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IMAGING (L MECTHLER, SECTION EDITOR)

The Role of Imaging in the Management of Cystic Formations of the Mobile Spine (CYFMOS)

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Abstract

Purpose of Review The purpose of this review is to give a better understanding of the pathogenesis of cystic formations of the mobile spine (CYFMOS) and the correlating imaging findings. This would help with medical decision-making, given the plethora of conservative, interventional, and surgical treatment options.

Recent Findings There has been a general understanding that CYFMOS are associated with degenerative spine changes. More recent articles however have suggested that identifying detailed imaging characteristics can assist in determining outcomes when CYFMOS are treated with interventional percutaneous methods or surgical decompression with or without concomitant fusion.

Summary CYFMOS although uncommon *are not a rare finding seen in the spine* when there is a background of degenerative spine changes. These cystic lesions are generally symptomatic by exhibiting mass effect on adjacent structure. Most treatments are aimed at decompression by interventional percutaneous or surgical means. Various imaging characteristics of these CYFMOS described in this article including their signal intensity, presence of spinal instability, particular patterns of adjacent degenerative changes, and imaging changes following interventional treatments can help guide physicians when managing these cases.

Keywords CYFMOS · Synovial cyst · Juxtafacet cyst · Spinal instability

Introduction/History

The association of synovial cystic lesions with articulating joints was first illustrated by Baker in 1877 [1]. Baker described the fluid distention of the gastrocnemio-semimembranosus bursa into the popliteal fossa resulting in a popliteal or "Bakers" cyst. These cystic lesions are not explicit to the lower extremities and may originate from, or form adjacent to any joint in the body. These cystic lesions frequently become symptomatic when they exhibit mass effect on adjacent structures [2, 3••]. This phenomenon was first described in the spine, in 1950, by Vosschulte and Borger, who reported on spinal nerve root compression by synovial cysts within the spine [2].

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Nomenclature/Anatomy

Within the spine, these cystic lesions have been given different names in the literature. The term "synovial cyst" depicts a cyst that has a direct connection with the facet joint, maintains its synovial lining, and has also been referred to as a "true cyst." "Ganglion cysts" or "pseudo cysts" generally lack a direct connection with a parent joint, lack a synovial lining, and are instead lined by fibrous connective tissue. The term "juxtafacet cysts" was introduced by Kao et al., in 1974, to encompass both of these subtypes, which in actuality belong to the same spectrum of disease [4]. The ambiguity of these terms was well illustrated in a 2007 article published by Christophis et al., who proposed the term "cystic formations of the mobile spine" (CYFMOS) to better characterize the heterogeneous histologic composition and anatomic locations of these cystic lesions [5].

A retrospective review by Christophis et al. recorded the frequency in location off 58 "juxtafacet cysts" in a sample of 53 patients and discovered that 32 were arising from the facet joint, 19 were in the ligamentum flavum, 1 was in the posterior longitudinal ligament, and 6 cysts did not have clear identified localization, primarily due to their large size [5]. Approximately one third of the facet cysts were found to have a synovial lining while two thirds did not. All of the remaining cysts located outside of the facet joint lacked a synovial membrane. There have been case reports, however, of cysts containing a synovial membrane outside of the facet joint, such as in the ligamentum flavum [6, 7]. The terms “synovial cysts,” “ganglion cysts,” and by association “juxtafacet cysts” therefore may falsely imply a link between the anatomic location and histologic composition.

In our opinion, although it is not discussed further in this article, we feel a more precise nomenclature should eventually be developed which independently characterizes the anatomic location, histological composition, and perhaps the underlying pathophysiologic mechanism. For the purposes of this paper however, we will continue to refer to these cystic lesions as CYFMOS. Use of this nomenclature helps avoid the obscurities between the anatomic location of these cysts with their histologic composition.

Pathogenesis

The term CYFMOS is also beneficial in that it hints at the role of spine degeneration and destabilization in the underlying pathogenesis, which is well supported by the literature [3••, 8–10]. A recent 2017 literature review performed by Burder et al. uncovered 2900 degenerative spinal cysts and clearly demonstrated a positive correlation between spine mobility and the development of degenerative spine cysts [3••]. Of the 2900 cysts, 2658 (91.7%) were located in the lumbar spine and majority of those cysts were located at L4/5, which is the spinal level with the greatest amount of translation and segmental motion [3••, 11]. An example of a L4/5 CYFMOS can be seen on (Fig. 1). Only 50 (1.7%) were identified in the thoracic spine with the majority located at T11/12 and T12/L1, which are the most mobile segments of the thoracic spine. There were also 192 (6.6%) located in the cervical spine, of which nearly half were located at C7/T1, which is again suspected to be due to the heightened mechanical stress on the joints at this level [3••]. An example of a C7/T1 CYFMOS can be seen on (Fig. 2).

The interrelation between paired facet joints and the intervertebral discs is also believed to play a key role in initiating the formation of CYFMOS and was first described by Kirkaldy-Willis and Faran in 1982 [12]. Lumbar degeneration was broken down into three phases. The first “dysfunction phase” is characterized by spinal segments which do not function normally and are only associated with minimal anatomic changes. In the second “instability phase,” there is loss of disc height with load transfer to the facet joints associated with loosening of facet capsules and ligaments, particularly in lateral bending and axial rotation [12–14]. During the “instability stage,” spondylolisthesis and facet effusions develop, which have been identified as a predisposing factors for the development of synovial facet cysts [15, 16]. In the third “stabilization phase,” increased pressure on the facet joints accelerates the degenerative articular changes, resulting in fibrosis around the facet joints, decrease in the degree of synovial effusions, and formation of osteophytes, leading to stiffness and restabilization [12–14, 17, 18].

Numerous histological studies have uncovered various contents of these cysts including serous, mucoid, and hemorrhagic material, as well as articular cartilage and bone fragments [19,

Fig. 1 CYFMOS at L4/5 with “Intermediate Signal” associated with sequestered disc. Sagittal and axial T2 sequence of the lumbar spine revealing a large L4/L5 CYFMOS adjacent to the left facet joint. The cyst is associated with an “Intermediate Signal” and is associated with a moderate left paracentral disc sequestration, resulting in severe spinal canal stenosis with compression of the cauda equina towards the right and compresses the exiting left L4 nerve root

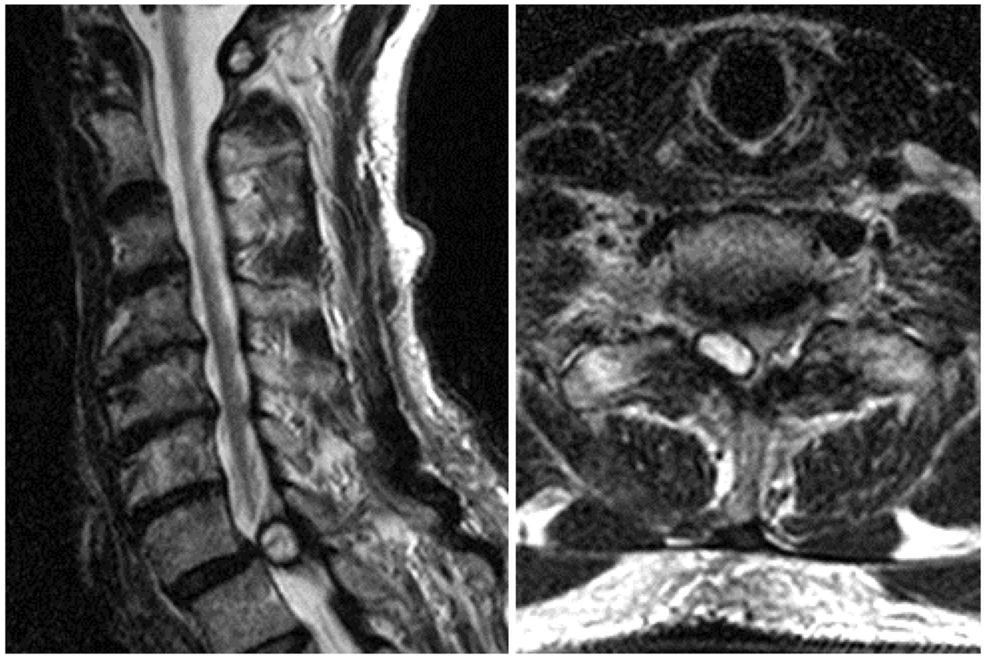

Fig. 2 CYFMOS at C7/T1 with "High Signal." Sagittal and axial T2 sequence of the lumbar spine revealing a large C7/T1 CYFMOS adjacent to the right facet joint. The cyst is associated with a "High Signal." The cyst is associated with severe spinal canal stenosis with compression of the spinal cord towards the left and compresses the exiting right C7 nerve root

20]. Histopathologic studies have also revealed fibrinoid and myxoid degenerative breakdown products, as well as granulation tissue, vessel proliferation, amyloid deposition, intracystic gas, and calcification [5, 21, 22]. The findings may suggest that the arthritic changes and instability result in the initial fissuring of the collagenous joint capsule with further cavitation and cystic formation through the egression of synovial fluid from the adjacent facet joint. These CYFMOS may subsequently migrate away from the facet joint and/or lose its synovial lining. These histological studies also suggest that there can be consecutive or concurrent inflammation and fibroblastic healing with further myxoid degeneration, intracystic hemorrhage, or calcification resulting in the potential heterogeneous intracystic components and imaging findings [5, 21]. An example of the heterogeneous intracystic T2 imaging signal intensities can be appreciated on (Fig. 1).

Clinical Presentation

CYFMOS frequently become symptomatic when they exhibit mass effect on adjacent structures. The review of 2900 degenerative spinal cysts by Burder et al. found that the most frequently occurring symptom was radiculopathy, involving 83% of the patients [3••]. Neck or back pain was found in 63%, myelopathy in 49%, sensory deficits in 40%, motor deficits in 32%, neurogenic claudication in 27%, cauda equina syndrome in 4%, and bilateral symptoms in 26% [3••].

As discussed above, the pathogenesis of CYFMOS is associated with the interrelation between the degeneration of paired facet joints and the intervertebral discs. Therefore, CYFMOS are commonly present in a background of low back pain associated with multiple degenerative spine changes. In the absence of clear cord or nerve root impingement, however, it can be difficult to attribute clinical symptoms to imaging findings of degenerative spine changes. Given the prominence of facet degeneration and inflammation in the formation of CYFMOS, these cases commonly occur in a background of facetogenic pain syndromes, which can present as point tenderness over the joint. There is also commonly guarding behavior with restricted range of motion at that level, associated with loss of flexibility. Pain is generally exacerbated with extension when there is increased load on the facets. Facet inflammation can also present with referred pain. In the lumbar region, facetogenic referred pain is commonly felt in the lower back and buttock region and rarely presents along the anterior aspect of the lower extremities or below the buttocks. In the cervical spine, facetogenic referred pain may be felt in the shoulders and upper back and is rarely present in the anterior or distal aspects of the upper extremities.

Treatment

From our review of the literature, there are a variety of treatment options for the management of CYFMOS with a lack of any clear guidelines. Conservative management with non-steroid anti-inflammatory drugs, physical therapy with bracing, and life style modification is reasonable for mild to moderate symptoms. There have been case reports in the literature of spontaneous remission with conservative management [23•, 24]. In many refractory cases, where there is correlating imaging pathology, percutaneous interventional procedures will be the next best step in management. Surgical intervention should be reserved for patients with substantial radiculopathy or myelopathy that are refractory to non-surgical management.

There have been several studies looking at interventional procedures for CYFMOS. In 1990, Parlier-Cuau et al. performed a retrospective case series of 30 patients, who had undergone lumbar facet steroid injections. Ten patients maintained good or excellent results at 6 months, and 14 patients required surgical intervention [25]. In 2009, Martha et al. performed a retrospective case series of 101 patients that underwent fluoroscopic-guided cyst injection with attempted rupture [26]. In this study, although 81% of patients had successful cyst rupture, 54% of them required subsequent surgery. Also in 2009, Allen et al. published a retrospective cohort study looking at fluoroscopic-guided lumbar facet rupture in 32 patients [27]. In this study, 72% of the patients had excellent long-term pain relief, with 11 patients requiring repeat procedure and only 6 of the patients ultimately requiring surgery [27]. In 2012, a single-center prospective study by Amoretti et al. performed percutaneous CT-guided intracystic and intra-articular steroid injections on 120 patients [28]. This study had the most promising results with 75% of patients obtained durable pain relief at 12 months, with either one or two injections, and did not require subsequent surgery.

In the literature, there are numerous surgical procedures for CYFMOS including complete laminectomy, hemilaminectomy, partial facetectomy, and additional minimally invasive resection techniques [29]. In addition to the various decompressive surgical procedures, concomitant fusion is generally recommended, if there is a significant component of instability prior to, or as a result of the decompressive surgical procedure [29, 30••].

With regard to medical decision-making associated with CYFMOS, most difficulties arise in patients who are refractory to conservative medical management and have undergone successful percutaneous cyst rupture with subsequent reoccurrence of the CYFMOS. In these situations, detailed imaging findings may help determine whether patients should subsequently undergo further imaging studies, repeat percutaneous interventional procedures, surgical decompression, or surgical decompression with fixation.

Significant Imaging Findings of CYFMOS Which May Guide Management

On diagnostic magnetic resonance imaging (MRI), true synovial cysts typically follow the signal characteristics of CSF and are generally hyperintense on T2 and STIR and isointense on T1. The signal can vary widely however, as we will describe based on its varying degrees of proteinaceous, hemorrhagic, or calcified contents. The rim of the cyst is generally T2 hypointense and is contrast enhancing after administration of gadolinium.

CT-guided interventional approaches are promising, predominantly due to their superior delineation of bony structures compared to fluoroscopy or MRI. This helps interventionists navigate around the background of degenerative osteophytic changes, commonly comorbid with CYFMOS. For diagnostic imaging however, CT is not the ideal imaging modality, given the low density of these cysts can make them difficult to distinguish from the CSF. Occasionally however, these cysts can be identified more easily, when they are associated with hyperdensities due to intracystic hemorrhage or calcification, or hypodensities due to intracystic gas.

Significance of Cyst Signal Intensity

In a retrospective review of 110 patients, who underwent CT fluoroscopic-guided rupture of symptomatic lumbar facet synovial cysts, the CYFMO were divided into three groups based on their T2 relaxation times to determine the relation between the T2 signal intensity and the percutaneous rupture rate [31]. The 134 cysts were broken down into groups labeled as: “High Signal” (54) which were isointense or hyperintense to CSF, “Intermediate Signal” (62) which were hypointense to CSF and hyperintense to muscle, and “Low Signal” (17) which were isointense or hypointense to muscle. Examples of CYFMOS with different signal intensities can be seen on (Figs. 1 and 2). This study found that initial successful rupture rate was higher in the “High Signal” 89% and “Intermediate Signal” 90% compared to the 65% rupture rate in the “Low Signal” group. A low T2 signal could be attributed to a higher protein content or prior hemorrhage, which would result in more viscous cystic contents making it more difficult to rupture. The “High Signal” group was only associated with a 29% subsequent need for surgical intervention compared to the 48% for the combined “Intermediate and Low Signal” groups.

Also of note, 45% of patients that underwent repeat percutaneous cyst rupture eventually required surgery, which was not significantly different from the 39% who underwent a single attempted rupture [31]. These findings suggest that a history of prior percutaneous interventional procedures is not a predictive factor regarding future need for surgical intervention.

Association of Post-rupture Thickness of the Cyst Wall and the Need for Subsequent Surgery

In 2017, a retrospective review of 24 patients who received 41 percutaneous synovial cyst ruptures was performed to evaluate the association between increased thickness of the T2 hypointense rim on post-rupture MRI and subsequent need for surgical intervention [32••]. This study revealed that increased thickness of the T2 hypointense rim was attributed to higher rates of subsequent surgical intervention ($p = 0.0411$). These findings could be attributed to an increase in blood products, inflammatory changes, or calcification. In this study, the mean increase in thickness of the T2 hypointense rim was 0.781 ± 0.84 mm in patients who required surgery. In patients who did not require surgery, the mean increase in the thickness of the T2 hypointense rim was only 0.083 ± 0.22 mm. These findings suggest that an increase in the T2 hypointense rim greater than approximately 0.3 mm post percutaneous intervention should be considered for surgical decompression with or without stabilization.

How to Diagnosis and Evaluate Spinal Instability

Diagnosing underlying spinal instability is also a crucial component of managing CYFMOS recurrence after interventional percutaneous procedures. Standing flexion-extension radiographs are the gold standard for diagnosing underlying lumbar degenerative spondylolisthesis [33, 34]. On these radiographs, translation greater than 5 mm, or changes in angulation greater than 10 degrees, can be considered unstable [35–38]. A cutoff of 3 mm of translation, indicating surgically correctable spondylolisthesis, is also commonly seen in the literature [39]. Standing kinetic MRIs, although not standard of care given their scarcity in clinical practice, are an additional resource for diagnosing spinal instability. A 2009 study performed by Jang et al. used standing kinetic flexion-extension MRIs to diagnosis instability when there was 3 mm of translation or changes in angulation greater than 10 degrees [40].

Mobbs et al., in a recent 2018 article, performed a clinical cohort of 166 patients as well as a comparative meta-analysis on percutaneous cyst aspiration, surgical decompression, and decompression with fusion. Their analysis revealed that instability associated with 15% anterolisthesis correlated with a significantly higher rate of cyst recurrence following decompression [30••]. Thus, we suggest patients with recurrent CYFMOS after percutaneous intervention, which are also diagnosed with segmental instability either on MRI with > 15% anterolisthesis or on standing flexion-extension radiographs, be considered for surgical decompression with concomitant stabilization.

When to Use Flexion-Extension Radiographs to Evaluate Further for Spinal Instability

There are several findings on conventional MRI that can raise enough of a concern for underlying instability to warrant follow-up standing flexion-extension imaging to diagnose spinal instability.

In 2007, a retrospective review of 139 patient's conventional MRIs and standing flexion-extension radiographs was performed by Chaput et al. Their analysis revealed that at the L4/5 level, there was a direct relationship between the degree of facet effusion, measured by the largest value perpendicular to the facet joint, and the probability of spondylolisthesis [18]. Their review found that a 1-mm effusion estimated a 29.6% probability of instability, a 2-mm effusion estimated a 60.3% probability of instability, and a 3-mm effusion estimated a 84.6% probability of instability [18]. Of note, this study had a rather sensitive cutoff, labeling patients with instability if there was only greater than or equal to 5% anterior translation, which is significantly less than the 15% anterolisthesis previously discussed by Mobbs et al. which should be considered for surgical fusion [18, 30••].

A 2017 retrospective review of the MRI findings in 94 patients, who underwent surgery for degenerative spondylolisthesis by Cho et al., found that the presence of high signal intensity in the facet joints was a strong indicator of underlying lumbar instability with a positive predictive value of 93.22% [14].

The same study by Cho et al. in 2017 found that more severe degrees of disc and facet degeneration measured, using the degenerative disc disease (DDD) Thompson criteria (grade 1–5) and sum of facet joint osteoarthritis (FJO) Grogan's score (3–12 points), were associated with decreased likelihood of instability [41, 42]. Detailed summary of these grading scales is depicted in Tables 1 and 2. In this study, the patients in the instability group were found to have Thompson grade 3.0 ± 0.77 DDD, compared to the stable group which had Thompson grade 3.96 ± 0.88 DDD. Patients in the

Table 1 Thompson criteria [43]

	Nucleus	Annulus	End plate	Vertebral body
Grade I	Bulging gel	Discrete fibrous lamellae	Hyaline, uniformly thick	Margins rounded
Grade II	With fibrous tissue peripherally	Mucinous material between lamellae	Thickness irregular	Margins pointed
Grade III	Consolidated fibrous tissue	Extensive mucinous infiltration with loss of annular-nuclear demarcation	Focal defects in cartilage	Early chondrophytes or osteophytes at margins
Grade IV	Focal disruptions	Focal disruptions	Fibrocartilage extending from subchondral bone; irregularity and focal sclerosis in subchondral bone	Osteophytes smaller than 2 mm
Grade V	Clefts extended through the nucleus and annulus	Clefts extend through the nucleus and annulus	Diffuse sclerosis	Osteophytes larger than 2 mm

Table 2 Grogan's scores of facet degeneration (sum of Grogan's score, 3–12) [42]

1—Facet cartilage degeneration	Uniformly thick cartilage covering both articular surfaces completely	1—Facet Sclerotic Degeneration	Uniform thin band of cortical bone	1—Facet tropism	0° of facet tropism
2—Facet cartilage degeneration	Cartilage covering the entire surface with eroded or irregular regions	2—Facet sclerotic degeneration	Thin band of cortical bone that extended into the space from the articular surface	2—Facet tropism	1–7° of facet tropism
3—Facet cartilage degeneration	Cartilage incompletely covering the articular surface with the underlying bone exposed to the joint space	3—Facet sclerotic degeneration	Dense bone that extended into the joint space but covered less than half the facet	3—Facet tropism	7–15° of facet tropism
4—Facet cartilage degeneration	Complete absence of cartilage except for traces evident on the articular surface	4—Facet sclerotic degeneration	Osteophytes or dense cortical bone that covered greater than half the facet joint	4—Facet tropism	> 15° of facet tropism

instability group were found to have FJO Grogans's score of 4.94 ± 2.23, compared to the stable group which had FJO Grogan's scores of 9.32 ± 1.83. These findings are intuitive given the previously discussed pathogenesis of these degenerative changes. The more advanced degrees of degeneration were more likely to have transitioned from the "instability phase" to the "stability phase" as described by Kirkaldy-Willis and Faran [14].

Given that spinal segmental instability is a dynamic process which evolves as the degenerative process progresses, the variable different degrees of degeneration involving different segments of a spinal region can ultimately dictate the composite degree of instability. These variables were examined in a 2009 study performed by Jang et al. previously discussed, which used standing kinetic MRI to evaluate 927 spinal segments from 309 patients and measured the degree of disc degeneration (using Pfirrmann's criteria), facet joint osteoarthritis (using the Fujiwara et al. method), and the ligamentum flavum hypertrophy (LFH), which was labeled as being present or absent [40, 44, 45]. Detailed summary of Pfirrman's criteria and Fujiwara grading scales is depicted in Tables 3 and 4. These variables were correlated with the presence of segmental instability set at a translational motion greater than 3 mm at the L3-4, L4-5, and L5-S1 levels when flexion-extension kinetic MRI views were later obtained. At L3-4 and L4-5, ligamentum flavum hypertrophy was individually identified as having a significant correlation with segmental instability. DDD and FJO at L3-4 were also individually correlated with segmental instability. At L4-5, which is the site of greatest physiologic translational movement and the most common location of CYFMOS, interrelations were identified between different combinations of degenerative changes which correlated with different grades of segmental instability. The combinations, which were associated with high rates of segmental instability at this level, were as follows: grade IV degenerative disc disease with grade III facet joint osteoarthritis, grade III facet joint osteoarthritis with the presence of ligamentum flavum hypertrophy, and grade IV degenerative disc disease with the presence of ligamentum flavum hypertrophy [40].

Of note, patients undergoing standing kinetic MRIs will invariably undergo flexion and extension views. The utility of this study therefore is obtained by extrapolating the findings to better understand the interrelation between the variable different degrees of degeneration involving different segments of spinal segments appreciated on conventional MRI.

Questionable Significance of CYFMOS Size and Need for Surgical Intervention

There are several additional imaging findings associated with CYFMOS with questionable significance, most notably, the size of the cyst. In the previously discussed 2017 retrospective review of 24 patients, who received 41 percutaneous synovial cyst ruptures, performed by Kwan, there was a statistical significance difference associated with cyst size and the need for subsequent surgery (p value = 0.0483). The average cyst size for cases that did not require surgery

Table 3 Pfirrman's classification of lumbar disc degeneration [45]

Grade I	(Normal) Uniform high signal in the nucleus on T2-weighted MRI
Grade II	Central horizontal line of low signal intensity on sagittal images
Grade III	High intensity in the central part of the nucleus with lower intensity in the peripheral regions
Grade IV	Low signal intensity centrally and blurring of the distinction between nucleus and annulus
Grade V	Homogeneous low signal with no distinction between nucleus and annulus

Table 4 Fujiwara grading scale for facet joint osteoarthritis [41]

Grade I	Normal
Grade II	Joint space narrowing or mild osteophyte
Grade III	Sclerosis or moderate osteophyte
Grade IV	Marked osteophyte

was 1.21 ± 0.34 cm while the average size for those who required surgery was 1.57 ± 0.51 cm [32••]. These findings suggest that a CYFMOS measuring approximately 1.5 cm or greater are more likely to require surgical intervention. These findings were inconsistent however, with the retrospective review ($n = 110$) of CT fluoroscopic-guided rupture of symptomatic lumbar facet synovial cysts by Cambron et al., who found no significance between cyst size and need for subsequent surgery [31].

There have been various grading systems, which have focused on the size of the CYFMOS. The previously discussed 2018 evaluation of a clinical cohort of 166 patients performed by Mobbs et al., looking at lumbar facet joint cysts, categorized CYFMOS by the presence or absence of at least 15% anterolisthesis and an extrapolation of the cyst size by measuring the associated percentage of spinal stenosis [30••]. Grade I was associated with 0–25% spinal canal stenosis with less than 15% anterolisthesis and it was suggested that these cases be managed with percutaneous intervention. Grades II and III were associated with 25–50%, and greater than 50% spinal canal comprise respectively, with less than 15% anterolisthesis, and were best managed with surgical decompression without fusion as the initial option. Grades IV and V were associated with at least 15% anterolisthesis, and less than or greater than 50% spinal canal compromise respectively, and it was suggested that these cases be managed with surgical decompression with concomitant fusion as the initial option. While this study suggests that in the absence of instability, greater than 25% spinal canal compromise can be used as an indication to skip percutaneous intervention and proceed with surgical decompression, prospective studies are required to confirm the validity of this grading scale.

Conclusion

Synovial cysts of the spine are relatively uncommon, occurring most commonly in the lumbar spine, followed by the cervical spine and thoracic spine at the most mobile segments. The cysts themselves may become symptomatic when they exhibit mass effect on adjacent structures causing neck or back pain, radiculopathy, neurogenic claudication, or cauda equina syndrome. Nomenclature has varied over the years based on location and histologic findings. Without a precise nomenclature, perhaps the best overall term for now is "cystic formation of the mobile spine," which also includes the role of spine degeneration and destabilization as the underlying pathogenesis. There are numerous treatment options, which include conservative management, percutaneous interventional procedures including cyst rupture, and surgical intervention with or without fusion. Imaging findings can serve as a potential treatment guide outlined above in Fig. 3. In the common dilemma of patients who have a recurrence of their CYFMOS after initial percutaneous intervention, magnetic resonance imaging (MRI) can be used to identify the cyst characteristics and signs of spinal instability to further guide the management of these

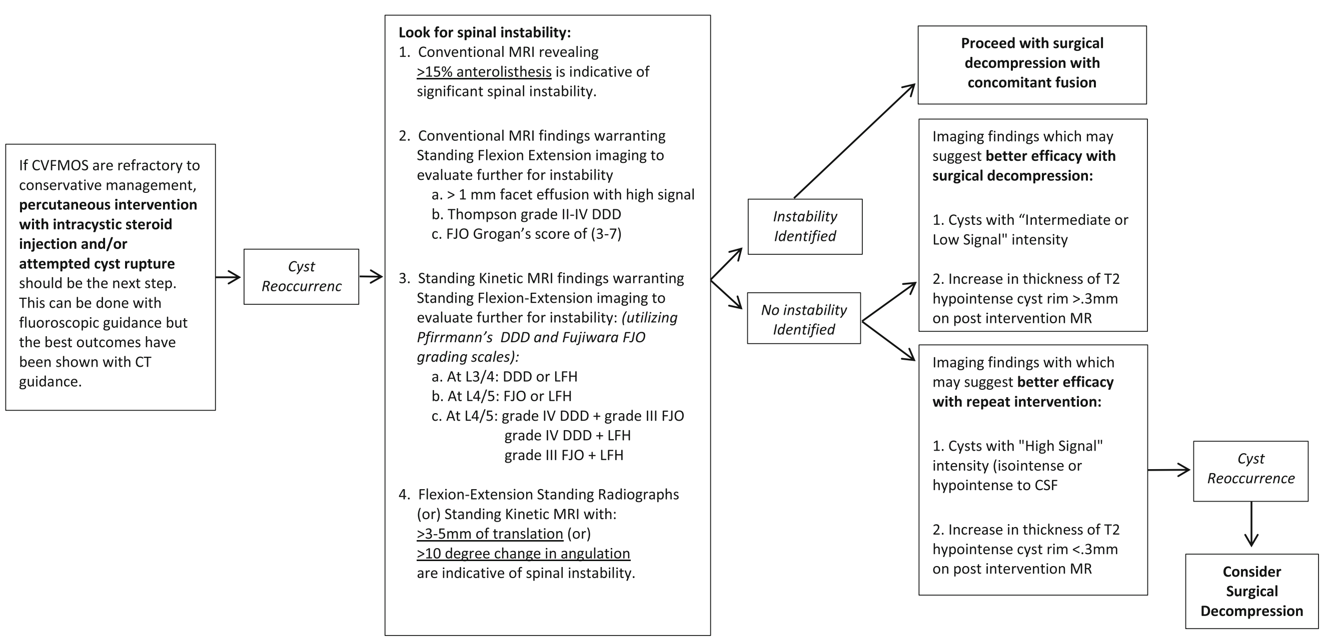

Fig. 3 Purposed treatment algorithm for CYFMOS based on imaging findings

patients. MRI findings, as detailed in Fig. 3, can triage patients into further evaluation with standing flexion-extension imaging, repeat percutaneous intervention, and surgical decompression with or without concomitant fusion.

Compliance with Ethical Standards

Conflict of Interest Amar Anand, Thomas J. Pfiffner, and Laszlo Mechtler declare no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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