Atlanto-axial Pannus in Patients with and without Rheumatoid Arthritis

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Key Indexing Terms: Atlanto-Axial Joint, Spine, Chondrocalcinosis, Rheumatoid Arthritis

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Running head: Atlanto-axial pannus

Abstract

Objective: Pannus formation in the atlanto-axial joint is a well-recognized complication of rheumatoid arthritis (RA). Occasionally, atlanto-axial pannus is reported when patients without a history of RA undergo magnetic resonance imaging (MRI) of the cervical spine. We sought to further characterize these patients.

Methods: The Partners HealthCare Research Patient Data Registry was free-text searched for 'atlanto-axial' AND 'pannus' in cervical spine MRI reports from 2001 to 2015. Cases with MRI reports describing pannus were reviewed. Clinical data were extracted by chart review in cases with confirmed atlanto-axial pannus (n=105).

Results: Twenty-nine patients (27.6%) had RA, all of whom except one carried this diagnosis at the time of the MRI scan. Only 1 of 77 patients without a history of RA was subsequently diagnosed with RA (1.3%, 95% CI 0.1-7.0%, median follow-up 3.6 years). Non-RA patients were significantly older (median age 79 v. 63 years, $p<0.0001$), less frequently female (55% vs. 86%, $p=0.0032$) and more likely to have undergone prior cervical spine surgery (18% vs. 0%, $p=0.016$) compared with RA patients. Thirty-four non-RA patients (44.7%) either had a clinical diagnosis of calcium pyrophosphate dihydrate (CPPD) disease or imaging evidence for tissue calcification. There were no significant differences in age or sex between the CPPD subgroup and other non-RA patients. Twenty-eight patients (26.7%) underwent cervical spine surgery.

Conclusion: Patients without RA diagnosis and incidental atlanto-axial pannus on cervical spine MRI are unlikely to suffer from previously unrecognized RA. Degenerative disease and tissue calcification may contribute to pannus formation in these patients.

Introduction

The term pannus (cloth, Latin) is used in several medical contexts. While pannus of the eye refers to a vascularized tissue invading the cornea in patients with trachoma, abdominal pannus describes the skin apron in morbidly obese patients (1, 2). In rheumatology, pannus refers to an aggressive structure in the inflamed rheumatoid joint that invades cartilage and bone, thereby causing irreversible joint damage (3). It is well established that pannus involving the atlanto-axial joint in rheumatoid arthritis (RA) can lead to instability and spinal cord injury due to compression of the cervico-medullary junction (4-6).

While most commonly associated with RA, the term pannus has also been used to describe retro-odontoid soft tissue masses in patients with calcium pyrophosphate dihydrate deposition (CPPD) (7), juvenile idiopathic arthritis (JIA) (8) and spondyloarthritis (9, 10), consistent with a primary role of inflammation in the pathogenesis of these conditions. Others have noted pannus-like lesions in patients with severe degenerative disease in the cervical spine (11, 12), and it has been suggested that instability might be the driver rather than a consequence of pannus formation in the atlanto-axial joint (13). Indeed, surgical fusion of the C1/C2 junction has been shown to result in regression of pannus tissue on repeat imaging (14-16).

We report here the results of a retrospective analysis of 105 patients with pannus in the atlanto-axial joint. Cases were identified by free-text searching radiology reports of cervical spine MRI studies. Less than one third of the patients had RA, while degenerative spine disease and evidence for tissue calcification were common.

Materials and Methods

Case identification

Our study was approved by the Partners HealthCare Institutional Review Board (IRB # 2016P001601). Partners HealthCare is an integrated not-for-profit healthcare system that includes Brigham and Women's Hospital, Massachusetts General Hospital, and other hospitals and institutions in Boston, MA. The Partners HealthCare Research Patient Data Registry (RPDR) (17) is a repository of clinical data from electronic medical record (EMR) systems of Partners HealthCare-affiliated institutions. We searched the RPDR for MRI studies of the cervical spine performed in patients 18 years or older between January 1, 2001 and December 31, 2015. The radiology reports for these studies were free-text searched using the terms 'atlanto-axial' (or 'atlantoaxial') and 'pannus' yielding 171 hits. MRI reports were retrieved and a single investigator (A.J.) read all MRI reports to exclude those that mentioned 'no pannus' or used similar language to describe the absence of pannus. A total of 117 records had MRI reports documenting 'definite' or 'possible' pannus in the atlanto-axial joint. For patients with multiple MRI studies, the earliest study with identified pannus was considered as index MRI and analyzed further.

MRI review

The original MRI studies were retrieved and two radiologists (J.M., an attending musculoskeletal radiologist with 4 years of experience, and J.S., a PGY-3 radiology resident) independently reviewed all cases using the following working definition for pannus: 'non-fluid signal intensity material either extending beyond the anterior, posterior, or superior cortical

margins of the dens, or erosive changes of the dens filled-in with non-fluid signal intensity material. Of the 117 cases, two cases could not be reviewed because the images were not available; a third case was excluded because the report mentioning pannus referred to a brain MRI study and the cranio-cervical junction was only partially imaged. Thus, a total of 114 cases were reviewed. In 73 cases, the clinical radiologist reading the study unambiguously reported the presence of pannus ('definite pannus'). The other 41 reports described the presence of pannus using qualifiers such as 'suggestion of', 'in keeping with', or 'possible' and were thus classified as documenting 'possible pannus'. The MRI studies were de-identified and reviewed in a random order. Each reader was blinded to age, sex, clinical diagnoses, as well as original pannus classification ('definite' versus 'possible'). T1-weighted, T2-weighted, and fluid-sensitive (either STIR or T2-weighted with fat suppression) sequences were evaluated, although there was some heterogeneity between studies with regard to acquired sequences. No cases were excluded based on technical factors such as motion artifacts or incomplete examinations; image quality was deemed adequate by both readers for all cases.

Data extraction

For all subjects with confirmed pannus, clinical data were extracted by chart review of EMR data. Each chart was reviewed to determine if there was a diagnosis of RA on the problem list, any history of positive rheumatoid factor (RF) or anti-cyclic citrullinated peptide (anti-CCP) antibody, or 'rheumatoid' mentioned in EMR notes. If any of these criteria were met, the chart was reviewed by a rheumatologist (J.E.) to confirm the diagnosis of RA. Similarly, each chart was screened to determine if there was a diagnosis of CPPD or pseudogout on the problem list,

or if the terms 'CPPD', 'pseudogout', 'chondrocalcinosis', or 'crowned' were mentioned in any EMR notes. If any of these criteria were met, the chart was then reviewed to determine whether the patient had a clinical diagnosis of CPPD or whether chondrocalcinosis was an incidental imaging finding. For patients who had undergone CT scanning of their cervical spine at any time, the images were retrieved and reviewed for the presence of calcification in the atlanto-axial joint. Additionally, each chart was reviewed for the presence of other inflammatory rheumatic conditions by reviewing the problem list, by searching for the terms 'arthritis', 'gout', 'SLE', 'lupus' in EMR notes, and by reviewing the most recent note written by a rheumatologist if one was present.

Charts were further reviewed for neurological symptoms or signs at the time of the index MRI that likely triggered the imaging study. Findings were classified into four categories: neck pain, radicular pain or headache, upper extremity motor or sensory deficit, and neurologic findings concerning for cervical myelopathy. Radicular pain was defined as pain radiating to the shoulders, arms, or head. Headache was grouped with radicular pain, as impingement of the upper cervical nerve roots may cause headache. Upper extremity motor or sensory deficits included any subjective or objective deficits such as numbness, tingling, reduced sensation, weakness, or hyporeflexia. Myelopathic symptoms and signs included new findings of any of the following: gait impairment, impaired balance, recurrent falls, bilateral upper extremity weakness, hand clumsiness, dyscoordination, concurrent upper and lower extremity weakness, and hyperreflexia. Any trauma preceding the index MRI was noted. In cases where signs or symptoms were not reported, the data was coded as missing and excluded from statistical analyses.

For patients who underwent surgery of the cervical spine, the dates and types of surgery were extracted from operative notes. Operative notes were reviewed to determine whether the surgery involved the atlanto-axial region or not. Based on available literature, occipito-cervical fusion, C1-2 fusion, posterior fossa craniectomy, pannus resection, and odontoid resection were considered to be surgeries involving the atlanto-axial region (14, 18, 19).

Statistical analysis

Baseline characteristics between groups were compared using the Wilcoxon rank-sum test for age and chi-square test for categorical variables. The Wilcoxon rank-sum test was used for age because this variable was not normally distributed. For the categories of race, prior cervical spine surgery, and specialty providing referral for MRI, Fisher's exact test was used given very small sample sizes in some categories. We set $\alpha=0.05$ to determine statistical significance, and all p-values were two-sided. The 95% confidence was calculated using the Wilson/Brown method. Data were analyzed using SAS 9.4 and Prism 7 (Graphpad).

Results

Confirmation of atlanto-axial pannus

By free-text searching the EMR of our hospital network, we identified 114 cases with 'definite' or 'possible' pannus mentioned in the radiology report of a cervical spine MRI study and images available for review. After the two radiologists independently reviewed the original MRI scans in a blinded manner, 100/114 (87.8%) studies were determined by both readers to be positive for pannus, 2/114 (1.8%) were concordantly read as negative for pannus, and

12/114 (10.5%) were discrepant between the two readers. The discrepant cases were reviewed in an additional reading session to arrive at a consensus interpretation, which resulted in classification of 5/12 as positive and 7/12 as negative for pannus. Thus, 105/114 (92.1%) cases were ultimately considered positive for atlanto-axial pannus (Figure 1) and analyzed further.

Patients with RA

Chart review revealed that 29/105 (27.6%) patients with confirmed pannus in the atlanto-axial joint had RA. Representative MRI images are shown in Figure 2. All except one patient carried the RA diagnosis at the time of the index MRI. Baseline characteristics of RA patients and non-RA patients are compared in Table 1. RA patients were significantly younger (median age 63, IQR 49-71) than non-RA patients (median age 79, IQR 72-85, $p<0.0001$) and more frequently female (86% vs. 55%, $p=0.0032$). Patients with RA were also more frequently referred for MRI evaluation by a rheumatologist (62% vs 4%, $p<0.0001$) and less likely to have a history of prior cervical spine surgery (0% vs. 18%, $p=0.016$). There were no differences with regard to race or indication for cervical spine imaging. Median disease duration in the RA patients was 19 years (IQR 6-69 years), and 73% (19/26 patients with available data) were seropositive. 19/29 (66%) RA patients were on biologic therapy prior to the index MRI.

Non-RA patients

EMR Data were available for a median 3.6 years (IQR 2.3-6.6 years) following the index MRI. Only one patient without pre-existing RA diagnosis was subsequently diagnosed with RA (1/77, 1.3%, 95% CI 0.1 to 7.0%). Looking for other inflammatory rheumatic diseases, we found

that 9/76 (11.8%) patients had a clinical diagnosis of CPPD disease and 23/76 (30.2%) had chondrocalcinosis on radiographs of peripheral joints. Excluding subjects without informative imaging studies (i.e. at least one radiograph of hand/wrist, hip/pelvis, or knee)(20) 23/53 (43.4%) had chondrocalcinosis in peripheral joints. 48/76 patients had a CT scan of the cervical spine at any time point, which in 29 cases (60.4%) demonstrated calcifications in the atlanto-axial joint. A representative example is shown in Figure 3. Together, 34/76 patients (44.7%) had either a clinical diagnosis of CPPD disease or imaging evidence of tissue calcification in the atlanto-axial joint or elsewhere. This CPPD group did not differ from the remaining 42 non-RA patients with regard to demographic variables (Table 2). We did not identify any large clusters of other inflammatory rheumatic diseases, although a few patients were noted to have JIA (n=1), SLE (n=1), gout (n=3), or spondyloarthritis (n=1).

Spine Surgery

In total, 28/105 patients (26.7%) underwent surgery of the cervical spine after the index MRI demonstrated atlanto-axial pannus (Table 3). Of those undergoing surgery, 4/28 (14.3%) had a fracture of the atlas or dens, compared with 7/75 (9.3%) who did not undergo surgery (p=0.4714). Surgery was performed a median of 38 days (IQR 6.5-93 days) after the index MRI. There was a trend that patients who underwent surgery had upper extremity neurological deficits (p=0.07) or myelopathic symptoms or signs (p=0.14) more frequently, and neck pain (p=0.13) or radicular pain (p=0.15) less frequently than conservatively managed patients.

Of those managed surgically, 17/28 patients (60.7%) underwent surgery involving the atlanto-axial region. There were no significant differences in age, sex, race, or symptomatology

between those who had surgery involving the atlanto-axial region and patients who had surgery of more caudal cervical spine levels. Surgical rates of the atlanto-axial region were not significantly different between patients with RA and those without (13.8 % vs 17.6%, p=0.64).

Discussion

Pannus in the atlanto-axial joint may develop via multiple mechanisms. In patients with RA, synovitis in the atlanto-axial joint can lead to inflammatory pannus formation akin to the destructive arthritis in peripheral joints (21). Similarly, in crowned dens syndrome, CPPD-induced inflammation may cause pannus formation (22). Other studies have suggested that atlanto-axial pannus may be the result of degenerative disease in the cervical spine leading to instability at the C1-C2 articulation and formation of reactive fibrous tissue (12, 23). Studies combining MRI or CT imaging with histological analysis have revealed heterogeneity in the appearance of the atlanto-axial pannus tissue (24, 25). While we have no histopathological data on the subjects in our cohort, the advanced age and history of prior cervical spine surgery in several non-RA patients supports the idea that degenerative changes (6) contribute to atlanto-axial pannus formation in this group. Our finding of atlanto-axial calcification in 60.4% of the non-RA patients who had a cervical spine CT is consistent with a previous study that reported an age-related increase in atlanto-axial calcification, with imaging findings of calcification in 34% of individuals aged 60 years or older and in 49% of individuals aged 80 years or older (26). Such atlanto-axial calcium deposits were shown to represent CPPD in one study (7). However, whether mineral deposition in the atlanto-axial joint is the primary driver of pannus formation or mostly a marker of degenerative disease in the cervical spine is unclear.

Prior studies have indicated that spine involvement is highly prevalent in RA, with evidence of pannus found in up to 62.5% of cases on MRI (27). Despite having access to a large database, including data from two academic centers with large rheumatology outpatient clinics, we identified only 29 cases of RA-associated atlanto-axial pannus. Several factors may have contributed to this relatively low number: (1) RA patients with atlanto-axial disease may not have symptoms warranting cervical spine imaging (27). (2) Providers may choose radiographs over MRI as the primary imaging modality in symptomatic RA patients with suspected atlanto-axial instability. (3) Patients may have been missed by our search algorithm because of spelling errors or inaccessible MRI reports. (4) A small amount of atlanto-axial pannus may not be reported by the radiologist in a routine clinical setting. (5) The prevalence of cervical spine involvement in RA may be declining. Most of the RA patients in our study were diagnosed before the widespread introduction of biologic therapy. While the number of RA patients was too low to detect any time trends, it is reasonable to assume that the current approach of treating RA early and aggressively is having a beneficial impact on the cervical spine (6).

One of the objectives of this study was to determine how frequently atlanto-axial pannus is the presenting finding of RA in previously undiagnosed patients (28). Importantly, we found only one patient who was diagnosed with RA after the index MRI demonstrated the presence of atlanto-axial pannus. This patient was a 70-year-old woman with a history of polymyalgia rheumatica and bilateral total knee arthroplasties who was treated with hydroxychloroquine for arthralgias at the time of the MRI study. She was seronegative but had erosive changes on hand radiographs that her treating rheumatologist attributed to hand osteoarthritis (OA). She was later diagnosed with RA by another rheumatologist. None of the

other 76 non-RA patients had chart evidence for RA development over a median follow-up period of 3.6 years. A clinically important conclusion from this study is therefore that it is highly unlikely that a patient with incidental pannus in the atlanto-axial joint on MRI who does not already have a diagnosis of RA will subsequently be diagnosed with RA. A one-time evaluation for current peripheral joint complaints should suffice to identify the rare patient with unrecognized RA. Extended follow-up to observe for the development of peripheral joint problems consistent with RA does not appear to be indicated. This is particularly true for older patients. Median age of the non-RA populations in our study was 79 (IQR 72-85). Most of these patients were over the age of 70, and only 2 patients without RA (2.6%) were less than 50 years old. One of these two had a history of JIA. The other had an atypical presentation of neck pain and stiffness without a clear rheumatologic diagnosis. This patient moved out of state and was lost to follow-up.

Roughly one quarter of patients in our study population underwent cervical spine surgery after the index MRI, and less than two-thirds of these cases involved surgical intervention at the atlanto-axial level. This suggests that the identification of atlanto-axial pannus was not considered to be an indication for surgery in the majority of cases. Insufficient data were available to compare long-term outcomes in patients undergoing cervical spine surgery and patients managed conservatively.

A major strength of our study is the identification of cases of atlanto-axial pannus by free-text searching a large, multi-hospital EMR database. This helped to ensure that cases were identified regardless of provider specialty or clinical setting, thereby reducing the risk for selection bias. Furthermore, MRI scans were reviewed by two blinded radiologists so that only

confirmed cases of atlanto-axial pannus were included in the analysis. Limitations include the retrospective study design, which required us to depend on documentation from the electronic health record; patients with incidental atlanto-axial pannus were not evaluated according to a pre-defined standard protocol. Another limitation is the reliance on data from a single, albeit large, healthcare system, which may have resulted in incomplete data for patients who also received care outside of the system. Additionally, as discussed above, cases of atlanto-axial pannus may have been missed in our database query due to spelling errors, word choices in the MRI report or underreporting of minor imaging abnormalities.

Conclusion

In this study of 105 patients with atlanto-axial pannus found on cervical spine MRI, 27.6% had RA. Only a single individual, representing 1.3% of subjects without pre-existing RA diagnosis, was diagnosed with RA after the index MRI, and this was a patient with longstanding peripheral joint complaints. This suggests that patients with incidental atlanto-axial pannus on cervical spine MRI are unlikely to suffer from previously unrecognized RA. The non-RA patients in our study were significantly older than the RA patients and frequently had evidence of tissue calcification, consistent with a role for degenerative disease or CPPD in the formation of atlanto-axial pannus in these patients. Although the term pannus is commonly associated with RA, the imaging finding of atlanto-axial pannus is clearly not pathognomonic for RA. More specific terminology and radiographic definitions of soft tissue masses about the atlanto-axial joint are desirable.

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References

1. Trompoukis C, Kourkoutas D. Trachoma in late greek antiquity and the early byzantine periods. Can J Ophthalmol 2007;42:870-4.
2. Zammerilla LL, Zou RH, Dong ZM, Winger DG, Rubin JP, Gusenoff JA. Classifying severity of abdominal contour deformities after weight loss to aid in patient counseling: A review of 1006 cases. Plastic and reconstructive surgery 2014;134:888e-94e.
3. Zvaifler NJ, Firestein GS. Pannus and pannocytes. Alternative models of joint destruction in rheumatoid arthritis. Arthritis Rheum 1994;37:783-9.
4. Del Grande M, Del Grande F, Carrino J, Bingham CO, 3rd, Louie GH. Cervical spine involvement early in the course of rheumatoid arthritis. Semin Arthritis Rheum 2014;43:738-44.
5. Joaquim AF, Appenzeller S. Cervical spine involvement in rheumatoid arthritis--a systematic review. Autoimmun Rev 2014;13:1195-202.
6. Zhang T, Pope J. Cervical spine involvement in rheumatoid arthritis over time: Results from a meta-analysis. Arthritis Res Ther 2015;17:148.
7. Kakitsubata Y, Boutin RD, Theodorou DJ, Kerr RM, Steinbach LS, Chan KK, et al. Calcium pyrophosphate dihydrate crystal deposition in and around the atlantoaxial joint: Association with type 2 odontoid fractures in nine patients. Radiology 2000;216:213-9.
8. Hospach T, Maier J, Muller-Abt P, Patel A, Horneff G, von Kalle T. Cervical spine involvement in patients with juvenile idiopathic arthritis - mri follow-up study. Pediatric rheumatology online journal 2014;12:9.
9. Quarta L, Corrado A, Melillo N, Trotta A, D'Onofrio F, Maruotti N, et al. Cervical myelopathy caused by periodontoid synovial pannus in a patient with psoriatic arthritis: A case report. Clin Rheumatol 2007;26:1380-2.
10. Rajak R, Wardle P, Rhys-Dillon C, Martin JC. Odontoid pannus formation in a patient with ankylosing spondylitis causing atlanto-axial instability. BMJ Case Rep 2012;2012.
11. Finn M, Fassett DR, Apfelbaum RI. Surgical treatment of nonrheumatoid atlantoaxial degenerative arthritis producing pain and myelopathy. Spine (Phila Pa 1976) 2007;32:3067-73.
12. Sze G, Brant-Zawadzki MN, Wilson CR, Norman D, Newton TH. Pseudotumor of the craniovertebral junction associated with chronic subluxation: MR imaging studies. Radiology 1986;161:391-4.
13. Grob D, Wursch R, Grauer W, Sturzenegger J, Dvorak J. Atlantoaxial fusion and retrodental pannus in rheumatoid arthritis. Spine (Phila Pa 1976) 1997;22:1580-4.
14. Lagares A, Arrese I, Pascual B, Gomez PA, Ramos A, Lobato RD. Pannus resolution after occipitocervical fusion in a non-rheumatoid atlanto-axial instability. Eur Spine J 2006;15:366-9.
15. Barbagallo GM, Certo F, Visocchi M, Palmucci S, Sciacca G, Albanese V. Disappearance of degenerative, non-inflammatory, retro-odontoid pseudotumor following posterior c1-c2 fixation: Case series and review of the literature. Eur Spine J 2013;22 Suppl 6:S879-88.
16. Bydon M, Macki M, Qadi M, De la Garza-Ramos R, Kosztowski TA, Sciubba DM, et al. Regression of an atlantoaxial rheumatoid pannus following posterior instrumented fusion. Clin Neurol Neurosurg 2015;137:28-33.

17. Weiss ST, Shin MS. Infrastructure for personalized medicine at partners healthcare. J Pers Med 2016;6.
18. Mallory GW, Halasz SR, Clarke MJ. Advances in the treatment of cervical rheumatoid: Less surgery and less morbidity. World J Orthop 2014;5:292-303.
19. Wu JC, Huang WC, Cheng H, Liang ML, Ho CY, Wong TT, et al. Endoscopic transnasal transclival odontoidectomy: A new approach to decompression: Technical case report. Neurosurgery 2008;63:ONSE92-4.
20. Abhishek A, Doherty S, Maciewicz R, Muir K, Zhang W, Doherty M. Chondrocalcinosis is common in the absence of knee involvement. Arthritis Res Ther 2012;14:R205.
21. Firestein GS, McInnes IB. Immunopathogenesis of rheumatoid arthritis. Immunity 2017;46:183-96.
22. Bouvet JP, le Parc JM, Michalski B, Benlahrache C, Auquier L. Acute neck pain due to calcifications surrounding the odontoid process: The crowned dens syndrome. Arthritis Rheum 1985;28:1417-20.
23. Tojo S, Kawakami R, Yonenaga T, Hayashi D, Fukuda K. Factors influencing on retro-odontoid soft-tissue thickness: Analysis by magnetic resonance imaging. Spine (Phila Pa 1976) 2013;38:401-6.
24. Stiskal MA, Neuhold A, Szolar DH, Saeed M, Czerny C, Leeb B, et al. Rheumatoid arthritis of the craniocervical region by MR imaging: Detection and characterization. AJR Am J Roentgenol 1995;165:585-92.
25. Czerny C, Grampp S, Henk CB, Neuhold A, Stiskal M, Smolen J. Rheumatoid arthritis of the craniocervical region: Assessment and characterization of inflammatory soft tissue proliferations with unenhanced and contrast-enhanced CT. Eur Radiol 2000;10:1416-22.
26. Chang EY, Lim WY, Wolfson T, Gamst AC, Chung CB, Bae WC, et al. Frequency of atlantoaxial calcium pyrophosphate dihydrate deposition at CT. Radiology 2013;269:519-24.
27. Younes M, Belghali S, Kriaa S, Zrour S, Bejia I, Touzi M, et al. Compared imaging of the rheumatoid cervical spine: Prevalence study and associated factors. Joint Bone Spine 2009;76:361-8.
28. Araújo F, Silva I, Sepriano A, Reizinho C, Marques L, Nero P, et al. Cervical spine involvement as initial manifestation of rheumatoid arthritis: A case report. Acta Reumatol Port 2015;40:64-7.

Table Legends

Table 1. Characteristics of patients with atlanto-axial pannus. Values are number (percent) unless indicated otherwise. Percentages were calculated excluding subjects with missing data.

Table 2. Characteristics of patients with atlanto-axial pannus without Rheumatoid Arthritis. Values are number (percent) unless indicated otherwise. Percentages were calculated excluding subjects with missing data.

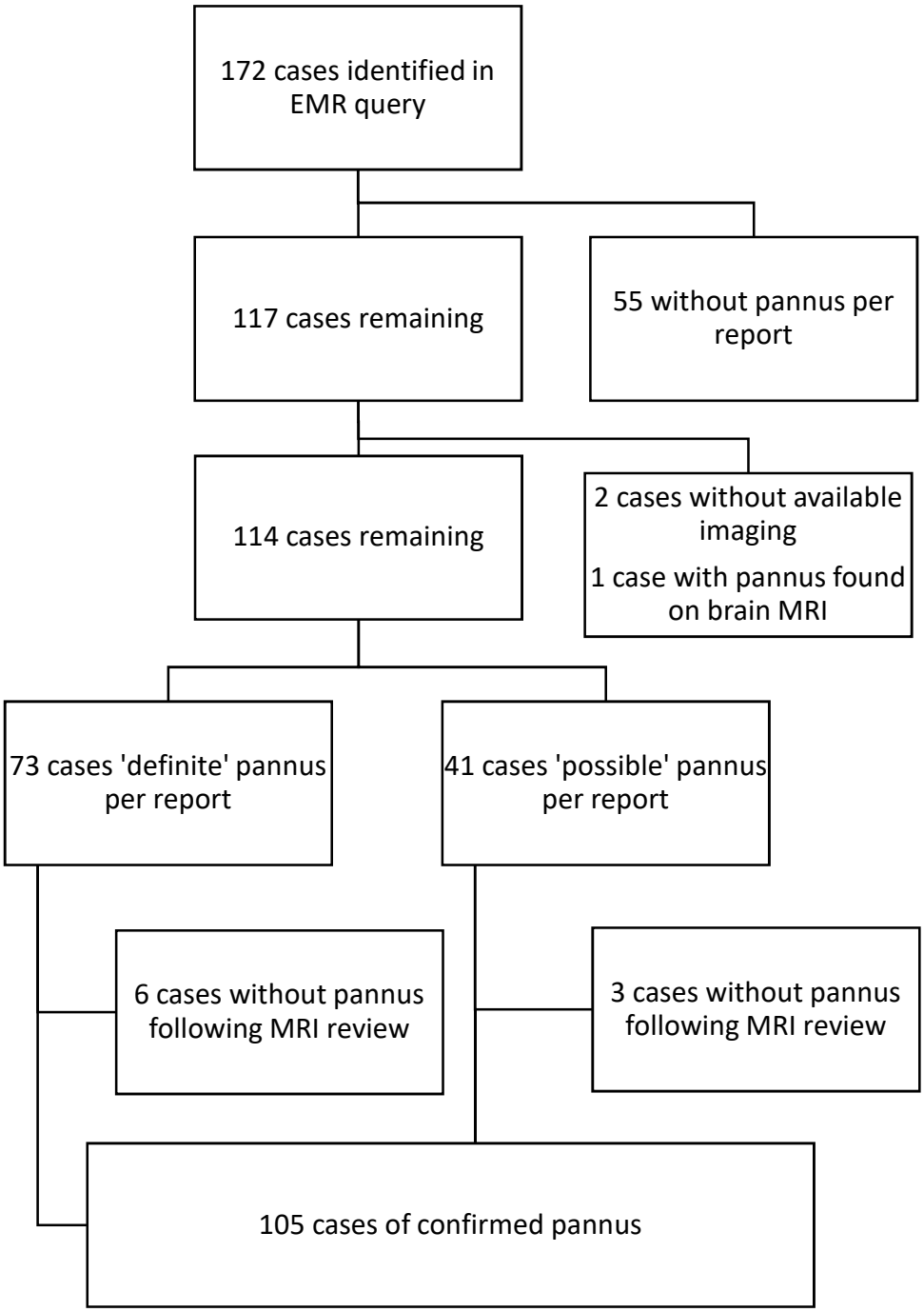
Table 3. Characteristics of patients with atlanto-axial pannus undergoing cervical spine surgery. Values are number (percent) unless indicated otherwise. Percentages were calculated excluding subjects with missing data.

Figure Legends

Figure 1. Flowchart showing the identification of cases with confirmed atlanto-axial pannus.

Figure 2. Atlanto-axial pannus in a 68-year-old male with a 6-year history of seropositive RA. (A) Sagittal T1-weighted MRI image demonstrating a soft tissue mass surrounding the odontoid process with mass effect on the thecal sac and spinal cord. There is associated bony erosion and abnormal marrow signal. (B) Axial T2-weighted MRI image from the same patient.

Figure 3. Atlanto-axial pannus in a 90-year-old female without RA presenting with neck pain and headaches. (A) Sagittal T2-weighted MRI image demonstrating a soft a tissue mass surrounding the odontoid process. (B) The sagittal CT image shows bony erosion of the odontoid with adjacent calcification (arrow). Marked degenerative changes are evident in the lower cervical spine. (C) The coronal CT image shows mineralization around the odontoid process (arrow). Note the degenerative changes in the lateral atlanto-axial articulations.



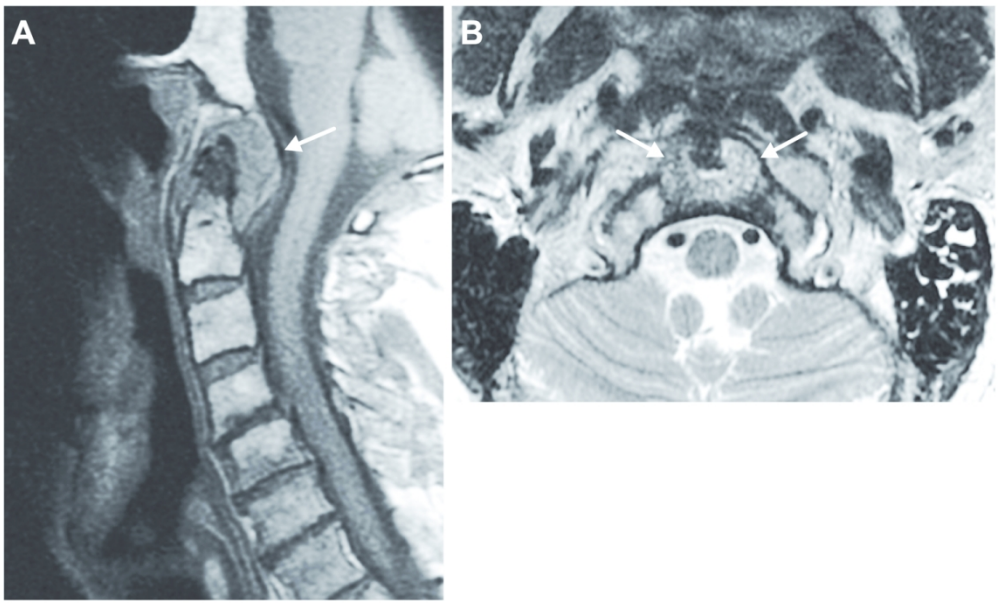
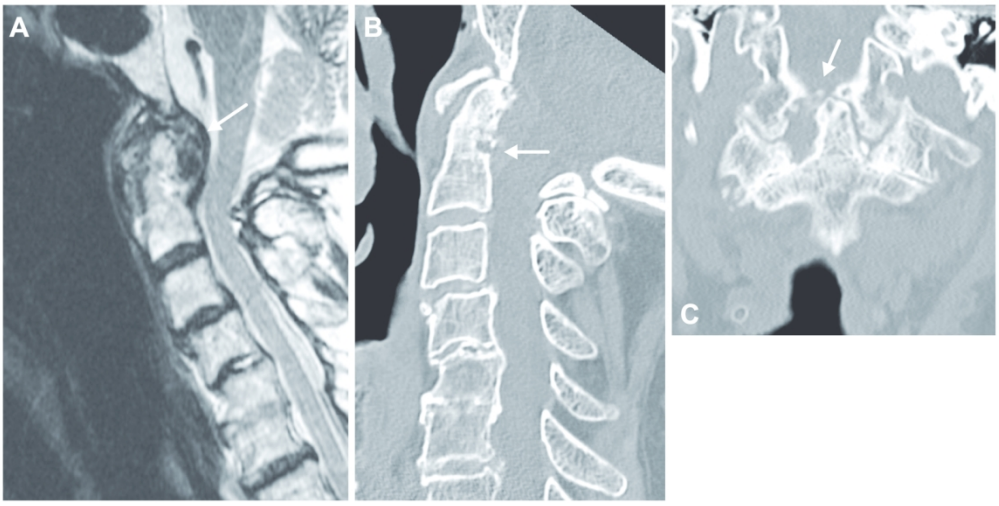


Figure 2. Atlanto-axial pannus in a 68-year-old male with a 6-year history of seropositive RA. (A) Sagittal T1-weighted MRI image demonstrating a soft tissue mass surrounding the odontoid process with mass effect on the thecal sac and spinal cord. There is associated bony erosion and abnormal marrow signal. (B) Axial T2-weighted MRI image from the same patient.

128x77mm (300 x 300 DPI)



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154x77mm (300 x 300 DPI)

Table 1.

Characteristics	**Total (n=105)**	**RA (n=29)**	**No RA (n=76)**	**p value**
Age, median in years (IQR)	75 (65-83)	63 (49-71)	79 (72-85)	**<0.0001**
Gender				**0.0032**
Female	67 (64)	25 (86)	42 (55)	
Male	38 (36)	4 (14)	34 (45)	
Race				0.49
White	87 (85)	22 (79)	65 (88)	
Hispanic	4 (4)	2 (7)	2 (3)	
Asian or Pacific Islander	3 (3)	1 (4)	2 (3)	
Black	8 (8)	3 (11)	5 (7)	
Pertinent clinical history				
Neck pain	69 (78)	22 (81)	47 (76)	0.56
Radicular pain or headache	37 (51)	9 (39)	28 (57)	0.15
Upper extremity motor or sensory deficit	36 (42)	11 (39)	25 (43)	0.74
Findings of myelopathy	36 (39)	12 (43)	24 (37)	0.59
Trauma	27 (26)	4 (14)	23 (32)	0.07
Prior cervical spine surgery	12 (13)	0 (0)	12 (18)	**0.016**
Cervical spine surgery after index MRI				
Any cervical spine surgery	28 (27)	6 (21)	22 (30)	0.35
Surgery of atlanto-axial region	17 (17)	4 (14)	13 (15)	0.78

Table 2.

Characteristics	**CPPD (n=34)**	**Other (n=42)**	**p value**
Age, median in years (IQR)	80 (73-86)	77 (71-84)	0.17
Gender			0.14
Female	22 (65)	20 (48)	
Male	12 (35)	22 (52)	
Race			0.68
White	29 (88)	36 (88)	
Hispanic	0 (0)	2 (5)	
Asian or Pacific Islander	1 (3)	1 (2)	
Black	3 (9)	2 (5)	
Pertinent clinical history			
Neck pain	24 (77)	23 (74)	0.77
Radicular pain or headache	12 (52)	16 (62)	0.51
Upper extremity motor or sensory deficit	12 (46)	13 (41)	0.67
Findings of myelopathy	12 (41)	12 (33)	0.51
Trauma	12 (35)	11 (28)	0.52
Prior cervical spine surgery	7 (21)	5 (15)	0.49
Cervical spine surgery after index MRI			
Any cervical spine surgery	12 (35)	10 (25)	0.33
Surgery of atlanto-axial region	5 (15)	8 (20)	0.62

Table 3.

Characteristic	Surgical (n=28)	Non-surgical (n=75)	p value	Surgery of AAR (n=17)	Other C-spine surgery (n=11)	p value
Age, median in years (IQR)	77.1 (69-84)	73.8 (63-83)	0.51	77.8 (69-79)	76.5 (68-85)	0.49
Pertinent clinical history						
Neck pain	16 (67)	52 (81)	0.15	11 (73)	5 (56)	0.41
Radicular pain or headache	6 (38)	30 (55)	0.23	4 (36)	2 (40)	1.00
Upper extremity motor or sensory deficit	14 (56)	22 (36)	0.09	7 (44)	7 (78)	0.21
Findings of Myelopathy	13 (50)	23 (34)	0.16	7 (41)	6 (67)	0.41
Trauma	9 (32)	18 (24)	0.42	5 (29)	4 (36)	1.00
Prior cervical spine surgery	5 (18)	7 (10)	0.33	3 (18)	2 (18)	1.00