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REVIEW ARTICLE

Disorders of paravertebral lumbar muscles: from pathology to cross-sectional imaging

Guillaume Bierry · Stéphane Kremer · Frauke Kellner · Maher Abu Eid · Adriana Bogorin · Jean-Louis Dietemann

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Abstract Paravertebral lumbar muscles are important for spine stabilization and mobility. They may be abnormal in several disorders that may be associated with pain or functional impairment. Special attention should be paid to the paravertebral muscles during imaging, so that a possible muscular disease is not overlooked, especially in patients with low back pain. This article reviews such imaging abnormalities.

Keywords Spine · Muscles · Magnetic resonance imaging (MRI) · Computed tomography (CT)

Introduction

Paravertebral muscles play a crucial role in spine stabilization and mobility [1]. After the muscles of the thigh, they account for the second biggest muscle mass of the body. Paravertebral muscles may not be sufficiently evaluated during computed tomography (CT) and magnetic resonance imaging (MRI) examinations of the lumbar spine in patients with low back pain, although they may be the source of the patients' symptoms.

May different abnormalities may be found in the paraspinal muscles, including neoplasm, infection, traumatism, congenital and immune myopathy, as well as abnormalities relating to the close anatomical and functional relationships between the spine and paravertebral muscles.

The aim of this article is to review the different abnormalities that can be found in the paravertebral lumbar muscles.

G. Bierry (✉) · S. Kremer · M. Abu Eid · A. Bogorin · J.-L. Dietemann
Department of Radiology 2, University Hospital, Hautepierre Hospital,
10 avenue Molière,
67098 Strasbourg, France
e-mail: guillaume.bierry@chru-strasbourg.fr

F. Kellner
Department of Radiology, Inselspital Bern,
Berne, Switzerland

Anatomy

Back muscles are organized in layers and divided into two categories: intrinsic muscles and extrinsic muscles (Fig. 1).

The extrinsic muscles (latissimus dorsi and serratus muscles) cover the intrinsic muscles and are mostly responsible for limb motion. They are not addressed in this article.

The intrinsic muscles regulate tonus and motion of the spine. Intrinsic muscles are divided in three groups: a deep layer (rotatores, interspinalis and intertransversarii muscles), a middle layer (multifidus muscle) and a superficial layer (sacrospinalis muscle formed by the longissimus and iliocostal muscles). Intrinsic muscles represent a muscular column with a cross-sectional area of approximately 10 cm^2 to 25 cm^2.

The multifidus muscle is located in the bilateral groove at the sides of the spinous processes and connects the spinal lamina with to the mammillary process of the vertebra two levels below the origin [2]. They induce extension, rotation and lateral flexion and mainly act as stabilizers of the spine in controlling intersegmental motion [3].

Intertransversarii and interspinalis muscles connect to the transverse and spinous processes, respectively, of two adjacent vertebrae. They can be considered as proprioceptive transducers helping in spinal positioning. Rotatores muscles connect transverse processes and laminae of two adjacent vertebrae.

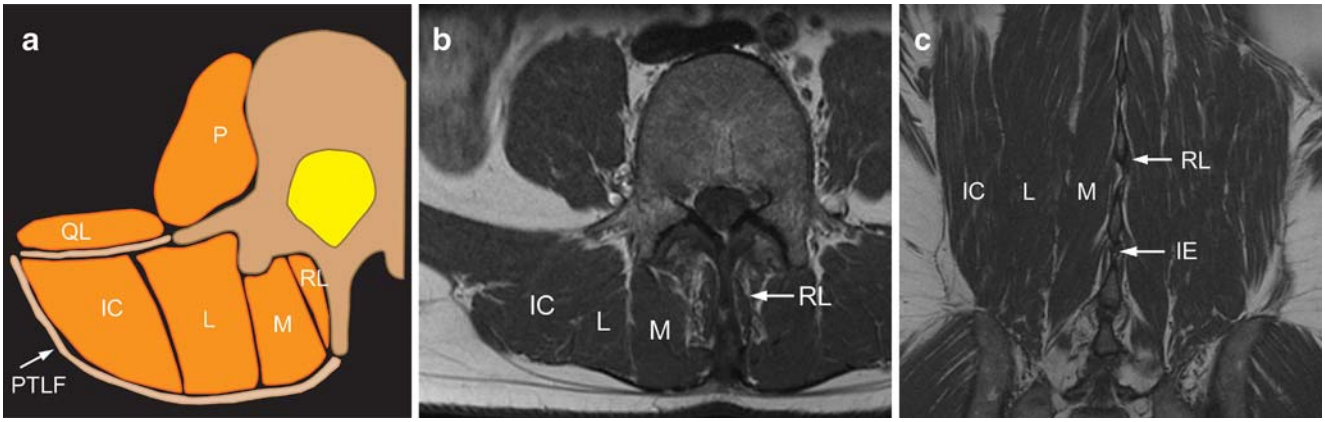

Fig. 1 Anatomy of the intrinsic back muscles. Line diagram of axial section at the level of L3 (**a**); axial (**b**) and coronal (**c**) T1-weighted MR images [time to repeat (TR) 450 ms; time to echo (TE 20) ms]. The superficial layer is the erector spinae muscle formed by longissimus (*L*) and iliocostal muscles (*IC*). The deep layer is composed of the multifidus muscle (*M*), the interspinalis muscle (*IE*) and the rotators lumborum muscles (*RL*). Intrinsic muscles are covered by the posterior thoraco-lumbar fascia (*PTLF*) and separated from the psoas muscle (*P*) and the quadratus luborum muscle (*QL*) by the middle thoracolumbar fascia

Erector spinae muscle is a vast musculotendinous mass formed by two muscular groups: the longissimus muscle, medially, and the iliocostal muscle, laterally. Longissimus muscle fibers arise from the lumbar and inferior thoracic transverse processes, while iliocostalis muscle fibers arise from the angles of the lower ribs and from the lateral one-quarter of the lumbar transverse processes. In the lumbar region, both muscle fibers attach to a robust aponeurosis, the erector spinae aponeurosis, attached to the medial sacral crest, lumbar spinous processes and ilium. During flexion, the erector spinae muscle controls rather than produces motion and prevents excessive motion [4]. During lateral bending and twisting, the erector spinae muscle both controls and produces motion.

The posterior ramus of the spinal nerve is responsible for innervation of the intrinsic muscles [5].

Histopathological and imaging aspects of muscular disorders

Acute muscular injury causes a non-specific hyperintensity caused by edema and bleeding. In subacute and chronic stages, normal muscular fibers degenerate, reflected by two patterns of atrophy: neurogenic and myogenic (Table 1).

Myogenic atrophy

Myogenic atrophy is due to direct injury of muscle cells and may be caused by infection, congenital myopathies, inflammatory diseases and trauma. Histopathological analysis demonstrates diffuse and heterogeneous involvement (Fig. 2). Besides muscle degeneration, there are signs of regeneration, scattered chronic inflammatory cells, fibrosis and focal areas of fatty tissue between degenerated fibers.

CT demonstrates decreased muscle density, without form changes [6]. On MR images, muscle signals are hyperintense on T2-weighted images and demonstrate enhancement after injection of gadolinium-containing contrast agent (Fig. 3).

Neurogenic atrophy

Neurogenic atrophy is a consequence of indirect muscle damage secondary to nerve injury. Muscle fibers without innervation degenerate.

On histopathological analysis, the distribution of atrophic fibers is more focal than in myogenic atrophy (Fig. 4). There is a “grouped atrophy” of the fibers that are clustered in “fish banks”. The atrophic fibers are small and angular, while adjacent fibers remain normal. Focal areas of fatty tissue can be observed between degenerated fibers.

CT shows decreased muscle size with contour modifications, but only slightly decreased density [7–9]. Involved muscles present with high signal intensity on T2-weighted MR images, hypointense signal on T1- weighted MR

Table 1 Characteristics of neurogenic and myogenic involvement on cross-sectional imaging

Parameter	Myogenic amyotrophy	Neurogenic amyotrophy
Distribution of involvement	Diffuse	Systematized, focal
Muscle shape	Conserved	Modified
Muscle size	Conserved	Reduced
CT density	Reduced	Reduced
MR signal		
T1	Hypointense	Hypointense
T2	Hyperintense	Hyperintense
Enhancement	Intense	Intense

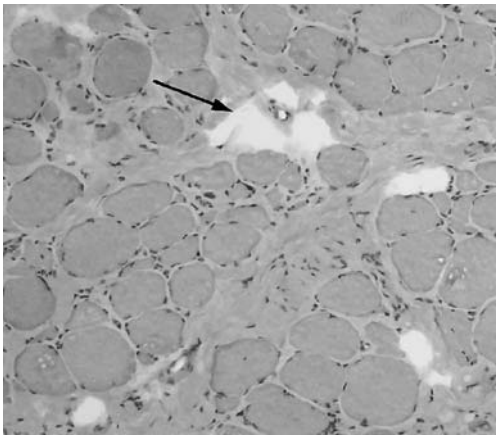

Fig. 2 Histopathologic aspect of myogenic atrophy. Diffuse involvement with presence of fibers of different sizes, with areas of fatty replacement (*arrow*)

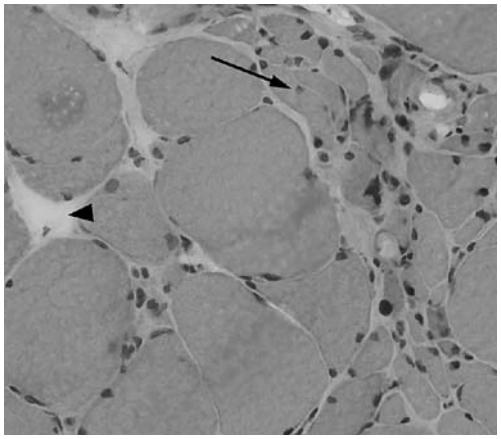

Fig. 4 Histopathologic aspect of neurogenic atrophy. Systematized involvement with degenerated fibers clustered in "fish banks" (*arrow*). Presence of fatty replacement (*arrowhead*)

images, and marked enhancement after intravenous injection of gadolinium (Fig. 5) [10–13].

Clinical relevance

In the acute phase of muscular injury, both of the myogenic and neurogenic type, there is muscular inflammation which may be associated with low back pain or even leg pain [10, 14].

At chronic stages, muscular atrophy with fatty infiltration is observed. The relationship between back pain, muscle weakness and chronic lumbar muscles at the chronic stage remains controversial [15–17].

Imaging

Exploration of the lumbar paravertebral muscles is most commonly performed with MRI. Besides the sagittal images typically included in standard imaging protocols, transverse and coronal T2-weighted MR sequences with fat saturation may be useful in the acute stage of muscular disorders [18]. Transverse and coronal gadolinium-enhanced T1-weighted MR sequences may also be used and are important for identification of muscle abscesses and neoplasms.

Specific abnormalities

Origins of the specific abnormalities

The anatomy of the lumbar spine may explain some of the abnormalities found in this region of the body. Paravertebral muscles cover several articulations, including the facet joints and the sacroiliac joints. Any abnormality affecting those articulations, such as joint infection or periarticular tumor, may involve the spinal muscles.

Degenerative disease of the lumbar spine can lead to direct and indirect injury of the spinal muscles. Discal loss of height and loss of congruence of posterior articulations may increase the range of motion of the involved spinal segments [10, 19]. This may lead to an acute or subacute

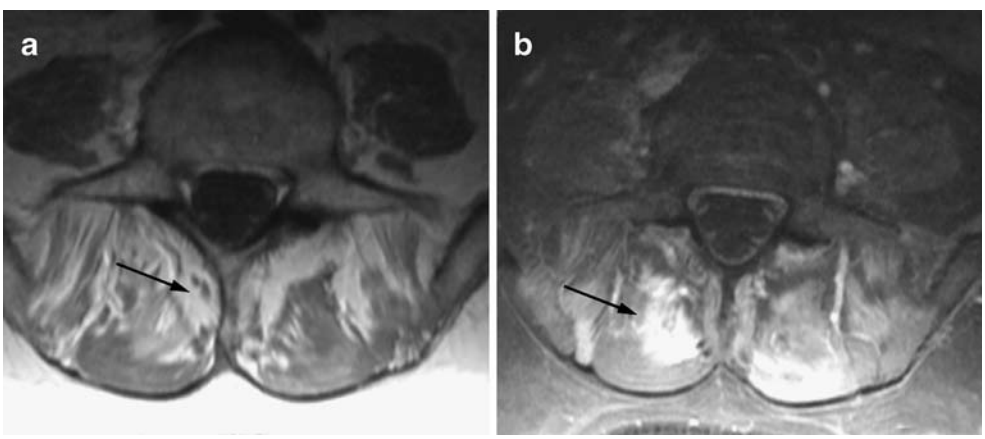

Fig. 3 Myogenic atrophy. **a** Axial T1-weighted MR image [time to repeat (TR) 460 ms; time to echo (TE) 25 ms] demonstrates diffuse and bilateral atrophy, with conservation of the general muscle shape and fatty replacement (*arrow*). **b** Axial gadolinium-enhanced T1-weighted MR image (TR 460 ms; TE 25 ms) shows area of high signal intensity inside the affected paravertebral muscle, revealing muscle edema (*arrow*)

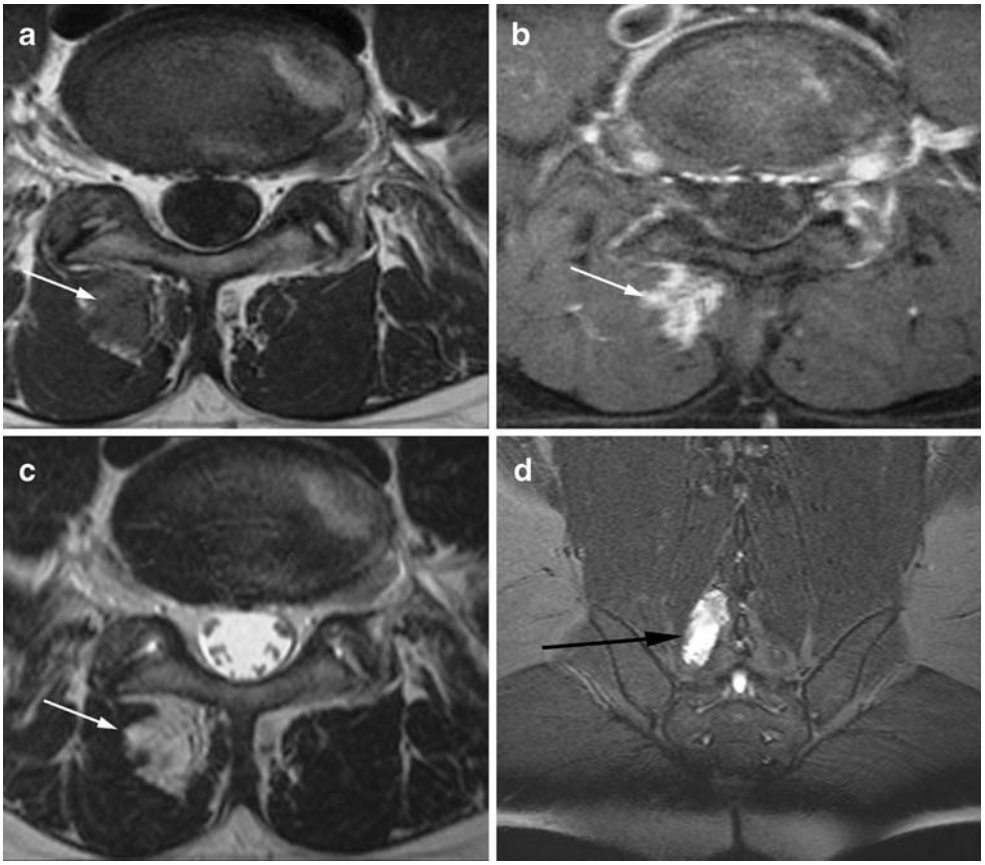

Fig. 5 Neurogenic atrophy. **a** Axial T1-weighted MR image [time to repeat (TR) 460 ms; time to echo (TE) 25 ms] demonstrates systematized involvement of the right multifidus muscle showing focal subtle high signal intensity associated with mild shape modification (*arrow*). **b** Focal enhancement of multifidus muscle after administration of contrast medium (*arrow*). **c** Axial T2-weighted MR image (TR 5 ms, 200 ms; TE 80 ms) shows high signal intensity revealing muscular edema inside the multifidus muscle (*arrow*). **d** Coronal gadolinium-enhanced T1-weighted MR image (TR 460 ms; TE 25 ms) allows determination of the craniocaudal involvement of the right multifidus muscle (*arrow*)

atrophy of the intrinsic muscles (multifidus and interspinalis muscles), demonstrated by signal hyperintensity on fat-suppressed T2-weighted MR images [18, 19]. This muscular atrophy can result from two different mechanisms: muscle avulsion or denervation can occur. The medial branch of the dorsal ramus of the spinal nerve, which innervates those muscles and especially the multifidus, runs into an osseofibrous tunnel realized by the mammillary accessory ligament, where it has a limited extension capacity [10]. The medial ramus can thus be injured in cases of increased spine mobility.

Spinal muscle atrophy in patients with low back pain

The role of the paravertebral muscles in patients with low back pain (LBP) remains controversial. A reduction in spinal muscle cross-sectional area on MRI and CT, with or without reduced muscle density on CT, may be found in patients with acute and chronic LBP, as well as LBP following surgery [8, 20–22].

In degeneration, the increased range of motion between the adjacent spinal segments [23] may induce increased stress to the muscular structures that can damage muscle directly (myogenic atrophy), or indirectly by traumatic denervation (neurogenic atrophy) [19] (Fig. 6). Neurogenic atrophy may also occur following lumbar surgery with spinal nerve injury (Fig. 7). The multifidus muscle is predominantly affected in patients with LBP, because of its exclusive innervation by the medial ramus of the dorsal root of the spinal nerve without segmental nerve supply as present in the others spinal muscles [24]. Its atrophy is, in

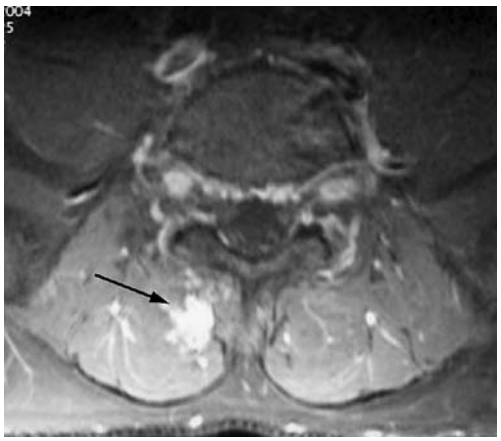

Fig. 6 Neurogenic degeneration of the right multifidus muscle in a 61-year-old patient with degenerative spine disorder and chronic low back pain. Presence of isolated multifidus muscle involvement (*arrow*) on gadolinium-enhanced T1-weighted image [time to repeat (TR) 460 ms; time to echo (TE) 25 ms] with shape modification ipsilateral to the patient's pain

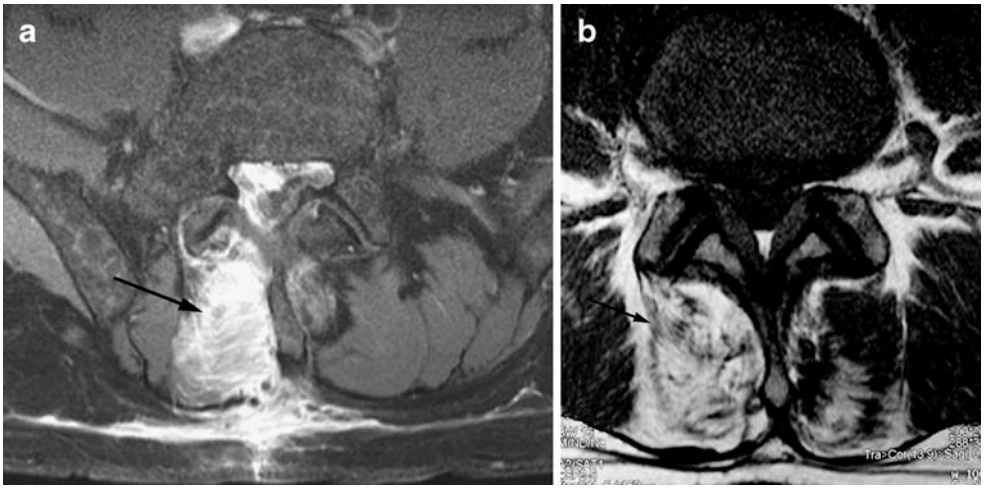

Fig. 7 Neurogenic degeneration of the right multifidus muscle after spinal surgery in a 65-year-old patient. **a** Extensive enhancement of the right multifidus muscle on gadolinium-enhanced T1-weighted image [time to repeat (TR) 460 ms; time to echo (TE) 25 ms] 1 month after surgery (*arrow*). **b** Intense atrophy with massive fatty replacement of multifidus muscle (*arrow*) 6 months after surgery

general, ipsilateral to the side of the pain and is concentrated at the level of the injured nerve.

Muscular atrophy in LBP may also be a consequence of pain [7]. Pain-related nervous inhibition of muscle activation limits mobility of the involved muscle groups in order to protect damaged tissue. The reduced activity induces muscular atrophy that can perpetuate LBP [24].

Camptocormia

Camptocormia (also called progressive lumbar kyphosis or bent-spine syndrome) is a reducible lumbar kyphosis that appears when the patient is in the standing position. Camptocormia affects patients older than 60 years and reflects an axial myopathy of controversial origin. Some authors considered camptocormia as a symptom of axial myopathy secondary to muscular diseases, such as polymyositis, dermatomyositis, mitochondrial myopathy, or generalized diseases, such as amyloidosis, hypothyroidism, paraneoplasic conditions or neurological disorders (Parkinson's disease, amyotrophic lateral sclerosis) [25, 26]. Others consider camptocormia as a primary axial myopathy with muscular disease restricted to the spinal muscles, with a possible genetic transmission [25, 27]. For those authors, the condition can involve the whole axial musculature and induce associated upper thoracic kyphosis with head drop [27].

An extensive myogenic atrophy is generally observed. Decreased muscular mass of the paraspinal spaces with an increase of fat is typical. The entire muscle is affected proportionally to the time span of the illness, with possible important cranial extension. The CT scan shows area of low density in the muscles, a heterogeneous structure widening of the fatty spaces between the different muscular bundles [25] (Fig. 8).

Lumbar myonecrosis and compartment syndrome

Myonecrosis is characterized by ischemia-induced muscle cell edema and necrosis and leads to myogenic atrophy. Myonecrosis can be observed in compartment syndrome, during which there is elevated pressure within an anatom-

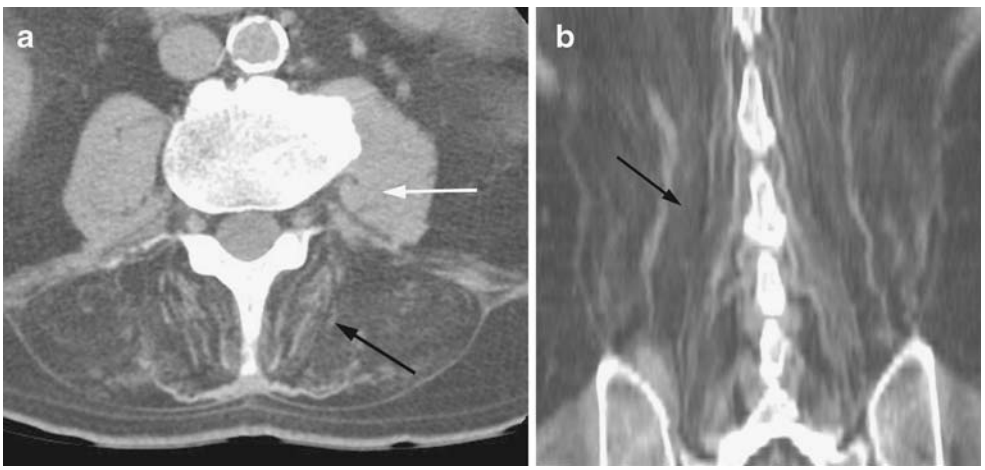

Fig. 8 CT aspect of lumbar camptocormia. **a**) Axial CT scan shows important muscle loss in paravertebral areas (*black arrow*) in an 80-year-old patient who had a reducible lumbar kyphosis for 10 years. Note the normal aspect of psoas muscles (*white arrow*). **b** Coronal reformation demonstrates the craniocaudal extent of muscle loss (*arrow*)

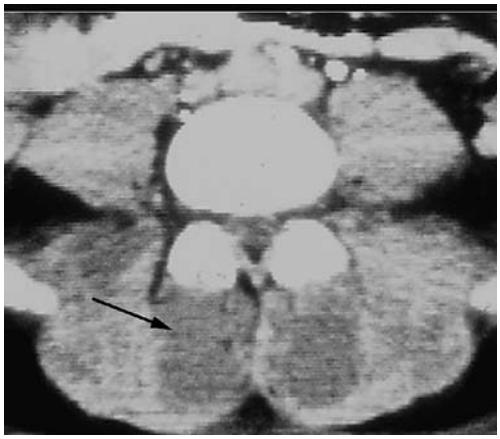

Fig. 9 Lumbar compartmental syndrome. Diffuse edema and myonecrosis of the paravertebral lumbar muscles appearing as low-density areas on axial CT scan (*arrow*) in a 55-year-old patient who had undergone prolonged retroperitoneal surgery

ically confined space leading to irreversible damage of the enclosed structures due to vascular compromise. A compartment syndrome can result from any condition with elevated intracompartmental pressure (trauma, hemorrhage, burns or intensive muscle activity). The erector spinae is surrounded by a well-developed fascial sheath and can suffer from compartment syndrome, especially after aortic or retroperitoneal surgery with hypoperfusion or occlusion of lumbar arteries [28, 29].

Patients with myonecrosis present with acute LBP, as well as swelling and tenderness of the affected muscles. The muscles Involved are characterized by hypodense areas on CT (Fig. 9) and hyperintensity on T2-weighted MR images, with marked enhancement after injection of contrast medium [28, 29].

Non-specific abnormalities

Infection

Lumbar muscles can be involved in infections which develop in the adjacent structures. They may be involved in spondylodiscitis, sacroiliitis, spondylarthritis or vertebral osteomyelitis. *Staphylococcus aureus* is most commonly found, followed by mycobacterial infections.

Involvement of paravertebral muscles is frequent in spondylodiscitis and results in myositis and abscess. Infectious myositis is associated with edema and cellular infiltration of polynuclear cells and lymphocytes. Myositis can be associated with phlegmonous changes of the subcutaneous tissue. Abscesses can become very large, in particular in tuberculous infections. They are typically well demarcated. Facet joint infection and osteomyelitis of posterior structures including the laminae are rare.

In focal myositis, CT demonstrates areas of decreased density corresponding to edema associated with muscular swelling. There is a loss of intramuscular fat tissue. On T1-weighted MR images muscles present with iso- to hypointense signal intensity. On T2-weighted MR images signal hyperintensity is found, and on contrast-enhanced images intense enhancement is found (Fig. 10). Muscle abscess appears as a thick-walled rounded structure, with a central area of hyperintense signal on T2-weighted MR images and a peripheral rim of enhancement on gadolinium-enhanced sequences (Fig. 10).

Primary bacterial infection of muscles is called pyomyositis [30] and is typically caused by *Staphylococcus*, *Streptococcus* or gram-negative microorganisms. The radiological aspect is comparable to contiguous infection.

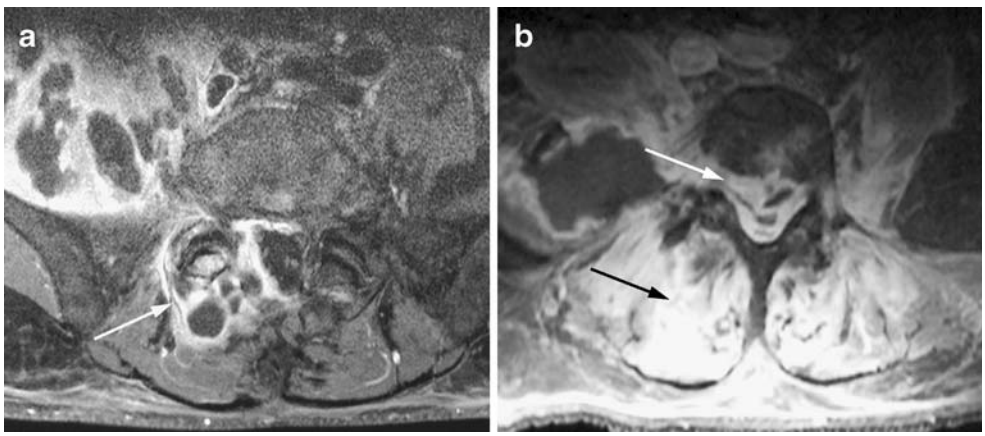

Fig. 10 Diffuse myositis and paravertebral muscle abscesses in a 44-year-old patient with pyogenic spondylodiscitis and facet joint involvement. **a** Axial gadolinium-enhanced T1-weighted MR image [time to repeat (TR) 450 ms; time to echo (TE) 20 ms] shows important enhancement of back muscles revealing extensive inflammation. Muscle abscesses are identified as round formations with central low-intensity T1-signal with peripheral rim enhancement (*arrow*). **b** Extensive myositis of the paravertebral muscles (*black arrow*) associated with epidural abscesses (*white arrow*) secondary to lumbar spondylodiscitis on axial gadolinium-enhanced T1-weighted MR image (TR 450 ms; TE 20 ms)

Reaction to adjacent osseous diseases

Muscles abnormalities may be the only radiological evidence of an adjacent bone disease such as fracture, inflammatory disease or bone neoplasm.

Spondylolysis

Spondylolysis can be missed in its initial stage, both on conventional radiographs and on CT. MRI may be useful for early diagnosis [31]. MRI demonstrates signal abnormalities within the interarticular portion and the adjacent pedicles [32, 33]. Additionally, MRI may identify signal abnormalities of the adjacent muscles, which may represent the only early sign of spondylolysis [18] (Fig. 11).

Neoplasms associated with reactive inflammatory soft tissue abnormalities

Spinal muscles adjacent to a neoplasm with reactive inflammatory soft tissue changes (osteoid osteoma, osteoblastoma, chondroblastoma) can present extensive muscle abnormalities, even including myolysis which may lead to atrophy with fatty replacement [34]. Myolysis induces a myogenic atrophy of muscles fibers, and this transformation has been sometimes reported as myxomatous [34]. A spasm of the affected muscles is responsible for a development of scoliosis [35]. On CT, muscular modifications appear as low-density edematous areas [36] (Fig. 12).

Congenital myopathies and muscular dystrophies

Myopathies affecting axial muscles are muscular dystrophies (myopathy of Duchenne–Becker), mitochondrial myopathy and glycogen storage abnormalities [37]. Affected muscles develop myogenic atrophy as muscle size decrease and muscle parenchyma is replaced by fat tissue and fibrous tissue (Fig. 13).

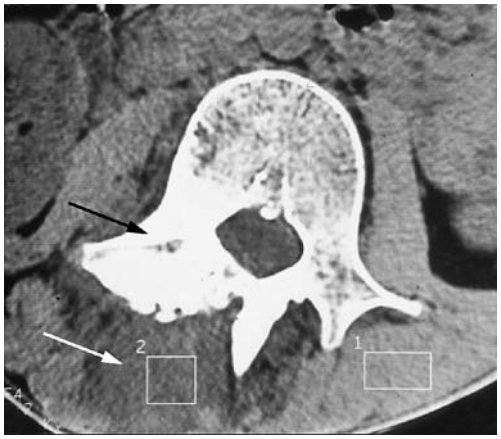

Fig. 12 The density of muscle masses were measured inside regions of interest (*white boxes*): unaffected muscles had a normal density (*box 1*) while involved muscles had an abnormal low density (*box 2*)

Cross-sectional imaging can help determine type (edema, inflammation, fat, fibrosis), degree, and localization of abnormalities. CT scan identifies low-density areas, and MRI identifies elevated signal intensity inside the paravertebral muscles that correspond to muscle replacement by fat, which is an accurate marker for the progression of the disease and correlates with both patient age and clinical stage [38].

Autoimmune myopathies

Inflammatory myopathies include polymyositis, dermatomyositis, myositis with malignancy, myositis associated with other autoimmune disorders (rheumatoid arthritis, systemic lupus erythematosus, mixed connective tissue

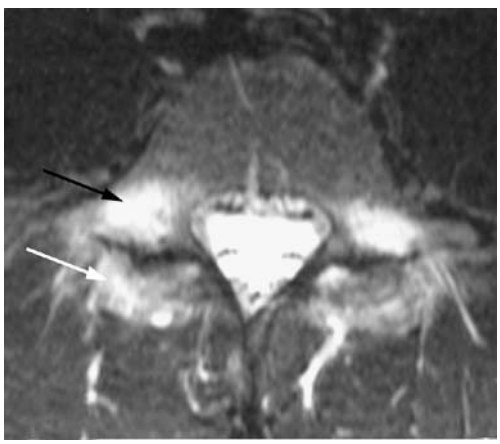

Fig. 11 Muscle edema in a 14-year-old patient with acute spondylolysis. Muscle edema (*white arrow*) and bone edema (*black arrow*) are shown as areas of high signal intensity on axial T2-weighted MR image [time to repeat (TR) 5200 ms; time to echo (TE) 80 ms]

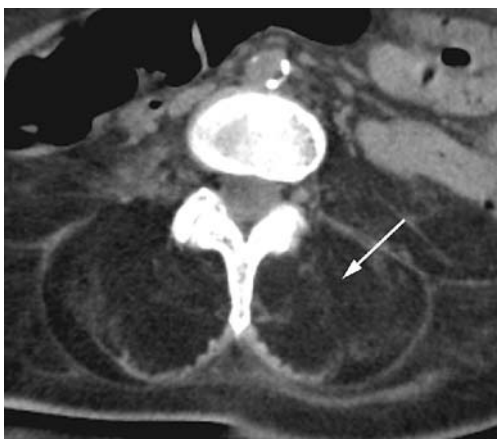

Fig. 13 Major myogenic atrophy in 60-year-old patient with mitochondrial myopathy. Intense and diffuse loss of muscular tissue with fatty replacement on axial CT scan (*arrow*)

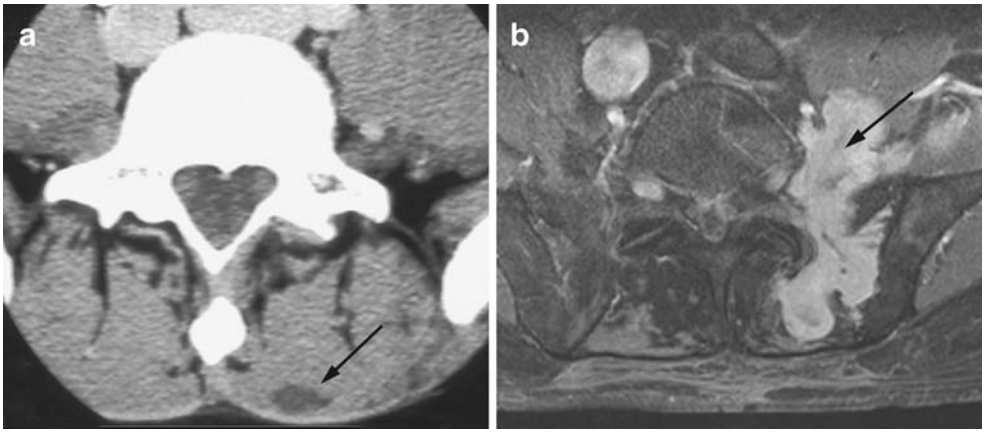

Fig. 14 Primary paravertebral tumors. **a** Intramuscular neurofibroma presenting as a hypodense tumoral formation on axial CT scan in a 37-year-old patient with type 1 neurofibromatosis (arrow). **b** Non-differentiated sarcoma in a 65-year-old patient, involving paravertebral muscles and latero-vertebral space and presenting as an enhanced mass on axial gadolinium-enhanced T1-weighted MR image [time to repeat (TR) 460 ms; time to echo (TE) 25 ms) (*arrow*)

disease), granulomatous (sarcoidosis), eosinophilic myositis, and inclusion body myositis. Their clinical evolution is usually characterized by a chronic and progressive course. The distribution of muscle lesions may vary from patient to patient, and muscle weakness can lead to severe disability [39–42]. Lumbar vertebral myopathies are rare.

MRI is particularly useful in the detection of disease activity and sequelae in patients suffering from myositis, especially in showing areas of edema, necrosis or fatty infiltration. MRI identifies focal structural muscle lesions, determines their extent, characterizes their composition, monitors therapies and indicates the optimal location for muscle biopsy [43].

Imaging cannot generally differentiate between the various autoimmune myopathies. Focal areas or a diffusely increased signal intensity are signs of disease activity in MRI. They correspond to cellular infiltration or edema [44]. Affected muscles are hypodense on CT. Their signal can appear normal or slightly hypointense on T1-weighted MR images and pronouncedly hyperintense on T2-weighted images [39–42]. Fatty infiltration, easily recognized on CT scans as focal areas of low density, is considered to be a sign of chronic inflammation of the muscle, which is not responsive to therapy [44].

Neoplastic diseases

Primary neoplasms

Paravertebral sarcomas are rare [45–48]. Tumors can develop from any cell type, and anarchic differentiation can occur. The literature reports cases of paravertebral liposarcoma, malignant fibrous histiocytoma, rhabdomyosarcoma, angiosarcoma, neurofibrosarcoma, chondrosarcoma, synovial sarcoma, and osteosarcoma [45].

The manifestation of paravertebral neoplasms is similar to those observed in other locations. Most tumors are heterogeneous with central necrosis, showing low signal intensity on T1-weighted MR images and high signal intensity on T2-weighted MR images, with an intense enhancement after injection of gadolinium (Fig. 14) [45–48].

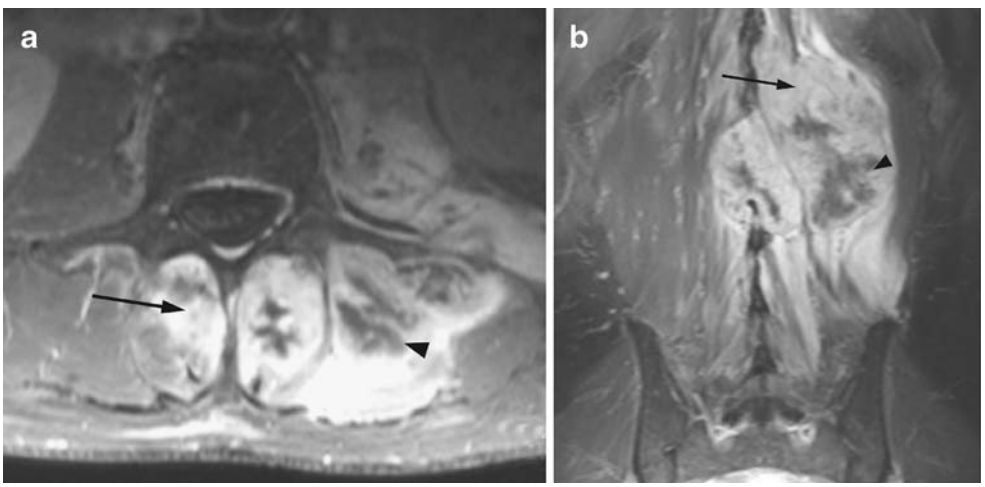

Fig. 15 Metastatic involvement of spinal muscles in a 78-year-old patient with bronchial carcinoma on axial (**a**) and coronal (**b**) gadolinium-enhanced T1-weighted MR images [time to repeat (TR) 460 ms; time to echo (TE) 25 ms]. Extensive myositis presents intense enhancement (*arrows* in **a** and **b**). Necrotic areas (*arrowheads* in **a** and **b**) present a central low-intensity signal and could be misdiagnosed as muscle abscesses

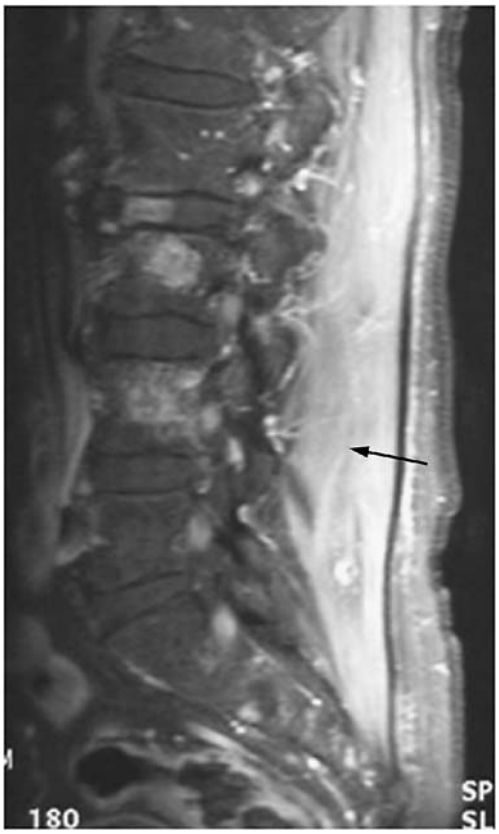

Fig. 16 Traumatic lesion of the paravertebral muscles. Extensive muscle strain in a 55-year-old patient with a history of acute lumbar pain after sudden hyperextension, appearing as extensive muscular high-intensity signal (*arrow*) on sagittal T2-weighted MR images [time to repeat (TR) 5200 ms; time to echo (TE) 80 ms]

Secondary malignant involvement

Paravertebral muscles are the most common sites of muscular metastatic involvement which may relate to the large muscle mass present close to the spine. Primary tumors are mostly carcinoma (carcinoma of the lung, colon, esophagus, pancreas, ovary and kidney), as well as leukemia and lymphoma [49, 50].

Imaging findings of metastatic disease are non-specific, with increased muscle volume, signal abnormality on MRI and commonly pronounced enhancement on CT or MRI, potentially mimicking abscesses (Fig. 15) [51, 52]. Muscle edema is commonly seen surrounding intramuscular metastasis.

Secondary involvement by a neoplasm of adjacent structures are more common than hematogenous spread [53].

Traumatic lesions

Traumatic lesions of the paraspinal muscles are rare. Depending on the mechanism, muscle strains or contusions can be observed.

Strains are painful injuries, typically caused by sudden contraction, for instance hyperextension (basketball, golf). Imaging shows characteristics of myogenic involvement. MR aspects range from myositis to hematomas, depending on the severity of the injury [53]. Myositis appears as focal or diffuse areas of high-intensity T2 MR signal with intense enhancement after injection of contrast medium (Fig. 16). Early hematomas present as focal areas of increased signal intensity on T2-weighted images. During follow-up, hyperintensity progressively decreases on T2-weighted images, while increased signal intensity may be observed on T1-weighted images.

Muscle contusions are typically caused by direct trauma (for instance in motor vehicle accidents and adjacent to gunshot wounds). MRI may demonstrate signal abnormalities caused by focal edema, hemorrhage and reactive muscle changes [54].

Conclusion

Muscle abnormalities may be missed on routine MR or CT examinations of the lumbar spine. Lumbar paravertebral muscles can be involved in numerous different diseases. Cross-sectional imaging may contribute to the correct diagnosis, allows precise biopsy, and may be used for therapy monitoring.

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