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INVITED REVIEW – OPEN ACCESS

An Overview of Imaging in Pediatric Spinal Infections

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ABSTRACT

Despite being rare than in adults, pediatric spinal infections (SIs) are important diseases that commonly lead to poor neurological prognosis morbidity and hospitalization. The etiology, location, and management are different for different ages. The majority of patients present with subtle and non-specific clinical symptoms that are difficult to diagnose. Therefore, imaging continues to be crucial for the diagnosis, localization, management, and follow-up of SI. In this review, we will discuss and highlight the imaging features of SI and complications according to affected locations.

Keywords: Imaging, intradural-extramedullary infections, pediatrics, spinal infections, spondylodiscitis

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INTRODUCTION

Spinal infections (SIs) in children are less common than in adults and are usually classified according to location as those affecting the spinal cord, the nerve roots, the vertebral body, the intervertebral disk, and epidural, intradural, and intrathecal space. The incidence of spinal infection below 20 years is 0.3:100,000 in developed countries (1). At diagnosis, the mean age is around 2–7 years (1). SIs are classified according to their etiologies as pyogenic (the most frequent), granulomatous (such as tuberculosis [TB] and brucellosis), fungal, and parasitic (2). Clinical presentation is often subtle and non-specific, causing a delay in the diagnosis (3). Radiologic imaging plays an important role in early detection, management, and follow-up and reduces the sequelae in SI. This review aims to discuss the radiologic spectrum of each type of pediatric spinal infection.

Studies on imaging in spinal infection deal with adult populations, and there are only limited studies data on pediatric SIs. Our search was performed on the PubMed databases using various combinations of the keywords: SIs, pediatrics, spondylodiscitis (SD), imaging, and intradural-extramedullary infections. The examined period of time was between the years 1994 and 2022.

EXTRADURAL INFECTIONS

Bacterial (Pyogenic) Spondylodiscitis

Children differ from adults in the routes and the site of pyogenic SIs. In younger children, the primary site of infection is the disk and the presence of perforating vascular channels across the growth plate allows for primary infection of the disk followed by secondary infection of the vertebral body. In older children, infection classically begins in the anterior vertebral endplates, in the form of microabscesses (4). Infection may spread into paravertebral and epidural spaces, vertebral bodies in proximity (5). Staphylococci and streptococci are the most common causative bacterial agents in SD. The incidence of pediatric discitis is bimodal; approximately 60% of childhood SD occurs in children aged 6 months–4 years. The second peak between 10 and 14 years has greater risk for vertebral osteomyelitis (6). The lumbar region (L3-4 and L4-5 interspaces) is the predominantly affected region in children. Radiographs may be normal or show narrowing disk space after 2–4 weeks. In the early stages, discitis manifest as an increased T2 signal and enhancement of the affected disk on post-contrast T1WI and followed by a decrease in height of the intervertebral disk. Signal changes within the endplates and subchondral regions are faint, initially. Low T1 and high T2 signals of the vertebral body, as well as heterogeneous contrast enhancement, may indicate the presence of acute or subacute inflammation (Fig. 1). Initially, cortical continuity of the endplates may be seen while the vertebral body may show a high signal on T2WI. With the loss of cortical continuity and destruction of the endplate, and also through the venous plexus, infection spreads to the disk and also to the neighboring vertebral body. Epidural extension with or without paraspinal extension is also another feature. In the chronic stages, findings such as new bone formation, osteophytosis, sclerosis, and ankylosis can be seen. Normalization of the T1 signal and decrease in T2 hyperintensity of the involved vertebral body may indicate healing (7).

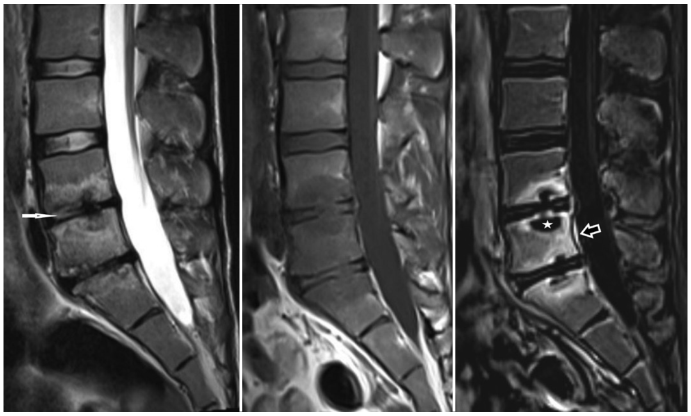

Figure 1. A 15-year-old boy with pyogenic spondylodiscitis. Sagittal T2WI and T1WI show a high signal of L4-5 intervertebral disk with loss of the intranuclear cleft (thin arrow), and Schmorl's nodes, irregularity of the related vertebral endplates. T2 WI demonstrates a bright signal in the adjacent vertebral bodies with heterogeneous enhancement noted on the post-contrast T1WI. Furthermore, anterior epidural enhancement was noted on post-contrast T1WI (hollow arrows)

Diffusion-weighted magnetic resonance imaging (DWI) has become helpful to determine the extent of pyogenic SD and differentiation of epidural phlegmon or abscesses. The abnormal magnetic resonance imaging (MRI) features on the vertebral body, disk, and paravertebral soft tissue may persist for 4–8 weeks to months despite antibiotic therapy (8). The spinal chronic recurrent multifocal osteomyelitis (CRMO) is a disorder diagnosed by exclusion from bacterial subacute or chronic osteomyelitis SD (9). Irregularity of one vertebral endplate, bone marrow edema, and vertebral body collapse are the non-specific MRI findings. However, absence of crossing the intervertebral space typically distinguish CRMO from pyogenic spondylodiscitis (9).

Tuberculous Spondylodiscitis

Spinal TB is common in children in the developing countries. In children, the disease is more indolent, aggressive, and more prone to developing abscesses. In children, TB most commonly affects the thoracolumbar region (5) According to the location, tuberculous infections have several radiologic features: Anterior, paradiscal, and central types. In the anterior type, the infection spreads through the anterior arterial pathways and travels underneath the anterior longitudinal ligament. During the early stages, relative preservation of the disk and disk space is seen (10) However, the disk may also be involved solely as it has a far richer blood supply during childhood. The anterior part of the vertebral bodies demonstrates a high signal on T2WI and a low signal with enhancement on postcontrast T1WI images. Spreading beneath the longitudinal ligament also causes paraspinal abscesses (Fig. 2) (5). The craniocaudal extension can result in skipping lesions of involved bones/disks, which are characterized by normal vertebral levels (3). Anterior type arises from the central body, leading to vertebra plana. Because of the preferential involvement of the anterior vertebral column, spinal TB causes body compression fracture and evident kyphosis in approximately 73.9% of all pediatric cases. The risk of late kyphosis in children with spinal TB relies on age (5 years), the

Figure 2. An 8-year-old boy developed painful torticollis and was diagnosed with tuberculous spondylitis. Sagittal images show patchy high T2 and T1 signals with the heterogeneous enhancement of C2 and destruction of the odontoid. Post-contrast T1WI demonstrates thickening and diffuse enhancement of adjacent soft-tissue pre-vertebral and adjacent to the odontoid process (stars)

extent of the disease (more than 2 vertebrae), level of involvement (thoracic), pattern of involvement, and end-plate damage (11). Buckling that leads to collapse of the spine at the dorsolumbar and lower dorsal spine is unique to childhood spinal TB. In the paradiscal types, which are very rare in children, the infection begins on the lateral sides of the disks, leading to decrease in disk space.

Brucella Spondylodiscitis

Brucellosis of the spine affecting children is very rare and only a few studies on pediatric spinal brucellosis have been published (12). Brucellosis commonly involves the lumbar spine followed by the thoracic and cervical spine (13) The imaging features of brucellosis can be indistinguishable from those of tuberculous spondylitis. Spinal brucellosis appears to be less aggressive than TB, and paraspinal calcification tends to be less than in TB (14, 15). Brucella spondylitis has two radiologic manifestations: The focal form, which involves only the anterior part of the superior endplate, and the diffuse form, which involves the whole vertebral body. Anterior osteophytes (parrot's beak), sclerosis, and osteoporosis of the involved vertebral body, and reduction of the disk space are the main imaging features (16). In Brucellar, SD infection begins from the initial infection point (frequently the frontal edge of the endplate) and then invading the disk and intervertebral disks are affected only after the vertebral bodies (16). Multilevel involvement was found to occur in 5%–36% of cases in the literature (17, 18). Healing phase begins almost concurrent with the inflammatory stage and intact vertebral architecture is typical.

Fungal Spondylodiscitis

Fungal infections of the spine are rare conditions that commonly affect immunocompromised patients. Spinal fungal infection includes SD, osteomyelitis, and meningitis. No specific radiological findings distinguish fungal infections (*Candida* and *Aspergillus*) from other discitis. Similar to TB, fungal SD tends to involve the anterior vertebral body and has a predilection for paraspinal intrusion, sparing the intervertebral disk due lack of proteolytic enzymes. Due to the relatively mild inflammatory changes, and low T1 and high T2 signals, contrast enhancement is indistinct. If the spondylitis contains T2 hyperintense paraspinal abscesses and intramedullary abscesses, *Candida* should be considered (7).

Spinal Epidural Abscess (SEA)

A SEA or empyema is a neurosurgical emergency requiring prompt diagnosis. The majority of cases develop by hematogenous dissemination from a previous infection and direct spread from a primary source of infection (discitis/dermal sinus). Sterile effusions and normal cerebrospinal fluid (CSF) do not typically show diffusion restriction. In the early phase, "phlegmon" refers to prominent epidural space and shows an intermediate signal on T1WI, and T2WI, together with homogeneous enhancement. Epidural abscess appears as high signal intensity on T2WI and low signal on T1WI with rimlike enhancement. Restricted diffusion of the necrotic center is the clue for an epidural abscess. Phlegmon can be treated medically while abscesses may require prompt surgical intervention (Fig. 3). TB "cold" or "Pott" abscess can involve subarachnoid, subdural, or epidural spaces as well (19). Calcification within the abscess on CT is almost always indicative of TB.

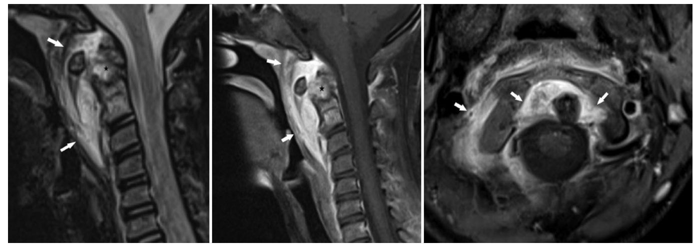

Figure 3. A 16-year-old boy with pyogenic spondylodiscitis and back pain. There is an extensive epidural collection, which is predominantly posterior in distribution, tracking down from the lower thoracic levels until the S3 levels, and demonstrating peripheral thick rim enhancement consistent with an abscess (arrows). It causes canal stenosis, predominantly at the mid and lower thoracic levels, and compresses the cord anterior

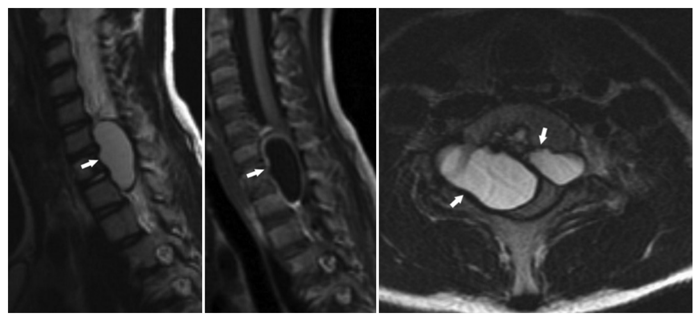

Figure 4. An 8-year-old girl with numbness in her left arm. On sagittal T2W, well-defined, thin-walled, cystic lesion (arrows) located in the intradural extramedullary space and compressing the spinal cord. Ring-like enhancement was also detected. On T2WI, cystic lesions extend to the neural foramen and compress the spinal cord

INTRADURAL EXTRAMEDULLARY INFECTIONS

Bacterial Subdural Abscess

Spinal subdural abscesses are a very rare entity following hematogenous spread from iatrogenic contamination and generally accompany pyogenic spondylodiscitis (20). The most common agent of spinal subdural space infection in childhood is *M. Tuberculosis*, and the thoracic region is the most common involved location (21). On MRI, the high signal in T2WI, the low signal in T1WI crescent-shaped thick-walled collection with rim enhancement, and restricted diffusion strongly suggest an abscess (22). The subdural abscess appears as a collection within the epidural fat and can be the primary manifestation of bacterial SI. Fat suppression in conjunction with contrast enhancement provides a distinction between epidural fat and subdural abscess (20, 22).

Tuberculous Arachnoiditis

Exudate around the lumbosacral segments of the spinal cord and nerve roots, results "block" the CSF that is seen hyperintense CSF locations. Acute imaging features of radiculomyelitis are diffuse enhancement of nerve roots and meninges. No intradural enhancement with thickening of nerve roots reflects adhesion inter-root adhesion in the chronic stage (12). "Fixed" peripherally nerve roots within the thecal sac lead to the typical "empty thecal sac" sign, on T2WIs (23).

Spinal Echinococcosis

The thoracic vertebra is the most commonly involved segment (50%), followed by the lumbar (20%), sacral (20%), and cervical (10%) segments (24). About 90% of cases localized to the bone and extradural space. Intradural-extramedullary lesions are more common in comparison to intramedullary. MRI demonstrates tube-like cystic lesions that are enhanced peripherally without significant edema and a hypointense fibrous capsule that surrounds the cyst (Fig. 4) (25).

INTRAMEDULLARY INFECTIONS

Bacterial Myelitis

In children, isolated bacterial myelitis is rare, and in the patients, there is usually a hematogenous or direct spread from a distant infection source. In bacterial myelitis, the most common causative pathogens are staphylococcus and streptococcus. Myelitis is the initial process and may progress into spinal cord abscesses if left untreated (26). Reported risk factors for spinal cord abscess include congenital dermal sinuses (27). Or infective endocarditis. The MRI appearance is swollen and edematous T2 hyperintense spinal cord extending over more than 2 segments. Patchy, ring-like enhancements have all been described (13). Cord abscess demonstrated ill-defined, T2 hyperintense, ring-enhancing lesions with low intensity on T1WI (Fig. 5). Hyperintensity on DWI helps to distinguish abscess from cystic intramedullary tumors (28).

Figure 5. A 1-year-old boy with a 20-day history of progressive paraplegia and bladder dysfunction. Sagittal T2WI and post-contrast T1WI images show thick septated multiple cystic cavities (white arrows) with rim enhancement (hollow arrows) at the thoracal and lumbar regions and spinal cord edema. It mimics spinal gliomas. The histopathological diagnosis was intramedullary abscess secondary to an infected dermoid cyst

Tuberculous Myelitis

Tuberculous myelitis manifests in several forms such as acute transverse myelitis, longitudinally extensive transverse myelitis, spinal tuberculoma, syringomyelia, and very rarely spinal tuberculous abscess (18). In the early stage, the spinal cord shows a variable degree of edematous swelling and enhancement extending over three or more spinal segments. The fibrin-coated nerve roots of the cauda equina show enhancement, and enhancement can be linear or nodular (23). Intramedullary spinal tuberculomas are less frequent than intradural extramedullary tuberculomas. Sharper margin, hyperintensity with a hypointense rim on T2WI, and ring-like enhancement strongly suggest tuberculoma (29).

Viral Myelitis

Herpes viruses, varicella-zoster virus (VZV), cytomegalovirus (CMV), and enteroviruses including poliovirus can result in myelopathy and radiculopathy. In acute viral myelitis, the spinal cord shows non-specific diffuse non-expansile T2 hyperintensity on MRI. Longitudinal serpiginous, enhancing lesions, and focal rounding lesions involving the ipsilateral dorsal column and posterior horn are the findings reported in VZV myelitis (26, 30). Hyperintensity on T2WI in the center of the spinal cord with and without enhancement was reported findings for CMV myelitis (13).

VZV Myelopathy

The symptoms and MRI features correspond closely with the dermatomal distribution of the lesions (26). Direct invasion of the spinal cord may appear as diffuse hyperintensity on T2WI due to edema focal or multifocal enhancement near the dorsal nerve root. Necrosis or hemorrhage within the cord may occur (31).

CMV Polyradiculopathy

CMV radiculitis or myelitis is known to usually develop in immunodeficient patients with HIV infection. MRI findings include diffuse enhancement and thickening of nerve roots, enhancement along with the anterior-posterior parts of spinal cord, and nodular leptomeningeal enhancement in the lower thoracic cord (13, 32).

FUNGAL MYELITIS

The most common fungal pathogens responsible for myelitis are *Aspergillus* and *Candida* (33). *Aspergillus* frequently causes spinal cord myelitis or meningomyelitis due to hematogenous dissemination. Spinal cord lesions in *Candida* SD are frequently caused by the vertebral collapse and/or spinal cord infarction, rather than by an associated epidural abscess (34).

CONCLUSION

Due to rarity and non-specific presentations, SIs may result in missed or delayed diagnosis in the pediatric age group. Conventional radiographs are not sensitive to SI. Imaging techniques, especially MRI, are crucial in the early detection and monitoring of SI. Hence, early diagnosis and prompt initiation of appropriate treatment may prevent potential complications of SIs such as the formation of abscesses, spinal deformities, and neurological impairment.

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