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1 **ABSTRACT**

2 This case report describes a patient who presented with cervical spinal pain and headaches
3 associated with atlanto-axial subluxation (AAS) secondary to rheumatoid arthritis (RA). For
4 physiotherapists, especially less experienced clinicians, the significant risks associated with
5 using manual assessment and treatment techniques in such a patient require careful
6 consideration right at the start of a consultation. The focus of the case is therefore on the
7 recognition of AAS in this patient with RA, highlighting the clinical findings that alert clinicians
8 to this possibility and explaining the requisite knowledge and skills required to safely and
9 effectively manage this patient. The use of screening tools to help clinicians identify possible
10 RA in its pre-diagnosis stage and the clinical signs and symptoms that raise the index of
11 suspicion for AAS, are discussed. The relevant contraindications and precautions associated
12 with manual treatments directed at the upper cervical spine, and which may have potentially
13 serious negative consequences, including quadriplegia and mortality, are addressed. Finally,
14 the implications for the use of manual assessment and treatment of patients with RA and co-
15 morbid AAS are addressed.

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19

20 **Key words:** rheumatoid arthritis, systems screening, red flags, risk benefit analysis, triage,
21 cervical spine instability

22

23 **Word count: (2978)**

24 **INTRODUCTION**

25 For physiotherapists using manual treatments in the assessment and management of patients
26 with rheumatoid arthritis (RA), awareness and identification of potentially serious articular and
27 peri-articular manifestations of the disease, including instability of the cervical spine, is
28 essential. While there is a need for vigilance with respect to extra-articular manifestations of
29 RA (see accompanying Professional Issue by Briggs et al., 2013), this paper focuses on the
30 upper cervical spine. The most frequently occurring instability in the cervical spine is anterior
31 atlantoaxial subluxation (AAS) (Wasserman et al., 2011; Yurube et al., 2012), where
32 progressive loss of the primary and secondary ligamentous integrity combined with bony
33 erosion of the odontoid process, associated with systemic inflammation as part of the RA
34 disease process, can result in dire consequences, including quadriplegia or death (Paus et al.,
35 2008; Wasserman et al., 2011). A high index of suspicion for AAS in patients with RA should
36 alert clinicians to the potential risks associated with manual assessment and treatment and
37 help ensure safe and effective patient care. The following case report on a patient with RA and
38 associated AAS takes a clinical practice focus, highlighting the importance of the requisite
39 clinical knowledge, reasoning and skills required to guide appropriate assessment and
40 management.

41

42 **CASE REPORT**

43 **Clinical History**

44 A 55 year-old female with a 35-year history of seropositive RA was referred to physiotherapy
45 for assessment and management of persistent, bilateral neck pain and headaches (Figure 1).

46 INSERT Figure 1 here

47 The neck pain radiated bilaterally from the suboccipital area to occipital and parietal areas,
48 with occasional shooting pain to both temples. She described hearing “clanking” and
49 “crunching” sounds in her neck, mainly on neck flexion or extension. The pain had been
50 present for five years, with recurrent episodes of increased neck pain associated with
51 increased bilateral suboccipital/occipital and parietal headaches. The neck pain and headaches
52 had noticeably worsened in the past two years and coincided with a change in her
53 occupational duties, which involved increased computer work requiring more sustained
54 postural demands and more frequent and repeated flexion/extension movements of the head
55 and neck. Pain was rated as moderately severe (average VAS 4-6 over 24 hours) and irritability
56 varied with workload, from moderate to low. Considered over a 24-hour period, her neck pain
57 and headaches worsened in the afternoons and improved in the mornings and on non-working
58 days, consistent with sustained postures associated with computer work. She had not had any
59 prior physiotherapy for her neck pain and headaches, relying primarily on simple analgesia and
60 regular exercise (walking and tai chi).

61 She denied experiencing any vertebrobasilar insufficiency (VBI) symptoms, or dysaesthesiae of
62 her lips or tongue, although she reported transient paraesthesia of her left foot and left distal
63 arm, which were not behaviourally linked to her neck pain and headaches and usually resolved
64 quickly, once she had adjusted her head and neck posture. There was no gait disturbance,
65 upper or lower limb weakness, or change in bowel or bladder function to suggest cauda equina
66 syndrome. Her RA was well controlled with a combination of disease-modifying anti-rheumatic
67 drugs (DMARDs). Her medical history is summarised in Table 1.

68 Based on her description of the neck “clanking”, and prior to her physiotherapy consultation,
69 she had been referred by her rheumatologist for plain radiographs and magnetic resonance
70 imaging (MRI) of the cervical spine. Plain radiographs revealed erosion of the odontoid peg,

71 and 5mm anterior subluxation of C1 on C2 on flexion (Figure 2a), which reduced to normal
72 (≤ 3 mm) with cervical extension (Figure 2b). MRI of the cervical spine revealed advanced
73 arthropathy at the articulation between the lateral masses of C1 and C2 on the left, associated
74 with marrow oedema. There was no evidence of cervical cord compression or an intrinsic
75 spinal cord signal abnormality.

76

77 INSERT Figure 2 here

78 INSERT Table 1 here

79

80 **Physical examination**

81 Examination of the cervical spine revealed a loss of the normal cervical lordosis. Active cervical
82 ranges were limited globally and associated with crepitus through range and end range pain:
83 extension to approximately 10 degrees with restriction throughout the entire cervical spine;
84 flexion was limited to 30 degrees, occurred primarily in the upper cervical spine and was
85 associated with an audible 'clunk' that was reproducible and not associated with any transient
86 cord symptoms or signs; lateral flexion and rotation were restricted bilaterally to
87 approximately 30 degrees. At rest, paraspinal cervical muscle overactivity was evident
88 bilaterally, primarily in the suboccipital region and the sternocleidomastoid muscles.
89 Examination of the hands revealed no evidence of active synovitis, with typical RA-type joint
90 deformities involving the wrists, metacarpophalangeal (MCP) and proximal interphalangeal
91 (PIP) joints, ankles and metatarsophalangeal joints. There was mild swelling and tenderness in
92 bilateral 1st carpo-metacarpophalangeal joints.

93 Neurological examination of both upper and lower limbs revealed normal power (5/5; grade 1
94 on the Ranawat classification (Ranawat et al., 1979)). With the exception of absent ankle jerks
95 bilaterally, reflexes were normal. Sensory testing indicated no loss or gain of sensitivity to light
96 touch, pressure and thermal stimuli in upper and lower limbs. Babinski was down-going and
97 Hoffman's sign was absent, plus there was no evidence of clonus.

98

99 **Treatment**

100 Physiotherapy treatment was conservative and comprised upper cervical isometric
101 stabilisation exercises, soft tissues stretches to pain onset, advice on use of active range of
102 motion rotational and side flexion exercises, and information about symptoms that would
103 prompt the patient to seek further assessment. Given the evidence for RA-associated AAS and
104 subaxial cervical subluxation in this case, the use of manual techniques was considered
105 inappropriate as these can further progress the AAS with potentially serious negative
106 consequences (see discussion). Treatment resulted in significant improvement of her neck
107 pain, although the neck pain and headaches still persisted. Appropriate ergonomic
108 adjustments were recommended for her workstation, along with regular change of position
109 and avoidance of sustained postures.

110

111 **Discussion**

112 Safely and effectively managing patients with a systemic disease like RA, especially for less
113 experienced clinicians, is challenging (Fary et al., 2012) . The challenge for clinicians includes
114 both knowledge (the 'know') and skills (the 'do') (Briggs et al., 2012). The 'know' includes
115 knowledge of RA as a clinically significant disease with associated co-morbidities; red flag
116 issues such as AAS; what to assess, why, when and how to interpret the clinical findings.
117 'Know' also includes the clinical indicators for when and how to facilitate timely access to

118 specialist care. The 'do' includes clinical skills to enable early diagnosis of RA and screening for
119 risk factors such as AAS; performing a standardised neurological examination; appropriate use
120 of screening tools; and safe assessment and management procedures.

121

122 The patient history, associated rheumatology referral and radiological images in this case
123 provided the clinician with timely, accurate information about RA-associated AAS, enabling
124 sound clinical decision-making and safe care. Clinicians need to be aware that involvement of
125 the cervical spine can occur early in RA (Paimela et al., 1997), and is common. The RA-
126 associated incidence of laxity, instability and subluxation of the AAS ranges from 17-85%
127 (Bouchaud-Chabot and Liote, 2002; Wolfs et al., 2009) with AAS being the most frequent
128 deformity (Wasserman et al., 2011), occurring in up to 50% of cases (Mukerji and Todd, 2011).

129 The clinical presentation can be variable (including minor pain with loss of function, significant
130 pain with loss of function, or loss of function with minimal pain), with symptoms commonly
131 associated with neck pain or compressive myeloradiculopathy (Mukerji and Todd, 2011),
132 highlighting the need for a thorough medical history and appropriate screening for red flags.

133

134 In this case, the clinical presentation suggested a significant nociceptively-mediated
135 contribution to her cervical pain and headaches, with the RA-associated inflammatory
136 component well controlled. If her cervical pain and related headache tended to occur in
137 parallel with peripheral joint disease flares, or if the symptoms fluctuated in a similar pattern
138 to the peripheral joint disease, consistent with nociceptive inflammatory pain, then
139 management with DMARDs would be required to address disease activity as a priority. As her
140 widespread peripheral joint problems were well controlled, it is likely that the mechanical
141 factors associated with the AAS and subaxial cervical subluxation were significant contributors
142 to her symptoms. Evidence consistent with this interpretation includes cervical symptoms that

143 were dominantly mechanically-patterned rather than inflammatory: better in the morning
144 without prolonged pain and stiffness; no sleep disturbance; and cervical pain and headaches
145 worsened with sustained postural load and computer work (and evidence for some
146 symptomatic relief associated with avoiding sustained load and workstation adjustments),
147 worse at the end of day and during the working week. Further, physical examination findings
148 are consistent with a dominant mechanical contribution to her cervical pain and headache, as
149 demonstrated by stimulus-response movement-related pain behaviours and limited soft tissue
150 sensitivity and an absence of any neurological compromise.

151

152 As the body chart was mapped to reflect the effective management of the RA condition (using
153 a treat-to-target approach), her additional disease-related widespread pain areas and
154 secondary osteoarthritis were not charted. While appropriate in this instance (based on the
155 preceding rationale), one advantage of mapping the additional pain areas on the body chart,
156 regardless of disease-activity, would be to facilitate clinical pattern recognition (Jones and
157 Edwards, 2008), thereby highlighting the need to expand questioning and screen for systemic
158 diseases such as RA. In this regard, current best practice guidelines (Royal Australian College of
159 General Practitioners, 2009; Royal College of Physicians, 2009) recommend timely on-referral
160 within 2 weeks of consultation if patients present with any of the following:

- 161 • the small joints of the hands or feet are affected;
- 162 • more than one joint is affected;
- 163 • there has been a delay of 3 months or longer between onset of symptoms and
164 seeking medical advice.

165 This approach would be particularly important if RA is not yet diagnosed, and when the
166 clinician is working in a primary care setting, acting as a first-contact practitioner and is
167 inexperienced.

168

169 **Clinical practice point: clinical pattern recognition and use of screening tools**

170 Mapping all the pain areas can help to facilitate the visual recognition of potential systemic
171 condition and expand the clinical reasoning process to screen for systemic diseases and
172 motivate on-referral. Use of standardised screening tools may assist clinicians identify early
173 (pre-diagnosis) RA in primary care. The gait, arms, legs and spine (GALS) locomotor screening
174 examination for RA (recently tested for use among physiotherapists) has high specificity,
175 suggesting utility as a physical screening test in primary care settings (Beattie et al., 2011). A
176 self-administered early inflammatory arthritis detection (EIA-3 Detection tool), developed for
177 use in primary care (Bell et al., 2010), may also be helpful. This history-based tool consists of
178 11 questions with Yes/No responses, covering dimensions of pain, stiffness and swelling.

179

180 This case demonstrated both AAS and subaxial cervical subluxation, consistent with
181 epidemiologic data indicating that the three most common presentations of cervical spine
182 involvement in RA-associated instability include AAS (65%), basilar invagination (20%) and
183 subaxial cervical subluxation (15%) (Wasserman et al., 2011). The “clanking” sound described
184 by the patient in this case, is a classic sign of instability and should have raised the index of
185 suspicion, particularly since a large proportion of cervical instabilities can be otherwise
186 asymptomatic (Collins et al., 1991; Neva et al., 2006). Plain radiographic images confirmed
187 AAS, demonstrating a 4-5mm anterior atlanto-dens interval (AADI) and subaxial cervical
188 subluxation. The AADI is the distance from the posterior margin of the anterior ring of C1 to
189 the anterior surface of the odontoid peg (Mukerji and Todd, 2011). The AADI typically
190 increases with progressive ligamentous laxity of primary (transverse ligament) and secondary
191 (alar ligaments) atlanto-axial restraints, with an anterior subluxation of greater than 10-12mm
192 implying destruction of all ligamentous restraints. In this case, the 4-5mm implies secondary

193 restraints are intact. However, the AADI does not correlate well with the risk of developing a
194 neurological deficit or with the extent of any neurological deficit because patients have
195 variable spinal canal diameters. Thus, the effect of a given degree of slip in a patient with a
196 wide canal will be less than that in a patient whose canal is congenitally narrow. The posterior
197 atlanto-dens interval (PADI) is considered a better method because the PADI directly measures
198 the spinal canal and can better indicate the degree of canal narrowing associated with AAS.
199 The PADI is the distance between the posterior surface of the odontoid peg and the anterior
200 margin of the posterior ring of the atlas (the normal spinal canal measures 17-29 mm at C1)
201 and a minimum PADI of 14 mm is required to avoid cord compression (Boden et al., 1993). The
202 sagittal diameter of the subaxial cervical spinal canal also better correlates with the presence
203 and/or extent of myelopathy and patients with subaxial cervical canal diameters of 13 mm or
204 less are at increased risk of myelopathy (Boden et al., 1993). In this case, while AAS and
205 subaxial cervical sUBLuxation were present, there was no evidence of significant cervical cord
206 compression, suggesting ample canal space.

207

208 While not evident in this case, reduced ROM has been described in RA-associated instabilities
209 as alternating with increased ROM, termed 'pseudostabilisation' by (Wasserman et al., 2011).
210 This ROM variability can be an indication of basilar invagination and is reportedly present in
211 40% of people with RA with the dens entering the foramen magnum and thereby reducing
212 available ROM (Boden, 1994; Boden et al., 1993). Basilar invagination (also termed 'superior
213 migration of the odontoid', 'cranial settling' or 'vertical sUBLuxation'), involves the axis
214 telescoping into the atlas, driving the odontoid peg upwards and this can cause brainstem
215 compression, producing facial sensory disturbance, dysphagia, or abnormalities in the lower
216 cranial nerves (Murkeji and Todd 2011). Suboccipital pain (as present in this case and typically

217 a consequence of C2 nerve root involvement (Heywood et al., 1988), is commonly associated
218 with AAS and occasionally subaxial cervical subluxation and basilar invagination.

219

220 **Clinical practice point: importance of neurological examination at baseline**

221 If upper cervical instability is suspected, undertaking a comprehensive neurological
222 examination at the first consultation is recommended. This should include upper and lower
223 limb reflexes, Hoffman, Babinski, clonus, motor and sensory function and checking gait for
224 imbalance. Clinical signs of a myelopathy include hyperreflexia, upgoing plantar (Babinski)
225 responses, positive Hoffman's signs or clonus, together with motor and sensory deficits.
226 Neurologic impairment can be classified using systems such as the Ranawat classes I-III B
227 (Ranawat et al., 1979), to establish the degree of neurologic compromise or Steinbrocker's
228 grades I-IV to classify functional limitation (Steinbrocker and Blazer, 1946). If still in doubt,
229 refer on for a medical review, as patients may be asymptomatic even in the presence of upper
230 cervical spine instability.

231

232 In the absence of radiological evidence or a specific diagnosis of AAS from the rheumatology
233 referral, and based on the body chart and behaviour of the cervical pain and headache alone,
234 the patient's symptoms might have been interpreted as cervicogenic in origin, thereby missing
235 AAS and the subaxial cervical subluxation. In that instance, assessment and treatment directed
236 at the upper cervical spine would be associated with clear risk as the performance of manual
237 techniques may further progress the AAS with potentially serious negative consequences,
238 including quadriplegia and mortality. In this regard, the use of craniovertebral instability (CVI)
239 tests requires consideration, although currently there are no related guidelines or diagnostic
240 criteria. Further, although the reliability of CVI (anterior shear and tectorial membrane)
241 screening tests has been reported in normal volunteers as moderate to substantial

242 (Osmotherly et al., 2012), according to a recent survey of Australian physiotherapists
243 (Osmotherly and Rivett, 2011) their use in clinical practice appears to be inconsistent. In the
244 absence of any clear guidance, the default position relies on clinicians having sound knowledge
245 and applying sound clinical reasoning to analyse the risk/benefit associated with these CVI
246 tests. In this clinical case, a common-sense approach based on the medical ethical precept
247 '*primum non nocere*', would be not to perform CVI tests: the potential risk to the patient far
248 outweighed any clinical benefit of establishing evidence for AAS. Furthermore, in the absence
249 of any prior medical review or radiology, it is advisable to request a medical review and raise
250 an index of suspicion for a CVI prior to undertaking any manual assessment or treatment of the
251 upper cervical spine. A mandatory review of radiological images prior to manual assessment or
252 treatment is appropriate subsequent to a medical review. If, as in this case, there is evidence
253 of osteoporosis or a suspicion of bone fragility, the use of strong manual treatments requires
254 further consideration.

255

256 **SUMMARY**

257 Clinical guidelines provide a mechanism by which physiotherapists can ensure best evidence
258 practice in assessing and managing patients with RA. However, knowledge must sit alongside
259 advanced clinical skills and sound clinical reasoning to ensure safe and effective care. For first
260 contact practitioners in particular, a high index of suspicion regarding AAS should assist in the
261 early recognition of a potential red flag pathology that contraindicates manual treatment and
262 requires immediate on-referral and appropriate investigation. The use of a systems approach
263 (triage and screening; appropriate on-referral), can facilitate the effective implementation of
264 an evidence-informed and safe approach to the assessment and management of patients with
265 RA.

266

267 **References**

- 268 Beattie KA, MacIntyre NJ, Pierobon J, Coombs J, Horobetz D, Petric A, et al. The sensitivity,
269 specificity and reliability of the GALS (gait, arms, legs and spine) examination when
270 used by physiotherapists and physiotherapy students to detect rheumatoid arthritis.
271 *Physiotherapy* 2011;97(3):196-202.
- 272 Bell MJ, Tavares R, Guillemin F, Bykerk VP, Tugwell P, Wells GA. Development of a self-
273 administered early inflammatory arthritis detection tool. *BMC Musculoskel Disord*
274 2010;11:50.
- 275 Boden SD. Rheumatoid arthritis of the cervical spine. Surgical decision making based on
276 predictors of paralysis and recovery. *Spine* 1994;19(20):2275-80.
- 277 Boden SD, Dodge LD, Bohlman HH, Rehtine GR. Rheumatoid arthritis of the cervical spine. A
278 long-term analysis with predictors of paralysis and recovery. *J Bone Joint Surg Am*
279 1993;75(9):1282-97.
- 280 Bouchaud-Chabot A, Liote F. Cervical spine involvement in rheumatoid arthritis. A review. *Joint*
281 *Bone Spine* 2002;69(2):141-54.
- 282 Briggs AM, Fary RE, Slater H, Bragge P, Chua J, Keen HI, et al. Disease-specific knowledge and
283 clinical skills required by community-based physiotherapists to co-manage patients
284 with rheumatoid arthritis. *Arthritis Care Res* 2012;64(10):1514-26.
- 285 Briggs AM, Fary R, Slater H, Ranelli S, Chan. Physiotherapy co-management of rheumatoid
286 arthritis: Identification of red flags, significance to clinical practice and management
287 pathways. *Man Ther*; 2013 (in press).
- 288 Collins DN, Barnes CL, FitzRandolph RL. Cervical spine instability in rheumatoid patients having
289 total hip or knee arthroplasty. *Clin Orthop Relat Res* 1991;(272):127-35.

290 Fary RE, Slater H, Chua J, Briggs AM. Translating policy into practice for community-based
291 management of rheumatoid arthritis: targeting professional development needs
292 among physiotherapists. *Int J Rheumatol* 2012; doi:10.1155/2012/240689.

293 Heywood AW, Learmonth ID, Thomas M. Cervical spine instability in rheumatoid arthritis. *J*
294 *Bone Joint Surg Br* 1988;70(5):702-7.

295 Jones MA, Edwards I. Clinical reasoning to facilitate cognitive-experiential change. In: Higgs J,
296 Jones MA, Loftus S, Christensen N editors, *Clinical reasoning in the health professions*,
297 Philadelphia: Elsevier Butterworth Heinemann, 2008; pp. 319-28.

298 Mukerji N, Todd NV. Cervical myelopathy in rheumatoid arthritis. *Neurol Res Int* 2011:153628.

299 Neva MH, Hakkinen A, Makinen H, Hannonen P, Kauppi M, Sokka T. High prevalence of
300 asymptomatic cervical spine subluxation in patients with rheumatoid arthritis waiting
301 for orthopaedic surgery. *Ann Rheum Dis* 2006;65(7):884-8.

302 Osmotherly PG, Rivett DA. Knowledge and use of craniovertebral instability testing by
303 Australian physiotherapists. *Man Ther* 2011;16(4):357-63.

304 Osmotherly PG, Rivett DA, Rowe LJ. The anterior shear and distraction tests for craniocervical
305 instability. An evaluation using magnetic resonance imaging. *Man Ther*
306 2012;17(5):416-21.

307 Paimela L, Laasonen L, Kankaanpaa E, Leirisalo-Repo M. Progression of cervical spine changes
308 in patients with early rheumatoid arthritis. *J Rheumatol* 1997;24(7):1280-4.

309 Paus AC, Steen H, Roislien J, Mowinckel P, Teigland J. High mortality rate in rheumatoid
310 arthritis with subluxation of the cervical spine: a cohort study of operated and
311 nonoperated patients. *Spine* 2008;33(21):2278-83.

312 Ranawat CS, O'Leary P, Pellicci P, Tsairis P, Marchisello P, Dorr L. Cervical spine fusion in
313 rheumatoid arthritis. *J Bone Joint Surg Am* 1979;61(7):1003-10.

314 Royal Australian College of General Practitioners. Clinical guideline for the diagnosis and
315 management of early rheumatoid arthritis, Melbourne: RACGP, 2009.

316 Royal College of Physicians. Rheumatoid arthritis: national clinical guideline for management
317 and treatment in adults, London: National Collaborating Centre for Chronic Conditions,
318 2009.

319 Steinbrocker O, Blazer A. A therapeutic score card for rheumatoid arthritis; a standardized
320 method of appraising results of treatment. N Engl J Med 1946;235:501-6.

321 Wasserman BR, Moskovich R, Razi AE. Rheumatoid arthritis of the cervical spine: clinical
322 considerations. Bull NYU Hosp Jt Dis 2011;69(2):136-48.

323 Wolfs JF, Kloppenburg M, Fehlings MG, van Tulder MW, Boers M, Peul WC. Neurologic
324 outcome of surgical and conservative treatment of rheumatoid cervical spine
325 subluxation: a systematic review. Arthritis Rheum 2009;61(12):1743-52.

326 Yurube T, Sumi M, Nishida K, Miyamoto H, Kohyama K, Matsubara T, et al. Incidence and
327 Aggravation of Cervical Spine Instabilities in Rheumatoid Arthritis: A Prospective
328 Minimum 5-Year Follow-Up Study of Patients Initially without Cervical Involvement.
329 Spine 2012 [E-published ahead of print].

330

331

332 **Figure legends**

333 **Figure 1.** The location of the patient's reported neck pain and headaches are shown in this
334 body chart. Note that the patient's widespread rheumatoid arthritis-associated joint
335 involvement and osteoarthritis are not mapped on this chart, indicating an effective treat-to-
336 target approach, consistent with the current best practice for management of rheumatoid
337 arthritis.

338

339 **Figure 2.** The plain radiographs of the cervical spine reveal : (a) a 5mm of anterior subluxation
340 (arrowed) of C1 on C2, reflected in an increased anterior atlanto-dens interval (AADI) on
341 flexion (Figure 2a); which is reduced with cervical extension (Figure 2b). There is also multilevel
342 cervical spondylosis with mild instability between flexion and extension at C2/3, as well as
343 further variable grade 1 spondylolistheses between C3/4 and C5/6 (not annotated).

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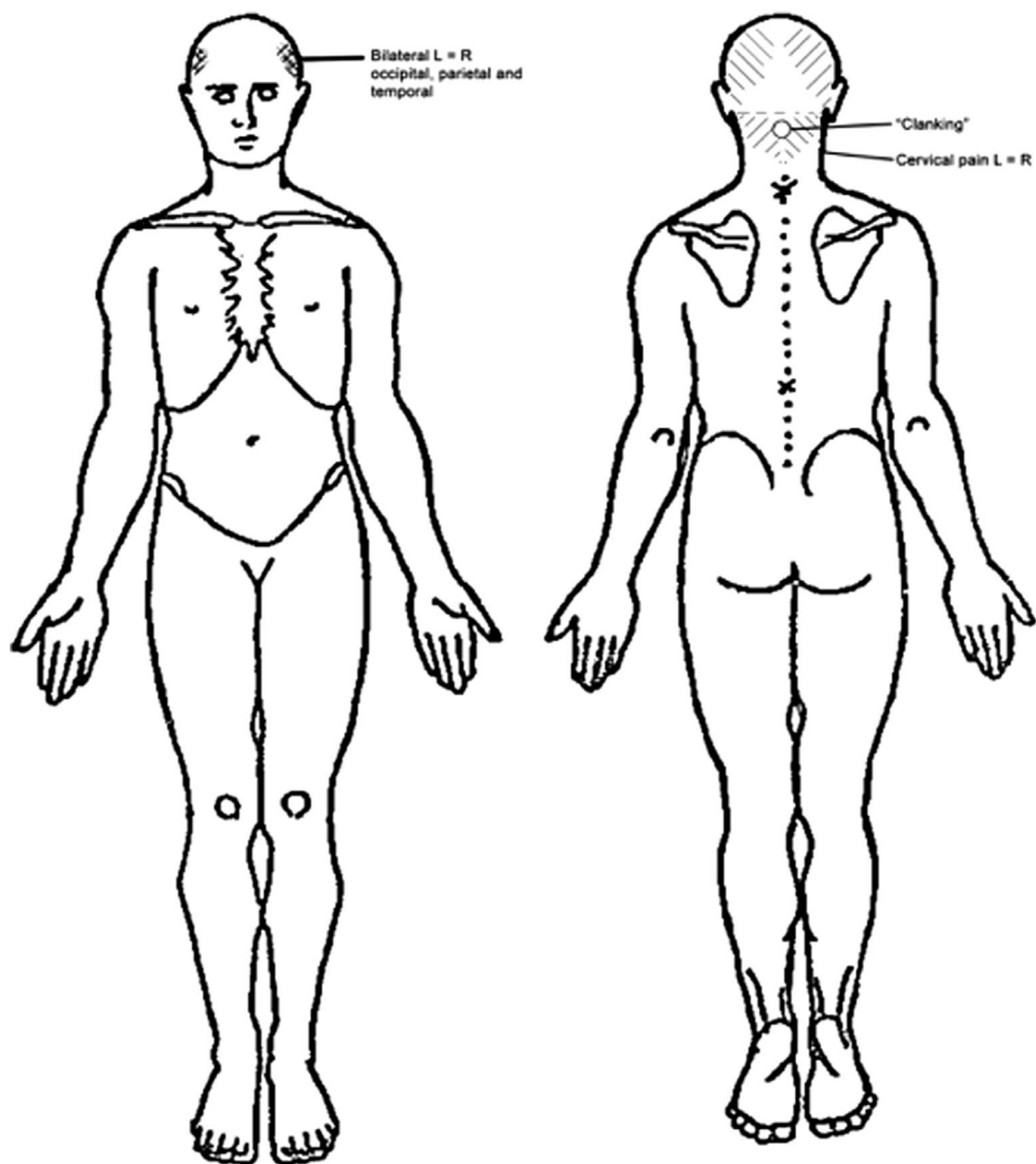


Fig. 1

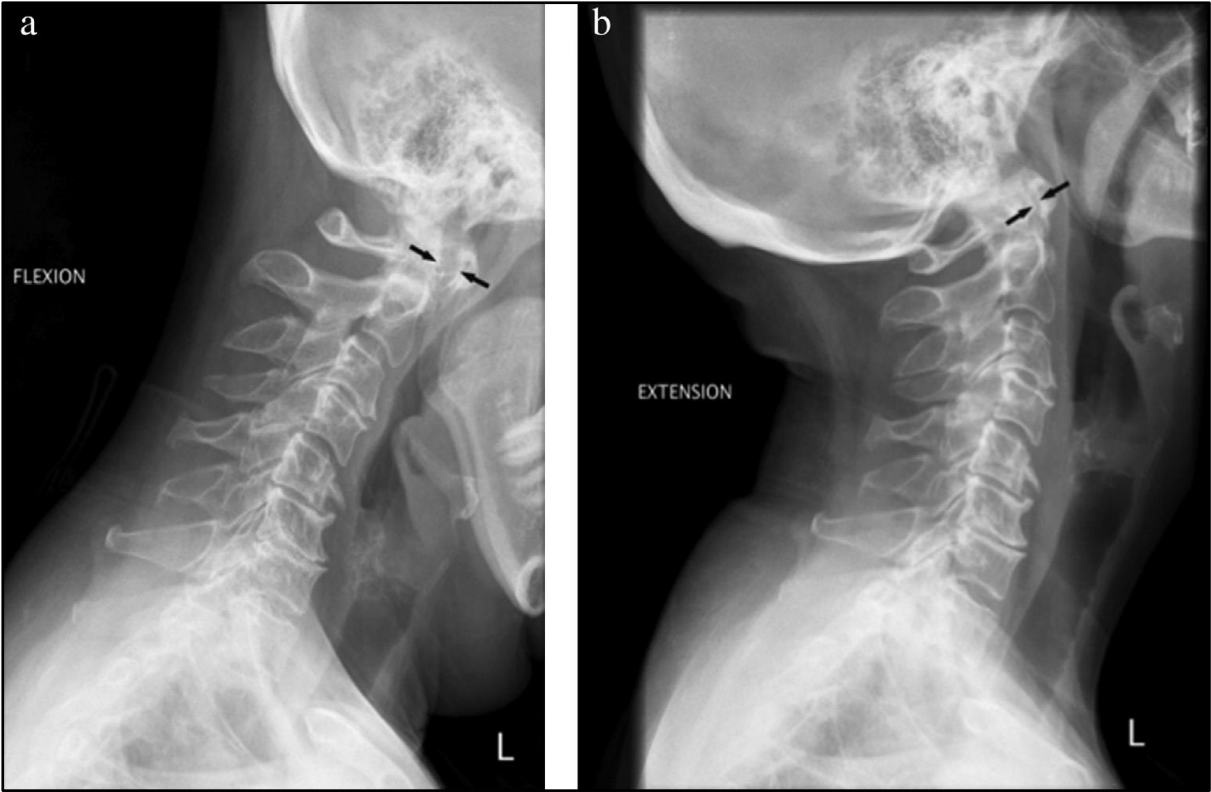


Fig. 2