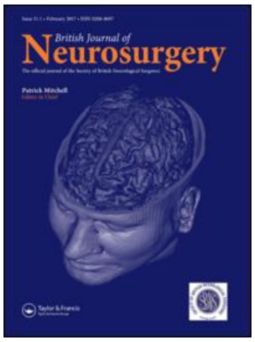

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TECHNICAL NOTE

Posterior arch reconstruction in cervical surgery to restore the global biomechanics of the Atlas: a technical note

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ABSTRACT

The posterior arch of the atlas is usually not considered one of the main stabilizers of the cranio-cervical junction, allowing surgeons to its removal when needed with a relative certainty to preserve the stability of the atlo-axial segment. However, these considerations do not reflect the importance to examine the integrity of the posterior arch in the whole biomechanics of the atlas. Authors like Gebauer and Panjabi revealed, respectively in experimental and clinical conditions, how the atlas responds to an axial loading force, proving that the whole atlas is involved into horizontal conversion of axial forces and providing evidence supporting the preservation of the posterior arch. Other authors evaluated the risk for anterior arch fracture following C1 laminectomy. In this technical note three different techniques of posterior atlas arch reconstruction after surgical iatrogenic disruption are presented, considering both neoplastic and degenerative disease.

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Atlas posterior arch; biomechanics of the atlas; cranio-cervical junction; atlas reconstruction; cranio-cervical stabilizers

Introduction

Many times in cervical surgery a iatrogenic disruption of the posterior arch of the atlas is performed, for degenerative or neoplastic diseases. The posterior arch of the atlas is not considered usually one of the main stabilizers of the cranio-cervical junction, allowing surgeons to its removal when needed with a relative certainty to preserve the stability of the segment, then without restoring its integrity at the end of the procedure.

However, these considerations do not reflect the importance to examine the integrity of the posterior arch in the whole biomechanics of the atlas. Authors like Gebauer and Panjabi revealed, respectively, in experimental and clinical conditions, how the atlas responds to an axial loading force, proving that the whole atlas is involved into horizontal conversion of axial forces and providing evidence supporting the preservation of the posterior arch.[1–6] Other authors showed the risk for anterior arch fracture following C1 laminectomy.[7–9] Basing on their contributions, the reconstruction of the atlas could preserve the global biomechanics of the vertebra in degenerative, traumatic or neoplastic disease after surgery.

In this technical note, three different techniques of posterior atlas arch reconstruction after surgical iatrogenic disruption are presented.

Case 1

A 63 years-old male patient came to our attention for motor impairment and pain in the superior right arm, progressively since 2 years. The symptoms worsened during the last three months with new onset of vertigo and subjective instability during the deambulation. The clinical examination did not reveal a radicular distribution of the upper right arm pain. Romberg test was positive with right deviation and Hoffman sign was slightly positive on the right hand. He performed contrasted cervical Magnetic Resonance Imaging (MRI) that showed a large extra-assial neoplasm located on the right antero-lateral surface of C1–C2 with compression of the spinal cord that resulted shifted to the left side. The lesion was characterized by a non-homogeneous contrast enhancement. According to the radiological features, it was supposed the hypothesis of meningioma.

The patient underwent surgery with a posterior approach; a linear incision was performed from the inion to the C3 processus spinosus. Then with a subperiosteal dissection the bilateral laminae of C2, the posterior arch of the atlas and the occipital squama were exposed. As a part of the approach to reach the tumor, the posterior arch of the Atlas was removed after bilateral archotomy at its lateral thirds with the ultrasonic aspirator (Sonopet, Nagakawa tip, Stryker Italia S.r.l. S.U. – Via degli Olmetti, 1–00060 Formello (RM)) after a pre-plating with titanium plates. With a median linear incision of the dura, the mass was removed. At the end of the excision the posterior arch was fixed in its physiological site, then avoiding a decompressive plasty because of the benign nature of the tumor. Surgical repositioning required about 7 min.

The post-operative course was linear and without complications; the patient was discharged with follow-up at 1–6–12 month. The hystopathology confirmed the hypothesis of meningioma (grade I WHO). After 1 year, the nearly complete regression of symptoms was observed. A Computerized Tomography (CT) scan showed no signs of new instability and revealed the complete ossification of C1 posterior arch (Figure 1).

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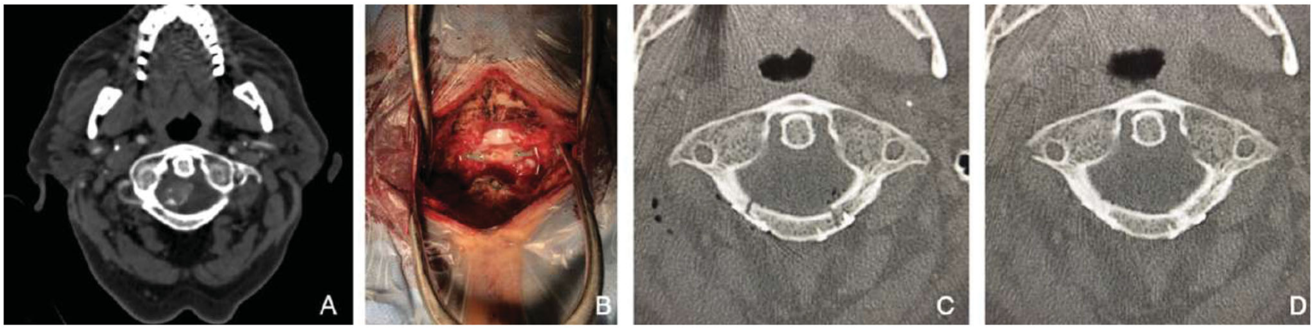

Figure 1. (A) A pre-operative CT scan showing the partially calcified meningioma. (B) Intra-operative reconstruction of the posterior arch with titan plates and screws. (C) C1 reconstruction, post-operative CT scan. (D) One-year follow-up showing the complete ossification of C1 posterior arch.

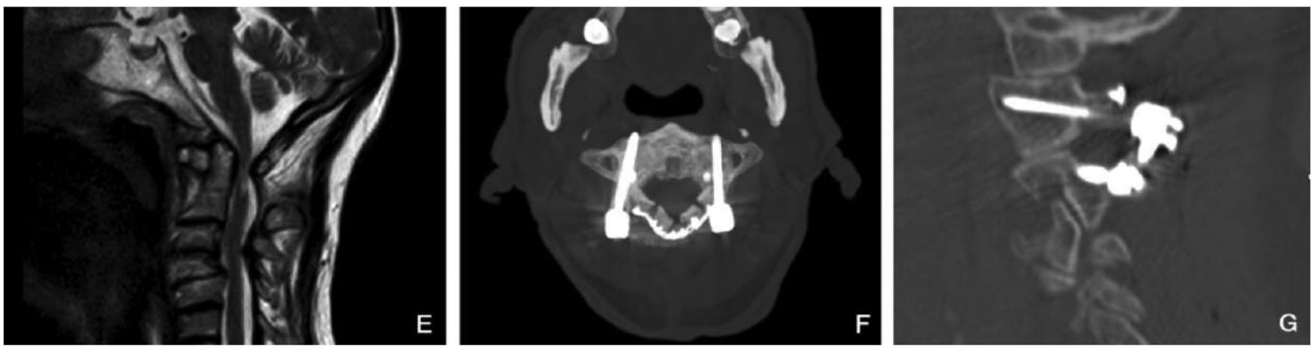

Figure 2. (E) T2-weigthed pre-operative MRI sequence showing a cranio-cervical junction stenosis with associated myelopathy. (F) Post-operative C1 posterior arch reconstruction resulting in canal decompression. (G) CT sagittal scan showing C1–C2 fixation following Harms technique.

Case 2

A 70 years old male patient with rheumatoid arthritis (RA) came to the attention of neurosurgeons for a progressive gait impairment associated with upper and lower limb paresthesias without radicular distribution. The clinical examination revealed the presence of the Hoffman and Babinsky signs bilaterally. Upper limbs fine movements were mildly impaired. The patient performed a cervical non-enhanced MRI that showed C1 anterolysthesis. This finding was associated with anterior compression of the dural sac and alteration on that level of spinal cord signal in T2 weighted sequence. The clinical and radiological findings were then suggestive for C1–C2 instability with associated myelopathy.

The patient underwent surgery with posterior approach and a C1–C2 arthrodesis, following Harms technique, was performed. The posterior arch of the atlas was removed cutting its lateral thirds with drilling. To support the decompressive goal of the procedure, the removed arch was split into two halves (Figure 2). A bone allograft was then placed and fixed between the two halves with two titanium plates and screws for each side. Finally, the continuity of the posterior arch was achieved through the fixation of the reconstructed posterior arch to the atlas with plates and screws. The restoration of the arch was performed in about 15 min. The C1 posterior arch reconstruction with archoplasty resulted in a larger canal space that contribute to the total cervical spinal cord decompression (Figure 2). Ossification of the posterior arch was registered at 1-year follow-up.

Case 3

A 51 years old female patient with Down syndrome and osteoporosis came to the attention of authors neurosurgeons for progressive gait impairment that worsened in the last 2 months. The clinical examination revealed the presence of pyramidal signs. She performed a non-enhanced cervical MRI that showed a cranio-cervical junction pathology with anterior compression of the dural sac given by degeneration of the junctional apparatus of the dens and instability. These findings were associated with myelopathy. The patient underwent surgery with posterior approach and a C1-C2 arthrodesis following Harms technique was performed. In this case, the decompression was achieved performing a C1 open door archoplasty using the ultrasonic aspirator and with the interposition of a cadaveric bone fragment, fixed with plates and screws. Surgical repositioning required about 16 min. The arch continuity was then restored with an enlargement of the spinal canal (Figure 3). At 1-year follow-up fusion was confirmed by a CT scan.

Discussion

Is restoration of posterior arch supported by evidence?

Surgeons commonly focused atlas stability on the evaluation of the transverse ligament (TAL) integrity, lateral masses placement and anterior arch continuity. The English literature, however, analyzed and highlighted the contribution of the posterior arch during axial forces. Gebauer et al. analyzed 40 isolated specimens testing the atlas with the application of pure axial forces to failure, excluding ligamentous side effects, at constant speeds of either 0.5 mm/s (Group 1) or 300 mm/s (Group 2) for low and high speed evaluation.[6] The fracture types were classified according to Gehweiler.[2] The distribution of the fracture types obtained at a low speed investigation (Type-I: isolated anterior arch, Type-II: posterior arch, Type-III anterior and posterior arch, and

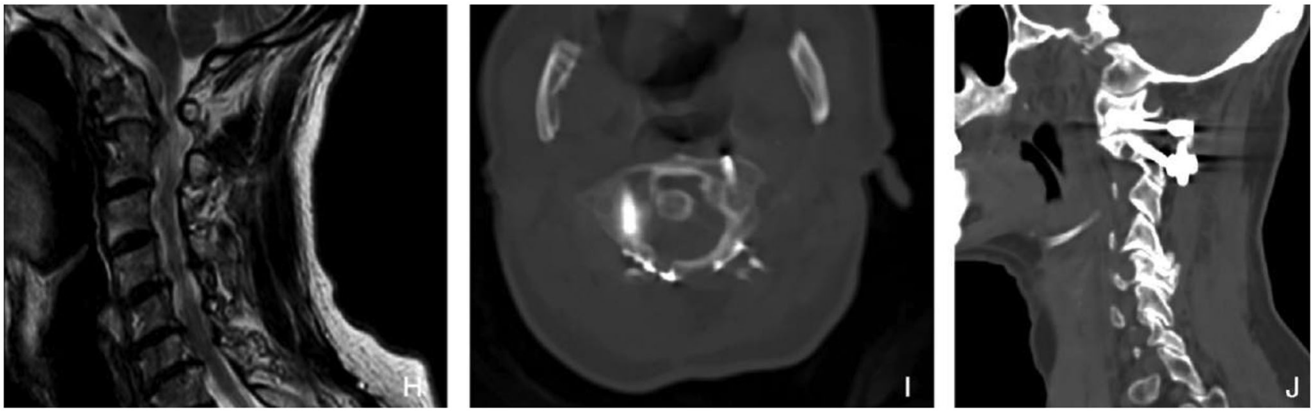

Figure 3. (H) T2-weigthed pre-operative MRI sequence showing cervical stenosis with associated myelopathy caused by ligamentous hypertrophy. (I) Post-operative CT scan showing posterior arch reconstruction with decompressive open-door archoplasty. (J) CT sagittal scan at one-year follow-up showing C1–C2 arthrodesis following Harms technique.

Type-IV: lateral mass) were similar to those observed clinically by Levine in 25 of 34 patients sustaining atlas fracture.[5] In view of this, isolated posterior arch fractures are described to occur in low speed axial loading both in experimental than in real conditions. This is why atlas posterior arch could play an important and underestimated role: it discharges axial forces in horizontals components, reducing the total loading on the lateral masses.

The physical mechanism underlining the forces distribution through the atlas under an axial loading was first described for the atlas burst fracture by Jefferson in 1920.[4] Jefferson noticed the 'lateral spreading of lateral masses caused by the divergence of the line of the force passing through the bone'. This theory was subsequently implemented by Panjabi who produced isolated atlas fracture in 10 upper cervical spine (C0–C3) specimens under axial loading.[6] Panjabi concluded that the mechanism for C1 burst fracture is the conversion of compressive into expansive or horizontals forces because of the wedge-shaped cross-section of C1 lateral masses. According to this theory, it is possible to better understand the atlas posterior arch behavior during an axial loading and justify either burst fractures or type II fracture as the result of the overloading forces through the atlas, overcoming then the conversion capability of compressive forces into horizontal forces. In a comprehensive view, the bone mineral content is an additional key point in the biomechanics of the atlas: previous studies outlined a significant positive correlation between the failure forces and the total bone mineral content of the atlas specimens for the slow speed applied forces (0.5 mm/s).[1–3,10] Shimizu showed that the incidence of anterior arch fracture after C1 laminectomy is not uncommon.[7] O'Shaughnessy et al. reported two cases of fracture after decompression for Chiari procedure.[8] Other papers were previous published investigating the same topic.[9]

These evidences could further justify the rationale to reconsider the importance of atlas posterior arch reconstruction. A iatrogenic surgical removal without repositioning decreases the possibility of horizontal forces discharge, even more in osteoporotic or RA patients. There is absence of evidences supporting or discouraging the restoration of the posterior arch after C1-C2 fixation – like in Cases 2 and 3 – but even in these cases the discharge of cranial forces still constitutes an issue, because how force vectors change caudally from the Occiput/atlas joint (preserved) and then along the fixation from C1 to C2 is unknown. Moreover, Cases 2 and 3 involved patients with RA, osteoporosis and Down syndrome and the possibility of hardware failure in these cases is not negligible.[11] The reconstruction of the arch provided then the possibility to achieve decompression but also to promote fusion gaining more bony area for arthrodesis.

Surgical cases

Three different types of atlas posterior arch reconstruction have been performed after iatrogenic disruption. In Case 1, the atlas posterior arch was removed to expose the surgical corridor and then restored by fixing it with titanium plates and screw. Otherwise, in the other two cases restoration of the posterior arch was not only finalized to the reconstruction itself, but considering the necessity to increase the canal diameter achieving a cervical spinal cord decompression. In Case 2, the atlas posterior arch was removed and divided into two halves; a bone allograft was placed in the middle of the arch to promote fusion and fixed with titanium plates and screws. In Case 3, the decompression was achieved performing a C1 open door archoplasty with the interposition of a cadaveric bone fragment. In all cases, fusion of the arch was achieved and confirmed at 1-year follow-up. Surgical repositioning and archoplasty were not high demanding and required, respectively, only 7, 15, and 16 min for Cases 1, 2, and 3.

Conclusion

The atlas posterior arch plays an underestimated role in the total biomechanics of the atlas contributing to the conversion of an axial load into horizontals components. In this technical note, three successful cases of different restoration of the posterior arch, respectively, in neoplastic, rheumatologic and degenerative disease are presented. Further study should investigate atlas biomechanics changes with or without reconstruction, even after atlo-axial fixation, to assess the real need for posterior arch preservation.

Disclosure statement

The authors declare no conflicts of interest.

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