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REVIEW ARTICLE

Thinking beyond pannus: a review of retro-odontoid pseudotumor due to rheumatoid and non-rheumatoid etiologies

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Abstract

Retro-odontoid pseudotumor, or mass-like retro-odontoid soft tissue thickening, is an uncommon but important imaging finding that may be associated with rheumatoid arthritis, crystal deposition diseases, as well as non-inflammatory conditions such as cervical degenerative changes and mechanical alterations. Retro-odontoid pseudotumor is commonly associated with atlantoaxial microinstability or subluxation. MRI and CT have an important role in the detection and diagnosis of retro-odontoid pseudotumor. However, due to a wide range of imaging characteristics and ambiguous etiology, it is a frequently misunderstood entity. The purpose of this article is to review relevant anatomy of the craniocervical junction; describe various imaging appearances, pathophysiology and histology in both rheumatoid and non-rheumatoid etiologies; and discuss differential diagnosis of retro-odontoid pseudotumor in order to help guide clinical management.

Keywords Atlantoaxial · Cervical spine · Odontoid · Pannus · Retro-odontoid pseudotumor · Rheumatoid arthritis

Introduction

Retro-odontoid pseudotumor, which we define as soft tissue proliferative changes at the atlantoaxial junction surrounding the region of the transverse ligament, is an uncommon but important imaging finding that may indicate clinically significant symptoms and systemic disease. Pseudotumor is a diverse entity commonly mislabeled as "pannus." In the setting of rheumatoid arthritis, retro-odontoid soft tissue proliferation is most commonly referred to as "pannus." However, since histological reports are sparse and do not always confirm inflammation, the more general term of retro-odontoid pseudotumor may be more accurate to describe soft tissue proliferation. The most common clinical dilemma when encountering a patient with imaging-detected retro-odontoid pseudotumor is: "Does this patient have rheumatoid arthritis?" Thickening of retro-odontoid soft tissue can be seen on MR or CT imaging in adults with both rheumatoid arthritis (RA) and non-RA etiologies [1]. Retro-odontoid pseudotumor can cause mass effect on the spinal cord, resulting in pain, myelopathy, or progression to paralysis in advanced cases [2–4].

Although pseudotumor may have suggestive features on imaging, there are no established criteria to diagnose retro-odontoid pseudotumor, and imaging manifestations can range from thickening of the retro-odontoid soft tissues to mass-like proliferative changes. However, the normal thickness of the transverse ligamentous complex should be less than 3 mm based on anatomic dissections [5], and reports of abnormal retro-odontoid soft tissue typically describe thicknesses greater than 3 mm [6, 7]. In the absence of frankly evident cord compression, the neurological implications of retro-odontoid pseudotumor cannot be reliably judged by supine static MR imaging, as neural compression may be brought on by instability from postural changes. Although retro-odontoid pseudotumor has been shown to be related to mechanical instability, previous studies have not shown a single specific cause for soft tissue proliferation, and it is difficult to predict which patients will develop pseudotumor. Given that retro-odontoid pseudotumor is an uncommon condition that cannot

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be diagnosed based on clinical symptoms alone, radiologists have an important role in detecting and diagnosing retro-odontoid pseudotumor on cross-sectional imaging.

The normal soft tissue anatomy of the retro-odontoid region consists of the cruciate ligament with a strong transverse ligament immediately adjacent to the nearly imperceptible longitudinal band, as well as the posterior longitudinal ligament and thecal sac (Fig. 1). The craniocervical junction consists of the base of the occipital bone and the uniquely shaped C1 and C2 vertebrae (Figs. 1 and 2). Unlike all other vertebrae, C1 does not have a body or spinous process and instead is predominantly ring-shaped. Given the synovial articulation between the transverse ligament and the odontoid, there is a potential space that can be affected by inflammatory, and reparative processes resulting in proliferative soft tissue.

In some cases, retro-odontoid pseudotumor has imaging characteristics that can suggest certain clinical etiologies, and the radiologist has an important role in its detection. In order to aid more accurate diagnosis, we will review the osseous, articular, and ligamentous anatomy of the craniocervical junction; explore the pathophysiology and imaging features of various types of retro-odontoid pseudotumor; and discuss the various etiologies of non-rheumatologic retro-odontoid masses.

Anatomy of the craniocervical junction

The C1 vertebra is known as the atlas, from the Greek mythological deity of the same name, who was condemned to support the weight of the universe on his shoulders [8]. The C2 vertebral body is commonly referred to as the axis, as C1 rotates relative to C2. The odontoid process of C2, also called the dens, is a peg-like protuberance that extends cranially from the body of C2 to articulate with the anterior aspect of C1. The portion of the C1 ring that extends anterior to the odontoid process is termed the anterior arch of C1 (or anterior arch of the atlas).

The craniocervical junction and C1-C2 articulation consist of several joints that allow complex flexion, extension, and rotational movements. The axis and atlas articulate via four synovial joints. The anterior median atlantoaxial joint is a pivot-type synovial joint that is the articulation between the anterior aspect of the odontoid process and the midline articular facet of C1. The posterior median atlantoaxial joint is the articulation between the odontoid process and the transverse ligament of C1. The posterior aspect of the odontoid process is covered by a fibrocartilaginous surface that allows free gliding motion against the transverse ligament [9, 10], and a small bursa may be present overlying the odontoid [9, 11]. The articulation between the odontoid and the transverse ligament

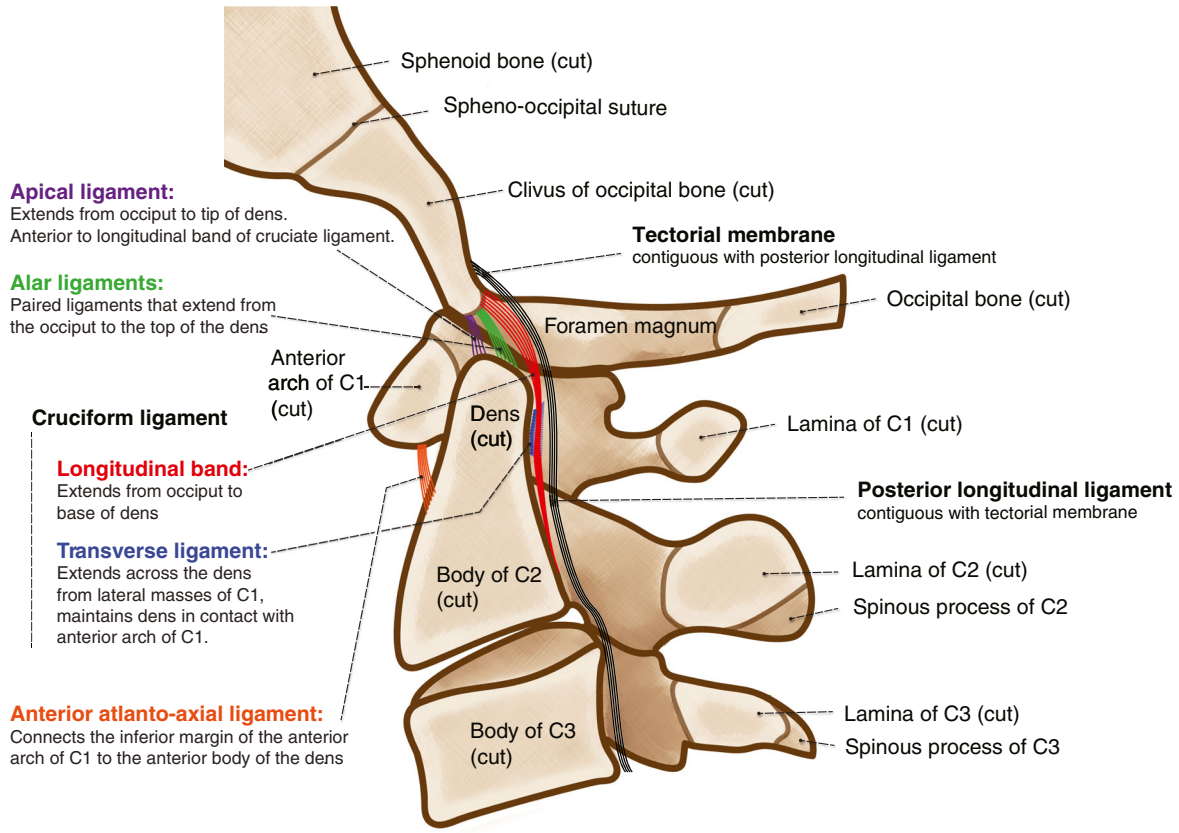

Fig. 1 Illustration demonstrating the osseous and ligamentous anatomy of the craniocervical junction, from a lateral view

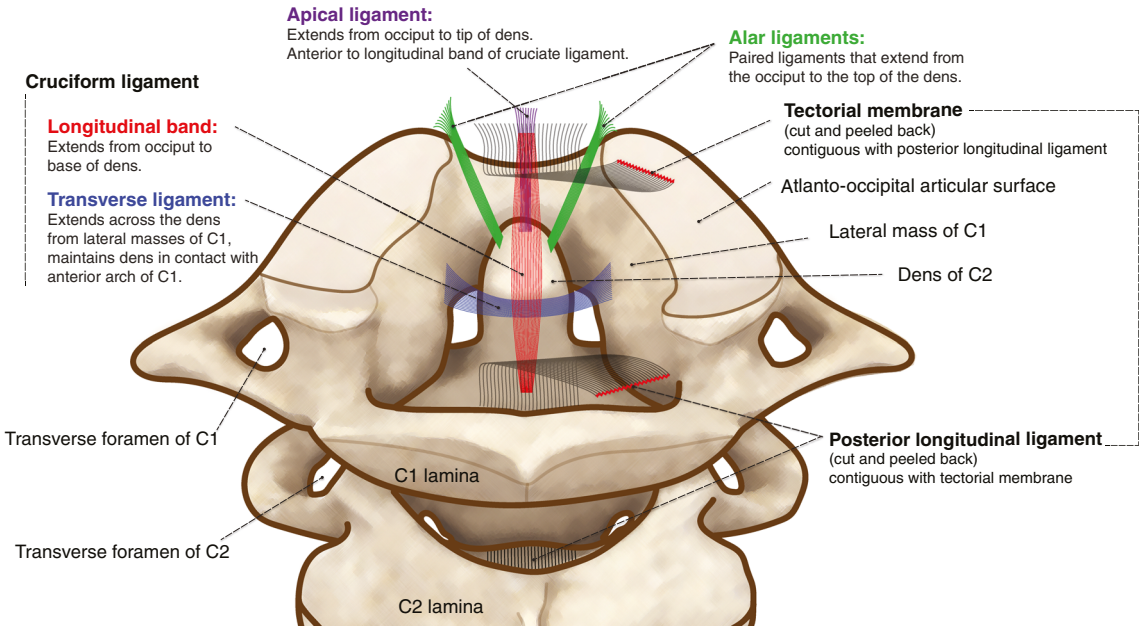

Fig. 2 Illustration demonstrating the osseous and ligamentous anatomy of the craniocervical junction, from a posterior top-down view

is one of the few osseous-ligamentous articulations in the human body, in addition to the talocalcaneonavicular joint [12] and the transverse acetabular ligament in the hip [13]. The paired lateral atlantoaxial joints are synovial plane type joints, also called arthrodial or gliding joints.

Several ligamentous structures are important passive stabilizers of the craniocervical junction (Figs. 1 and 2). The primary stabilizer of the C1-C2 articulation is the transverse ligament, which extends across the posterior aspect of the dens connecting the lateral masses of C1. The transverse ligament is a component of the cruciform ligament, which also consists of relatively thin, longitudinally oriented superior and inferior bands. The transverse ligament allows only 3 to 5 mm of anterior movement and approximately 6 mm of lateral movement before rupturing [14]. Secondary stabilizers of the atlanto-occipital junction include the apical and alar ligaments [15–17], which attach from the dens to the basion of the foramen magnum and the occipital condyles, respectively. An additional stabilizer, the tectorial membrane [16] is attached to the anterior rim of the foramen magnum, lies dorsal to the transverse ligament, and inserts into the body of C2.

Destruction of the ligamentous and capsular support structures of the craniocervical junction may result in atlantoaxial instability (AAI) [2]. A comprehensive discussion of cervical instability [18] is beyond the scope of this review focused on retro-odontoid pseudotumor, but a basic understanding of AAI is essential, given that there are several reports of this pattern of instability in patients with retro-odontoid pseudotumor. AAI is present when there is excessive motion between the axis and the atlas. In the setting of RA, AAI is thought to be due to transverse ligament laxity (e.g., in patients with Down syndrome) [19] or ligament rupture caused by synovial inflammation [20, 21]; and in patients without RA, ligamentous insufficiency may be due to degeneration and altered mechanical forces [22, 23], or inflammatory changes from other arthritides such as psoriatic arthritis [24] or ankylosing spondylitis [25].

Imaging techniques

Radiographs are the primary imaging modality for the assessment of instability. Neutral radiographs alone may underdiagnose subluxation of the cervical spine by 48% [26], and therefore flexion-extension radiographs are recommended in patients with RA. One of the most common radiographic measurements to assess for anterior atlantoaxial instability is the anterior atlanto-dental interval (AADI) between the posterior margin of the anterior arch of C1 and the anterior cortex of the dens. The AADI should be less than 2.5 mm in the absence of atlanto-axial instability [27]. With AADI values greater than 3 to 5 mm in the adult patient (Fig. 3), destruction of the entire ligamentous complex must be suspected [9, 28]. However, radiographic assessment may be challenging due to overlapping structures [29], magnification effect, and variability of technique.

Multidetector computed tomography (MDCT) with multiplanar reformatted images is useful for identifying bony erosions, fracture, alignment, relationship of the joints, and presence of pseudotumor [18]. MDCT can also determine whether there is mineralization within the retro-odontoid pseudotumor or in the peri-odontoid ligaments, which can be seen in the setting of hydroxyapatite deposition disease

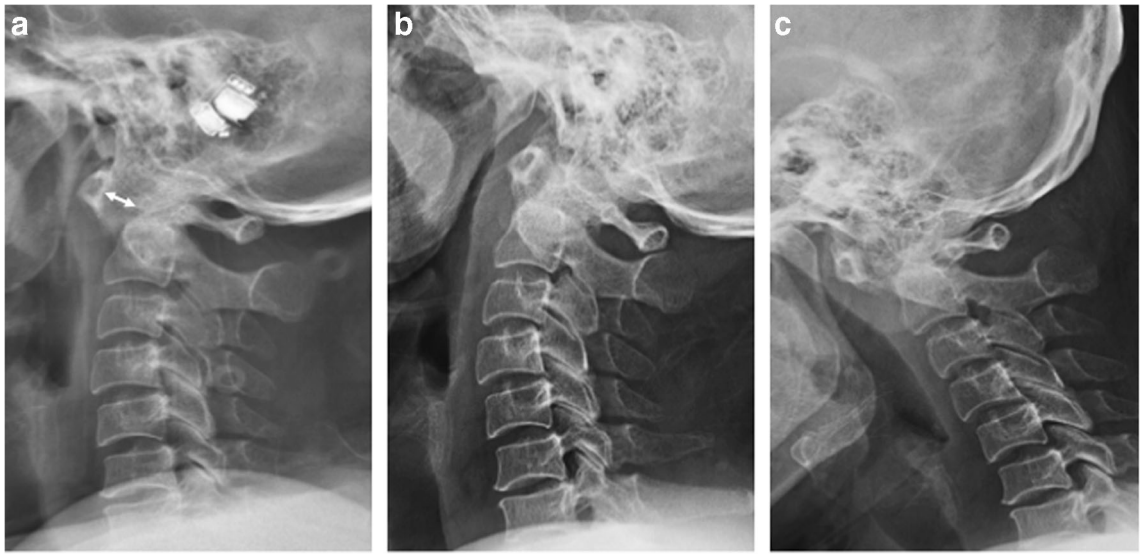

Fig. 3 **a** A 45-year-old woman with 25-year-long history of rheumatoid arthritis with atlantoaxial instability. Cervical spine radiograph in neutral position demonstrates widening of the atlantoaxial interval measuring 11 mm (*double arrow*). **b**, **c** The atlantoaxial interval is measured at the mid-portion of the arch of C1. Extension (**b**) and flexion (**c**) radiographs show anterior atlantoaxial instability, with increase in the atlantoaxial interval in flexion

(HADD) or calcium pyrophosphate deposition (CPPD). MDCT is also useful for surgical planning prior to decompression and fusion.

Magnetic resonance imaging (MRI) is the gold standard for the evaluation of retro-odontoid pseudotumor. While conventional radiography may detect advanced cervical spine changes, MRI has been shown to be more sensitive and specific for early craniocervical involvement by RA [30]. T2-weighted sequences can identify edema within the odontoid, the pseudotumor itself, adjacent segments of the cervical spine, and degree of spinal cord compression. Pre-contrast T1-weighted sequences may identify the presence of hemorrhage, fibrous tissue, and mineralization. Post-contrast T1-weighted images are useful to assess vascularity of the pseudotumor. Although flexion-extension MRI protocols have been described [31], this has not achieved widespread use. MRI is recommended in all patients with clinical myelopathy or any detected abnormality on radiographs.

Retro-odontoid pseudotumor in patients with RA

RA is a chronic inflammatory and highly destructive arthropathy that affects many joints throughout the appendicular and axial skeleton. RA can cause marked functional limitations and severe morbidity. Following the small peripheral joints, the cervical spine is the second most commonly involved region [32–34]. The entire cervical spine can be affected by RA, and it has been estimated that signs and symptoms of cervical spine involvement, including neck pain and radiculopathy, may develop in 60–80% of patients with longstanding disease [18, 20]. Characteristic findings on imaging include odontoid erosion, facet erosion and fusion, intervertebral disc space narrowing, erosion of vertebral body margins, as well as occiput-C1-C2 and subaxial subluxations [20]. Some degree of retro-odontoid soft tissue thickening can be seen in up to 83% of RA patients [35], although progressive thickness of pseudotumor is not associated with increased atlantoaxial instability [6]. The vast majority of RA patients with retro-odontoid pseudotumor have a clinical history of longstanding peripheral joint involvement; conversely, a new diagnosis of RA based on the isolated presence of retro-odontoid pseudotumor would be rare, with only a few reported cases in the literature [36].

Retro-odontoid pseudotumor demonstrates a variety of imaging appearances and corresponding histology (Figs. 4, 5, and 6). It has long been recognized that there may be inflammatory, fibrous, or combined components in patients with RA [37], and these types have been termed hypervascular pannus (hyperintense on T2-weighted images and enhancing); hypovascular pannus (intermediate signal intensity on T2-weighted images and intermediately enhancing); and fibrous pannus (low signal intensity on all sequences and non-enhancing) [35]. Corresponding post-mortem histologic analysis in patients with hypervascular pannus demonstrated granulation tissue with inflammatory cells and vascular proliferation, while hypovascular and fibrous pannus showed dense fibrous tissue without vascular proliferation [35]. Similar types of retro-odontoid pseudotumor have also been identified and classified on CT on the basis of enhancement and confirmed histologically, with erosions of the odontoid process noted in 57% of patients [38].

AAI and/or pseudotumor may occur in patients with or without RA. Indeed, AAI is a much more common

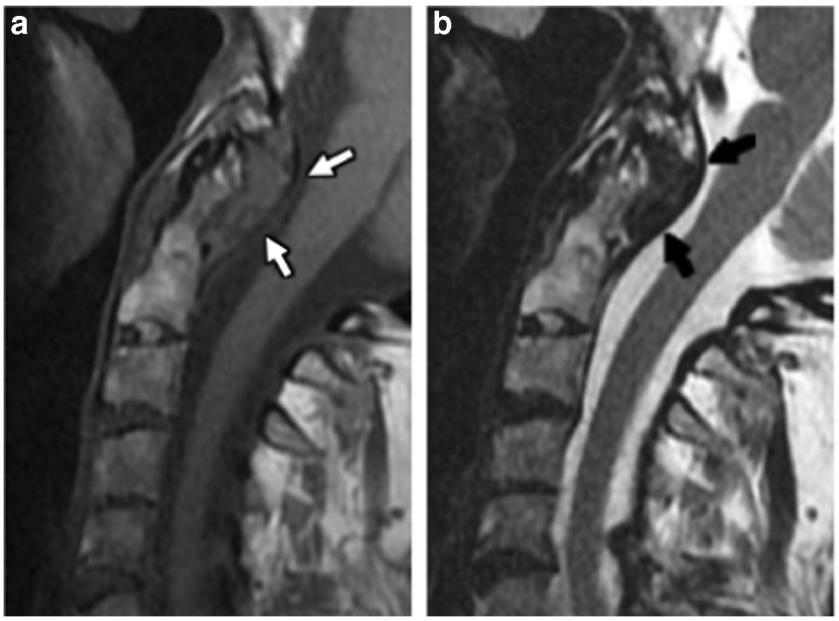

Fig. 4 **a** A 77-year-old woman with longstanding history of rheumatoid arthritis and heterogeneous, predominantly low signal intensity pseudotumor. Sagittal T1-weighted MR image demonstrates T1 isointense (to brain) soft tissue (*arrows*) posterior to the dens. **b** Sagittal T2-weighted MR image demonstrates T2 hypointense soft tissue (*arrows*) posterior to the dens, which has been described as "fibrous pannus" and "pseudotumor-type pannus" in patients with RA. Of note, there is a more heterogeneous, T2 hyperintense component more cranially

manifestation of rheumatoid cervical spine involvement than retro-odontoid pseudotumor [6]. Neurological compromise from AAI is a serious consequence of RA and major cause of death. The prevalence of AAI in patients with RA ranges from 10 to 86% [34, 39–41], and the all-cause mortality rate of patients with AAI is eight-times that of patients without radiographic evidence of subluxation [4]. Interestingly, a 2015 meta-analysis [42] showed that over the last 50 years, there has been a 27% decrease in the prevalence of AAI in patients with RA, which may be related to improved disease control with medications such as disease-modifying anti-rheumatic drugs (DMARDs).

Two large reports independently found that in RA patients with retro-odontoid pseudotumor and AAI, the retro-odontoid soft-tissue thickness correlated inversely with the atlantodental interval (ADI) [6, 43]; meaning that more advanced atlantoaxial instability (increased ADI) was seen in patients with decreased retro-odontoid soft-tissue thickness. Previous experimental work demonstrated that the transverse ligament ruptures after about 3 to 5 mm of anterior subluxation of the atlas [14]. Based on a 2016 study of 201 patients with RA, Dohzono et al. [6] hypothesized that the transverse ligament is likely ruptured in patients with atlantoaxial instability, which may decrease mechanical stress on the transverse

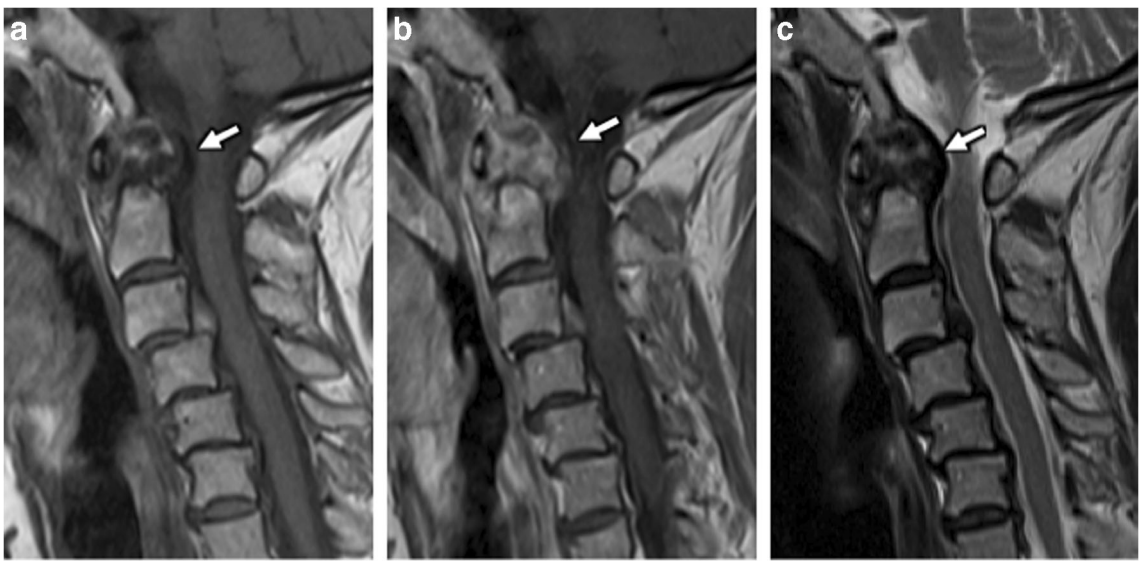

Fig. 5 **a** A 64-year-old woman with 21-year-long history of rheumatoid arthritis with mixed signal intensity ("hypovascular") pseudotumor. Sagittal T1-weighted pre-contrast demonstrates T1 hypointense tissue around the odontoid dens. **b** Sagittal T1-weighted image demonstrates enhancement of the retro-odontoid soft tissue. **c** Sagittal T2-weighted image demonstrates mixed signal intensity of pseudotumor with areas of T2 hyperintense signal

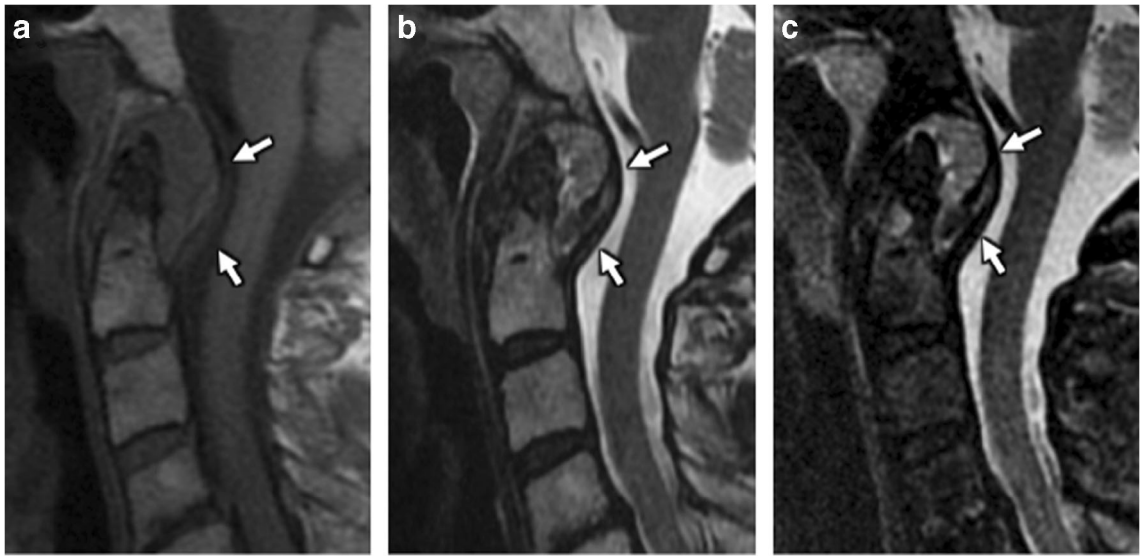

Fig. 6 **a** A 68-year-old man with history of long-standing rheumatoid arthritis with "pannus-type" pseudotumor, which tends to enhance and has also been called "hypervascular pannus" when contrast is administered. Sagittal T1-weighted image demonstrates T1 isointense (to brain) soft tissue posterior to the dens. **b**, **c** Sagittal T2-weighted image (**b**) and STIR (**c**) MR images demonstrate T2 heterogeneously hyperintense soft tissue proliferation (*arrows*) posterior to the dens. Contrast was not administered in this case

ligament and result in decreased retro-odontoid soft tissue thickness in the setting of advanced AAI.

The largest study of retro-odontoid soft-tissue thickness was performed by Tojo et al. in 2013 [7]. These authors measured retro-odontoid soft tissue thickness in 503 consecutive patients undergoing cervical spine MR and showed that the mean retro-odontoid soft tissue thickness in RA patients is 3.7 mm; however, only 70/503 (14%) of the study patients had RA. Although this paper primarily documents non-RA patients, it is valuable in comparing the two cohorts. The authors correlated retro-odontoid soft tissue thickness with presence of degenerative change, RA, and dialysis. They found that increased retro-odontoid soft tissue thickness correlated significantly with male sex (3.8 vs. 3.5 mm), presence of degenerative changes (3.8 vs. 3.5 mm), and dialysis treatment (4.8 vs. 3.7 mm). There was no statistically significant association between increased retro-odontoid soft tissue thickness and RA diagnosis; however, none of the RA patients in this cohort had documented AAI. Moreover, the specific MR imaging appearance of the retro-odontoid soft tissue was not compared between patients with and without RA.

Retro-odontoid soft tissue in patients without RA

Non-rheumatoid retro-odontoid pseudotumor has been reported in patients with and without atlantoaxial instability in several case reports and case series. A common theme in these patients appears to be increased motion at the craniocervical junction, diagnosed on flexion-extension radiographs, which may be compensatory due to subaxial cervical spondylosis or related to prior trauma [44, 45]. The imaging appearances of retro-odontoid pseudotumor described in these reports can be varied, and to our knowledge there are no distinguishing imaging features that can reliably differentiate rheumatoid from non-rheumatoid etiologies in retro-odontoid pseudotumor. In 1986, in one of the first MR imaging studies of the craniocervical junction, Sze et al. [1] described pseudotumor in three non-rheumatoid patients with atlantoaxial instability. Two of the patients had longstanding cervical spine degenerative disease, and one had a history of remote cervical spine trauma. Each of these patients had a retro-odontoid mass that demonstrated low signal intensity on T1- and T2-weighted images. Histologic analysis after resection revealed non-malignant fibrous and granulation tissue, and the authors suggested that long-term trauma and mechanical irritation were the underlying cause of these masses.

Non-rheumatoid retro-odontoid masses (Fig. 7) may also occur in the absence of atlantoaxial instability [7, 45–47]. In 1991, Crockard et al. [48] described five elderly patients without atlantoaxial instability or RA but with retro-odontoid masses demonstrating T1-signal isointense to brain. Histologic analysis demonstrated acellular non-inflammatory masses consisting of material resembling a degenerated intervertebral disc. The authors posited that these non-inflammatory masses were due to ligamentous degeneration and tearing, possibly instigated by a partial tear of the transverse ligament, followed by a cycle of attempted repair and mass formation, ultimately resulting in fibrocartilaginous metaplasia and fibrovascular ingrowth.

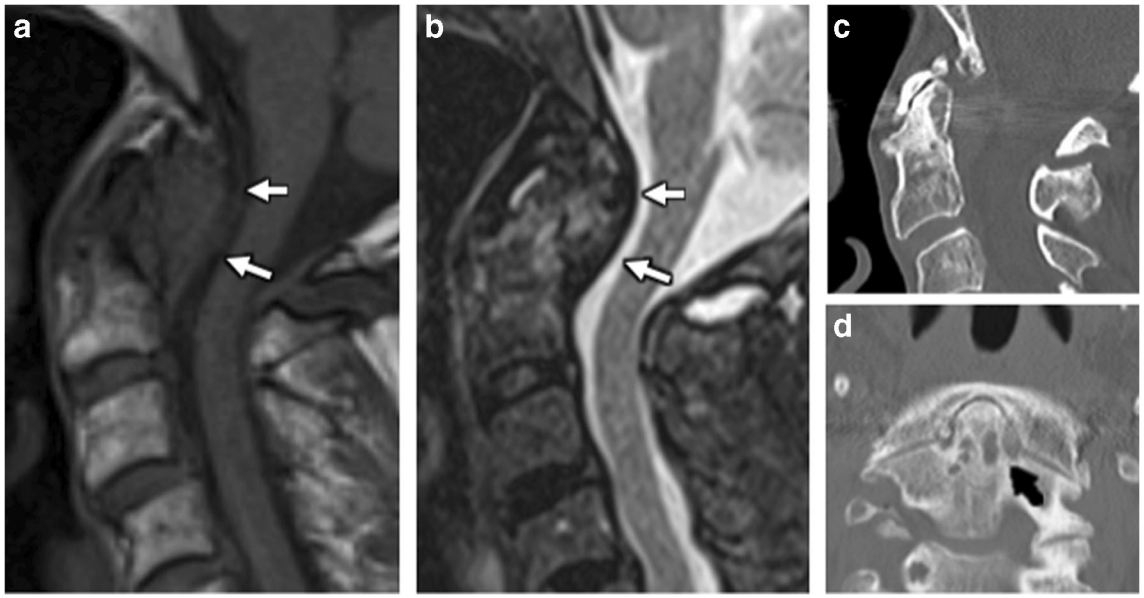

Fig. 7 **a** A 67-year-old woman with mixed signal intensity pseudotumor and erosive bony change from a non-rheumatoid etiology, differential includes CPPD, PVNS, gout, osteoarthritis, or hemodialysis-associated amyloidosis. Sagittal T1-weighted MR demonstrates T1 isointense soft tissue (*arrows*) posterior to the dens. **b** Sagittal T2-weighted image shows regions of mixed T2 hyperintense and hypointense signal in the pseudotumor, with mild reactive bone marrow of the odontoid. **c** Sagittal CT demonstrates no evidence of chondrocalcinosis. **d** Coronal CT demonstrates multiple small erosions of the odontoid dens

Diffuse idiopathic skeletal hyperostosis (DISH) limits the range of motion of the involved cervical segments and may also contribute to compensatory hypermobility at the craniocervical junction, potentially leading to pseudotumor formation. In 2002, Patel et al. [49] described five patients with DISH and concomitant retro-odontoid masses. The masses were described as slightly hypointense to brain on T1-weighted images with regions of both hypointensity and hyperintensity on T2-weighted sequences, corresponding to hypertrophic ligamentous, osseous, and chondral tissue with interspersed granulation tissue on histology.

As demonstrated in these diverse reports, retro-odontoid pseudotumor has been reported in patients with a variety of degenerative and mechanical alterations of the cervical spine. There may be an overlapping spectrum of ligamentous injury, microinstability, and soft tissue proliferation present in both RA-related and non-inflammatory causes of retro-odontoid pseudotumor (Fig. 8).

Regression of retro-odontoid pseudotumor

Multiple reports have demonstrated regression of retro-odontoid pseudotumor after surgical stabilization of the craniocervical junction, both in patients with and without RA [7, 23, 37, 44, 50–55]. Based on experience in 22 patients with RA, atlantoaxial instability, and retrodental pannus, Grob et al. [52] described four grades of pannus, ranging from grade 1 (little/no pannus) to grade 4 (massive pannus with neural compression). After C1-C2 posterior cervical fusion, regression in the degree of pannus was noted in 19/22 patients; the three patients without regression had relatively lower grade of pannus (grade 1 or grade 2). The mechanism of pseudotumor regression in patients with RA after stabilization is not clear, but this phenomenon suggests that there may be an element of mechanical etiology in the formation of retro-odontoid pseudotumor. Once the motion at the C1-C2 articulation is stabilized after fusion, the cycle of injury, inflammation, and repair may be alleviated.

After surgical fixation to address the underlying mechanical abnormality, multiple reports have also described spontaneous regression of retro-odontoid pseudotumor in patients without RA [44, 56, 57] or AAI [23]. In 2007, Sinha et al. collated 22 studies of non-mineralized retro-odontoid pseudotumor (which the author termed *cicatrix*) following odontoid fractures and showed that these masses spontaneously regress after surgical fixation [57]. In 2013, Sono et al. [44] described six non-RA patients with retro-odontoid pseudotumor that showed average thickness decreasing from 8.9 to 5.3 mm after fixation ($p < 0.01$).

Differential diagnosis of non-rheumatologic retro-odontoid proliferative changes

Mass-like proliferative changes about the dens have been described in several disease processes, including chondrocalcinosis [58], hemodialysis-associated amyloidosis [59–61], pigmented

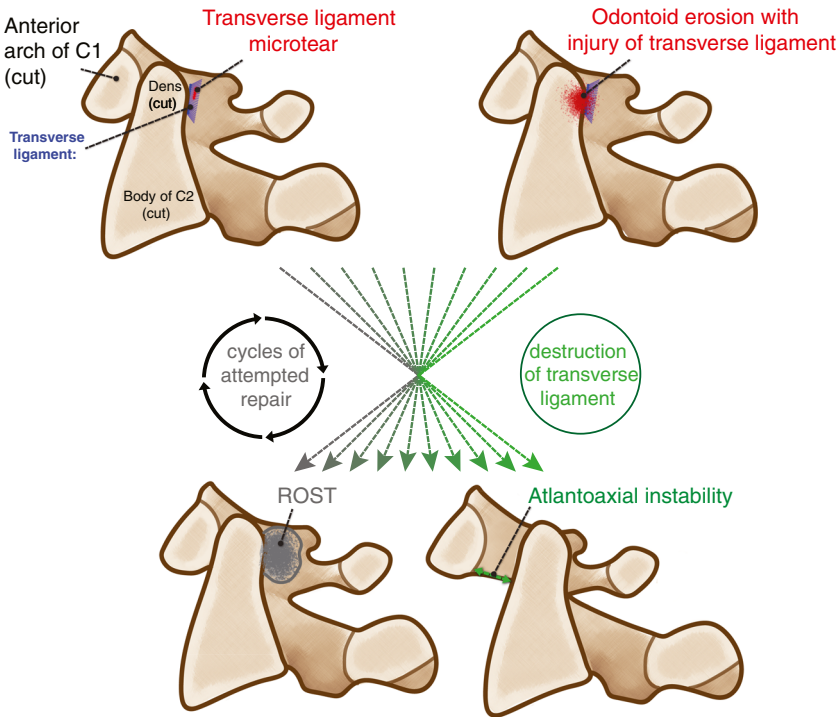

Fig. 8 Illustration demonstrating potential sequelae of transverse ligament injury – either mechanical or due to erosive changes of RA – which may lead to spectrum of changes including pseudotumor formation and/or atlantoaxial instability

villonodular synovitis (PVNS) [62–64], chronic odontoid fracture [65], and gout [66]. Additionally, retro-odontoid synovial cysts [67], epidural lipomatosis [68], epidural hematoma [69, 70], and ossification of the posterior longitudinal ligament [71] may occur in the retro-odontoid epidural region, although imaging characteristics of these entities should be diagnostic. Imaging characteristics of various etiologies of retro-odontoid pseudotumor are listed in Table 1.

Calcium pyrophosphate deposition disease

Chondrocalcinosis represents deposits of calcium pyrophosphate dihydrate crystals [75] into hyaline and fibrocartilage, although crystals can also be deposited in any intra-articular or peri-articular structure including ligaments, synovium, and capsule. Manifestations of CPPD in the cervical spine include calcific deposits in the transverse ligament, longitudinal ligaments, supraspinous and interspinous ligaments, intervertebral discs, facet joints, and annulus fibrosis. The calcifications of CPPD tend to be linear and diffuse. In addition, a well-recognized fulminant manifestation of retro-odontoid CPPD is termed the "crowned dens syndrome" [76–78], which may present clinically with occipital pain and neck stiffness. Posterior neck pain, fever, and increased serum inflammatory markers can be seen with CPPD and are relieved by NSAIDS and/or steroids [76], and mass-like proliferative changes can be present at the craniocervical junction [58]. Associated pyrophosphate arthropathy of the cervical spine includes narrowing of intervertebral discs, bony sclerosis, osteophyte formation, often with bony erosions and subchondral cysts [79, 80]. Chondrocalcinosis can be difficult to differentiate from other causes of retro-odontoid pseudotumor on MR imaging (Fig. 9). While mineralization on CT imaging helps to narrow the differential, hydroxyapatite deposition can also cause crowned dens and appear identical [81].

Hemodialysis-associated amyloidosis

A long-term complication of dialysis is accumulation of β2-microglobulin as amyloid fibrils in joints and periarticular structures, with the shoulder and cervical spine being the most common sites. It has been proposed that dialysis results in amyloid and inflammatory deposits at the craniocervical junction over time [7] and produces retro-odontoid pseudotumor [59–61, 82]. Characteristic imaging features include bony erosion and cystic change.

Pigmented villonodular synovitis

PVNS is a proliferative, destructive, non-malignant tumor of the synovial membranes. Although most commonly seen in the knees and hips, PVNS can also occur in the spine. In a review of 28 publications reporting 56 patients with spinal PVNS, 36% of the cases occurred in the cervical spine [80]. There are several case reports of PVNS causing a retro-odontoid pseudotumor [63, 64]. PVNS

Table 1 Imaging features of various causes of retro-odontoid pseudotumor

Etiology	T1 signal	T2 signal	STIR signal	Ossification	Erosions	Histopathology
Rheumatoid arthritis						
Hypervascular pannus	High	High	High	No	Yes	Granulation tissue with large amount of inflammatory cells, angioblasts, vessels, and edema [35, 38]
Hypovascular pannus	Low	High, mixed	Low			Connective tissue with poorly vascularized collagen fibers [35, 38]
Fibrous pannus	Low	Low	Low			Nonvascularized fibrous connective tissue with few cells [35, 38]
Osteoarthritis	Low	Low	Low	No	Rarely	Dense fibrous tissue proliferation with immature bone formation [72]
Retro-odontoid synovial cyst	Low	High	High	No	No	Degenerative ligamentous changes with inflammatory reaction [22, 67]
Hemodialysis-associated amyloidosis	Low to intermediate	Low to intermediate	Low	No	Yes	Extracellular deposition of the fibrous protein β2-microglobulin [59, 60]
CPPD	Low	Variable, heterogenous	Low	Yes	Yes	Inflammatory cells with positively birefringent rhomboid crystals (calcium pyrophosphate) [73]
PVNS	Low to intermediate	Low to intermediate	High	No	Yes	Mononuclear histiocytes mixed with multinucleated giant cells; interspersed hemosiderin deposition [62]
Ossification of Posterior Longitudinal Ligament	Low	Variable	Low	Yes	No	Formation of ossific-calcific components in the PLL [71]
Gout	Low	Variable, heterogenous	High	Yes, faintly calcified	Yes	Deposition of monosodium urate crystals [74]
Fracture	Low	High, mixed	High	Yes	Maybe	Callus formation, remodeling of fracture, reactive fibrous changes [65]
Epidural lipomatosis	High	Low	Low	No	No	Mature adipose tissue [68]
Epidural hematoma	High	Low	Low	No	No	Blood clot [69, 70]

lesions appear as masses of heterogeneously low signal intensity with susceptibility artifact, or "blooming" on gradient recall echo (GRE) sequences [79], secondary to hemosiderin content. Rarely, PVNS can form osteolytic bone lesions [83].

Odontoid fracture

Odontoid fractures in the setting of blunt trauma can result in nonunion and pseudoarthrosis [65]. The most common type of odontoid fracture is type II, which occurs at the junction of the odontoid base and the body of the axis. Type II odontoid fractures have the highest incidence of bony nonunion and malunion [84]. Poor healing can lead to altered movement. Chronic irritation from increased motion of the fracture fragment and/or malalignment can result in formation of a fibrous soft tissue mass around the fracture site [85] (Fig. 10). In a nontraumatic setting, retro-odontoid pseudotumor has been associated with os odontoideum [86] and may be a result of chronic atlantoaxial instability.

Gout

Gout may rarely occur at the craniocervical junction [66]. Gouty tophi can be faintly calcified and are associated with bony erosions as well as elevated serum uric acid levels. The MRI appearance of a tophus can be indistinguishable from a deposit of calcium hydroxyapatite crystals [74]. Dual-energy CT may be diagnostic, given its ability to distinguish urate and calcific mineralization due to differences in attenuation on the 80- and 140-kVp acquisitions [87].

Retro-odontoid synovial cyst

Retro-odontoid synovial cysts have been reported in elderly patients due to degenerative changes of the atlantoaxial joints [88] or transverse ligament [22]. Synovial cysts of the transverse ligament have also been reported to be associated with atlantoaxial instability [89]. While a simple fluid signal intensity cystic structure should not be a diagnostic challenge, a complex appearance with neovascularization and hemorrhage has also been reported [22].

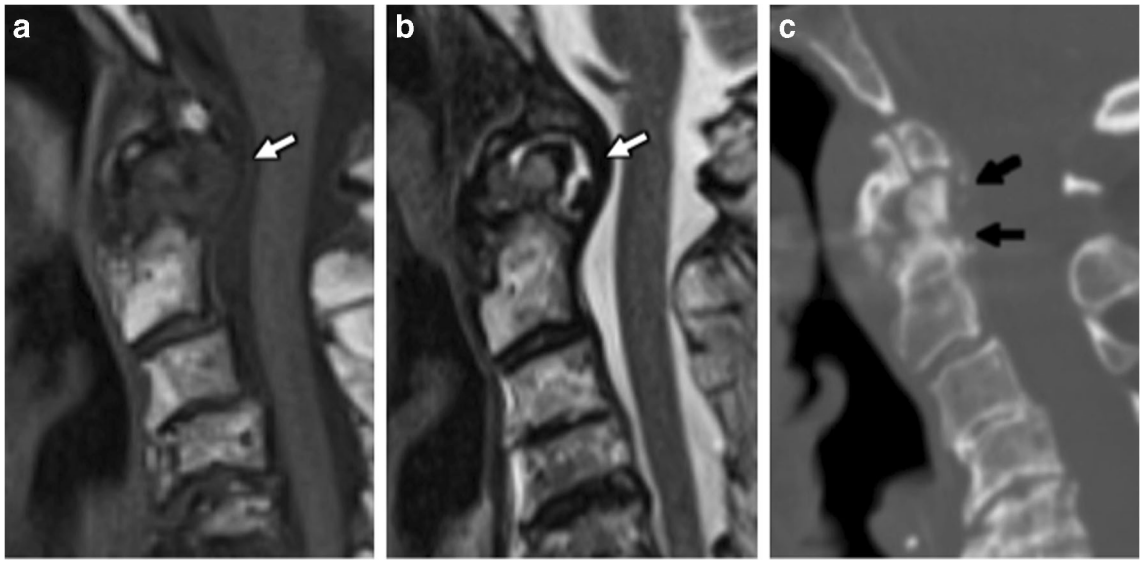

Fig. 9 **a** An 80-year-old woman with no history of RA, with chondrocalcinosis about the dens. Sagittal T1-weighted demonstrates T1 hypointense soft tissue (*arrow*) posterior to the dens. **b** Sagittal T2-weighted image demonstrates T2 heterogeneously hyperintense soft tissue (*arrow*) posterior to the dens. **c** Sagittal CT image shows amorphous mineralization surrounding the dens (*arrows*), in keeping with chondrocalcinosis

Ossification of the posterior longitudinal ligament

Ossification of the posterior longitudinal ligament (OPLL) [71] may be a variant of diffuse idiopathic skeletal hyperostosis [90]. OPLL decreases the space available for the spinal cord and can result in radiculopathy and myelopathy. Calcifications can be central or paracentral, and can be identified on CT. OPLL may also result in dural ossification [91]. In contrast to pseudotumor, which can have varied signal intensity and is centered at the posterior aspect of the dens, OPLL is isointense to cortex (low signal intensity on T1- and T2-weighted sequences), and usually extends caudal to the craniocervical junction.

Conclusions

Retro-odontoid pseudotumor is an uncommon entity with varied and overlapping imaging appearances described on MRI in patients with and without RA. Although the clinical

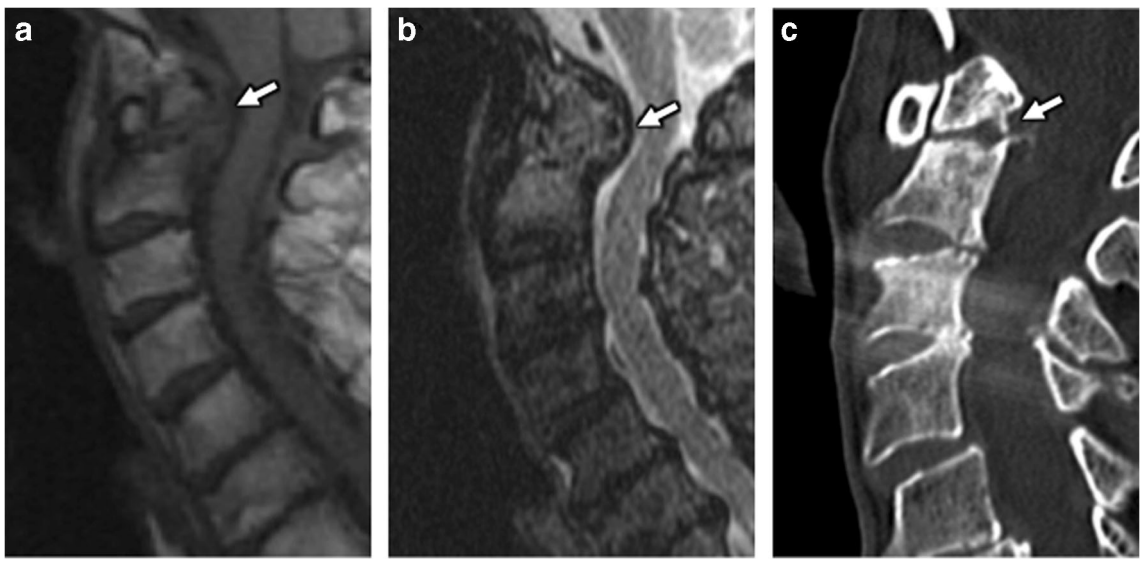

Fig. 10 **a** An 82-year-old woman with history of chronic dens fracture and soft tissue proliferation about the dens. Sagittal T1-weighted image demonstrates T1 hypointense soft tissue (*arrow*) posterior to the dens. **b** Sagittal T2-weighted image demonstrates heterogeneously T2 hyperintense soft tissue (*arrow*) posterior to the dens. **c** Sagittal CT image demonstrates a chronically nondisplaced type II fracture of the odontoid dens with sclerosis of the fracture margins (*arrow*)

significance of incidentally discovered retro-odontoid pseudotumor remains to be fully elucidated, a new diagnosis of RA would be very uncommon in the absence of peripheral joint involvement. Repetitive cycles of ligamentous injury and repair likely drive the development of these lesions, initiated by transverse ligament damage from inflammation, minor trauma, degenerative changes, or altered biomechanics. Regardless of the etiology, spontaneous regression of retro-odontoid pseudotumor is commonly observed following surgical fusion, further supporting the theory that excessive motion at the craniocervical junction may be a major contributing factor in the development of abnormal soft tissue. Although patients with or without RA cannot be reliably differentiated based on imaging characteristics of pseudotumor, understanding the various appearances of this entity can help narrow the differential diagnosis and optimize patient management.

Compliance with ethical standards

The above authors have no disclosures. The work has not been previously presented or published elsewhere. No IRB approval was required.

Conflict of interest The authors declare that they have no conflicts of interest.

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