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CASE REPORT

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The first histological observation of a C1 posterior arch defect

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Deficiencies in the posterior arch of C1 have been well-studied with incidences ranging from 5.65% to 3% and five different classifications. Unfortunately, there is a paucity of information describing the detailed anatomy, muscle attachments, and histology of cases with a C1 posterior arch deficiency. We found a case of an isolated unilateral posterior arch defect in the 83-year-old male cadaver. Histology revealed that the posterior arch defect was filled with collagen fibres and fibrocartilaginous tissue without muscle or bony tissues. This is the first report detailing the histological findings of a posterior arch defect of C1. (Folia Morphol 2023; 82, 2: 386–390)

Key words: posterior arch, atlas, cervical vertebra, anatomy, histology

INTRODUCTION

Deficiencies in the posterior arch of C1 have been well-studied with incidences ranging from 5.65% to 3% and five different classifications [4, 6]. Posterior arch deficiencies are known to be variable in clinical presentation, ranging from neck and head pain or neurologic deficiencies, but most commonly are an incidental radiologic finding [4]. Cases have often been diagnosed following trauma to the cervical spine [11]. As a result, these deficiencies are known to be difficult to diagnose, and may be confused with fractures following trauma [10, 12, 13]. Patients with a posterior arch defect may be advised to reduce recreational activities or return to normal activity. As complications of C1 posterior arch deficiencies are not well known, there are currently no guidelines for return to activity following diagnosis [2].

Unfortunately, there is a paucity of information describing the detailed anatomy, muscle attachments, and histology of cases with a C1 posterior arch deficiency. We present a case report of an isolated unilateral posterior arch defect in order to further elucidate

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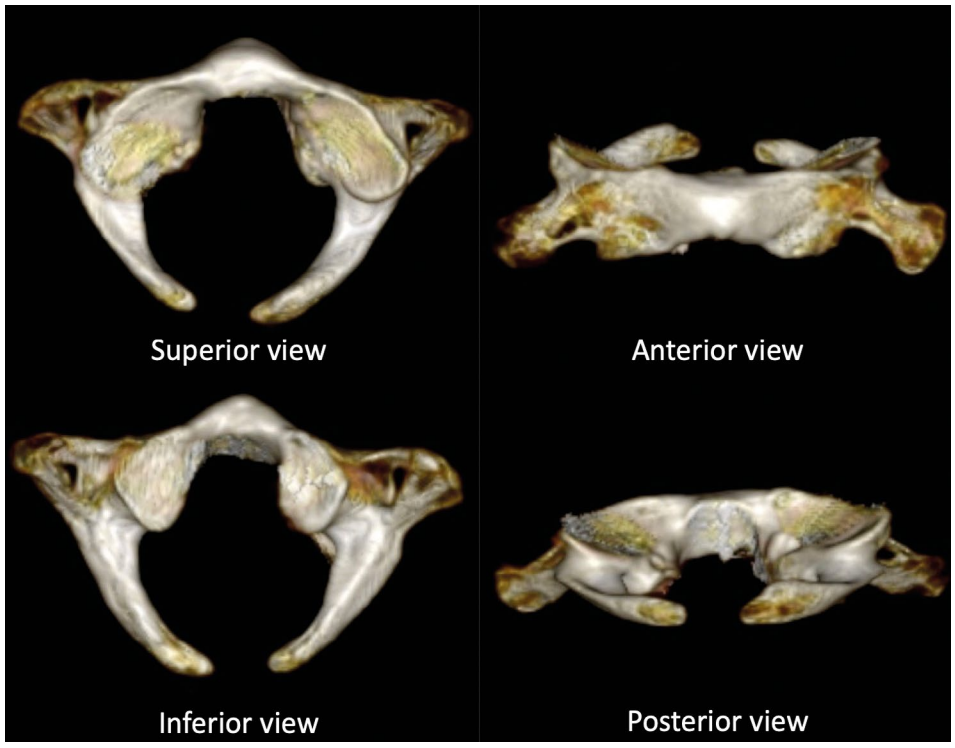

Figure 1. Computed tomographic images of the C1 posterior arch defect.

the specific anatomy and histology of posterior arch defects, allowing for better recognition during surgery of the surgical spine and to improve diagnosis and understanding of C1 posterior arch defects.

CASE REPORT

Prior to a neck dissection of the fresh-frozen cadaver, computed tomographic (CT) images were taken. The specimen was a Caucasian fresh-frozen male cadaver whose age at death was 83-year-old. Incidentally, a posterior arch defect (PAD) of the atlas was noted during predissection CT examination of the specimen (Fig. 1). The defect was mostly on the left side and approximately 10 mm wide. The specimen was then dissected to see the relationship between the PAD and the left rectus capitis posterior minor (RCPm) muscle origin. Once the RCPm on both sides were found, the posterior arch of C1 was palpated and defect of the posterior arch on the left RCPm origin was found. The left RCPm originated from the fibrous connective tissue that filled the defect (Figs. 2, 3).

The tissue in the PAD was then harvested with attached posterior arch for histological evaluation. The sagittal sections of both the PAD on the left and posterior arch on the right were obtained with 5 μm slices and stained with Masson trichrome staining. The slides were observed with a light microscope. Histology revealed that the PAD was filled with collagen fibres and fibrocartilaginous tissue without muscle or bony tissues (Fig. 4). The present study was performed in accordance with the requirements of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

DISCUSSION

Curriano et al. [4] previously published five classes of posterior arch deficiencies: type A, a midline defect in the posterior arch, type B, a unilateral defect in the posterior arch, type C, bilateral defects, type D, absence of the posterior arch with an isolated persistent posterior tubercle, and type E, complete absence of the posterior arch. Type B most closely correlates to the posterior arch defect described in the present case study. A radiographic study by Hyun et al. [6] studied 3273 skulls in an effort to categorize the prevalence of each type, finding 181 skulls with some type of posterior arch deficiency. Type A was the most common, making up 151/181 of skulls with defects (81.6%) [6]. Type B, presented in this case study, was found to make up 15/181 cases (8.1%), with an overall prevalence of 0.46% [6]. Senoglu et al. [14] evaluated 1354 cases including 1104 patients, 166 dried bones,

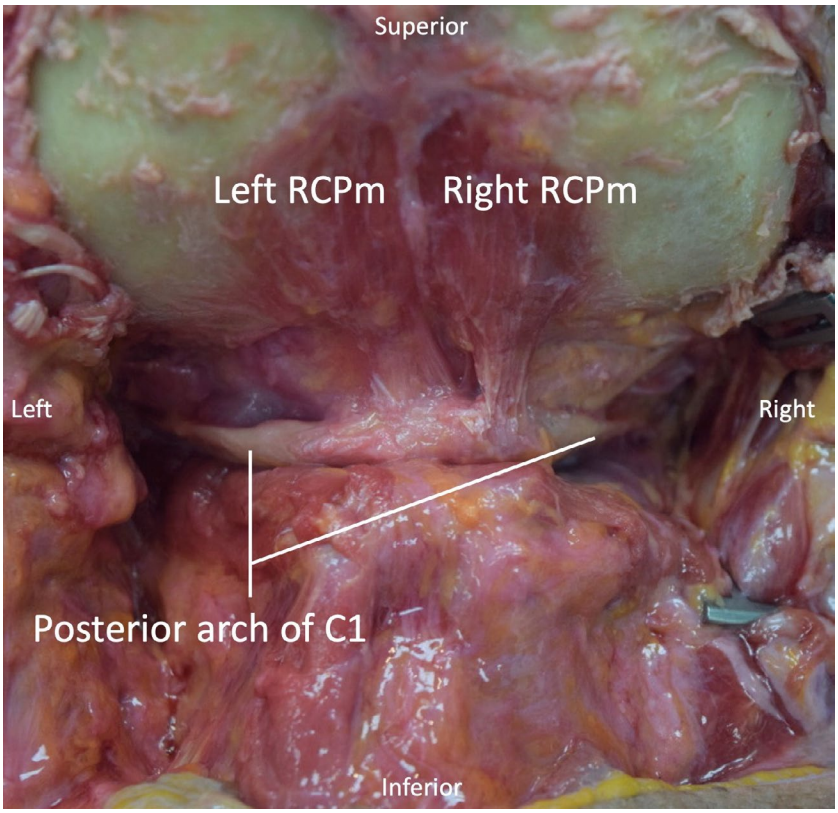

Figure 2. Anatomical exposure of the posterior arch defect. Both the right and left rectus capitis posterior minor (RCPm) muscles are shown.

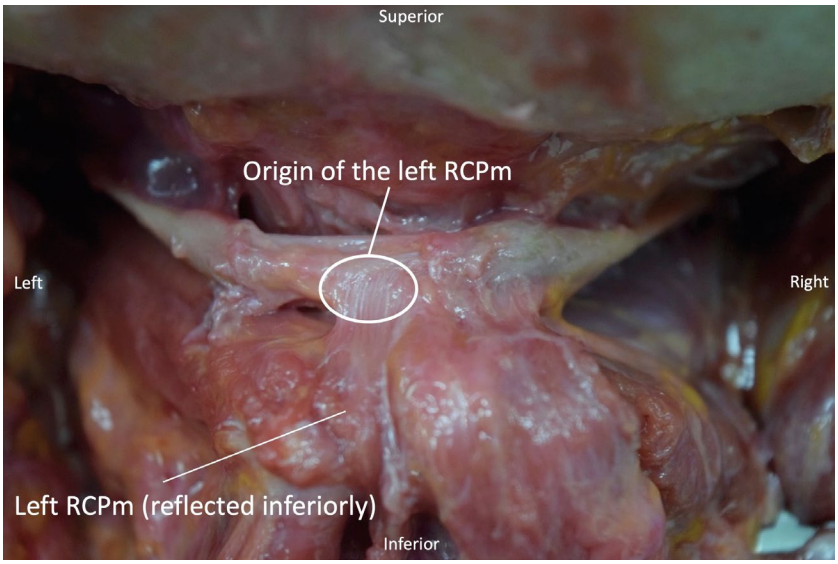

Figure 3. Both right and left rectus capitis posterior minor (RCPm) muscles are turned inferiorly to see their origins.

and 84 fresh cadavers and found 2.95% (40/1354) had the C1 posterior arch deficiency.

Previous studies have reported that patients with a C1 posterior arch deficiency probably have stable cervical spines despite the defect, likely due to the development of a dense fibrous membrane across the width of the defect, spanning then entire posterior in patients with completely absent posterior arches [2, 4]. Studies on autopsy and surgical specimens have demonstrated these variants were bridged by connective tissue rather than cartilage, and a study by Geipel [5] surveying "anterior" arch defects of C1

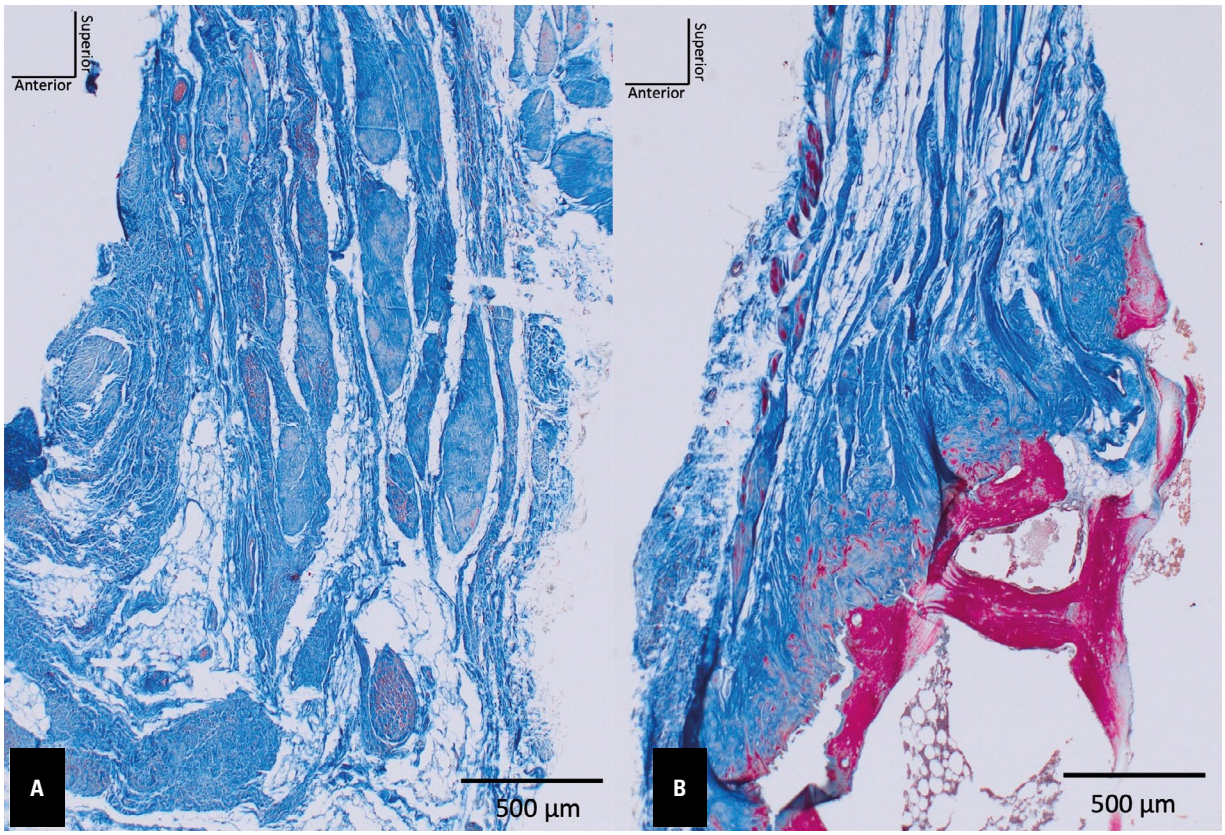

Figure 4. Masson-trichrome stain of the posterior arch of C1. Note that the posterior arch defect of C1 is filled with collagen fibres and fibrocartilaginous tissue (**A**) and the posterior arch of C1, slightly right of centre, is shown for comparison (**B**).

reported histological findings of a fibrocartilaginous bridge [8]. In the event of an absent posterior tubercle, the rectus capitis posterior minor and interspinalis cervicis may instead attach to the spinous process of C2, resulting in a compensatory hypertrophy and enlargement of the spinous process [4].

Historically, posterior arch defects have been difficult to distinguish from traumatic injuries such as Jefferson fractures [2, 10, 12, 13]. Arch defects can be differentiated by looking for smooth well-corticated margins on CT with no soft tissue swelling or stranding on CT or magnetic resonance imaging [2, 6, 10]. Lack of fracture callus performed on post-mortem anatomical studies may also help differentiate between a congenital defect, particularly in rare cases such as type B arch defects which may more closely mimic a traumatic event [13].

Embryology and development

The embryology of the spine begins with gastrulation and formation of somatic mesoderm and the notochord, condensation into somites, formation of dermatomes and sclerotomes, and then formation of membranous somites and resegmentation into vertebrae, ending with chondrification of vertebrae and subsequent ossification [3]. Defects in the C1 posterior arch are generally thought to be due to errors in chondrification, rather than ossification [4, 6]. The atlas normally develops from three primary ossification centres: one midline centre that later develops into the anterior arch of C1, and two lateral masses that extend posteromedially to form the posterior arch of C1 [3, 9]. By the seventh gestational week, the lateral centres have formed the posterior arch, fusing completely by year four [3, 5, 9]. Failure of fusion of these two ossification centres is responsible for the development of defects in the posterior arch [9].

Another developmental cause is found in cases of a dystopic *os odontoideum*. In these patients, the tip of the odontoid process separates from the remaining portion of C2, fusing with the clivus near the foramen magnum [1]. This has been seen to result in hypoplasia of the posterior arch and hypertrophy of the anterior arch, similar to previously reported cases of posterior arch defects [1, 4, 6]. Notably, it is unclear if this variant is congenital or due to trauma [1].

Rarely, an anterior arch defect of C1 may be present in addition to a posterior arch defect, forming a bipartite atlas [2, 4, 6]. Development of this anterior arch defect is thought to be related to posterior arch defects, due to isolated anterior arch defects having a much lower prevalence than a bipartite atlas [6]. The current consensus is that the development of this anterior arch defect is due to biomechanical changes that occur with posterior arch defects, although the exact cause is debatable. One proposed mechanism by Allam et al. [2] states the anterior arch defect occurs due to subclinical fracture of the anterior arch due to the posterior arch anomaly. One study by Hyun et al. [6] found that trauma was unlikely to form a major role due to the lack of correlation between anterior arch defects and patient age, instead suggesting that absence of the posterior arch affects increased axial load of the anterior arch, affecting development as it ossifies later in childhood. Other studies have found that patients with posterior arch variations may have hypertrophy of the anterior arch, suggesting that defects in the posterior arch does affect the development of the anterior arch [4].

Analysis of anatomical variations can contribute to obtaining an actual, not idealised image of the inside of the human body, which is of crucial importance in everyday clinical practice [15].

CONCLUSIONS

This is the first report detailing the histological findings of a posterior arch defect of C1.

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Conflict of interest: None declared

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