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Upper cervical spine injuries: Indications and limits of the conservative management in Halo vest. A systematic review of efficacy and safety

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ABSTRACT

Introduction: The integrity of the upper cervical spine is essential for survival and function, because of the neurovascular structures contained within its bony elements. Fractures of the upper cervical spine (C1–C2) are frequent. This systematic review assesses the efficacy and safety of the conservative management in Halo vest for patients with upper cervical spine fractures.

Materials and methods: Two reviewers independently identified studies in English, by a systematic search of CINAHL, Embase, Medline, HealthSTAR, and the Cochrane Central Registry of Controlled Trials, from inception of each database to 28 January 2010, using various combinations of the keywords terms "odontoid fractures", hangman's fractures", "axis fractures", "axis", "atlas", "Jefferson fractures", "C1 arch fractures", "C1 fractures", "C2 fractures", "cervical spine", "injuries", "fracture", "trauma", "neck injury", "surgery".

Results: A total of 43 citations were obtained. An additional 4 papers were obtained from the reference list of the studies included. The 47 studies that were included described a total of 1078 patients with C1–C2 fractures managed by halo fixator.

Conclusions: The halo fixator has a well defined place in the management of fractures of the cervical spine. Clearly, studies of higher level of evidence, for instance large randomised trials, should be conducted, even though the available evidences suggest that management of upper cervical spine facture with halo fixator is safe and effective.

Introduction

Fractures of the upper cervical spine (C1–C2) are frequent.[33,42,63,85] Fractures of C1 account for approximately 2–15% of acute cervical fractures, while fractures of C2 account for approximately 17–25% of acute cervical fractures.[20,44] The integrity of the upper cervical spine is essential for survival and function, because of the neurovascular structures contained within its bony elements. At the upper cervical spine, there is the transition from brainstem to spinal cord, and the upper cervical spine protects the enclosed neural elements, allowing at the same time a substantial portion of the head motion.[47]

Lately, various anterior and posterior surgical procedures have been developed for the operative stabilisation of injuries to the upper cervical spine, with good clinical results.[4,5,20,48] The surgical management of odontoid fractures via an anterior surgical approach has the potential advantage to maintain rotational motion at the atlantoaxial joint. However, this approach has several complications, including neural or vessel injury, oesophageal and pharyngeal perforation, and airway obstruction.[18,20,21,63] C1–C2 fusion techniques have been successfully used in these patients, but loss of motion at the atlantoaxial joint will ensue, with consequent severe impairment of the activities of daily living.[55] Although these procedures result in a high fusion rate, they cause an almost 50% reduction in cervical rotation, and a 10% reduction in flexion and extension.[4] Motion at C1–C2 is primarily rotational, which accounts for 50% of the axial rotation of the head on the neck.[55]

Perry and Nickel first developed the original halo system in 1959[58] to provide cervical immobilisation and obtain occipito-cervical fusions in 19 patients with cervical instabilities or paralysis as the result of poliomyelitis. They[58] identified the cranial portion of the device developed by Bloom during the Second World War as the direct inspiration for the cranial portion of their halo design.[56,67] In the last 50 years, stabilisation of the cervical spine through halo fixation has evolved dramatically, with enhancement of the vest design and improvement of the protocol

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for application and follow-up.[7,38,76] The halo fixator has been used for several years as a first line tool to stabilise the cervical spine, before the development of internal fixation.[6] Although halo fixator provides the most rigid immobilisation of any currently available orthoses, it does not rigidly immobilise the cervical spine. Today, the halo fixator continues to have a well defined place in the management of cervical spine pathologies with a high degree of instability.[6,80]

The halo vest has several indications in the management of patients with upper cervical spine injuries, as well several drawbacks.[51] The complications of halo vest immobilisation are patient discomfort, pin-site infection, osteomyelitis, nerve injury, dural penetration and CSF leakage, intracranial abscesses, dysphagia, pin-site scar formation, restriction of respiratory function, and loss of reduction.[19,61,62] The poor tolerability of the halo vest in the elderly has been also questioned.[51].

This systematic review assesses the efficacy and safety of the conservative management with the halo vest for patients with upper cervical spine fractures.

Materials and methods

Literature search and data extraction

Two reviewers (UGL and SC) independently identified studies, in English, by a systematic search of CINAHL, Embase, Medline, HealthSTAR, and the Cochrane Central Registry of Controlled Trials, from inception of the database to 28 January 2010, using various combinations of the keywords terms "odontoid fractures", hangman's fractures", "axis fractures", "axis", "atlas", "Jefferson fractures", "C1 arch fractures", "C1 fractures", "C2 fractures", "cervical spine", "injuries", "fracture", "trauma", "neck injury", "surgery".

All articles relevant to the subject were retrieved, and their bibliographies hand searched for further references in this context. The two reviewers scanned the bibliographies of all retrieved studies and other relevant publications, including reviews and meta-analyses, for additional relevant articles. The personal collection of papers of the senior authors (NM and VD) was also included.

Two reviewers (UGL and SC) screened the titles and abstracts of the citations identified independently and in duplicate, and acquired the full text of any article that either judged potentially eligible. These reviewers independently applied eligibility criteria to the methods section of potentially eligible trials. Eligible studies had to report on conservative management in halo vest of patients with upper cervical spine injuries. Only articles published in peer-reviewed journals were included in this systematic review. We resolved disagreements by discussion.

Two reviewers (UGL and LD) extracted data from each eligible study independently and in duplicate. Data included personal information of the patients, methodology, details on interventions, and reported outcomes.

Among eligible studies, we found substantial diversity in the types of fracture for whom the halo vest was applied. An experienced cervical spine surgeon (VD) grouped the participants into different type of fractures: C1 arch fractures, Jefferson fractures, odontoid fractures, hangman's fractures, other axis fractures. Regarding clinical and radiographic outcomes, we presented data in the original units of measurement.

The studies were also assessed by two reviewers (UGL and LD) independently and in duplicate with use of the level of evidence rating introduced in the *American Volume of The Journal of Bone and Joint Surgery* in 2003.[84] We resolved disagreements by discussion.

We planned to use Review Manager (RevMan.Version 5 forWindows) to calculate the magnitude of treatment effect. However, because only case series were retrieved, no pooling of data was possible.

Results

Identification and selection of studies

A total of 43 citations were obtained from searches of the various electronic bibliographies. An additional 4 papers were obtained from the reference list of the studies included. The study selection process and reasons for exclusions are summarised in Fig. 1. The 47 studies that were included described a total of 1078 patients with C1–C2 fractures managed by halo fixator.

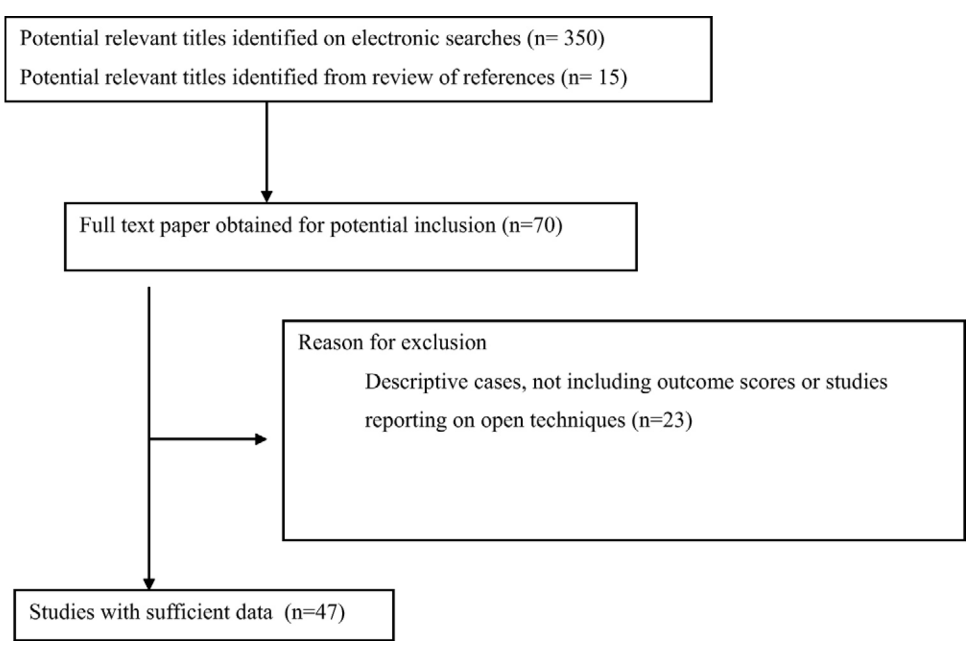

Fig. 1. Details of the investigations excluded and included in the study.

Table 1
C1 arch fracture (Jefferson) (n.r. = not reported).

Study	Level of study	Number of patients	Follow up	Displacement (mm)	Efficacy				
					Union	Non-union	Mal-union	Need for surgery after management with halo	Patient satisfaction
Apuzzo et al.[2]	IV	1	6–18 months	n.r.	0	1	0	1	n.r.
Cooper et al.[14]	IV	1	30 months	n.r.	1	0	0	0	n.r.
Daentzer and Florkemeier[16]	IV	4	6.6 months	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Ekong et al.[24]	IV	1 (+odontoid type II) 2 (+odontoid type III)	30 months	n.r.	1	2	0	2	n.r.
Glaser et al.[27]	IV	3 1 (+odontoid type II)	n.r.	n.r.	3	1	0	n.r.	n.r.
Lind et al.[46]	IV	7 1 (+odontoid type II)	2–7 years (mean 3 years)	n.r.	71	00	00	00	n.r.
Seljeskog[70]	IV	5	n.r.	n.r.	5	0	0	0	n.r.
Zimmerman et al.[87]	IV	2	8 months	n.r.	2	0	0	0	n.r.

Efficacy

Atlas injuries

Within fractures of the atlas, a distinction was made between ring and arch fractures.

Jefferson fracture

We identified Jefferson fractures (Table 1). The rate of fusion was reported only in 24 patients. Healing of the fracture was demonstrated in 20 of 24 patients (83%). The remaining 4 patients developed a non-union. Three of these patients required additional surgery for the management of non-union. Five patients had an odontoid fracture in addition to a ring fracture (type II, $n = 3$; type III, $n = 2$).

C1 arch fracture

Six patients had an isolated arch fracture. Healing was observed in 5 of these 6 patients.[9,41,49,78,83]

Axis fracture

Odontoid fracture

We identified 660 odontoid fractures, of which 511 were odontoid type II, 147 odontoid type III, and 2 odontoid type I fractures classified in accordance with Anderson and D'Alonzo.[1]

Odontoid type I fracture: Healing was observed in all type I fractures (100% rate of healing).[81,83]

Odontoid type II fracture: Outcome was reported for 407 of 511 patients (Table 2). Healing occurred in 290 of 407 patients (71%). There were 495 isolated fractures and 16 combined C1/C2 injuries.

Odontoid type III fracture: An odontoid type III fracture was diagnosed in 147 patients (Table 3). Outcome was reported for 141 of 147 patients. Healing occurred in 133 patients (94%). There were 135 isolated fractures and 6 combined C1/C2 injuries.

Hangman's fracture

A hangman's fracture was diagnosed in 310 patients. Outcome was reported for 297 patients. An isolated hangman's fracture was found in 306 patients, and 4 presented a combined C1/C2 injury (Table 4). Healing was reported in 276 of 297 patients (93%).

Non-classifiable C2 fractures

Non-classifiable fractures of C2 were reported in 88 patients (Table 5). Outcome was available for 80 patients: 77 of 80 patients (96%) healed.

Safety

Most studies reported the overall complications, without specifying the type of fracture or the patient in whom they occurred. Therefore, a formal report of the encountered complications in relation to the type of fracture was not possible. In Table 6, we report the overall complications of halo fixation. When possible, we reported also on the specific complications.

279 complications occurred in 1014 patients (27.5%). The most frequently encountered complications were pin site infections ($n = 78$), loss of reduction ($n = 59$), and pressure sores ($n = 34$).

Discussion

Several case series are now available to document outcomes and complications of conservative management in halo vest for the management of patients with upper cervical spine fractures. However, we were not able to retrieve randomised controlled trials.

The studies included in this review were not homogeneous: they differ in study design, type of patients, type of fractures, and type of outcomes assessed. Not all data from the selected papers were available, and most papers describe low quality (mainly grade IV level of evidence) case series.

The present investigation has also highlighted an increasing number of articles being published in the last few years, indicating growing interest and development in this field. Although the halo vest for the management of patients with upper cervical spine fractures has been introduced in the spinal surgery community approximately 50 years ago, there are no published randomised controlled trials. However, when reporting conservative management in the halo vest in patients with upper cervical spine injuries, case series make a useful contribution to a systematic review. The published case series represent the experience of centres in a range of different countries and health care systems. We did not use quality features of case series as inclusion or exclusion criteria for our review, as we wanted to include all case series likely to be regarded as relevant by clinicians, and because of the absence of standard validated criteria for quality assessment.

With case series, more than other types of studies, authors choose what and when to publish, and journals may be less likely to publish case series without "interesting" data, such as a large "treatment effect" or notable complications. Bias in this systematic review may be driven by some of the same factors that contribute to publication bias in case series, including, for example, the desire of clinicians to demonstrate their best results and "advertise" the success of an intervention to which they feel personally committed.[11]

Table 2
Odontoid type II fracture (n.r. = not reported).

Study	Level of study	Number of patients	Follow-up	Odontoid displacement (mm)	Efficacy				
					Union (*n*)	Non-union (*n*)	Mal-union (*n*)	Surgery after management with halo (*n*)	Patient satisfaction
Apuzzo et al.[2]	IV	1 (plus C1ring)	6 months	n.r.	0	1	0	1	n.r.
Bucholz and Cheung[9]	IV	17	12–24 months	n.r.	15	2	0	2	n.r.
Cantore et al.[10]	IV	2	n.r.	n.r.	2	0	0	0	n.r.
Clark and White[13]	II	37	n.r.	n.r.	25	7	3	8	n.r.
Della Torre et al.[17]	IV	25	6 months	n.r.	22	3	0	n.r.	n.r.
Daentzer and Florkemeier[16]	IV	6	6.6 months	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Dickman et al.[22]	IV	5 (plus C1arch)	41 months	The case with non-union had initial dislocation = 5 mm	4	1	0	1	n.r.
Ekong et al.[24]	IV	11 1 (plus C1ring)	30 months	n.r.	6 0	5 0	0 0	5 1	n.r.
Glaser et al.[27]	IV	17 1 (plus C1 ring)	n.r.	n.r.	16 0	0	1 (posterior translation 9mm) 1 (anterior translation 6mm)	0	n.r.
Greene et al.[28]	III	81	45 months	n.r.	n.r.	n.r.	n.r	n.r	n.r.
Hadley et al.[29]	III	24	n.r.	Range 0–15 mm	18	6	0	4	n.r.
Hanigan et al.[31]	III	1 (+Jefferson fracture)	51 months	5 mm posterior	1	0	0	0	n.r.
Hanssen and Cabanela[32]	III	10	34 months (mean)	No displacement in 4 cases, 10 mm posterior in 1 case 7 mm anterior in 1 case, 7 mm posterior in 1 case, and 3 mm posterior in 1 case	8 (delayed in 3 cases)	2	0	0	n.r.
Koivikko et al.[36]	III	69	12.2 months	2.2 mm (mean)	32	37	n.r.	n.r	n.r.
Komadina et al.[37]	IV	9	12 months	Range 2–7 mm	7	2	0	0	n.r.
Kuntz et al.[39]	III	8	13 months	Range 0–11 mm (mean 5.4 mm)	4	4	n.r.	4	n.r.
Lennarson et al.[40]	III	33	17,6 months	n.r.	22	11	n.r.	n.r	n.r.
Lesoin et al.[41]	IV	1 (plus C1ring) 1 (plus C2 corpus)	n.r.	n.r.	0 1	1 0	0 0	n.r.	n.r.
Lind et al.[45]	IV	9 1 (plus C1 ring) 1 (plus C2 arch)	2 years	Range 0–5 mm	8 1 1	1 0 0	0	n.r.	n.r.
Maiman and Larson[50]	III	1	n.r.	4 mm	0	1	0	1	n.r.
Muller et al.[54]	IV	21	47.2 months	n.r.	18	3	0	3	n.r.
Pepin et al.[57]	III	3	n.r.	n.r.	2	1	0	0	n.r
Polin et al.[59]	III	20	Minimum 10 weeks	n.r.	15	5	0	0	n.r.
Ryan and Taylor[66]	III	9	21 months	7.3 mm (range: 1–17 mm)	4	5	n.r.	n.r.	n.r.
Schiess et al.[68]	IV	4	7 months	3: no displacement 1: 2 mm	4	0	0	0	n.r.
Schweigel[69]	III	20	n.r.	n.r.	17	3	0	n.r.	n.r.
Seljeskog[70]	III	15	n.r.	n.r.	14	1	0	1	n.r.
Stoney et al.[73]	II	22	Min 3 months	n.r.	18	4	0	n.r.	n.r.
Thompson[75]	IV	1 (plus C1arch)	n.r.	n.r.	1	0	0	0	n.r.
Wang et al.[81]	IV	5	Min 3 months	n.r.	4	1	0	n.r.	n.r.
Weller et al.[82]	IV	2 (+C1 fracture)	21 months	n.r.	0	2	0	2	n.r.
Ziai and Hurlbert[86]	III	17	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.

Table 3
Type III odontoid fractures (n.r. = not reported).

Study	Level of study	Number of patients	Follow-up	Odontoid displacement (mm)	Efficacy				
					Union (*n*)	Non-union (*n*)	Mal-union (*n*)	Surgery after management with halo (*n*)	Patient satisfaction
Bucholz and Cheung[9]	IV	9	12–24 months	n.r.	9	0	0	0	n.r.
Cantore et al.[10]	IV	4	n.r.	n.r.	4	0	0	0	n.r.
Clark and White[13]	II	16	n.r.	40% none 60% 4.5 mm (mean)	13	1	2	2	n.r.
Daentzer and Florkemeier[16]	IV	6	6.6 months	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Dickman et al.[22]	IV	4 (plus C1 arch fracture)	41 months	n.r.	4	0	0	0	n.r.
Ekong et al.[24]	IV	4 1 (plus C1 ring fracture)	30 months	n.r.	4 0	0	0	0 1	n.r.
Glaser et al.[27]	IV	12	n.r.	n.r.	12	0	0	0	n.r.
Hadley et al.[29]	III	16	n.r.	n.r.	16	0	0	0	n.r.
Hanssen and Cabanela[32]	III	14	34 months (mean)	Range 0–15 mm	14 (delayed in 1 case)	0	0	0	n.r.
Lind et al.[45]	IV	6	2 years	Range 0–4 mm	6	0	0	0	n.r.
Komadina et al.[37]	IV	5	12 months	Range 3–6	5	0	0	0	n.r.
Muller et al.[54]	IV	7	47.2 months	n.r.	7	0	0	0	n.r.
Pepin et al.[57]	III	3	n.r.	n.r.	2	1	0	n.r.	n.r.
Sonntag and Hadley[71]	IV	26	n.r.	n.r.	25	n.r.	n.r.	n.r.	n.r.
Wang et al.[81]	IV	10	Min 3 months	n.r.	10	0	0	0	n.r.
Weller et al.[82]	IV	2 (1 + C1 fracture)	21 months	n.r.	2	0	0	0	n.r.

Table 4
Hangman's fracture (n.r. = not reported).

Study	Level of study	Number of patients	Follow-up	Odontoid displacement (mm)	Efficacy				
					Union (*n*)	Non-union (*n*)	Mal-union (*n*)	Surgery after management with halo (*n*)	Patient satisfaction
Bucholz and Cheung[9]	IV	12	12–24 months	n.r.	12	0	0	0	n.r.
Bransford et al.[8]	IV	61	n.r.	n.r.	55	6	n.r.	n.r.	n.r.
Chan et al.[12]	IV	4	10.8 months	n.r.	4	0	0	0	n.r.
Cooper et al.[14]	IV	7	30 months	n.r.	7	0	0	0	n.r.
Coric et al.[15]	IV	3	14.2 months	>6 mm	3	0	0	0	n.r.
Daentzer and Florkemeier[16]	IV	6	6.6 months	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Dickman et al.[22]	IV	3 (plus C1 arch fracture)	41 months	Range 0–7 mm	3	0	0	0	n.r.
Glaser et al.[27]	IV	23	n.r.	n.r.	23	0	0	0	n.r.
Greene et al.[28]	IV	56	3 years, 9 months	n.r.	56	0	0	0	n.r.
Hadley et al.[29]	III	16	n.r.	n.r.	16	0	0	0	n.r.
Hughes et al.[34]	IV	2	–	–	2	0	0	0	–
Levine and Edwards[43]	IV	34	36 months	Range 0–5 mm	30	1	0	1	n.r.
Lind et al.[45]	IV	1 (plus odontoid type II)	2 years	n.r.	1	0	0	0	n.r.
Marton et al.[52]	IV	9	3 months–6 years	n.r.	9	0	0	0	n.r.
Muller et al.[53]	IV	8	44.2 months	n.r.	4 (1 patient developed an intracranial abscess after a pin-track infection)	4	0	0	n.r.
Prolo et al.[60]	IV	1	6 months	n.r.	1	0	0	0	n.r.
Roda et al.[65]	IV	1	16 months	n.r.	1	0	0	0	n.r.
Rockswold et al.[64]	IV	15	6 months	n.r.	14	1	0	n.r.	n.r.
Seljeskog[70]	III	5	n.r.	n.r.	5	0	0	0	n.r.
Starr and Eismont[72]	IV	5	6 months	4: no displacement 1: 10 mm	5	0	0	0	n.r.
Taller et al.[74]	IV	7	24 months	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Vaccaro et al.[77]	III	31	17 months	Range 3–10 mm	25	0	0	6 (re-application of traction	n.r.

Table 5
Non-classifiable C2 fractures (n.r. = not reported).

Study	Level of study	Number of patients	Follow-up	Displacement (mm)	Efficacy Union (n)	Non-union (n)	Mal-union (n)	Surgery after management with halo (n)	Patient satisfaction
Bucholz and Cheung[9]	IV	5	12–24 months	n.r.	5	0	0	0	n.r.
Bransford et al.[8]	IV	3	n.r.	n.r.	3	0	0	0	n.r.
Cooper et al.[14]	IV	5	30 months	n.r.	5	0	0	0	n.r.
Daentzer and Florkemeier[16]	IV	8 (2 comminuted, 6 body)	6.6 months	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
German et al.[26]	IV	1 (C2 body)	7.1 months	n.r.	1	0	0	0	n.r.
Hadley et al.[29]	IV	13	n.r.	n.r.	12	1	0	n.r.	n.r.
Hadley et al.[30]	IV	36	–	–	35	–	–	–	–
Hughes et al.[34]	IV	2	–	–	2	0	0	0	n.r.
Iizuka et al.[35]	IV	1 (posterior part of the body and unilateral spinous process of the axis)	8 months	n.r.	1	0	0	0	n.r.
Lesoin et al.[41]	IV	1	n.r.	n.r.	1	0	0	0	n.r.
Lyddon[48]	IV	5	–	–	4	–	–	–	–
Thompson[75]	IV	1	n.r.	n.r.	1	0	0	0	n.r.
Verduyn[78,79]	IV	1	n.r.	n.r.	1	0	0	0	n.r.
Dickman et al.[22]	IV	6	41 months	Range 0–7 mm	6	0	0	0	n.r.

Randomised controlled trials are important because they can provide reliable evidence of treatment effects. In contrast, case series rank lower in the hierarchy of evidence, because they are inherently susceptible to bias, and, in the absence of a control group, causal relationships between interventions and outcomes cannot be definitely established. Case series may also be useful sources of evidence on safety, because they often have relatively long follow-up and large sample size, and their inclusion criteria may be less strict than those of randomised controlled trials.[11]

Fractures of the atlas

Most fractures of the atlas can be managed with immobilisation in a halo vest. Patients with non-union or persisting pain should undergo surgery. Complications of fractures of the atlas include post-traumatic osteoarthritis as a consequence of a displaced lateral mass fracture. C1–C2 fusion can be an option for patients with atlantoaxial instability or painful atlantoaxial arthritis. The management of non-union and severe mal-union of unstable atlas fracture resulting in painful torticollis is an occiput to C2 fusion.[3]

Odontoid fractures

Odontoid fractures are classically divided suing Anderson and D'Alonzo's system[1] according to the anatomic level of the fracture. Type I fractures occur at the tip of the odontoid process, are generally stable and can be managed conservatively. Type II fractures occur at the junction between the base of the odontoid process and the body of the axis. These are unstable and often require surgery.[60] Patients with non-displaced or minimally displaced fractures that are easily reduced can be treated with the halo fixator. Marked morbidity and even mortality are associated with odontoid fractures. The most common causes of complications are missed injuries and non-union.[3] Non-union has been reported in up to 10% of patients after odontoid screw fixation, and in around 4% or less of patients undergoing C1–C2 fusions using either wire constructs or transarticular screw fixation. Primary neurological injury is not common in patients with odontoid fractures, but it can be severe, ranging from cranial nerve injuries to quadriplegia.

Bipedicular fractures of the axis with spondylolisthesis ("hangman's fracture")

The classification system for this injury was first described by Effendi et al.[23] and later modified by Levine and Edwards.[44] The classification is based on translation and angulation between C2 and C3. Type I injuries are bilateral pars fractures with translation less then 3 mm and without angulation. CT scanning may show a fracture line into the vertebral body, extending cranially to the transverse foramen, potentially injuring the vertebral artery. These lesions are better managed with a halo vest. Type IA or atypical traumatic spondylolisthesis of the axis is similar to standard type I fractures, with associated angulations or translations.[43]. In type II fractures, the C2–C3 disc and posterior longitudinal ligament are injured, resulting in translation of more then 3 mm and marked angulation. Fractures with an oblique fracture line and minimal translation (but significant angulation) are classified as type IIA. Closed reduction and external immobilisation with halo is often able to achieve healing. Type III injuries are a combination of pars fracture with dislocation of the C2–C3 facet joints. These injuries are very unstable, and can be associated with neurological deficits. They require open reduction and internal fixation via a posterior approach or, rarely, anterior C2–C3 fixation. One of the most important complications of the management of patients with

Table 6
Overall complications of halo fixation (n.r. = not reported).

Study	Number of patients	Overall complications	Pin complications	Intraparenchymal, epidural, or subdural abscesses related to pin penetration	Pressure sores to the ears (from inadequate positioning of the halo) and to the trunk	Difficulty swallowing	Loss of reduction or progression of the spinal deformity	Cranial nerve palsies from excessive traction	Other
Apuzzo et al.[2]	6	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Bucholz and Cheung[9]	109	1	1 (severe pin site infection)	–	–	–	–	–	n.r.
Chan et al.[12]	188	30	11 (pin site infection) 4 (pin slippage)	2	11	–	–	–	2 (radicular pain caused by fracture dislocation)
Clark and White[13]	53	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Cooper et al.[14]	26	7	3 (pin site infections)	n.r.	3 (skin breakdown)	n.r.	n.r.	n.r.	1 (loss of reduction after a fall)
Coric et al.[15]	6	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Daentzer and Florkemeier[16]	29	14	9 (pin infection)	2 (liquorrhea)	1 (decubitus ulcer)	–	–	–	2 (halo ring dislocations)
Dickman et al.[22]	18	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Ekong et al.[24]	22	10	5 (pin site infection) 3 (loosening)	n.r.	1	n.r.	2 (redislocation while in halo vest)	n.r.	n.r.
Gelalis et al.[25]	1	1	–	1 (brain abscess in the right parietal lobe + generalized seizures)	–	–	–	–	–
Glaser et al.[27]	203	43	14 (pin site infections)	n.r.	4 (skin breakdown over the scapula)	n.r.	23	n.r.	1 (severe rash beneath the halo vest) 1 (liner infested by maggots)
Greene et al.[28]	254	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Hadley et al.[29]	69	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Hanssen and Cabanela[32]	24	6	3 (pin site infection)	n.r.	n.r.	n.r.	n.r.	n.r.	3 (cervical stiffness after halo removal)
Koivikko et al.[36]	69	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Lennarson et al.[40]	33	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Lesoin et al.[41]	5	0	0	0	0	0	0	0	0
Levine and Edwards[43]	34	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Lind et al.[45]	14	7	5 (pain from pin sites)	–	2	–	–	–	–
Lind et al.[46]	83	91	50 (pin loosening – pain) 18 (pin site infection)	1	3	–	8 (redislocation)	–	11 (halo ring dislocation)
Marton et al.[52]	21	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Muller et al.[54]	29	8	3 (pin site infection)	–	–	–	5 (loss of reduction	–	–
Muller et al.[53]	16	2	1 (pin site infection)	1 (brain abscess)	–	–	–	–	–
Pepin et al.[57]	6	2	1 (minor pin inflammation) 1 (scalp cellulitis)	–	–	–	–	–	–
Polin et al.[59]	38	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Prolo et al.[60]	30	6	3 (pin slippage) 2 (pin site cellulitis)	–	2	–	–	–	–
Rockswold et al.[64]	99	41	12 (pin site infection) 5 (pin loosening)	1	7 (skin breakedown)	–	14	–	–
Roda et al.[65]	1	0	–	–	–	–	–	–	–
Ryan and Taylor[66]	10	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Schiess et al.[68]	4	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Schweigel[69]	65	3	2 (pin site infection) 1 (pin slippage)	–	–	–	–	–	–

Table 6 (*Continued*)

Study	Number of patients	Overall complications	Pin complications	Intraparenchymal, epidural, or subdural abscesses related to pin penetration	Pressure sores to the ears (from inadequate positioning of the halo) and to the trunk	Difficulty swallowing	Loss of reduction or progression of the spinal deformity	Cranial nerve palsies from excessive traction	Other
Seljeskog[70]	91	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Stoney et al.[73]	22	1	1 (pin site infection)	–	–	–	–	–	–
Taller et al.[74]	7	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Thompson[75]	11	6	3 (pin loosening) 1 (pin site infection) 2 (pin slippage)	–	–	–	–	–	–
Vaccaro et al.[77]	31	n.r.	n.r.	n.r.	n.r.	n.r.	6	n.r.	n.r.
Wang et al.[81]	16	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Ziai and Hurlbert[86]	29	n.r.	n.r.	n.r.	n.r.	n.r.	1	n.r.	n.r.
Zimmerman et al.[87]	2	0	–	–	–	–	–	–	–

these fractures is non-union, which can be managed by internal fixation. In patients managed with halo fixation, successful fracture healing of traumatic spondylolisthesis of C2 occurs in around 95%, even in the presence of displacement of the pars interarticularis. The formation of a painless long pedicle may produce successful healing. Today, surgical indications for a C1–C3 stabilisation are very limited, as surgery is not able to provide firm stability, and may evolve in non-union.

Conclusions

In a typical systematic review focusing on the management of upper cervical spine facture with halo fixator, case series contributed substantially to the available evidence base, and their results complemented the absent evidence available from randomised controlled trials. As case series only are included in the present review, potential biases must be taken into account, including: biases inherent in this study design, over-representation of specialist centres with likely better results than routine clinical practice, publication bias, possible multiple publication of results from the same patients in several series.

Clearly, studies of higher levels of evidence, for instance large randomised trials, should be conducted, even though the available evidences suggest that management of upper cervical spine facture with halo fixation is safe and effective. Future trials should use validated functional and clinical outcomes, adequate methodology, and be sufficiently powered.

Conflict of interest

None declared.

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