North American Spine Society Journal (NASSJ) 1 (2020) 100004

Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Case Studies

Pearls for addressing traumatic cranio-cervical instability in a patient on extracorporeal membrane oxygenation (ECMO) ☆

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ARTICLE INFO

Keywords:
Atlantoaxial dislocation
Atlanto-occipital dislocation
Craniocervical dissociation
ECMO
Extracorporeal membrane oxygenation
Traumatic spinal cord injury

ABSTRACT

Background: Concurrent craniocervical dissociation in a multi-trauma patient requiring venous-venous extracorporeal membranous oxygenation (ECMO) poses significant challenges in its management.
Purpose: This article describes the nuances of the surgical decision-making in a complex case of a polytrauma patient with craniocervical dissociation who required concurrent ECMO.
Study design/ setting: Case report and literature review
Methods: The authors describe a complex case of a patient with craniocervical dissociation requiring ECMO and who was managed surgically in a level 1 trauma centre in Victoria, Australia after sudden neurological deterioration whilst in a halo-vest. A literature search using appropriate medical subject headings and keywords was performed to identify published cases of craniocervical dissociation in patients requiring concurrent ECMO.
Results: Literature search yielded twenty-seven articles, with only two relevant articles identified for full text review. Only one article was found to be relevant, which however did not provide detailed discussion on surgical aspect of the pathology.
Conclusion: To the authors' knowledge, this is the first report of management of craniocervical dissociation in a patient requiring ECMO due to polytrauma focused on the nuances of the complex surgical decision-making which is required for proper management of such critical condition.

Introduction

Craniocervical dissociations (CCD) in the form of either atlantoaxial dislocation (AAD) or atlanto-occpital dislocation (AOD) are rare but significant pathologies. AAD can be defined using atlanto-dental interval (ADI) of more than 3mm in adults. For cases of C1 fractures, rule of Spence is another useful indicator, determined by measuring the overhang of lateral masses of C1 on C2 [1]. AAD is often associated with significant disruption of integrity of odontoid or transverse and alar ligaments, and is usually secondary to trauma, congenital or inflammatory processes [2]. Wang et al [3] presented a clinically oriented classification system, ranging from dynamic instability to bony dislocation (Table 1), providing a generalised treatment algorithm based on severity of pathology.

Extracorporeal membrane oxygenation (ECMO) is a form of cardiopulmonary bypass aimed at providing medium-term (days to weeks) support for patients with cardiac and/or respiratory failure. Two main types of ECMO are of veno-arterial (VA) ECMO and veno-venous (VV) ECMO, with the main distinguishing feature being the type of vascular access, and therefore the system(s) being supported. VA-ECMO is generally used for patients with cardiac or cardiopulmonary failure, while VV-ECMO is utilised for patients with isolated respiratory failure without cardiovascular compromise [4]. With ECMO becoming increasingly available, along with its gradually diversified indications, its use in trauma-related circumstances had also been gaining traction.

Patients presenting with trauma-related CCD while concurrently requiring VV-ECMO support are therefore rare, but will no doubt be increasingly encountered in future with advancement of care provided. This case aims to provide some insights and pearls in surgical management of such patients.

Case description

A 19-year-old male was intubated at scene post motorbike accident. On arrival, he was severely decompensated hemodynamically. Trauma protocol imaging revealed left anterior 2-4th rib fractures with

☆ Funding Disclosures: No financial support declared.
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https://doi.org/10.1016/j.xnsj.2020.100004
Received 20 January 2020; Received in revised form 1 May 2020; Accepted 1 May 2020
Available online 8 May 2020

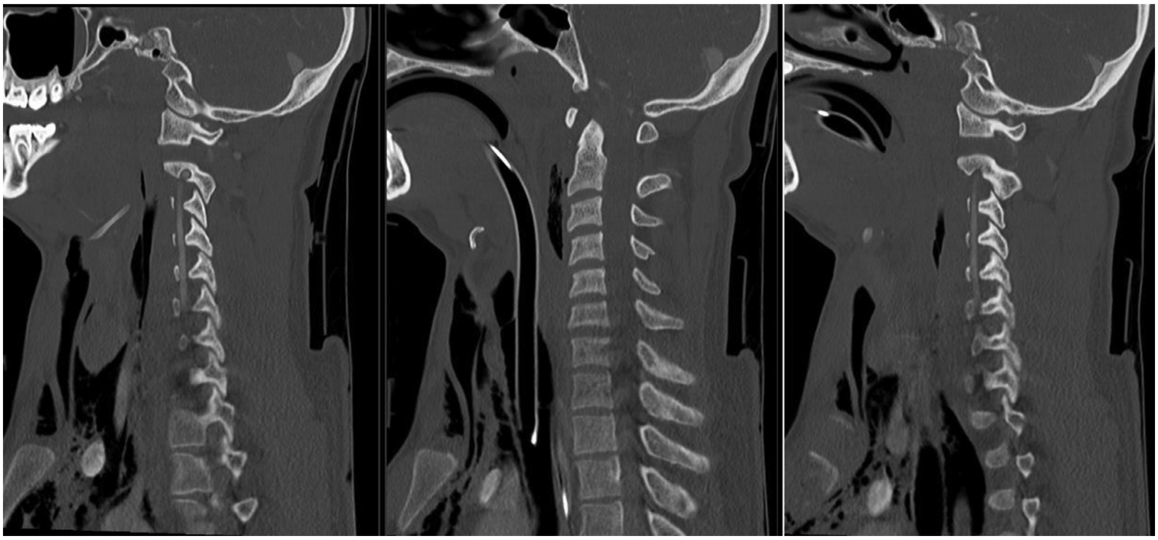

Fig. 1. CT sagittal views of cervical spine in bone window at midsagittal and bilateral facets showing a type 2 AOD using Traynelis classification with basion-dens interval (BDI) measuring 14.5 mm, and AAD with atlantodental interval of 6.5 mm. Notably, bilateral C1-2 facets were significantly distracted, consistent with a highly unstable injury.

Table 1
Clinically descriptive classification provided by Wang et al, with emphasis on severity of dislocation and its reducibility.

Class	Description	Management
I	Dynamic instability	Posterior fusion
II	Reducible dislocation	Reduction under general anaesthesia and posterior fusion
III	Irreducible dislocation	Transoral release +/- ventral decompression AND posterior fusion
IV	Bony dislocation	Ventral decompression

bilateral hemopneumothoraxes, left main bronchus rupture, unstable cranio-cervical injuries, left clavicle fracture, left comminuted scapular fracture, and right open femur fracture. He had an Injury Severity Score (ISS) of 50.

After initial emergency room stabilization, the patient had VV-ECMO inserted due to severe respiratory failure with significant difficulty with mechanical ventilation. As the patient had an open femoral fracture, the right internal jugular vein was cannulated for vascular access. He subsequently underwent thoracotomy and left bronchial end-to-end anastomosis as well as external fixation of his femoral fracture.

His initial CT cervical spine, as shown in Fig. 1, demonstrated BDI of 14.5 mm, ADI of 6.5 mm, and significant distraction/subluxation between C1-2 facets. Magnetic resonance imaging (MRI) of the brain and spine was performed on the following day, which confirmed significant ligamentous injuries involving anterior atlanto-occipital membrane, tectorial membrane, cruciform ligament and apical ligament, but an otherwise intact spinal cord (Fig. 2). Altogether, these were consistent with a case of severe CCD, mainly of AAD. His craniocervical injury was managed with spinal immobilization using a halo-thoracic brace as he was deemed extremely high risk for a posterior spinal procedure, with plan for definitive craniocervical fusion after decannulation of the vvECMO. Mean arterial blood pressure (MAP) was maintained following current spinal cord injury (SCI) guidelines [5]. Neurological assessment during intermittent cessation of sedation demonstrated patient was obeying up to shrugging of shoulders, demonstrating intact motor functions to a certain extent.

Unfortunately, the patient suffered an acute neurological deficit day 5 post injury (without provocation), at which point he was not able to move beyond his neck. Due to his haemodynamic instability, he did not have a post bracing lateral view cervical radiograph. An urgent CT cervical spine revealed further posterior translation of C2, increased ADI and subluxation of C1-2 facets, resulting with critical narrowing of the canal diameter (Fig. 3). Given his neurological deterioration and significant change demonstrated on CT scan with canal diameter of 10mm (from previously 16 mm), additional imaging of MRI was not performed. At this point, he was brought into surgical theatre for an emergent C1 and C2 posterior decompression and C0-4 posterior instrumented fixation.

The surgery was well planned with anticipated challenges thought off in advance and mitigated. Surgical nuances to be considered include patient positioning, difficulty in haemostasis and positioning of screw fixation.

In our case, a Jackson Table was used to position the patient. As this was a posterior cranio-cervical procedure with significant instability, it would have been ideal to use one of the main selling features of the Jackson Table, where the patient could be positioned supine and then rotated to the prone position, using the so-called 'rotisserie' double-table device. Following a discussion with the anaesthetic team, perfusionists, nursing staff and theatre technicians, this positioning method was deemed potentially unsafe as it was uncertain what was the decannulation risk of the internal jugular vein accessed ECMO device, a wide bored, rigid cannula affixed to the skin with tapes and sutures. In our case, we eventually opted to log-roll the patient with the head fixed using Mayfield fixation device, with immediate position check using image intensifier radiographs. We do however acknowledge that some centres may prefer to flip the patient using Jackson table alone, which would be very reasonable.

Intraoperatively, significant difficulty with haemostasis was encountered during tissue dissection, despite meticulous dissection with the aid of diathermy and adjuncts such as oxidized regenerated cellulose, absorbable gelatin sponge and thrombin-gelatin matrix. After discussion with anaesthetic team, patient was also given intraoperative tranexamic acid and irradiated platelets. Despite that, patient still required 3 bags of packed red blood cells transfusion.

Another surgical nuance in this case is the placement of the C1 lateral mass screws. This screw is usually placed through the posterior part of the pars of C1, with dissection down to this area can at times lead to significant blood loss. In this case, we utilised an alternative trajectory through the posterior arch of C1 using neuronavigation, which had been previously described [6,7]. The acknowledgment of the vertebral artery coursing superior to the posterior arch and the utility of the Medtronic Midas 10MH217L drill bit in creating the path for the screw as guided by neuronavigation and confirmation with 2-D fluoroscopy is crucial in

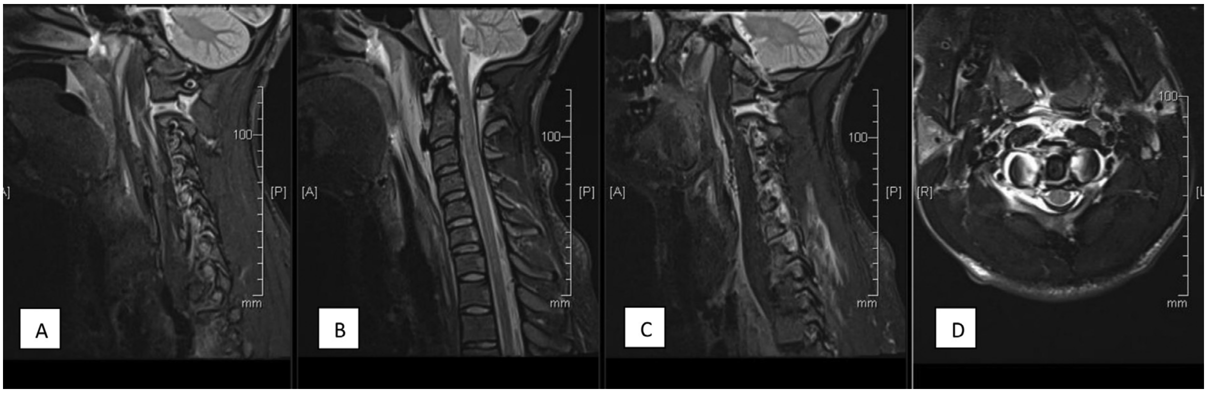

Fig. 2. A-C: Short tau inversion recovery (STIR) sequence at parasagittal view at right C1-2 facet, midsagittal view and left parasagittal view at left C1-2 facet demonstrated significant ligamentous injuries involving tectorial membrane, anterior atlanto-occipital membrane, cruciate ligaments and associated with significant bilateral C1-2 facet subluxation. D: axial view of T2 sequence at dens level of cervical spine demonstrated no spinal cord injury or significant canal stenosis.

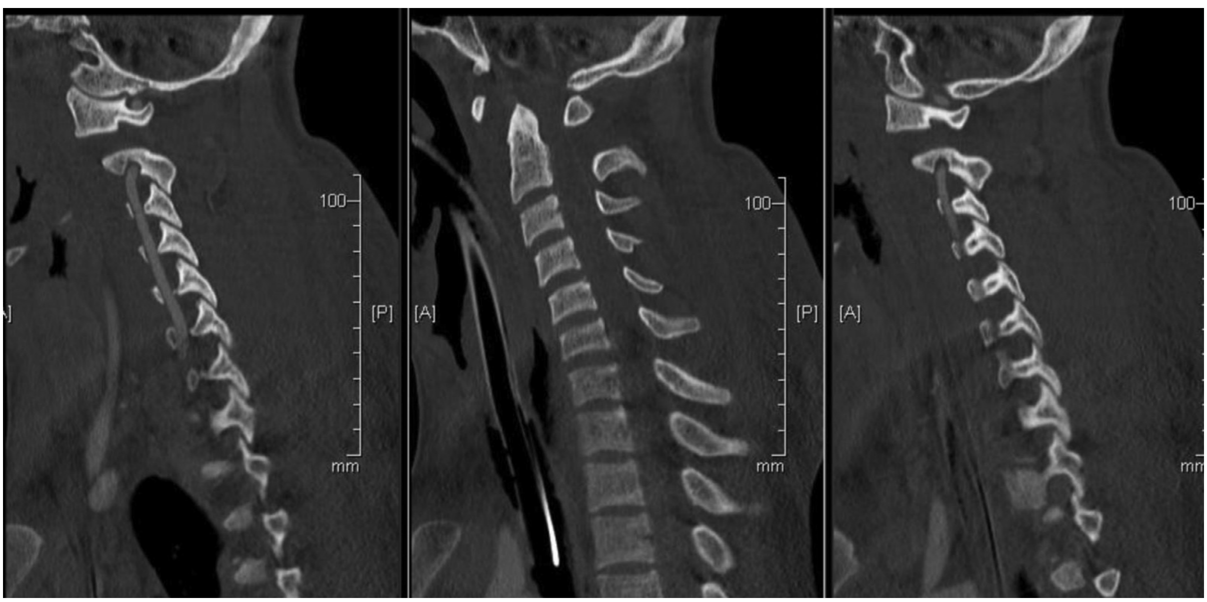

Fig. 3. From left to right: CT sagittal views at right C1-2 facet, midsagittal view and left C1-2 facet showing significant increase of ADI to 12 mm and conversely a reduction of canal diameter to 10 mm. This is also associated with increased BDI to 17 mm and further subluxation of C1-2 facets. Also note the soft tissue lump posteriorly, likely an indicator of venous congestion.

ensuring adequate haemostasis by avoiding dissection into or around the vertebral venous plexus.

Postoperative imaging (Figs. 4 and 5) showed stable construct with improved ADI and BDI as well as bilateral C1-2 facet alignment, resulting with improved canal diameter. At the 6-week mark, he was a C4 AIS-D SCI grade [8].

Literature review

A systematic electronic search using Medline, PubMed, EMBASE, Cochrane Database of Systematic Reviews, and Google Scholar was performed from the databases' date of inception to December 2nd, 2019. For the searches, combinations of the following MeSH (medical subject headings) terms and keywords were used to query the databases: "spinal stabilization" OR "spinal fusion" OR "spinal cord injury" OR "craniocervical dissociation" OR "occipitocervical dissociation" OR "atlanto-occipital dissociation" OR "atlantoaxial dislocation"; AND "extracorporeal oxygenation" OR "ECMO." Cumulatively, the search yielded 27 articles. A review of title and abstract of the 27 studies identified two articles for full text review. Only the article by Lotzien et al was found relevant.

In the series by Lotzien et al [9], the authors described 7 patients who had ECMO support due to acute respiratory distress syndrome. Four of the seven patients had spinal fusions, but were all done prior to ECMO cannulation. The article however did not describe in detail on the surgical intervention. Therefore, this case report is the first to provide a detailed surgical insight on occipitocervical fusion in patients with craniocervical dissociation and SCI requiring concurrent ECMO.

Discussion

This unique case highlighted four main discussion points: (i) Instability of a high cervical dissociative injury; (ii) Challenges faced with operating room set up and positioning of patient; (iii) Challenges faced with a high flow vascular system in operative region; and (iv) Time to surgery.

Instability of a high cervical dissociative injury

Conventionally, high cervical dissociative injuries have been managed with halo-thoracic bracing either in anticipation of definitive surgical intervention or when non-surgical management had been opted. As reported by Kato et al in their case study [10], our case re-affirmed

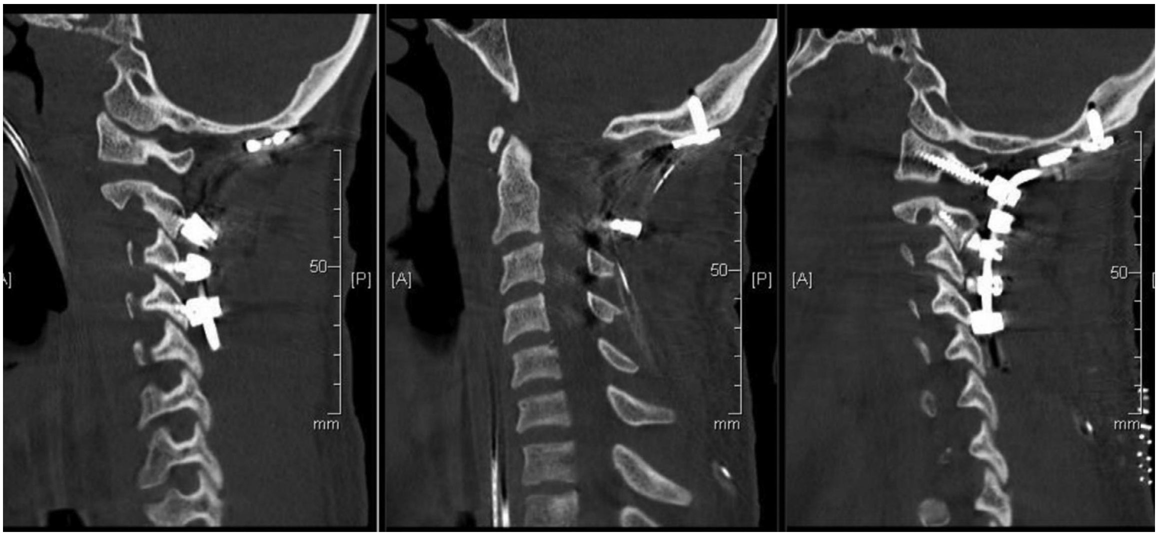

Fig. 4. From left to right: postoperative CT sagittal views at right C1-2 facet, midsagittal view and left C1-2 facet showing improved ADI, BDI and bilateral C1-2 facet alignment, with resulting significantly increased canal diameter. Trajectory of left C1 screw was also shown, traversing from posterior arch of C1 into its lateral mass.

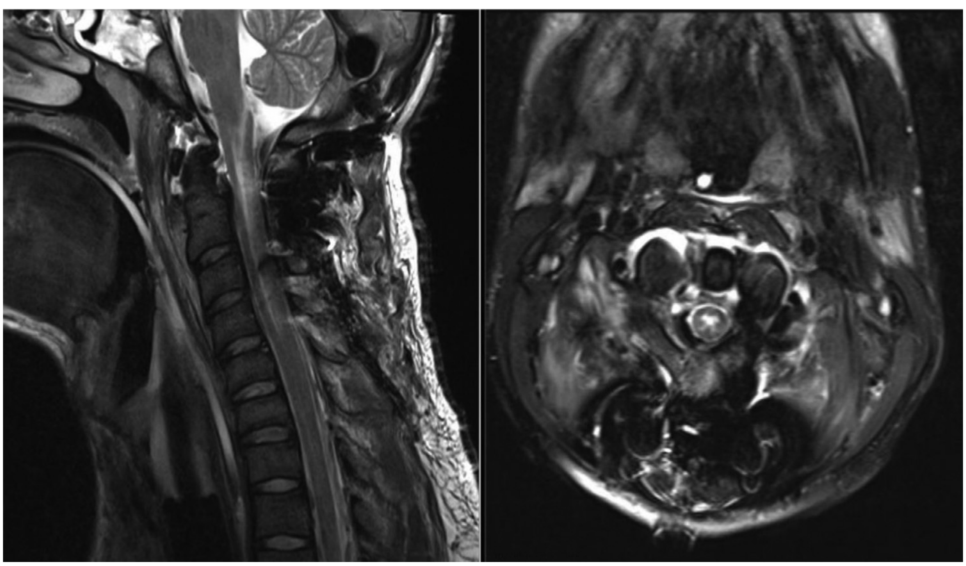

Fig. 5. midsagittal and axial views of T2-weighted cervical spine MRI performed post-operatively showed adequate spinal cord decompression (especially on axial view) despite significant cord signal change and artefacts caused by metalware.

that neurological deterioration can occur due to the inherent instability of the injury type or as a result of suboptimal placement of the brace. In addition, due to the haemodynamic instability of the patient, a post brace-fitting radiograph was not performed. As such, post bracing imaging are crucial especially in cases like this.

Challenges faced with operating room set up and positioning of patient

Any surgical patient with an ECMO device requires an operating room, which is significant in terms of size to accommodate the machinery and personnel operating the device. The anaesthetic team number is usually also doubled with the case complexity. As such, the operating room setup including the scrub setup and imaging equipment has to be well thought of to ensure smooth workflow in an already extremely difficult case.

Challenges faced with a high flow operative region vascular system

While the location of a jugular vein accessed ECMO cannula does not interfere with surgical access, it significantly increases the venous pressure in the operative field due to high cervical intravascular pressure with resulting tissue oedema. As such, in the first instance, surgical intervention in these patients should be avoided or postponed if possible whilst the ECMO cannula is in-situ.

However, if surgery is to be performed, increased intraoperative bleeding should be anticipated especially in multi-trauma patients with known poor cardiovascular reserve. In these cases, coagulopathies should be corrected pre-operatively and clinicians should have a low threshold to transfuse anaemic patients with packed red blood cells prior to surgery. One may also consider to administer adjuncts such as tranexamic acid at induction of anaesthesia. Modifications to placement of C1 screws as described in case summary also enable easier access and help with reduction of blood loss.

Timing to surgery

It is generally accepted as standard of care that surgical decompression for traumatic spinal cord injured patients with neurological deficit should be performed as soon as feasible [11]. Newer papers with good follow up have suggested surgical decompression should be performed more urgently within 8 hours. These papers [12,13] have shown that there are merits in surgical decompression to be performed as sooner to achieve better neurological improvement. In our case, the patient was operated on and fully decompressed at the 6-hour mark post deterioration. As said earlier, he has shown a 3 grade AIS improvement in 6 weeks.

Conclusion

This case highlights an extremely complex case requiring multidisciplinary collaboration and is the first described case of craniocervical stabilization and decompression in a patient with jugular vein ECMO access device. It also highlights the importance of adherence to current traumatic SCI guidelines, and understanding the surgical pearls and nuances ensuring optimal patient outcomes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2020.100004.

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