[2] Silber JS, Anderson DG, Vaccaro AR, Anderson PA, McCormick P, NASS. Management of postprocedural discitis. Spine J. 2002;2:279–287.
[3] Chen SH, Lee CH, Huang KC, Hsieh PH, Tsai SY. Postoperative wound infection after posterior spinal instrumentation: analysis of long-term treatment outcomes. Eur Spine J. 2015;24:561–570. doi:10.1007/s00586-014-3636-9.
[4] Beiner JM, Grauer J, Kwon BK, Vaccaro AR. Postoperative wound infections of the spine. Neurosurg Focus. 2003;15:E14.
[5] Smith JS, Shaffrey CI, Sansur CA, Berven SH, Fu K-MG, Broadstone PA, et al. Rates of infection after spine surgery based on 108,419 procedures: a report from the Scoliosis Research Society Morbidity and Mortality Committee. Spine. 2011;36:556–563. doi:10.1097/BRS.0b013e3181eadd41.
[6] Patel H, Khoury H, Girgenti D, Welner S, Yu H. Burden of surgical site infections associated with select spine operations and involvement of Staphylococcus aureus. Surg Infect (Larchmt). 2017;18:461–473. doi:10.1089/sur.2016.186.
[7] Ee WWG, Lau WLJ, Yeo W, Von Bing Y, Yue WM. Does minimally invasive surgery have a lower risk of surgical site infections compared with open spinal surgery? Clin Orthop Relat Res. 2014;472:1718–1724. doi:10.1007/s11999-013-3158-5.
[8] Koutsoumbelis S, Hughes AP, Girardi FP, Cammisa FP, Finerty EA, Nguyen JT, et al. Risk factors for postoperative infection following posterior lumbar instrumented arthrodesis. J Bone Joint Surg Am. 2011;93:1627–1633. doi:10.2106/JBJS.J.00039.
[9] Meredith DS, Kepler CK, Huang RC, Brause BD, Boachie-Adjei O. Postoperative infections of the lumbar spine: presentation and management. Int Orthop. 2012;36:439–444. doi:10.1007/s00264-011-1427-z.
[10] Shifflett GD, Bjerke-Kroll BT, Nwachukwu BU, Kueper J, Burket J, Sama AA, et al. Microbiologic profile of infections in presumed aseptic revision spine surgery. Eur Spine J. 2016;25:3902–3907. doi:10.1007/s00586-016-4539-8.
[11] Bémer P, Corvec S, Tariel S, Asseray N, Boutoille D, Langlois C, et al. Significance of Propionibacterium acnes-positive samples in spinal instrumentation. Spine. 2008;33:E971–E976. doi:10.1097/BRS.0b013e31818e28dc.
[12] Sampedro MF, Huddleston PM, Piper KE, Karau MJ, Dekutoski MB, Yaszemski MJ, et al. A biofilm approach to detect bacteria on removed spinal implants. Spine. 2010;35:1218–1224. doi:10.1097/BRS.0b013e3181c3b2f3.
[13] Jo JE, Miller AO, Cohn MR, Nemani VM, Schneider R, Lebl DR. Evaluating the diagnostic yield of computed tomography-guided aspirations in suspected post-operative spine infections. HSS J. 2016;12:119–124. doi:10.1007/s11420-016-9490-z.
[14] Enoch DA, Cargill JS, Laing R, Herbert S, Corrah TW, Brown NM. Value of CT-guided biopsy in the diagnosis of septic discitis. J Clin Pathol. 2008;61:750–753. doi:10.1136/jcp.2007.054296.
[15] Atkins BL, Athanasou N, Deeks JJ, Crook DW, Simpson H, Peto TE, et al. Prospective evaluation of criteria for microbiological diagnosis of prosthetic-joint infection at revision arthroplasty. The OSIRIS Collaborative Study Group. J Clin Microbiol. 1998;36:2932–2939.
[16] Schwotzer N, Wahl P, Fracheboud D, Gautier E, Chuard C. Optimal culture incubation time in orthopedic device-associated infections: a retrospective analysis of prolonged 14-day incubation. J Clin Microbiol. 2014;52:61–66. doi:10.1128/JCM.01766-13.
[17] Gelalis ID, Arnaoutoglou CM, Politis AN, Batzaleksis NA, Katonis PG, Xenakis TA. Bacterial wound contamination during simple and complex spinal procedures. A prospective clinical study. Spine J. 2011;11:1042–1048. doi:10.1016/j.spinee.2011.10.015.
[18] Parvizi J, Azzam K, Ghanem E, Austin MS, Rothman RH. Periprosthetic infection due to resistant staphylococci: serious problems on the horizon. Clin Orthop Relat Res. 2009;467:1732–1739. doi:10.1007/s11999-009-0857-z.
[19] Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, et al. New definition for periprosthetic joint infection: from the Workgroup of the Musculoskeletal Infection Society. Clin Orthop Relat Res. 2011;469:2992–2994. doi:10.1007/s11999-011-2102-9.

2.3. DIAGNOSIS: IMAGING

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QUESTION 1: What is the optimal mode of imaging in the diagnosis of spine infections? If magnetic resonance imaging (MRI) is contraindicated, what imaging modality should be used?

RECOMMENDATION: MRI remains the gold standard for the diagnosis of spinal infection, with sensitivity and specificity above 90%. In the presence of MRI contraindications, consider a combination of modalities, such as computed tomography (CT), positron emission tomography-CT (PET-CT), and single photon emission CT (SPECT)+67Gallium or Gallium-67.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Plain radiography should be the initial exam performed for all patients with non-specific spine or back complaints. In patients with spinal infections, early radiographic findings will occur two weeks to three months after the onset of symptoms. Plain radiographic findings characteristic of a spinal infection include disc space narrowing, end plate irregularity, loss of end plate contour, subchondral defects and/or hypertrophic or sclerotic bone formation. Disc space narrowing has been reported as the most consistent plain radiographic finding occurring in 74% of cases [1]. Late plain radiographic findings include vertebral body collapse, pathologic fractures, segmental kyphotic collapse and/or bony ankylosis. Plain radiography has reported sensitivity of 82% and specificity of 57 to 59% in subjects with pyogenic spondylodiscitis [2,3]. While this modality may not provide the highest level of diagnostic quality, it can give clinicians an understanding of global and focal alignment, deformities associated with infectious processes and mechanical stability [4]. Plain radiographs may also be used for post-treatment surveillance and/or monitoring for potential late deformity or instability associated with these diseases.

CT is an advanced imaging technique that can be utilized for diagnosing spinal infections. It provides higher resolution and multiplanar imaging of the bony architecture. CT findings characteristic of spinal infections can include cystic bony changes, gas within vertebral discs, endplate osteolysis surrounding the vertebral disc and/or paravertebral soft tissue swelling or abscess formation [5–7]. The addition of contrast media during computed tomography can help better delineate the edges of paravertebral abscesses and edematous musculature [5–7]. In cases with neurological deficits or new onset radiculopathy, post-myelogram CT scan can provide excellent detail of the spinal canal and poten-

tial epidural and/or subdural abscesses [8]. In cases where myelogram is performed, it is recommended to analyze the cerebral spinal fluid to rule out meningitis [9]. SPECT is a scintigraphic CT modality that has increased bone contrast resolution, and when combined with technetium or gallium, has high sensitivity and diagnostic accuracy for spinal infections. SPECT with gallium has been shown to be superior to SPECT + technetium and is now the recommended imaging modality for patients with MRI contraindications [10].

MRI remains the gold standard for early and accurate diagnosis of spinal infections [11–20]. MRI has a reported sensitivity of 96%, specificity of 93% and diagnostic accuracy of 94% [18]. MRI has higher accuracy for differentiating degenerative and neoplastic conditions from infections in patients presenting with severe back pain of unknown etiology [11]. While MRI may provide the most detailed information for diagnosing possible infections, it does not reduce the need for tissue biopsy for histological analysis. T1-weighted and T2-weighted sequences should be obtained. The most common MRI findings consistent with spinal infections show decreased vertebral body intensity with poor differentiation between the disc and body on T1-weighted images and increased disc space intensity with marked decreased vertebral body intensity on T2-weighted images [16,18,20]. Utilizing gadolinium contrast can enhance MRI ability to detect and delineate epidural abscesses [21]. All publications consider MRI the gold standard imaging modality for spinal infections and recommend it should be used in all patients without MRI-specific contraindications.

Radionucleotide studies are another modality that is useful for diagnosing spinal infections. These include technetium-99m bone scans, gallium-67 scans, and indium-111 labeled leukocyte scans. Pathologic changes have been shown to appear sooner on radionucleotide studies compared to plain radiography [22–27]. Gallium scans have demonstrated earlier diagnosis of disc-space infections compared to technetium scans and have a reported sensitivity of 89%, specificity of 85% and accuracy of 86% [22,23,28]. Technetium-99m scans have a reported sensitivity of 90%, specificity of 78% and accuracy of 86%.18 When both gallium and technetium scans are performed together, the sensitivity is increased to 90%, specificity 100% and accuracy is 94%.18

Indium-111 scans are known to be sensitive for appendicular skeletal infections, however sensitivity is low in the spine [29–32]. In patients with low-virulence chronic infections, indium-111 scans can provide false-negative results due to white blood cell pooling with any inflammatory process [31]. Indium scans may also result in false-positive results in neoplastic conditions. One important advantage of indium-111 scans is the ability to differentiate non-infectious conditions such as hematoma or seroma in patients with unclear soft tissue etiology. This may be a valuable diagnostic step when investigating possible postoperative infections. Overall, most publications endorsed less utility for radionucleotide studies versus MRI. However, in patients with MRI contraindications, technetium-99m combined with gallium-67 studies is another method that has high sensitivity, specificity and diagnostic accuracy similar to MRI.

There is no single diagnostic test with 100% accuracy for these devastating diseases. A full diagnostic workup includes laboratory studies, blood cultures, imaging and tissue histological analyses. It is generally accepted that plain radiography should be the first imaging study obtained, however, diagnostic sensitivity is low. MRI remains the gold standard with the highest sensitivity, specificity and accuracy compared to other modalities. In the presence of MRI contraindications, clinicians should utilize SPECT+gallium-67 or gallium-67 and technetium-99 combined scans to achieve similar diagnostic accuracy as MRI.

REFERENCES

[1] Sapico FL, Montgomerie JZ. Pyogenic vertebral osteomyelitis: report of nine cases and review of the literature. Rev Infect Dis. 1979;1:754–776.
[2] Grados F, Lescure FX, Senneville E, Flipo RM, Schmit JL, Fardellone P. Suggestions for managing pyogenic (non-tuberculous) discitis in adults. Joint Bone Spine. 2007;74:133–139. doi:10.1016/j.jbspin.2006.11.002.
[3] Jevtic V. Vertebral infection. Eur Radiol. 2004;14 Suppl 3:E43–E52. doi:10.1007/s00330-003-2046-x.
[4] Cornett CA, Vincent SA, Crow J, Hewlett A. Bacterial spine infections in adults: evaluation and management. J Am Acad Orthop Surg. 2016;24:11–18. doi:10.5435/JAAOS-D-13-00102.
[5] Golimbu C, Firooznia H, Rafii M. CT of osteomyelitis of the spine. AJR Am J Roentgenol. 1984;142:159–163. doi:10.2214/ajr.142.1.159.
[6] Kattapuram SV, Phillips WC, Boyd R. CT in pyogenic osteomyelitis of the spine. AJR Am J Roentgenol. 1983;140:1199–1201. doi:10.2214/ajr.140.6.1199.
[7] Lardé D, Mathieu D, Frija J, Gaston A, Vasile N. Vertebral osteomyelitis: disk hypodensity on CT. AJR Am J Roentgenol. 1982;139:963–967. doi:10.2214/ajr.139.5.963.
[8] Brant-Zawadzki M, Burke VD, Jeffrey RB. CT in the evaluation of spine infection. Spine. 1983;8:358–364.
[9] Fraser RA, Ratzan K, Wolpert SM, Weinstein L. Spinal subdural empyema. Arch Neurol. 1973;28:235–238.
[10] Love C, Patel M, Lonner BS, Tomas MB, Palestro CJ. Diagnosing spinal osteomyelitis: a comparison of bone and Ga-67 scintigraphy and magnetic resonance imaging. Clin Nucl Med. 2000;25:963–977.
[11] Abram SR, Tedeschi AA, Partain CL, Blumenkopf B. Differential diagnosis of severe back pain using MRI. South Med J. 1988;81:1487–1492.
[12] Bruns J, Maas R. Advantages of diagnosing bacterial spondylitis with magnetic resonance imaging. Arch Orthop Trauma Surg. 1989;108:30–35.
[13] Carragee EJ. Pyogenic vertebral osteomyelitis. J Bone Joint Surg Am. 1997;79:874–880.
[14] Carragee EJ. The clinical use of magnetic resonance imaging in pyogenic vertebral osteomyelitis. Spine. 1997;22:780–785.
[15] Carragee EJ, Kim DH. A prospective analysis of magnetic resonance imaging findings in patients with sciatica and lumbar disc herniation. Correlation of outcomes with disc fragment and canal morphology. Spine. 1997;22:1650–1660.
[16] Dagirmanjian A, Schils J, McHenry M, Modic MT. MR imaging of vertebral osteomyelitis revisited. AJR Am J Roentgenol. 1996;167:1539–1543. doi:10.2214/ajr.167.6.8956593.
[17] Ledermann HP, Schweitzer ME, Morrison WB, Carrino JA. MR imaging findings in spinal infections: rules or myths? Radiology. 2003;228:506–514. doi:10.1148/radiol.2282020752.
[18] Modic MT, Feiglin DH, Piraino DW, Boumphrey F, Weinstein MA, Duchesneau PM, et al. Vertebral osteomyelitis: assessment using MR. Radiology. 1985;157:157–166. doi:10.1148/radiology.157.1.3875878.
[19] Post MJ, Quencer RM, Montalvo BM, Katz BH, Eismont FJ, Green BA. Spinal infection: evaluation with MR imaging and intraoperative US. Radiology. 1988;169:765–771. doi:10.1148/radiology.169.3.3055039.
[20] Shih TT, Huang KM, Hou SM. Early diagnosis of single segment vertebral osteomyelitis–MR pattern and its characteristics. Clin Imaging. 1999;23:159–167.
[21] Post MJ, Sze G, Quencer RM, Eismont FJ, Green BA, Gahbauer H. Gadolinium-enhanced MR in spinal infection. J Comput Assist Tomogr. 1990;14:721–729.
[22] Bruschwein DA, Brown ML, McLeod RA. Gallium scintigraphy in the evaluation of disk-space infections: concise communication. J Nucl Med. 1980;21:925–927.
[23] Dux S, Halevi J, Pitlik S, Rosenfeld JB. Early diagnosis of infective spondylitis with Gallium-67. Isr J Med Sci. 1981;17:451–452.
[24] Adatepe MH, Powell OM, Isaacs GH, Nichols K, Cefola R. Hematogenous pyogenic vertebral osteomyelitis: diagnostic value of radionuclide bone imaging. J Nucl Med. 1986;27:1680–1685.
[25] Haase D, Martin R, Marrie T. Radionuclide imaging in pyogenic vertebral osteomyelitis. Clin Nucl Med 1980;5:533–537.
[26] Osenbach RK, Hitchon PW, Menezes AH. Diagnosis and management of pyogenic vertebral osteomyelitis in adults. Surg Neurol. 1990;33:266–275.
[27] Waldvogel FA, Papageorgiou PS. Osteomyelitis: the past decade. N Engl J Med. 1980;303:360–70. doi:10.1056/NEJM198008143030703.
[28] Norris S, Ehrlich MG, McKusick K. Early diagnosis of disk space infection with 67Ga in an experimental model. Clin Orthop Relat Res. 1979:293–298.
[29] Merkel KD, Fitzgerald RH, Brown ML. Scintigraphic evaluation in musculoskeletal sepsis. Orthop Clin North Am. 1984;15:401–416.
[30] Fernandez-Ulloa M, Vasavada PJ, Hanslits ML, Volarich DT, Elgazzar AH. Diagnosis of vertebral osteomyelitis: clinical, radiological and scintigraphic features. Orthopedics. 1985;8:1144–1150.
[31] Whalen JL, Brown ML, McLeod R, Fitzgerald RH. Limitations of indium leukocyte imaging for the diagnosis of spine infections. Spine. 1991;16:193–197.
[32] Wukich DK, Van Dam BE, Abreu SH. Preoperative indium-labeled white blood cell scintigraphy in suspected osteomyelitis of the axial skeleton. Spine. 1988;13:1168–1170.