Medicolegal

Spinal Epidural Abscess and Medical Malpractice: The Role of Diagnostic Imaging in Legal Cases

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Rationale and Objectives: Spinal epidural abscess (SEA) is a rare but serious infection that can lead to permanent neurological deficits. Despite guidelines recommending MRI for diagnosis, SEA is frequently missed in initial assessments due to the use of CT. This article examines medical malpractice lawsuits involving missed SEA diagnoses, focusing on the legal implications of imaging decisions and diagnostic delays.

Materials and Methods: A search was conducted in the Westlaw legal database to identify malpractice cases related to missed SEA diagnoses in which CT imaging was performed. Boolean search terms included "misdiagnosis," "missed," "epidural abscess," and "CT scan." 27 cases were identified, of which six were determined to be relevant following manual screening. Each case was analyzed for medical and legal considerations, including diagnostic delays, imaging limitations, standard-of-care breaches, and litigation outcomes.

Results: In all analyzed cases, diagnoses were delayed due to use of CT rather than MRI. Courts were more likely to rule in favor of plaintiffs when delays resulted in paraplegia or quadriplegia, with significantly higher monetary awards for severe neurological outcomes. Some cases demonstrate nuanced legal arguments, such as whether SEA should be detected during evaluation for other conditions.

Conclusion: Missed SEA diagnoses often stem from inappropriate use of CT. Lowering the threshold for MRI in patients with back pain could improve diagnostic accuracy but may increase healthcare costs and imaging burden. Radiologists should be aware of CT's limitations and explicitly document them. Further guidelines are needed to standardize the appropriate use of imaging in back pain evaluations.

Key Words: Spinal epidural abscess; Misdiagnosis; Missed diagnosis; Malpractice; Diagnostic imaging.

Abbreviations: SEA Spinal Epidural Abscess

INTRODUCTION

Spinal epidural abscess (SEA) is a pyogenic infection in the vertebral canal with devastating neurological sequelae. Though still rare, the incidence of SEA is increasing, likely due to rising intravenous drug use.[1–4] SEA is frequently missed on initial assessment, and more than 60% of patients do not present with the classic triad of fever, back pain, and neurological deficit.[5–9] The presenting complaint is often back pain, which prompts physicians to seek musculoskeletal causes, such as muscle spasm and degenerative disc disease.[2,10–12] Therefore, ancillary tests such as white cell count, ESR, and CRP are not performed.[5,6,10,13,14] Patients develop progressive neurological deficit with a speed proportionate to the rate of expansion of the abscess within the tight real estate of the vertebral canal, often leading to permanent neurological deficits, despite surgical decompression.

Guidelines are clear that MRI is the imaging of choice for suspected SEA, followed by nuclear medicine.[15,16] The sensitivity of MRI for SEA is 90%, owing to its superior soft tissue contrast,[3,17–19] and lawsuits arise not because SEA is missed on MRI, but missed on CT. This occurs for the following two reasons: CT has a dismal sensitivity for SEA (6–18%)[20,21] and because CT is not obtained by the referring physician to rule out SEA, but to assess for the presence of bony abnormalities.[22]

When first described by Morgagni in 1761,[23] SEA was considered a fatal diagnosis; aseptic techniques and antibiotics have since reduced mortality rates, to 5%.[2,24] The reduction in mortality of SEA paradoxically increases the exposure to liability for missed SEA, as it is now considered an

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imminently treatable condition. We have analyzed select lawsuits involving SEA, to understand and explore the legal nuances of causation.

METHODS

The Westlaw legal database (Thomson Reuters, New York, NY) was queried for medical malpractice litigations relating to missed SEAs that involved CT scanning. Search strategies involved "Plain Language" and "Advanced" search types, including Boolean combinations of the terms: "misdiagnosis," "missed," "epidural abscess," "CT" and "CT scan" (Supplemental Material). 27 cases were identified, of which six cases were determined to be relevant after manual screening and were included within our analysis (Table 1).

MUSCULOSKELETAL PAIN—THE UMBRELLA DIAGNOSIS

Adae, a 50-year-old diabetic, presented to the emergency department with fever, chest pain radiating to the left arm, back pain, and high blood pressure, prompting a suspicion of acute coronary syndrome, which was excluded by negative cardiac biomarkers. A negative CT angiogram excluded aortic dissection and acute abdominal pathology. In the ED, she was apyrexial and her symptoms abated. Her back pain was attributed to musculoskeletal process and she was discharged. Adae re-presented to a different ED two days later with back pain, where CT chest excluded pulmonary embolism and a CT head suggested sinusitis. She was discharged on antibiotics for the sinusitis.

One week after the initial presentation, Adae re-presented to the ED with bilateral lower extremity weakness. MRI of the lumbar spine showed an SEA, which was treated by decompressive laminectomy. The neurological deficits persisted and Adae had fecal and urinary incontinence. A lawsuit was filed against the initial emergency department and treating physician, for failing to consider SEA and ordering MRI despite the fever. After multiple appeals, Adae was awarded $2.3 million in damages.

Linda, a 25-year-old female, with a history of substance abuse and incarceration, saw multiple physicians in the prison system, for shoulder and back pain over a four-week period. This purportedly began after moving furniture, for which she received X-rays of her shoulder and spine, which ruled out bony injury. She was diagnosed with a muscle sprain and prescribed analgesia. She was never pyrexial but developed non-specific neurological symptoms, such as paresthesia of hands and feet, for which CT head, thoracic and lumbar spine were obtained and were normal. It was only when Linda lost motor function of the legs that MRI of the spine was obtained; this showed a thoracic SEA, which was decompressed. Linda had residual paralysis and incontinence.

Linda filed a lawsuit against her treating physicians for the delayed diagnosis of SEA. Though there was conflicting

TABLE 1. Overview of Analyzed Cases Retrieved From the Westlaw Legal Database (Thomson Reuters, New York, NY)

Case Participants	Patient Sex	Initial Presentation	Jurisdiction	Patient Outcomes	Verdict
Adae v. State	F	Pyrexia; chest/back pain radiating to the left shoulder and arm	Court of Appeals of Ohio, Tenth District, Franklin County	Permanent paraplegia, urinary and fecal incontinence	P $2.3 million
Allen v. Sarah Bush Lincoln Health Center	M	Pyrexia; neck and shoulder pain; generalized weakness; high white blood cell count	Appellate Court of Illinois, Fourth District	Permanent injury of the spinal cord	P $14 million
Auld v. McLaren Regional Medical Center	M	Back pain with a history of Marfan's syndrome	Michigan Supreme Court	Permanent paraplegia	D
Menschik v. Heartland Regional Medical Center	F	Dysphagia; pain in thoracic spine, chest, arms, legs; high white blood cell count	Missouri Court of Appeals, Western District	Partially regained ability to walk following surgery	D
Thomas v. Southern Health Partners Inc	F	Recurrent falls; neuropathy	United States District Court, E.D. Kentucky, Northern Division at Covington	Permanent paraplegia, urinary and fecal incontinence, and paresthesia	Ongoing
Wittig v. Huang and Crawford	M	Traumatic injury, given an epidural catheter for analgesia	Appeals Court of Massachusetts, Middlesex	Lasting neuropathy with bladder and bowel dysfunction	D

D, Defendant; F, Female; M, Male; P, Plaintiff.

evidence when symptoms from Linda's SEA developed, the court found that Linda undisputedly developed a "sufficiently serious medical" while detained—that is, a need that "has been diagnosed by a physician as mandating treatment or one that is so obvious that even a lay person would easily recognize the necessity for a doctor's attention." The lawsuit was complicated by the fact that the prison physicians, as government officials, were shielded from liability. Nevertheless, the court found it possible that the healthcare staff's policies and training were inadequate, resulting in harm to Linda. As of late 2024, this case is ongoing.

Delayed diagnosis of SEA is akin to a missed diagnosis because complications, such as paraplegia or incontinence, become permanent, despite decompression of the abscess. Both Adae and Linda initially received CT rather than MRI. In his analysis of missed SEA cases, trial lawyer Randell C. Ogg asserts that "any delay in making a referral to a specialist may be the basis for a malpractice claim" when ascertaining viable legal strategy.[25] Furthermore, in their analysis of 56 SEA malpractice cases, DePasse et al. reported that juries are more likely to rule in favor of plaintiffs who become paraplegic or quadriplegic, with significantly higher monetary awards compared to those with only pain or isolated weakness. They also found that delays in diagnosis or treatment increased this likelihood of award to plaintiffs.[26]

ESTABLISHING CAUSATION

Allen, a middle-aged male, visited the ED after feeling a "pop" in his neck accompanied by acute pain radiating through his right shoulder and neck after physical activity, where he was diagnosed with a muscle sprain and discharged on analgesics. Over the next four days he developed a fever of 103 F, as well as weakness and paresthesia from the neck down to his waist. The emergency physician ordered a full blood count and CT neck, informing Allen that the CT scan was normal but his white blood cell count was elevated, making it likely a viral infection. Allen was discharged with stronger analgesia and advised to wait until the supposed infection subsided.

The next day Allen re-presented to the ER after becoming ataxic and losing motor function in his limbs. He was referred to the neurologist who ordered an MRI; this revealed an SEA, which was surgically drained. Despite this, Allen remained paraplegic. Allen sued the hospital, arguing that the initial emergency physician failed to adequately examine Allen, order a sedimentation rate test, order imaging appropriate to this presentation, and refer to an appropriate specialty.

Expert witnesses in emergency and internal medicine, and orthopedic surgery, argued that the standard of care was breached because Allen presented with the classic SEA triad—which should prompt any physician, regardless of specialty, to request an urgent spine MRI. They also emphasized that an MRI should have still been ordered even after Allen's initial CT scan, due to CT's dismal sensitivity. Allen was awarded $14 million in damages.

Menschik, an adult female, presented with dysphagia, weakness and severe neck pain radiating to her chest, back arms and legs, but no fever. Her physician ordered a chest X-ray, CBC, and CT scans of her chest and spine. Her white cell count was elevated. The radiologist noted prevertebral soft tissue swelling, and localized fluid and diagnosed a retropharyngeal abscess. Metal implants from fusion surgery resulted in artifacts, obscuring the vertebral canal. Though he later testified that the artifact obscured the epidural space, he did not report this limitation or advise follow-up MRI. Of note, the incidence of co-existing SEA and retropharyngeal abscess is rare. A meta-analysis found 5 of 854 SEA patients also had a retropharyngeal abscess,[12] though it did not answer the obverse—how frequent are SEAs in patients with retropharyngeal abscess?

The retropharyngeal abscess was surgically drained. However, post-operatively, Menschik experienced progressive loss of sensation and motor power in the lower limbs and eventually paraplegia. MRI of the cervical spine showed "large disc herniation at C6-C7 with edema or epidural extension of an abscess" and "hyperintensity within the spinal canal and/or cord." Menschik underwent tracheostomy and the neurosurgeon surgically drained the abscess, removed the anterior C4-C5 and C5-C6 plates and performed an anterior cervical diskectomy and fusion of C6-C7. Menschik remained paraplegic and incontinent following surgery.

Subsequently, Menschik filed a lawsuit alleging negligence against the treating physicians, attributing her complications to their inadequate communication, insufficiently thorough examinations, and delayed necessary surgery following MRI that should have been ordered more urgently. The verdict ruled in favor of the defending physicians. Menschik appealed unsuccessfully.

Auld, an adult male with Marfan syndrome and previous aortic dissection presented to the ER with abdominal pain radiating to his back. CT angiogram showed a stable dissection; Auld was discharged but returned two days later with severe back pain. This time he was admitted to the observational ward. The next morning, Auld became paraplegic and was transferred to a tertiary care hospital where he received an urgent CT angiogram of the spine followed by MRI, which showed a thoracic SEA causing cord compression. Despite rapid surgical drainage and decompressive laminectomy, Auld's paraplegia could not be reversed.

Auld filed a negligence case with the Genesee County Circuit Court against the emergency physicians in the first hospital for failing to diagnose SEA in a timely manner. The defendants were accused of breaching the standard of care by failing to order imaging of the spine, failing to refer to a Marfan specialist, and failing to consider Marfan-related differentials. The plaintiff's emergency medicine expert witness said that Auld should have received an MRI to investigate dural ectasia and that this would have led to

discovery of the SEA "by serendipity." He asserted that "[t] his case is not about identifying the spinal epidural abscess right off the bat it's about looking for dural ectasia and then finding the abscess." A neurosurgeon, later called by Auld to testify on proximate cause, posited that up to 90% of Marfan syndrome patients experience dural ectasia and that Auld had an "[o]ver 90%" of recovery had he received surgery before tertiary center transfer. However, the defense highlighted a Marfan Foundation document referenced by this latter expert, which stated that "in 99% of people with dural ectasia, it occurs in the lowest part of the spine because that is where the fluid pressure is greatest when standing."

Deposing the plaintiff's expert testimonies, the defendants successfully argued that the standard of care—MRI or CT of the lumbar spine to exclude dural ectasia—would have failed to visualize Auld's thoracic SEA. The defendants successfully filed for partial summary judgment, meaning that they were assessed to have incomplete but sufficient evidence to resolve the case without trial. Auld subsequently filed a successful appeal on the basis that the selected expert deposition was insufficient evidence for complete dismissal. The granting appeals court's statement included that "the applicable standard of care under plaintiff's presenting circumstances called for a "proper" evaluation of the entire spine as described previously, not just that part of the spine where dural ectasia is statistically most likely to occur." However, this appeal was ultimately dismissed by the Michigan Supreme Court.

Wittig, a 55-year-old man, sustained multiple ribs fractures after a motor vehicle accident. The anesthesiologist placed a T6 epidural catheter for pain relief. The next day, Wittig developed a pneumonia for which antibiotics were commenced. After four days, he developed belt-like abdominal pain and weakness in the lower extremities. A resident ordered a CT scan of the abdomen. The catheter was removed, the tip cultured, and vancomycin initiated; Wittig began to develop neck pain. The culture grew *S. aureus* several hours later. A neurologist who was consulted strongly suspected SEA and ordered an urgent MRI, which revealed a thoracic SEA with extensive collection between T2–T8 and reduction of the spinal canal diameter by nearly 50%, prompting urgent surgical drainage and extensive T2–T10 laminectomy.

Wittig, who suffered permanent neurological damage and incontinence, filed a suit against the hospital and the doctors involved in his care. At trial, expert testimonies from a neurosurgeon, anesthesiologist and neurologist emphasized that earlier referral to the neurologist would have led to earlier diagnosis and mitigated the extent of neurological damage. Consequently, the jury agreed that neurological damage may have been less severe if the MRI had been performed earlier, but the exact causal link between timing and injury was conjectural. The court ruled in favor of the defendants.

Allen's case was a more straightforward presentation of SEA. With Menschik, the SEA was obscured by both the artifact and the presence of a retropharyngeal abscess which was diagnosed and treated. The legal nuances in the latter paralleled the medical nuances. With Auld, the jury did not fall for the "diagnosis by serendipity argument"—though the outcome of such a case may well be different with different juries. Wittig presented an interesting dilemma—although there is no doubt that the longer it takes to diagnose SEA, the more likely it will cause permanent neurological damage. What is uncertain is whether the diagnosis was made in a reasonable manner given the appearance of the patient's symptoms.

IS THERE NUANCE IN MEDICAL MALPRACTICE TRIALS?

The legal arguments furnished by plaintiffs and defense attorneys are often nuanced. It can be legally complex to determine whether there has been a breach in the standard of care. However, in almost all medically documented cases of SEA, the timeframe for diagnosis and treatment was pivotal in legally determining whether standard of care was breached.[26,27] Put succinctly by French et al: the most important factor governing prognosis and litigation outcomes is whether SEA is diagnosed and treated within 48 h of admission.[27] In our analysis, the cases of Allen and Adae reinforce this notion. However, as in the case of Menschik, there are exceptions, and juries do understand the difficulties in reaching diagnosis of SEA when the presentation is not classic.

For cases in which referring physicians are found liable, the amount awarded to plaintiffs has been found to correlate with injury. DePasse et al. determined that cases involving debilitating neurologic sequelae or paralysis were more likely to rule in the plaintiff's favor, awarding significantly higher monetary amounts than for those without lasting neurological injury.[26] This was consistent with other published analyses; however, Shantharam et al. found no differences in awarded outcomes between quadriplegic and paraplegic plaintiffs.[28]

Physicians may anticipate that defending strategies can consider emphasizing that the rarity and rapid progression of SEA result in narrow therapeutic timeframes, meaning that timely antibiotic treatment and surgical intervention may not prevent lasting neurological damage.[25]

CONCLUSION

Spinal epidural abscesses are missed in the ER because they are rare and manifest, initially, with non-specific symptoms such as back pain. Litigation risk can trickle down to radiologists because CT scans, often obtained to investigate back pain, cannot assess the vertebral canal, so abscesses are not discovered. The simple solution would be to lower the threshold for the suspicion of SEA, but this has consequences. If SEA is to be excluded in everyone with back pain, then the number of urgent spine MRIs would increase considerably.

Although the legal implications of SEA are disproportionately significant to their statistical likelihood, one

must be careful not to change the practice of medicine based on only a few cases. While radiologists could include a disclaimer explaining the limitations of CT and articulate in no uncertain terms that CT cannot assess the contents of the vertebral canal, this becomes a slippery slope. As an alternative, there could be general education for emergency medicine physicians relating to imaging limitations and SEA, and professional radiological societies should also be clear in their guidelines that CT has no role in the initial diagnosis of SEA. Though there are a plethora of guidelines for specific conditions such as suspected SEA, which inform physicians how imaging should be ordered, there is a relative paucity of guidelines which address how imaging is actually ordered in the real world. This is important, because radiologists and referring clinicians should understand how to interpret the results of an imperfect imaging test for non-specific symptoms. We recommend the creation of guidelines for "CT in back pain."

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDIX A. SUPPORTING INFORMATION

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.acra.2025.04.027.

REFERENCES

1. Long B, Carlson J, Montrief T, et al. High risk and low prevalence diseases: spinal epidural abscess. Am J Emerg Med 2022; 53:168–172. https://doi.org/10.1016/j.ajem.2022.01.008
2. Darouiche Rabih O. Spinal epidural abscess. Massachusetts Medical Society N Engl J Med 2006; 355(19):2012–2020. https://doi.org/10.1056/NEJMra055111
3. Sendi P, Bregenzer T, Zimmerli W. Spinal epidural abscess in clinical practice. QJM 2007; 101(1):1–12. https://doi.org/10.1093/qjmed/hcm100
4. Patel AR, Alton TB, Bransford RJ, et al. Spinal epidural abscesses: risk factors, medical versus surgical management, a retrospective review of 128 cases. Spine J 2014; 14(2):326–330. https://doi.org/10.1016/j.spinee.2013.10.046
5. Vakili M, Crum-Cianflone NF. Spinal epidural abscess: a series of 101 cases. Am J Med 2017; 130(12):1458–1463. https://doi.org/10.1016/j.amjmed.2017.07.017
6. Davis DP, Wold RM, Patel RJ, et al. The clinical presentation and impact of diagnostic delays on emergency department patients with spinal epidural abscess. J Emerg Med 2004; 26(3):285–291. https://doi.org/10.1016/j.jemermed.2003.11.013
7. Baker Ann S, Ojemann Robert G, Swartz Morton N, et al. Spinal epidural abscess. Massachusetts Medical Society N Engl J Med 1975; 293(10):463–468. https://doi.org/10.1056/NEJM197509042931001
8. Rigamonti D, Liem L, Sampath P, et al. Spinal epidural abscess: contemporary trends in etiology, evaluation, and management. Surg Neurol 1999; 52(2):189–197. https://doi.org/10.1016/S0090-3019(99)00055-5
9. Davis DP, Salazar A, Chan TC, et al. Prospective evaluation of a clinical decision guideline to diagnose spinal epidural abscess in patients who present to the emergency department with spine pain: clinical article. American Association of Neurological Surgeons J Neurosurg Spine 2011; 14(6):765–770. https://doi.org/10.3171/2011.1.SPINE1091
10. Darouiche RO, Hamill RJ, Greenberg SB, et al. Bacterial spinal epidural abscess. Review of 43 cases and literature survey. Medicine 1992; 71(6):369–385.
11. Tang H-J, Lin H-J, Liu Y-C, et al. Spinal epidural abscess—experience with 46 patients and evaluation of prognostic factors. J Infect 2002; 45(2):76–81. https://doi.org/10.1053/jinf.2002.1013
12. Reihsaus E, Waldbaur H, Seeling W. Spinal epidural abscess: a meta-analysis of 915 patients. Neurosurg Rev 2000; 23(4):175–204. https://doi.org/10.1007/PL00011954
13. Danner RL, Hartman BJ. Update of spinal epidural abscess: 35 cases and review of the literature. Clin Infect Dis 1987; 9(2):265–274. https://doi.org/10.1093/clinids/9.2.265
14. Artenstein AW, Friderici J, Holers A, et al. Spinal epidural abscess in adults: a 10-year clinical experience at a tertiary care academic medical center. Open Forum Infect Dis 2016; 3(4):ofw191. https://doi.org/10.1093/ofid/ofw191
15. Sexton D. Spinal epidural abscess (Accessed). In: Connor RF, editor. UpToDateWolters Kluwer; 2024.
16. Walls RM, Hockberger RS, Gausche-Hill M, editors. Rosen's emergency medicine: concepts and clinical practice. Ninth edition.,Philadelphia, PA: Elsevier; 2018.
17. Ledermann HP, Schweitzer ME, Morrison WB, et al. MR imaging findings in spinal infections: rules or myths? Radiology 2003; 228(2):506–514. https://doi.org/10.1148/radiol.2282020752
18. Modic MT, Feiglin DH, Piraino DW, et al. Vertebral osteomyelitis: assessment using MR. Radiology 1985; 157(1):157–166. https://doi.org/10.1148/radiology.157.1.3875878
19. Cheung WY, Luk KDK. Pyogenic spondylitis. Int Orthop 2012; 36(2):397–404. https://doi.org/10.1007/s00264-011-1384-6
20. Rausch V, Bannas P, Schoen G, et al. Diagnostic yield of multidetector computed tomography in patients with acute spondylodiscitis. RöFo - Fortschritte Auf Dem Geb Röntgenstrahlen Bildgeb Verfahr 2017; 189(04):339–346. https://doi.org/10.1055/s-0043-101864
21. Shroyer S, Boys G, April MD, et al. Imaging characteristics and CT sensitivity for pyogenic spinal infections. Am J Emerg Med 2022; 58:148–153. https://doi.org/10.1016/j.ajem.2022.05.050
22. Ortiz AO, Levitt A, Shah LM, et al. ACR Appropriateness Criteria® suspected spine infection. J Am Coll Radiol 2021; 18(11):S488–S501. https://doi.org/10.1016/j.jacr.2021.09.001
23. MORGAGNI JoB. De Sedibus, et Causis Morborum per Anatomen Indagatis. Venice: Ex Typographia Remondiniana; 1761.
24. Connor DE, Chittiboina P, Caldito G, et al. Comparison of operative and nonoperative management of spinal epidural abscess: a retrospective review of clinical and laboratory predictors of neurological outcome: clinical article. J Neurosurg Spine 2013; 19(1):119–127. https://doi.org/10.3171/2013.3.SPINE12762
25. Ogg Randell C. Epidural abscess: the missed diagnosis, a correct initial diagnosis and immediate treatment are essential to prevent this spinal infection from causing paralysis. TRIAL 1999; 75:77.
26. DePasse JM, Ruttiman R, Eltorai AEM, et al. Assessment of malpractice claims due to spinal epidural abscess. J Neurosurg Spine 2017; 27(4):476–480. https://doi.org/10.3171/2016.12.SPINE16814
27. French KL, Daniels EW, Ahn UM, et al. Medicolegal cases for spinal epidural hematoma and spinal epidural abscess. Orthopedics 2013; 36(1):48–53. https://doi.org/10.3928/01477447-20121217-09
28. Shantharam G, DePasse JM, Eltorai AEM, et al. Physician and patients factors associated with outcome of spinal epidural abscess related malpractice litigation. Orthop Rev 2018; 10(3):7693. https://doi.org/10.4081/or.2018.7693