0
R	5	5	5	5	5	5	0	0	0	0	0	0	0

SAB = shoulder abduction; EF = elbow flexion; EE = elbow extension; WE = wrist extension; IO = interossei; GRIP = grip; HF = hip flexion; HE = hip extension; KF = knee flexion; KE = knee extension; DF = dorsiflexion; PF = plantar flexion; EH = extensor hallucis longus

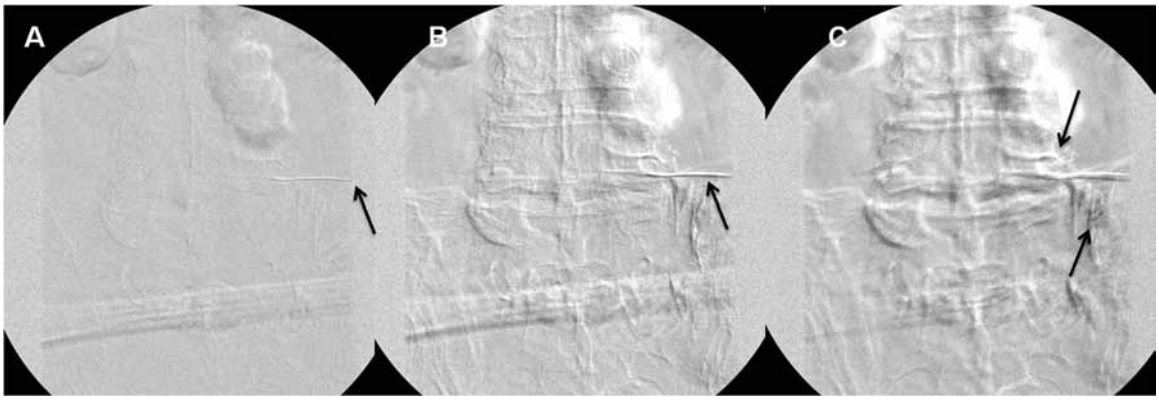

Fig. 1. *Digital Subtraction Angiography. A. Needle (arrow) entering right L5-S1 transforaminal space; anteroposterior view. B. Injection phase: arrow represents needle; C. Injection phase: Arrows point to spread of contrast medium. No definitive arterial injection observed.*

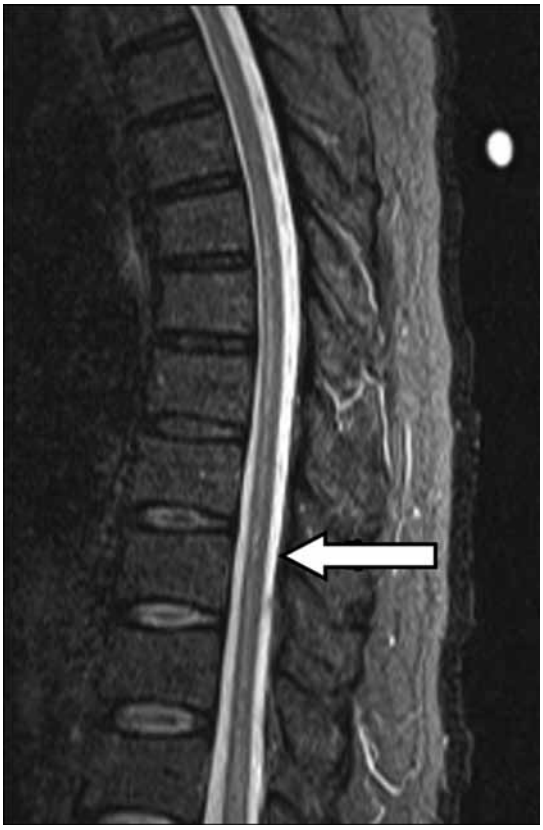

Fig. 2: *Sagittal T2-weighted short-tau inversion recovery sequence showing small hyperintense focus at T7-T8 level.*

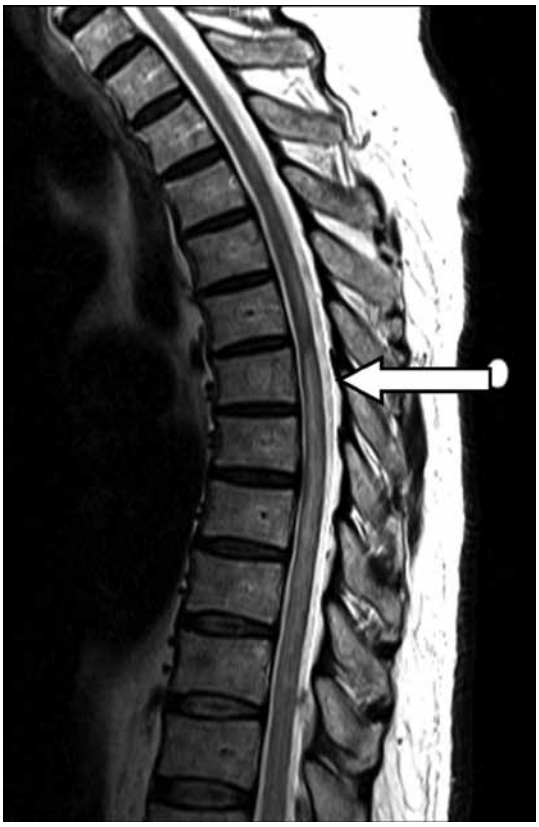

Fig. 3. Sagittal T2-weighted magnetic resonance imaging. Note black arrow pointing to hyperintense signal starting at T6 level.

panying development of mild spinal cord expansion (Figs. 3 and 4). The patient was diagnosed with paraplegia from acute spinal cord infarction. At discharge to an acute inpatient rehabilitation program, the patient had persistent bilateral lower extremity paralysis, and incontinence of bowel and bladder functions.

Discussion

Transforaminal epidural steroid injections have become increasingly utilized since Derby et al described them in 1993 (25). Since then, instances of central nervous system dysfunction due to vascular compromise and infarction have been reported and attributed primarily to intravascular injection of particulate steroids leading to embolization of radicular and medullary arteries (1,26).

Several methods have been proposed to reduce the risk of intravascular injection, with recommendations for needle selection, technique, imaging, medication selection, and considerations to limit scope of care to fellowship-trained practitioners. A discussion of several of these factors follows.

Needle Selection

The selection of the ideal needle for TFESI is controversial. A sharp, cutting type Quincke spinal needle was utilized in the present case. Nahm et al (27), in a prospective study conducted on 1,088 patients, performed 2,145 transforaminal injections using a Quincke-type spinal needle and identified an incidence of intravascular injections of 6.1% during lumbar TFESI (27). Some proponents recommend using short-beveled or blunt-type needles (17,28) to reduce the risk of direct vessel trauma, and large-diameter needles (less than 22-gauge), to reduce the risk of cannulating a vessel (17,28). In one report, blunt tip needles were not shown

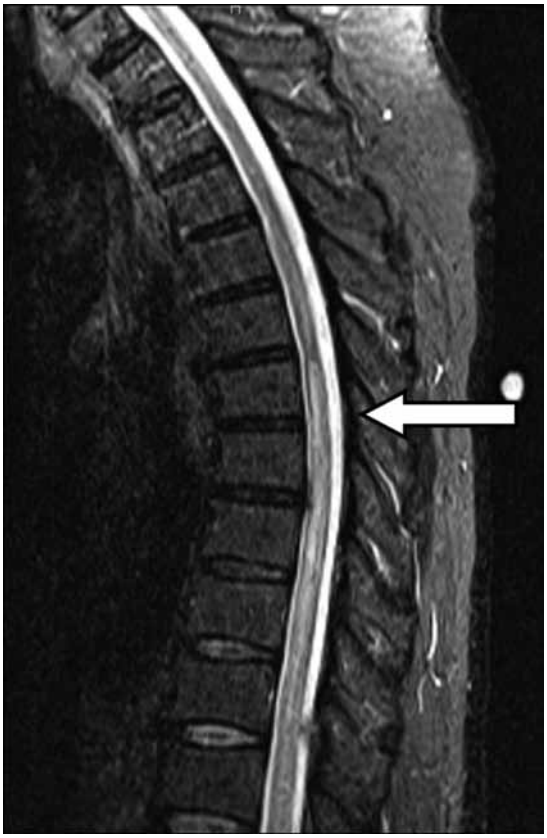

Fig. 4. *Sagittal short-tau inversion recoverymagnetic resonance imaging. Note arrow pointing to hyperintense signal starting at T6 level.*

to prevent intravascular injection during cervical TFESI (29). Smuck et al (30) found that short-bevel needles compared to long-bevel needles did not reduce the risk of unintentional vascular injection in lumbosacral transforaminal epidural injections (30).

Test Dose

Prior to injecting medication, a test dose of local anesthetic may be performed. The objective of this is to observe patients for transient neurologic impairment such as agitation, motor deficit and/or paresthesias, or other systemic symptoms (31,32). Alternatively, subarachnoid placement of 5 or 10 mg of lidocaine is probably sufficient to cause at least a transient, partial motor conduction block of the lower extremities. Smuck et al (32) conducted a study with 678 cervical TFESI, and the overall incidence of a positive anesthetic test dose was 0.59% (4/678). In this study, all 4 patients with a positive response to the anesthetic received one mL of 1% lidocaine (32). In the present case, the test dose was not protective in preventing intravascular uptake, although the small volume used (0.5 mL) was probably insufficient to detect any symptoms related to an intravascular injection. However, we believe that higher doses and/or concentrations of local anesthetic may have prevented this catastrophic outcome. The patient was observed for 2 minutes after the test dose, before a mixture of one mL of 1% lidocaine with 80 mg triamcinolone acetonide was injected. Smuck et al (32), in their retrospective study, showed that all 4 positive test dose responses were reported within seconds of the anesthetic injection. This may raise another question, that being "How long after injecting a test dose should we wait and observe our patients before we inject corticosteroid medication?"

Steroid Selection

Recent catastrophic outcomes have necessitated examination of the medications utilized in epidural steroid injections. Microscopic examination of corticosteroids has quantified the sizes of particulates in different preparations (17,33-35). Tiso et al (17) found particles greater than 50 µm in 8.57% of samples of methylprednisolone acetate; 3.70% of triamcinolone acetonide; and 3.70% of dexamethasone. MacMahon et al (35) examined samples of methylprednisolone and triamcinolone, and found both to contain crystal aggregation particles ranging from 1 to greater than 100 µm, which have the potential to occlude the medullary arterioles measuring 10-15 µm in diameter.

Particulate corticosteroids have been championed in the past based on the hypothesis that their duration of action would be greater based on the depot of the larger, slower absorbing particles. In 2006 Dreyfuss et al(31) showed that dexamethasone was slightly less effective than triamcinolone, although the difference was neither statistically nor clinically significant.

Kim and Brown (36), in a randomized study, compared the efficacy and safety of dexamethasone phosphate (DP) with methylprednisolone acetate (MPA) for lumbar radiculopathy. The recipients of DP (nonparticulate) had a statistically nonsignificant trend toward less pain relief and shorter duration of action compared to those that received MPA. Lee et al (37), in 159 patients, found no significant difference between particulate or nonparticulate steroids following cervical TFESI.

The embolization properties of particulate steroids have been studied in an animal model. Okubadejo et

al (38) studied 11 pigs anesthetized under general endotracheal anesthesia. Catheters were inserted from the femoral artery up to the vertebral arteries where either MPA or DP was injected. None of the pigs that received MPA were able to be weaned from ventilator support, while the pigs that received DP all made a full recovery. Additionally, histopathologic examination of the animals that received particulate steroids showed evidence of ischemic changes.

Imaging

Furman et al (39) showed that detecting blood during needle aspiration is only 44.7% sensitive when used in lumbosacral TFESI. Houten and Errico (40) reported negative aspiration in 3 cases of paraplegia following lumbosacral transforaminal injections. Thus, aspiration before injection to confirm the absence of blood in the needle hub is not reliable in preventing intravascular injection.

Imaging with fluoroscopy or CT has become the standard of care for most interventional neuraxial procedures (41). Epidural injections by trained practitioners without image guidance has showed misplacement of the needle tip in 30-40% of cases (41-44), with more dismal results in patients with failed back surgery syndrome (45). Performing a transforaminal epidural injection is likely not possible without anteroposterior, lateral, and oblique views on fluoroscopy, which are necessary to adequately assess needle tip placement near the neuroforamen.

Contrast medium, in conjunction with continuous, or "live" fluoroscopy, has been shown to identify intravascular injection. Intravascular injection may be missed up to 57% of the time with static fluoroscopy techniques (46). It may be difficult to visualize and capture fleeting images of vascular contrast medium uptake, as it is quickly diluted and carried away by the passing blood flow (46), especially in the case of simultaneous epidural and intravascular injection (47). In a series of 191 lumbosacral TFESI, Smuck et al(47) found the incidence of simultaneous epidural and vascular injection was 8.9%—more than double the incidence of a vascular injection alone (4.2%) and consistent with the findings of Kim et al (3).

Recently, DSA has been utilized to identify intravascular injection (2,48). Real-time DSA digitally "subtracts" the baseline radiograph from serial images. It has demonstrated greater accuracy in detecting intravascular injections compared to blood aspiration or live fluoroscopy (49). During a series of 87 lumbar transforaminal epidural injections, Lee et al (49) found 20 cases of intravascular injection utilizing DSA. Of these cases, real-time fluoroscopic guidance with contrast medium predicted 12 of the 20 instances of intravascular contrast injections.

In a study of 134 patients, where 177 cervical TFESI's were performed, Mclean et al (50) compared real-time fluoroscopy to DSA. Intravascular injection was detected in 18% of cervical TFESIs with real-time fluoroscopy vs. 32.8% when DSA was used ($P = 0.0471$).

There are disadvantages to digital subtraction angiography. Using DSA increases the radiation exposure to the patient, physician, and staff. Additionally, there is the increased cost of adding digital subtraction to fluoroscopy equipment.

Possible Mechanisms of Injury

We believe that infarction of the spinal cord resulted from intra-arterial injection of the particulate corticosteroid triamcinolone through a sharp, cutting needle into a radiculomedullary artery. The artery of Adamkiewicz, the largest feeder artery in the thoracolumbar region, usually occurs between the levels of T8 and L2, (51) although Takase et al (52), utilizing helical CT, were able to demonstrate bilateral large anterior segmental arteries in 24% (15 of 63) of patients. Biglioli et al (53) studied the anterior spinal artery and spinal cord circulation in 31 adult cadavers, and showed that the origin of the artery of Adamkiewicz varied from T9 to L5, and that the diameter varies from 730 to 1330 μm (53). However, in greater than two-thirds of cadavers, the artery was found alongside the lumbar nerve roots (53).

A variable inferior accessory radiculomedullary artery (artery of Desproges-Gotteron), originating from the internal iliac artery has been demonstrated to supply the conus medullaris; it arises at either the L5 or S1 level (54). This variant has also been implicated in cases of spinal cord ischemia (40). There is also a possibility that medication was injected into a dilated and well-developed collateral artery. The present patient was 80 years old, with a history of hypertension and dyslipidemia. He most likely has atherosclerotic changes in the aorta and intercostals and spinal arteries with tortuous vessels including occlusions at multiple levels, and probably a very well-developed collateral circulation which supplies the spinal cord (55). Hong et al (55), in their study conducted on cadavers, showed that vessels typically seen only microscopically may be very enlarged in patients with extensive atherosclerosis.

Even though we believe that this patient suffered from acute spinal cord infarction due to an intra-arterial injection of a particulate corticosteroid administered via a sharp-beveled needle, there are alternative plausible mechanisms of injury, such as needle-induced vasospasm and mechanical disruption of the vasculature. Vasospasm was presented as a likely cause of brainstem stroke following fluoroscopically guided cervical epidural steroid injection (56). Suresh et al (57) showed cerebellar and brainstem infarction as a complication of CT-guided cervical TFESI. Wallace et al (58) published 2 cases of arterial disruption after cervical selective nerve root blocks with fluoroscopic guidance.

A catheter-guided transforaminal technique may be considered as an alternative to needle placement and injection. Choi and Barbella (59) conducted a study using lumbar interlaminar ventral epidural injections in 40 patients achieved by using an epidural catheter placed at the ventrolateral side of the nerve root. They have shown that catheter-guided injections with lumbar placement of a 19-gauge, radiopaque, spring-tipped epidural catheter through a 17-gauge Tuohy needle may be an effective way of placing corticosteroid medications at the ventrolateral side of the nerve root. If that technique had been utilized in the present case, it is possible that the more malleable and less sharp tip of the catheter would have avoided entry into an arterial structure and hence, prevented the observed outcome.

There is also a possibility of using extension tubing to avoid the risk of moving the needle tip. Accidental needle movement, even undetectable to the human hand during the change from a contrast medium filled syringe to a corticosteroid filled syringe, may cause serious complications (32).

Conclusion

In the present patient, digital subtraction angiography performed twice and an anesthetic test dose did not prevent a catastrophic spinal cord infarction and resulting paraplegia. DSA use is clearly not foolproof, and even in well-trained hands, may not be sufficient to identify potentially life-or-limb threatening consequences of lumbar TFESI.

The use of sharp, cutting, bevel needles (Quincke spinal needles) also needs to be further studied with consideration for other options. Utilizing blunt needles or larger bevel needles may minimize the chances of this event occurring. Removing consideration of using particulate steroid medications is another obvious outcome of this catastrophe, although the use of nonparticulate agents remains controversial due to the perception that their respective duration of action is less than that of the particulate ones.

We support further studies to reduce the possibility for devastating injury following TFESI, and believe that this report should open further discussion regarding the addition of these events during the informed consent process, even for lumbar TFESIs.

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