Supplementary Table 1. Supplemental summary of literature

Study	Results
Pathophysiology	
Shi et al.[1]	Histopathologic examination of retro-odontoid pseudotumors found 11 different underlying etiologies. Included 3 subtypes of RA-associated pannus: hypervascular, hypovascular, and fibrous/inflammatory. May include combinations of the above.
Choy[7]	Histopathological examination demonstrated cell types associated with the underlying condition plus inflammatory cells, fibrous cells, and granulation tissue; suggestive of a repetitive injury/repair cycle
Choy[7] Gillick et al.[8] Pal.eolog et al.[9]	Synovial membranes are damaged by monocytes, while bone is destroyed by osteoclasts activated by CD4+ T cells; angiogenesis prompted by inflammatory cytokine VEGF has been found to play a critical role in initiation and propagation of pannus due to its role in vascular permeability as well as cartilage and bone degradation
Blaksin and Avagliano[10] Anderson and D'Alonzo[11] Sinha et al.[3]	Trauma may result in nonunion and pseudoarthrosis of an odontoid fracture; type II odontoid fracture is most commonly associated with non- or malunion. Spontaneous regression is demonstrated following surgical fixation.
Sekijima et al.[12] Baysal. et al.[13] Shidham et al.[14]	CPPD crystals may deposit into the transverse ligament, longitudinal ligament, intervertebral discs, facet joints, and annulus fibrosis may result in "crowded dens syndrome." CPPD is difficult to distinguish from other etiologies on MRI, alone.
Tojo et al.[15] Wada et al.[16]	Hemodialysis-associated amyloidosis causes accumulation of β-2 microglobulin in the form of amyloid fibrils and inflammatory deposits in joints and surrounding structures
Finn et al.[17] Roguski et al.[18] Chhieng et al.[19] Giannini et al.[20]	PVNS proliferative, destructive, nonmalignant tumor of synovial membranes with inflammation and joint degeneration; up to 36% occurrences in the cervical spine.
Structural and functional concerns for stability	
Yang et al.[21]	Symptoms of pseudotumor-associated instability: sphincter disturbances, respiratory distress, and lower cranial nerve dysfunction. Symptoms of atlantoaxial subluxation range from minor axial neck pain to death.
Yang et al.[21] Chikuda et al.[22] Yamada et al.[23]	Radiographical evaluation of AAI/AAS: may include analysis of ROM, McGregor line for evaluation of basilar invagination; AAS has ADI >5 mm
Chikuda et al.[22]	Radiographical evaluation of pseudotumor: MRI isointense to hypointense relative to the spinal cord on T1-weighted images and hypointense in T2-weighted images; evaluate the transverse ligament in T2.
Ventral decompression	
Joaquim et al.[26] Landi et al.[30] Gladi et al.[31] Young and Boyko[32] Oseni et al.[33] Schomacher et al.[57]	Indications for ventral decompression: calcification ventral to the odontoid process, calcification of the lesion, severe anterior mass effect that cannot be addressed by a posterior-only procedure
Joaquim et al.[26] Gladi et al.[31] Shawky et al.[35] Duntze et al.[36] Eloy et al.[37] Platt et al.[38]	Ventral approach bony resection options: partial odontoidectomy with or without preservation of C1, full odontoidectomy with or without C1 arch preservation, sparing of the dens (rare), partial drilling at the inferior portion of the anterior arch of C1. Achieved by transoral or endonasal approaches.
Shawky et al.[35] Platt et al.[38] Dickman et al.[39]	Odontoidectomy alters AA biomechanics, yields iatrogenic instability.
Joaquim et al.[26] Gladi et al.[31] Duntze et al.[36] Platt et al.[38] Iacoangeli et al.[40]	Ventral decompression without fixation: elderly, concerns for patient frailty/inability to tolerate a prolonged, invasive, and/or multistage procedure, AND no pre- or postoperative spinal instability AND ability to comply with routine radiological follow-up.

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Supplementary Table 1. Continued

Study	Results
Gladi et al.[31] Shawky et al.[35] Platt et al.[38] Periini et al.[42] Shriver et al.[43] Komotar et al.[44] Zwagerman et al.[45] Chibbaro et al.[46] Hadjipanayis et al.[47] Aldahak et al.[48]	EA: inferior boundary - NPL. More favorable plane for C1 arch preservation. Benefits: mucosal incisions in the nasopharynx, decreased likelihood of trauma to retropharyngeal tissues, improved oropharyngeal function postoperatively, less overall time intubated, faster return to feeding, decreased overall recovery time and shorter LOS, use of endoscope is standard (improved FOV). Limitations: steep learning curve and potential for severe neurological morbidity and mortality (intimate relationship between the surgical corridor and the brainstem), limitations to access and intraoperative field of view for management of intraoperative complications (e.g., vascular injury). MC complication: CSF leak. 30-day mortality rate: 4.4%.
Shawky et al.[35] Platt et al.[38] Periini et al.[42] Shriver et al.[43] Komotar et al.[44]	Transoral: boundaries-provides greater caudal access, limited superiorly unless the hard and soft palate are split (may result in VPI). Limitations: incises the oropharynx, commonly uses microscope (partially obstructs view)-may use endoscope, steep learning curve and potential for severe neurological morbidity and mortality. MC complication: tracheostomy. 30-day mortality rate: 2.9%.
Joaquim et al.[26] Periini et al.[42] Zwagerman et al.[45] Chibbaro et al.[46] Liu et al.[50] Fang et al.[51]	Postoperative use of lumbar drain for management of CSF leak status post ventral approach: not routinely used.
Dorsal decompression	
Suetsuna et al.[52] Kakutani et al.[53]	C1 laminoplasty or laminectomy without instrumentation/fusion: indications- instrumentation was unfavorable as in the case of high riding vertebral artery and preserving ROM in patients without atlantoaxial instability.
Naito et al.[54] Oohori et al.[55]	High cervical lateral approach: An option when a traditional posterior approach does not provide adequate decompression. Provides access for partial resection and sampling for histological analysis. Limitations: inability to achieve complete resection, recommendation to extend no further caudally than the C3 level, a deep, narrow field of view, risk to the vertebral artery, facial and accessory nerve as well as their associated branches, and necessary resection of the C2 nerve root when it crosses the operative field.
Schomacher et al.[57]	Transdural approach: May be done +/- instrumentation. Benefits - minimal to no retraction on the spinal cord, posterior midline incision is conducive to addition/extension of instrumentation as needed. Contraindications-Calcification of the lesion as demonstrated on CT and imaging suggesting adherence of the lesion to dura and/or surrounding tissue. Limitations: requires intraoperative U/S, neuromonitoring, training in microsurgical spinal intradural resections.
Posterior instrumentation	
Boden et al.[62] Wu et al.[63]	O-C fusion: indications- lesion impingement upon the medulla +/- upper cervical cord as a result of cranial settling, leading to subaxial subluxation or extensive destruction of the OA joint, CVJ instability or destruction of the atlanto-occipital joint, iatrogenic destabilization following ventral +/- dorsal decompression.
Gladi et al.[31] Young et al.[32] Platt et al.[38] Kanziora et al.[60] Joaquim et al.[26] Landi et al.[30] Young et al.[32] Bydon et al.[58] Lanset et al.[66]	C1–2 fusion: indications - instability, curtail progressive degeneration of the transverse ligament resulting in forward slippage of the atlas over the axis that would eventually progress to irreducible AAK. Posterior fixation may provide spontaneous lesion regression without direct resection.

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Supplementary Table 1. Continued

Study	Results
External orthoses	
Schomacher et al.[57]	Used +/- surgery. Mechanism of action: limit motion, reduce graft loading and migration, facilitates fusion
Oseni et al.[33] Elliott et al.[67] Zarghooni et al.[68] Vale et al.[70] Nakazawa et al.[71] Lu and Lee[72]	Conservative management (independent of surgery): indications- patients who cannot undergo surgery or when surgery is technically challenging. May correct, improve, or prevent progression of an existing deformity, to stabilize and immobilize weak or damaged spinal segments, to reduce the axial load of the spine, and to limit unnecessary motion. Treatment period: rigid collar (8 weeks), soft collar (4 weeks) with cervical CT each 1 month × 3 months, each 2 months × 1 year

RA, rheumatoid arthritis; VEGF, vascular endothelial growth factor; CPPD, calcium pyrophosphate dihydrate deposition disease; MRI, magnetic resonance imaging; PVNS, pigmented villonodular synovitis; AAI/AAS, atlantoaxial instability/atlantoaxial subluxation; ROM, range of motion; ADI, atlantodental interval; AA, atlantoaxial axis; EA, endonasal approach; NPL, nasopalatine line; LOS, length of stay; MC, most common; CSF, cerebrospinal fluid; VPI, velopharyngeal insufficiency; CT, computed tomography; O-C, occipital-cervical; FOV, field of view; U/S, ultrasound; OA, occipitoatlantal; AAK, atlantoaxial kyphosis.