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MRI Findings of Arachnoiditis, Revisited. Is Classification Possible? /

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Abstract

Background

Prior imaging studies characterizing lumbar arachnoiditis have been based on small sample numbers and have reported inconsistent results.

Purpose

To review the different imaging patterns of lumbosacral arachnoiditis, their significance, and clinical implications.

Study type

Retrospective.

Population

A total of 96 patients (43 women; average age 61.3 years) with imaging findings of arachnoiditis (postsurgical: N = 49; degenerative: N = 29; vertebral fracture: N = 6; epidural and subdural hemorrhage: N = 3, infectious: N= 1; other: N = 8) from January 2009 to April 2018.

Field strength/Sequence

Sagittal and axial T2-weighted Turbo Spin Echo at 1.5 T and 3 T.

Assessment

Chart review was performed to assess the cause of arachnoiditis, and imaging was reviewed by two musculoskeletal and three neurology radiologists, blinded to the clinical data and to each other's imaging interpretation. Previous classification included a three-group system based on the appearance of the nerve roots on T2-weighted images. A fourth group was added in our review as “nonspecified” and was proposed for indeterminate imaging findings that did not fall into the classical groups. The presence/absence of synechiae/fibrous bands that distort the nerve roots and of spinal canal stenosis was also assessed.

Statistical tests

The kappa score was used to assess agreement between readers for both classification type and presence/absence of synechiae.

Results

Postsurgical (51%) and degenerative changes (30%) were the most common etiologies. About 7%–55% of arachnoiditis were classified as group 4. There was very poor classification agreement between readers (kappa score 0.051). There was also poor interreader agreement for determining the presence of synechiae (kappa 0.18) with, however, strong interreader agreement for the presence of synechia obtained between the most experienced readers (kappa 0.89).

Data Conclusion

This study demonstrated the lack of consensus and clarity in the classification system of lumbar arachnoiditis. The presence of synechia has high interreader agreement only among most experienced readers and promises to be a useful tool in assessing arachnoiditis.

Evidence Level

3

Technical Efficacy

Stage 2

Lumbosacral arachnoiditis is a progressive inflammatory disease of the arachnoid membrane of the spinal cord[1, 2] The inflammation and hyperemia recruit macrophages and enzymes, which are washed off by the continuous flow of the cerebrospinal flow, delaying the healing process.[3, 4] In time, fibroblast production and collagen formation result in scarring and adherence of the nerve roots.[2]

Arachnoiditis was first described as a complication of granulomatous infections of the spinal cord.[5] It is now well established that degenerative disease, including disc disease and spinal canal stenosis, postmyelography and intrathecal injections, trauma, subarachnoid hemorrhage, and tumors can cause arachnoiditis.[2, 5-7] Guillain–Barre syndrome,[7] ankylosing spondylitis,[7] and genetic predisposition to keloid formation[8] have also been reported. However, spine surgeries and disc disease represent the majority of the etiologies.[6]

The most common clinical presentation is back and radicular leg pain. Symptoms are usually absent at onset and progressively worsen. Sensory and motor symptoms are seen less commonly and include weakness, paraplegia, and bowel and bladder dysfunction[7] . Long[6] studied 3000 patients with failed back syndrome, 321 of whom had arachnoiditis (10% prevalence); 94% of these patients complained of back pain worsened by physical activity, 81% presented with leg pain, and 14% had bowel and bladder dysfunction. The diagnosis of arachnoiditis is difficult because of the variability of its symptoms[5] and thus is a diagnosis of exclusion. However, some studies[7, 11] demonstrated no correlation between imaging and clinical findings and suggested that treatment decision of arachnoiditis should be built upon clinical history and physical exams.

Traditionally, adhesive arachnoiditis was described on computed tomography (CT) myelography as clumping and adhesions of the nerve roots, and it was categorized into two groups: Type 1 is described as adhesion of the nerve roots to the meninges and is considered a mild disease, and type 2 is more advanced and is seen as narrowing and irregularity of the thecal sac secondary to obstruction by fibrous tissue.[12]

CT myelography has been replaced with the advent of magnetic resonance imaging (MRI). A study by Ross et al comparing MRI with CT myelography for detection of adhesive arachnoiditis, confirmed an accuracy of 99% with a sensitivity of 92% and specificity of 100%.[3] Delamarter et al compared CT myelography to MRI lumbar spine in 24 patients and showed 100% association.[5] These two studies categorized adhesive arachnoiditis into three groups.[3, 5] In group 1, the nerve roots are clumped in the center of the thecal sac. In group 2, the nerve roots adhere to the periphery of the thecal sac, resulting in an entity described as empty sac. In group 3, the nerve roots form a mass in the thecal sac. These findings are best depicted on T2-weighted images due to the better delineation of the nerve roots by the bright cerebrospinal fluid.[3, 5]

Therefore, adhesive arachnoiditis can be defined both clinically and radiologically.

Thus, the aim of this study was to examine the reliability and reproducibility of the radiological classification method of arachnoiditis. The primary aim was to investigate the consistency of the classification system and our secondary objective was to determine the prevalence of synechia and spinal canal stenosis.

Materials and Methods

Study Population

This is a retrospective, single-institution study, approved by the institutional review board with a waiver for written informed consent. We examined our retrospective data using the keyword search "arachnoiditis" in all MRI lumbar spine reports performed from January 2009 until April 2018. Exclusion criteria were reports concluding with no evidence of arachnoiditis; follow-up studies (to avoid redundancy); and arachnoiditis ossificans, an exceedingly rare entity where clumping of the nerve roots are associated with calcifications in the thecal sac associated with "blooming" artifact on MRI[11] (see Fig. 1, flow chart for patient inclusion).

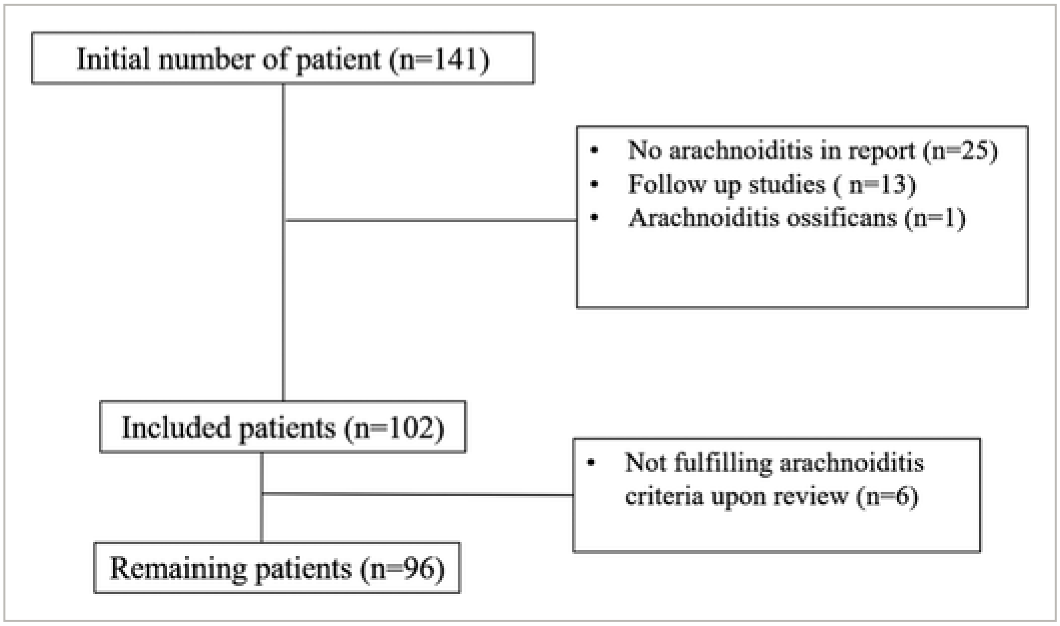

FIGURE 1

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Caption

Flow chart for patient inclusion.

MRI Protocol

Imaging was performed on both 1.5-T (N = 58) and 3-T (N = 38) magnets (Phillips Healthcare, Eindhoven, The Netherlands). The standard protocol included axial and sagittal T1-weighted and T2-weighted Turbo Spin Echo (TSE) and sagittal short-tau inversion recovery (Table 1: MR parameters used on two different magnets). Gadolinium-based contrast intravenous administration was not provided routinely.

TABLE 1. MR Parameters Used on Two Different Magnets

	TE (msec)	TR (msec)	ST (mm)	NSA	FOV (mm)	Matrix size

	TE (msec)	TR (msec)	ST (mm)	NSA	FOV (mm)	Matrix size
Sagittal T2W						
1.5 T	120	3000–4000	4	2	160	180 × 236
3.0 T	120	2000–4000	4	1	160	160 × 216
Axial T2W						
1.5 T	100	3315	4	2	200	200 × 137
3.0 T	100	2500–6000	3	2	200	252 ×140

TE = echo time; TR = repetition time, ST = slice thickness; NSA = number of signal averaged; FOV = field of view; MR = magnetic resonance; T2W = T2 weighted.

Qualitative MRI Assessment

Two trained musculoskeletal and three trained neurology radiologists (NK reader 1, HM reader 2, KG reader 3, JA reader 4, and KR reader 5) with, respectively, 23, 15, 2, 3, and 3 years of experience reviewed the 96 patients. Arachnoiditis was assessed at the level of the cauda equina below the conus medullaris. The presence of arachnoiditis was evaluated on axial and sagittal T2-weighted images of the lumbar spine. The diagnosis of arachnoiditis was established and classified into three groups based on previously published MR criteria in the literature.[3, 5] Examples are shown in Figs. **2–4**-**2–4**. A fourth group is proposed in this study, where the nerve root thickening and clumping does not fit unambiguously into any of the three categories of the above classification system and is designated “unspecified.” Figure **5** demonstrates an example of such a case. A combination of the above groups may be observed in a single patient where different findings may be noted at different levels below the conus medullaris (Fig. **6**). An additional imaging finding, the presence of synechia, was also noted; a synechia was defined as a fibrous band that distorts the nerve roots and is distinguished from them by being discontinuous and not following the typical nerve course through a neural foramen.

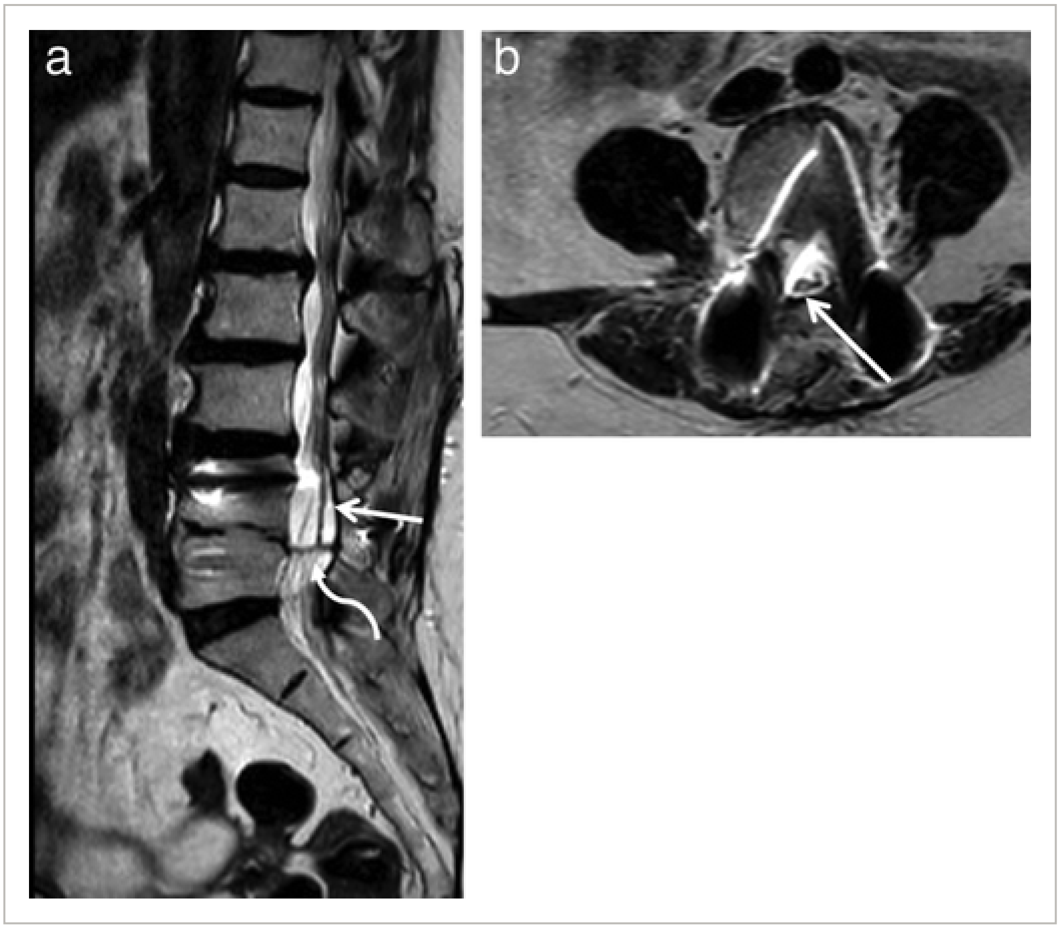

FIGURE 2

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Caption

A 59-year-old female status post L4 laminectomies and L4–S1 fusion. Sagittal (**a**) and axial (**b**) T2W TSE show clumping of the nerve roots as a single central cord (arrow) in the center of the thecal sac (group 1). A linear low T2 horizontal band at L4–L5 correspond to a synechia (curved arrow).

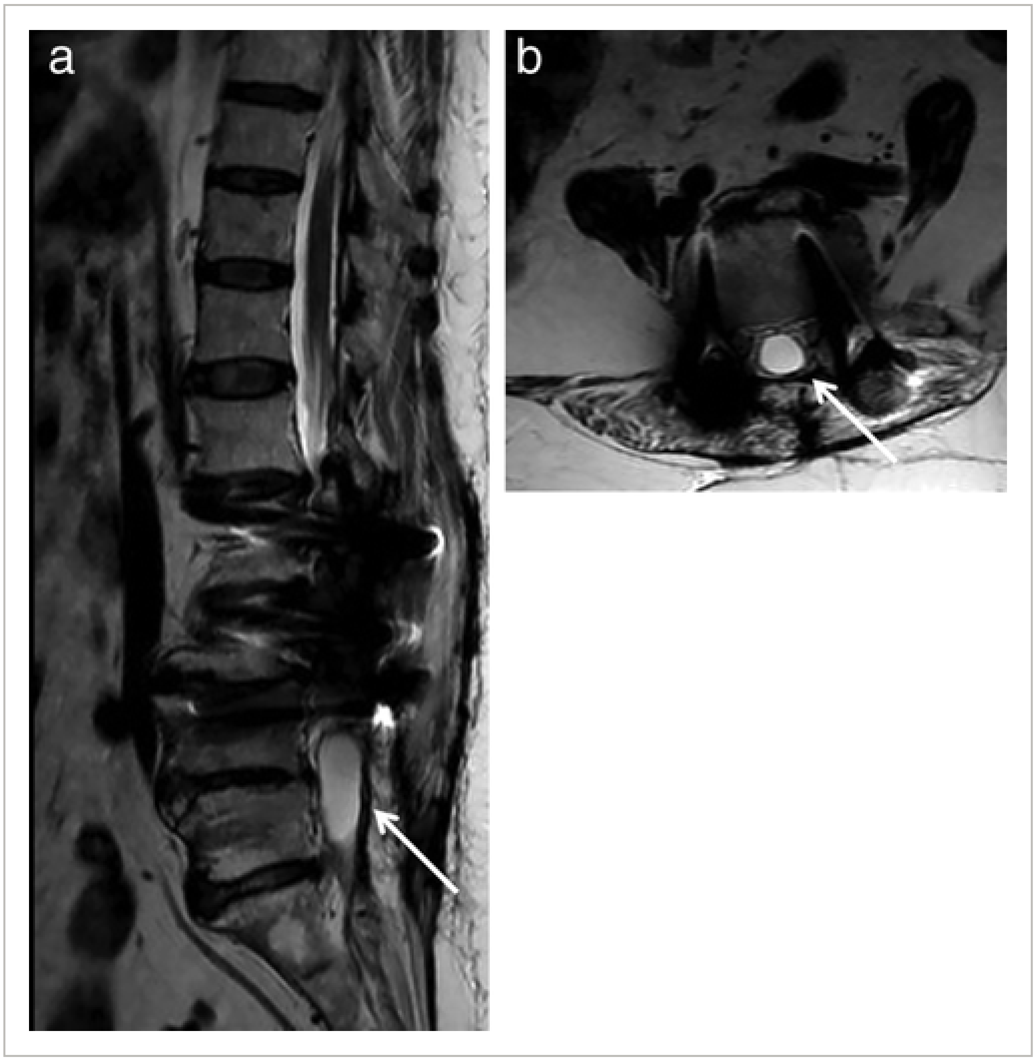

FIGURE 3

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Caption

A 63-year-old female status post L2–L5 fusion. Sagittal (**a**) and axial (**b**) T2W TSE show adherence of the nerve roots to the thecal sac at L4–L5 giving the appearance of empty sac (arrows) (group 2).

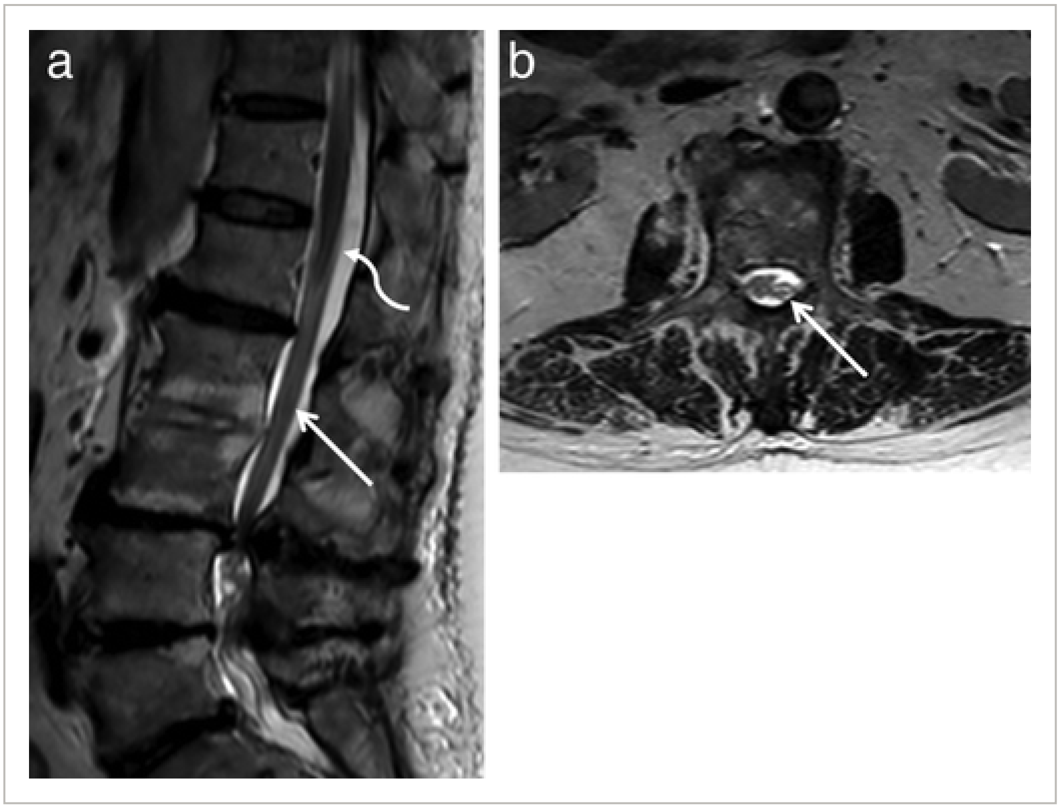

FIGURE 4

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Caption

A 72-year-old man with degenerative disc disease. Sagittal (**a**) and axial (**b**) T2W TSE show clumping of the nerve roots in the thecal sac, appearing as mass like (arrows) and as a continuation of the conus medullaris (curved arrow) (group 3). Severe spinal canal stenosis at L3–L4 and L4–L5 levels.

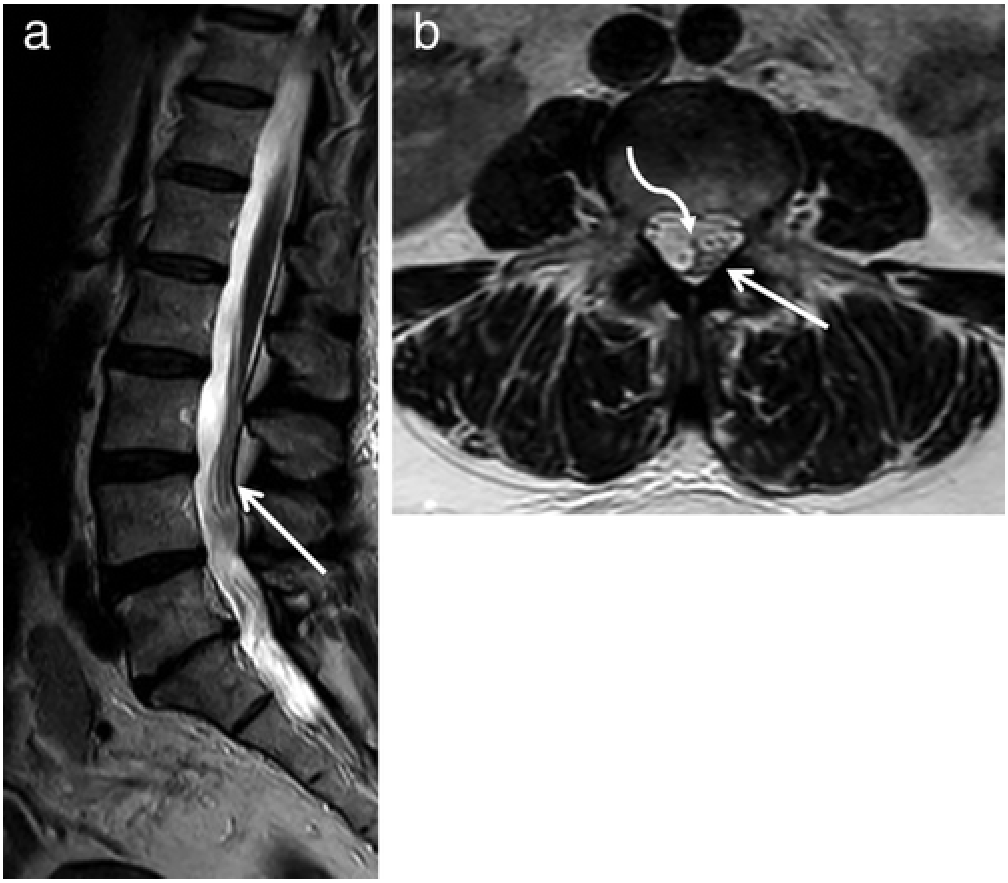

FIGURE 5

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Caption

A 53-year-old female with degenerative disc disease. Sagittal (**a**) and axial (**b**) T2W TSE show clumping of the nerve roots and their displacement to the left side of the thecal sac (arrows) (group 4). Synechia (curved arrow) is projecting to the center of the thecal sac.

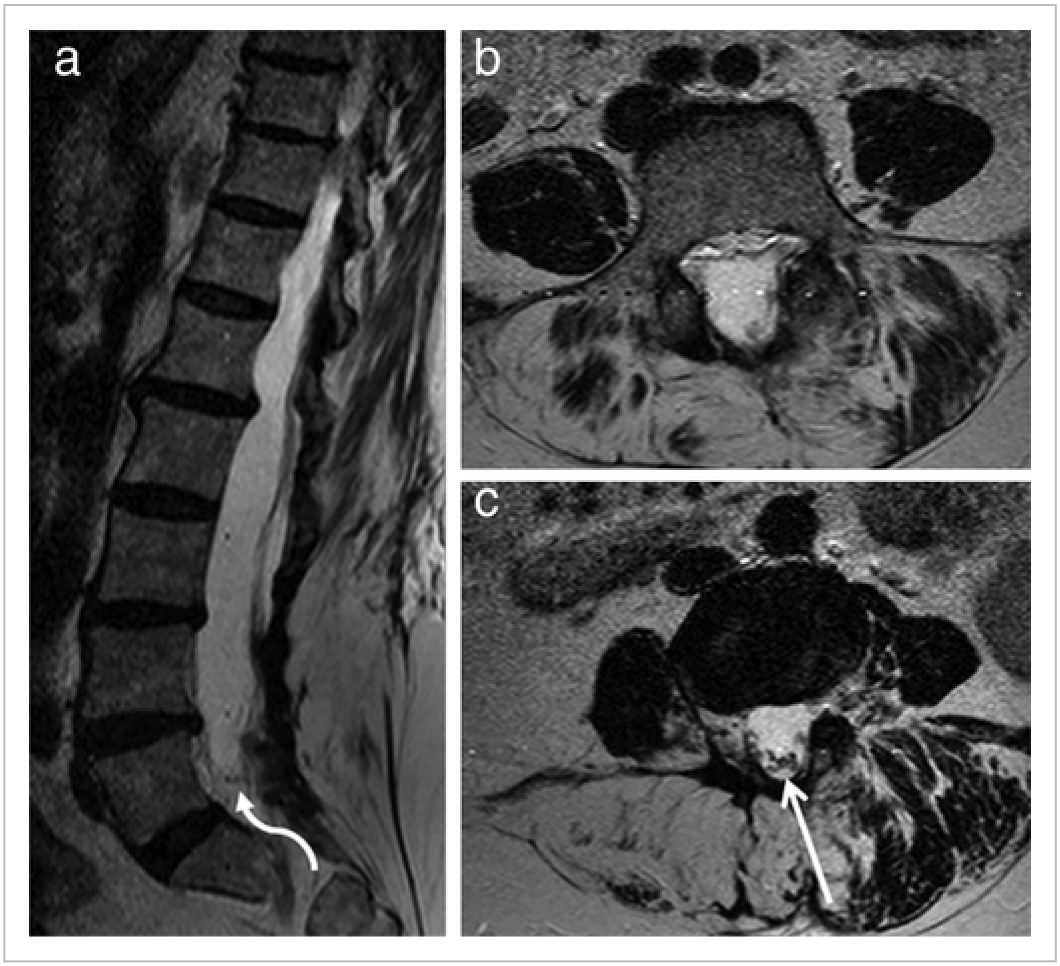

FIGURE 6

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Caption

A 53-year-old female status post L4–L5 laminectomies. Sagittal (**a**) and axial T2W TSE (**b** and **c**). At L4–L5 (b), clumping of the nerve roots in the thecal sac giving the empty sac appearance (group 2). At L3–L4 (c), clumping of the nerve roots posteriorly in the thecal sac (arrow) in an unspecified pattern (group 4). Synechia seen at L5 (curved arrow).

Interreader agreement between our five readers for the arachnoiditis classification and the presence of synechia was performed. The same analysis was performed comparing between the more experienced readers/musculoskeletal radiologists and between the junior readers/neuroradiologists. Cases were divided into 1.5 T and 3 T, and interreader agreement was also calculated in each group of patients.

When present, severe spinal canal stenosis was described and defined as lack of CSF and/or epidural fat within the lumbar canal.[13]

Statistical Analysis

wThe relative prevalences of each category of arachnoiditis and presence of synechiae and spinal canal stenosis were calculated. The statistical analysis was performed using SPSS Inc. build 1.0.001327. Fleiss's kappa score was used to assess agreement between readers for the four groups of arachnoiditis and for the presence of synechiae.

A *P*-value of less than 0.05 was considered the cutoff level for statistical significance.

Results

Patients Characteristics

The search netted 141 results. After excluding negative and follow-up studies and one case of arachnoiditis ossificans, a total of 102 patients were analyzed. Six out of these patients did not have radiologic findings of arachnoiditis when reviewed by two senior readers (100% interreader agreement). The remaining 96 patients' clinical charts and MR studies were reviewed, and demographic data were obtained. Detailed clinical information and symptomatology were not available to perform comprehensive analysis. Our final study yielded 96 patients, 53 (55.2%) men and 43 (44.8%) women with an average age of 61.3 ± 16.7 years.

The etiologies of arachnoiditis were as follows based on clinical information and radiological imaging: postsurgical 49 (51%), degenerative 29 (30%), vertebral fracture 6 (6%), epidural and subdural hemorrhage 3 (3%), infectious 1 (1%), and other (tethered cord, syringomyelia, epidural lipomatosis, post epidural injections) 8 (9%) (Table 2: Demographics and etiology).

TABLE 2. Demographics and Etiologies

	Total (*N* = 96)
Age (years), average (SD)	61.3
Gender	
Male	53 (55.2)
Female	43 (44.8)
Etiology	
Postsurgical	49 (51)
Degenerative	29 (30)
Vertebral fracture	6 (6)
Epidural and subdural hemorrhage	3 (3)

	Total (*N* = 96)
Infectious	1 (1)
Other [a]	8 (9)

Numbers in parentheses are percentages.

[a] Other causes: tethered cord, syringomyelia, epidural lipomatosis, and postepidural injections.

Imaging Findings

Imaging findings are summarized in Fig. 7. For reader 1, *N* = 34 in group 4 (35%); for reader 2, *N* = 52 in group 4 (54%); for reader 3, *N* = 53 (55%) in group 4; for reader 4, *N* = 16 in group 4 (17%); and for reader 5, *N* = 7 in group 4 (7%).

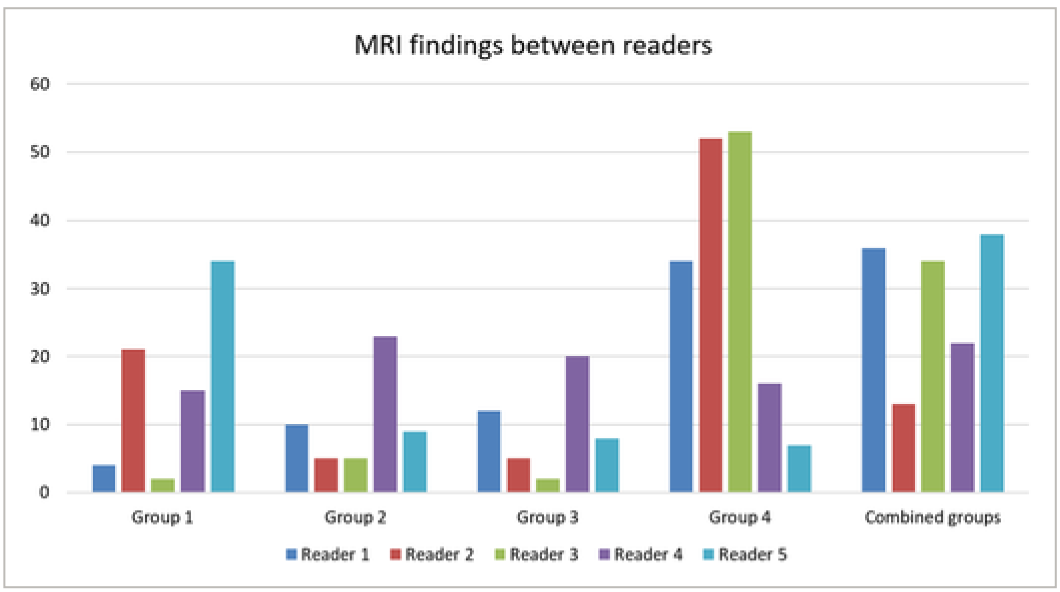

FIGURE 7

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Caption

Magnetic resonance imaging (MRI) findings between readers.

There was poor to no agreement between readers with a kappa score of 0.051 ($P < 0.05$) when analyzing each of the above groups and combinations.

For the presence of synechiae, reader 1 described its presence in 52 out of 96 patients (54%), reader 2 in 57 out of 96 (59%), reader 3 in 70 out of 96 patients (73%), reader 4 in 58 out of 96 patients (60%), and reader 5 in six out of 96 (6%). There was poor interreader agreement between the five readers with a kappa score of 0.183 ($P < 0.05$).

The two most experienced readers (Readers 1 and 2) who are both musculoskeletal readers had fair interreader agreement for arachnoiditis classification with a kappa score of 0.19 and $P < 0.05$ and strong interreader agreement for synechia with a kappa score of 0.89 and $P < 0.05$. The three neuroradiologists with less than 5 years of experience had none to slight interreader agreement for the arachnoiditis classification and synechia with kappa scores of 0.027 and 0.033, respectively, with $P < 0.05$.

For the cases performed on the 1.5 T magnet, there was none to slight interreader agreement for the arachnoiditis classification and presence of synechia with kappa scores of 0.048 and 0.177, respectively, and $P < 0.05$. For the cases performed on the 3 T magnet, there was none to slight interreader agreement for the arachnoiditis classification and presence of synechia with kappa scores of 0.058 and 0.189, respectively, and $P < 0.05$.

There was 100% agreement between readers on the presence of severe spinal canal stenosis in a total of 17 cases. Of those cases, 12 were observed in postsurgical intervention patients and the rest ($N = 5$) were associated with degenerative disc disease alone.

Discussion

Lumbosacral arachnoiditis is an inflammatory disease of the arachnoid membrane.[1,2] It has been described secondary to multiple etiologies, most commonly intrathecal contrast injection, lumbosacral spine surgery, and degenerative disc disease.[6] However, with the decrease in the use of lumbar contrast injection, lumbar spine surgery and degenerative disc disease represent the primary etiologies. This was confirmed in our study where 51% of patients had history of spine surgery and 29% had degenerative spondylosis. Only one patient in our series had arachnoiditis secondary to epidural injection.

Three small studies[3,5,7] have previously attempted to identify the MRI findings in arachnoiditis, two of which[3,5] included up to 24 patients and described the development of a classification system comprising three groups. Our study examined 96 patients and found that a considerable portion of patients with clumped nerve roots did not satisfactorily fall into any one of these three groups. For this reason, we created a fourth group labeled as “unspecified,” to better reflect the variability of the imaging findings. A new study by Parenti et al[11] showed only 57% of their patients who fit the conventional classification of arachnoiditis. This is consistent with our observation that the conventional classification system falls short in encompassing the entire spectrum of arachnoiditis, thus the use of the fourth unspecified group. Up to 40% of the patients demonstrated imaging patterns that fell within more than one group. This is consistent with a previous study describing arachnoiditis involving more than one vertebral level.[3] In our study, there was poor interreader agreement in classification between our five readers, regarless of field strength and regardless of experience, which is partly attributed to the presence of variable appearances at different levels and to the absence of clear transition between the groups. Hence, establishing a reproducible classification system is challenging, and at present, there is limited radiological value.

The presence of synechiae—fibrous bands distorting the nerve roots—is part of the imaging findings in arachnoiditis and has a prevalence up to 38%.[7] This is characterized by discontinuous linear low-intensity arachnoid septations extending to the periphery. These are probably a consequence of prior inflammation and likely contribute to symptomatology.[7] In our study, there was poor interreader agreement for assessing the presence/absence of synechiae. Four of the readers reported prevalences ranging between 53% and 73%, higher than those reported in the literature (38%), while one reader reported synechiae in only 6% of the cases. We postulate that this wide variability may reflect lax criteria for defining synechiae. More rigorous imaging criteria and standardization may prove useful for surgeons in planning interventions. There was no change in interreader agreement when analyzing the subgroups of 1.5 T and 3 T.

The two most experienced readers (readers 1 (NK) and 2 (HM)) had strong interreader agreement. The junior radiologists (also the neuroradiologists group) had poor interreader agreement. This could be attributed to multiple confounding variables. It highlights the importance of longer experience in lumbar spine interpretation, especially in complicated cases. One potential source of bias is that the first two readers are working together in the same institution, but also a source of better standardization and consistency of the diagnostic criteria.

Spinal canal stenosis has been described as a predisposing factor for arachnoiditis[6] and was found in approximately 20% of our cases. Of these, the majority were postsurgical (epidural scarring and/or recurrent disc herniation).

Limitations

In this study, we did not evaluate nerve root enhancement. This was partially because, in this retrospective study, only approximately one-third of patients were given intravenous contrast agents. Indeed, in accordance with the American College of Radiology imaging guidelines, contrast administration is not needed for the evaluation of degenerative disease in the spine. However, several studies have described contrast enhancement of the clumped nerve roots in the setting of arachnoiditis,[7, 14] and we suggest incorporating this in future investigations.

A further limitation is that detailed clinical information and symptomatology were not available to perform analysis on the association of specific imaging findings with symptoms (eg, back pain and dermatomal/radicular pain). Future prospective studies will be very helpful in shedding light on this clinical–radiological correlation.

Conclusion

The interreader agreement for categorizing lumbar arachnoiditis (four-group classification) was very poor, thus limiting the clinical benefit from this classification. The interreader agreement for determining the presence/absence of synechiae within the thecal sac was also poor except between the more senior readers. Additional studies with more rigorous criteria and incorporating contrast agents are needed to determine how imaging findings may be used to assess arachnoiditis.

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