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CASE REPORT

Reduction of cervicothoracic spondyloptosis in an ambulatory patient: when traction fails

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INTRODUCTION: Cervical spondyloptosis is a rare complication of high-energy trauma which often results in significant patient morbidity and mortality. The authors present a case of spondyloptosis of C7 over T1 with minimal radicular symptoms and otherwise complete spinal cord sparing. This case highlights the surgical challenges faced with cervical spondyloptosis and the techniques used when traction fails.

CASE PRESENTATION: A 21-year-old man with no significant past medical history presented after a high-speed motor vehicle collision with cervicothoracic pain and mild hand grip weakness in addition to numbness of the fourth and fifth digits bilaterally (American Spinal Injury Association Impairment Scale Grade D). Computed tomography imaging revealed spondyloptosis of C7 over T1, a fracture of the C2 vertebral body, and a burst fracture of C3. To relieve spinal cord compression and restore sagittal realignment, closed reduction was attempted, however this resulted in perching of the bilateral C7–T1 facets, leading to an open posterior approach. The patient underwent C7 laminectomy, bilateral C7–T1 facetectomy, and manual reduction using a Mayfield skull clamp followed by C2–T3 fixation. Postoperatively, pain was diminished, sensory disturbances were resolved and the patient was otherwise neurologically stable.

DISCUSSION: There is a role for closed traction for reduction of cervical spondyloptosis, however, its role is debated especially when the patient is predominately neurologically intact. In this setting, the spine surgeon may be required to change traction and operative strategies in order to minimize potentially harmful manipulation while restoring sagittal realignment and stabilizing the spine for preservation of neurological function.

Spinal Cord Series and Cases (2023)9:46 ; https://doi.org/10.1038/s41394-023-00604-3

INTRODUCTION

Spondyloptosis, also known as grade V spondylolisthesis, is defined as complete anterior dislocation of one vertebral body in relation to another and often results from motor vehicle collisions and falls [1]. Cervical spondyloptosis is a rare occurrence with high patient morbidity due to spinal cord compression and/or transection with a mortality rate of 13.5% [1]. This injury pattern may damage the arterial system with reports of devastating stroke due to carotid [2] and vertebrobasilar [3] injury. However, cases of partial or complete neural sparing have been described [4–17]. In this report, we present the case of a patient who was involved in a high-speed motor vehicle accident resulting in spondyloptosis of C7 over T1, a fracture of the C2 vertebral body, and a burst fracture of C3, with only minimal radicular symptoms affecting the intrinsic hand muscles. The surgical decision-making is detailed and discussed in relation to other approaches described in literature with a particular focus on the algorithm used for decision-making when traction fails to reduce the spondyloptosis.

CASE PRESENTATION

A 21-year-old male with no significant past medical history was involved in a high-speed motor vehicle collision, in which he was the driver, and struck on the driver's side with immediate loss of consciousness. Upon extraction from the vehicle, he was taken to an outside institution where imaging showed fracture of the C2 vertebral body, a C3 burst fracture, bilateral laminar fractures of C7, spondyloptosis of C7–T1 (Fig. 1), and a fracture of the left radius. Computed tomography (CT) angiogram revealed vertebral artery injury at the level of the right C6 transverse foramen, with reconstitution at the level of C1. The left vertebral artery was dominant. The patient was admitted to the outside hospital and transferred to the trauma surgery floor service at our institution. Neurosurgery was consulted upon arrival of the patient. The patient endorsed 7/10 cervicothoracic pain radiating down his left shoulder into his left hand, numbness in the left fourth and fifth digits, and moderate pain in the bilateral shoulders and left wrist at the site of the radial fracture. Neurological exam revealed 4/5 hand intrinsic strength bilaterally with decreased sensation in the C8 dermatome. With the exception of bilateral intrinsic hand weakness and dysesthesia in the C8 dermatome, the patient had intact strength and sensation in his upper and lower extremities without hyperreflexia. The patient was grade D on the American Spinal Injury Association Impairment Scale (AIS).

Operative procedure

The patient was taken emergently to the operating room, 18 h post-trauma, where an attempt was made to reduce the spondyloptosis

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Received: 4 November 2022 Revised: 22 August 2023 Accepted: 24 August 2023
Published online: 05 September 2023

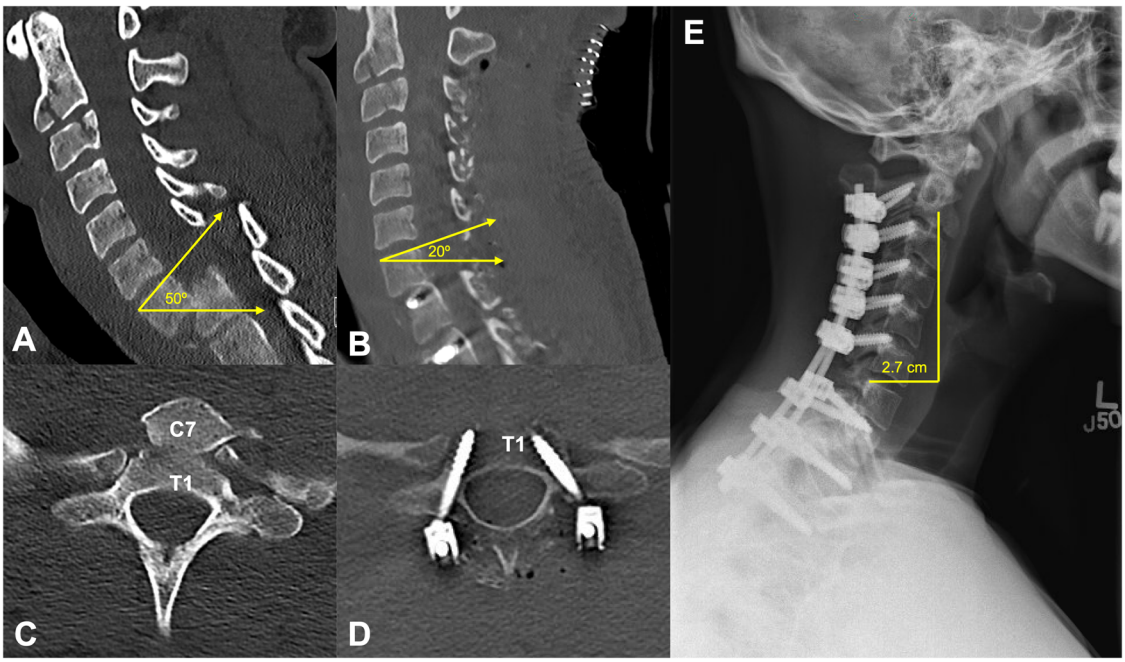

Fig. 1 Traumatic spondyloptosis of C7 over T1. Caption: Preoperative sagittal (**A**) and axial (**C**) CT demonstrates spondyloptosis of C7 over T1 in addition to C2 vertebral body fracture and C3 burst fracture. C7 slope, defined as the angle between a horizontal reference line and a line parallel to the upper endplate of C7, is indicated in yellow both preoperatively (**A**) and postoperatively (**B**), demonstrating reduction from 50° to 20° respectively. Postoperative sagittal (**B**) CT demonstrates reduction of spondyloptosis after C7/T1 facetectomy with manual reduction in addition to C2–T3 fixation and axial (**D**) demonstrates T1 pedicle screw placement. Postoperative C2–7 SVA, the distance from the posterior superior C7 vertebral body to a plumbline from the centroid of C2, was 2.7 cm (**E**).

of C7 on T1 using craniocervical traction. The patient was intubated using in-line cervical stabilization and placed under general anesthesia. An arterial line was placed and the mean arterial pressure (MAP) was maintained greater than 80 mmHg. Neuromonitoring was used throughout the operative course including motor evoked potentials (MEPs) and somatosensory evoked potentials (SSEPs). The patient was positioned supine in Gardner-Wells tongs. Weight was serially added beginning with 10 pounds. After each additional 10 pound increment, neuromonitoring of MEPs and SSEPs was checked and fluoroscopy was utilized to determine whether reduction was achieved. A total of 75 pounds of weight was used in traction; however, the inferior articular facet of C7 remained perched on the superior articular facet of T1 (Fig. 2). In addition to traction weight, manual flexion and distraction was attempted however was unsuccessful. There was firing of the bilateral T1 nerve roots however no changes in MEPs or SSEPs were observed throughout the traction. At this point, there was considerable distraction across multiple disc spaces and the decision was made to convert to an open posterior approach for reduction. The cervical traction was removed, and a Mayfield skull clamp was placed with the patient positioned prone. A midline cervicothoracic incision was fashioned, and the spinous processes, lamina, and facet joints from C2 to T3, as well as the transverse processes of T1–T3 were exposed. The lamina of C7 was floating freely above the spinal cord and was easily removed. The dura was noted to be without tension. A dural laceration on the right side of the spinal cord with CSF leak was encountered and repaired with 4–0 nurolon suture and a fibrin sealant patch. Manual flexion and distraction using the Mayfield clamp was attempted however reduction was not achieved. Bilateral facetectomy of C7–T1 was then completed. Manual flexion and distraction was then attempted again and successfully reduced the spondyloptosis. Fixation from C2 to T3 was performed using pars screws at C2, lateral mass screws from C3 to C6 and pedicle screws from T1 to T3. Rods were placed from C2 to T3, decortication was completed and local autograft and demineralized bone fibers were placed for graft extension.

Postoperative course

The patient tolerated the procedure well and was admitted to the neurological intensive care unit postoperatively. A MiamiJ collar was maintained at all times and MAP was maintained above 85 mmHg for 48 h after surgery. The patient did not have any signs of spinal cord injury, only nerve root injury (C8 nerve root), the patient was auto-mapping >85 on own mmHg, and therefore the MAP goal was relaxed. The patient transferred out of the intensive care unit on postoperative day three. Steroids were not given to the patient due to the inconclusive role they plan in treatment of spinal cord injury. Additionally, it did not appear that a spinal cord injury had occurred. Immediate postoperative CT imaging (Fig. 1 A–D) revealed adequate reduction of spondyloptosis with a reduction in C7 slope from 50° to 20°. C7 slope, defined as the angle between a horizontal reference line and a line parallel to the upper endplate of C7, is one of the most reliable parameters to analyze the cervical sagittal balance with a value of >40° considered abnormal [18]. Postoperative C2–7 sagittal vertical alignment (SVA), the distance from the posterior superior C7 vertebral body to a plumbline from the centroid of C2, was 2.7 cm (Fig. 1E) with normal parameters defined as <4 cm [18]. Scoliosis radiographs on postoperative day four (Fig. 3) demonstrated excellent sagittal alignment and placement of instrumentation. The patient remained neurologically stable throughout his hospital stay and was discharged home on postoperative day five with instructions to continue to wear the cervical collar. At the six week follow-up appointment, the patient had recovered bilateral upper extremity sensation and imaging revealed stable alignment and instrumentation (Fig. 4). The intrinsic hand muscles were 4 + /5 strength bilaterally, otherwise he had full strength and was ambulating without issue. He reported mild neck pain and was taking acetaminophen as needed. He also reported tingling down his left arm, for which gabapentin was prescribed. The patient was instructed to continue to wear the cervical collar, except when seated or sleeping. At his most recent follow-up appointment six months

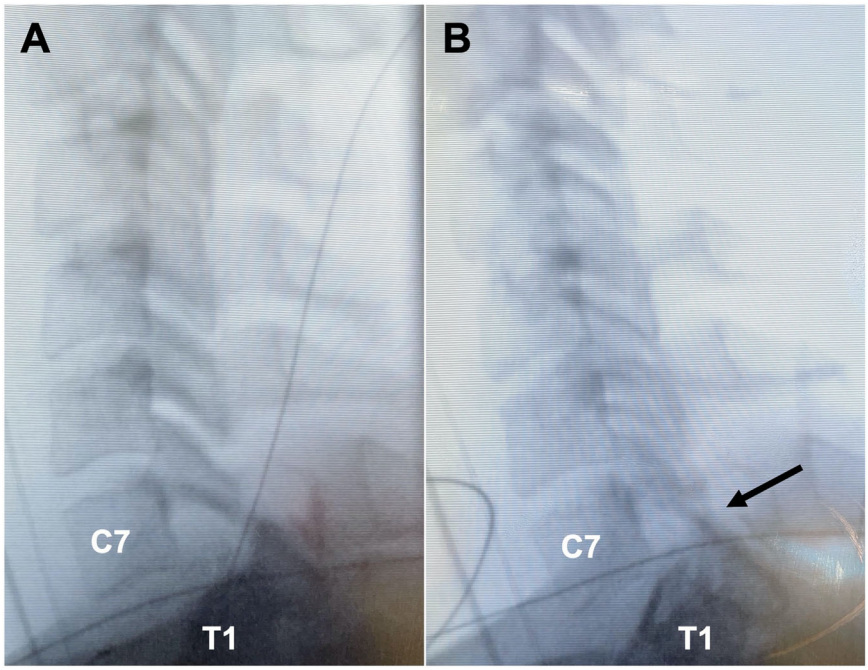

Fig. 2 Intraoperative fluoroscopy images. Caption: Intraoperative fluoroscopy images during closed reduction attempt demonstrate jumped inferior articulating process of C7 over the superior articulating process at T1 with 60 lbs of cervical traction (**A**). **B** shows perched facet (indicated by black arrow) with 75 lbs of traction.

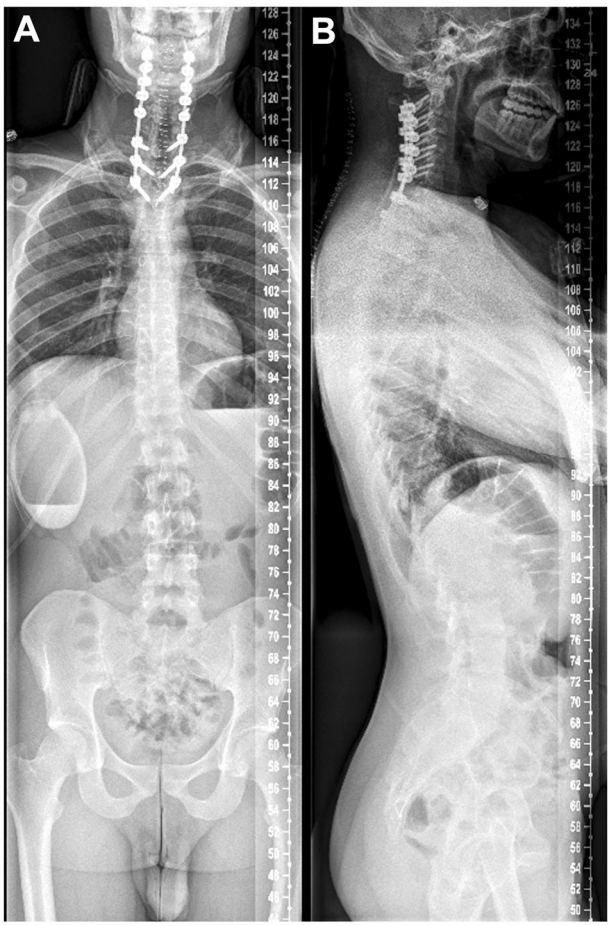

Fig. 3 Postoperative scoliosis radiographs. Caption: Standing anteroposterior (**A**) and lateral (**B**) scoliosis radiographs on postoperative day 4.

postoperatively, the patient reported resolution of neck pain and reduced left arm tingling, with motor strength of 5/5 throughout the bilateral upper and lower extremities. He is able to return to work without restriction.

DISCUSSION

Closed craniocervical traction, when used in the treatment of traumatic spinal cord injury, is performed with the goal of decompressing the spinal cord rapidly and restoring anatomic alignment in preparation for stabilization. This can typically be conducted with minimal consequence [4]. While up to 140 lbs of traction have been shown to be safe and effective in closed reduction of cervical spine dislocation [19], weights much lower than 140 lbs may result in significant disc space distraction such that the benefit of increasing traction may not outweigh risk of over-manipulation of the spinal column with potential damage to the spinal cord, nerve roots, and/or vertebrobasilar vasculature [6]. In cases of failed or incomplete closed cervical reduction of spondyloptosis, for example in our case when the C7 facet was perched on T1 with considerable disc space distraction, conversion to an open approach is advised. If manual distraction additionally fails, reduction may be achieved by performing a posterior surgical approach with manual reduction. Magnetic resonance imaging (MRI) to evaluate for disc herniation prior to closed reduction and/or open posterior cervical surgery is controversial and is advised by some spine surgeons [20]. Preoperative MRI was not performed in this case for the following reasons: (1) the delay in intervention due to obtaining the MRI, (2) the risk of further injury during transportation for MRI with a highly unstable spine, (3) the low likelihood that the information obtained would change operative planning and (4) immediate closed reduction does not appear to be associated with neurological deterioration when performed correctly [21–24]. In regard to approach and surgical levels in this case, an anterior approach was initially favored with craniocervical traction and staged posterior fixation. This would allow for anterior and posterior column support. Unfortunately, reduction could not be

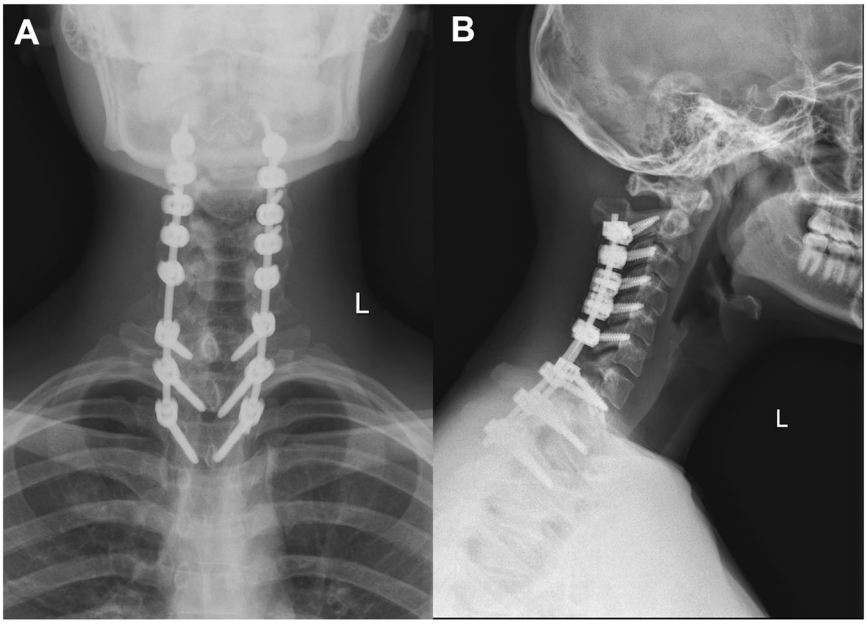

Fig. 4 Postoperative cervical radiographs. Caption: Anteroposterior (**A**) and lateral (**B**) cervical radiographs six weeks postoperatively.

achieved with craniocervical traction and therefore the surgery was converted to a posterior approach. Since there were fractures of the C2 vertebral body, C3 burst fracture and the spondyloptosis at C7/T1, it was decided to include C2 in the fusion and two levels below the spondyloptosis to provide a robust fusion and potentially avoid an anterior surgery.

The patient suffered a vertebral artery injury noted on preoperative CT angiogram. The right vertebral artery was injured at the level of the C6 transverse foramen, with reconstitution at the level of C1. The left vertebral artery was dominant and without injury, the carotid arteries were patent and there was no injury to intracranial vasculature. Vertebrobasilar injury is a known coexistent injury in cervical spondyloptosis [2, 3]. There have been reports of closed cervical traction pursued over the course of several days resulting in ischemic stroke in patients with vertebral artery or internal carotid artery dissection [2]. In this case, the patient was taken immediately to the operating room to reverse the injury and there was no concern for ischemic injury and therefore the vertebral artery injury was managed conservatively. Treatment with aspirin may have been a reasonable option however heparin in this traumatic setting requiring surgery was deemed too risky.

Review of the literature reveals 69 patients reported with traumatic cervicothoracic spondyloptosis in 48 studies (Table 1) [1–15, 17, 25–56]. The majority of patients were male (72.5%) and the most common level of spondyloptosis was C7/T1 (39.1%) followed by C6/7 (29.0%). The most common presenting AIS grade was E (34.8%) followed by grade A (26.1%). In a review of the management of 66 patients with cervical spondyloptosis from multiple countries, 51 cases utilized closed reduction via transcranial traction, of which 17 cases (33%) were reduced completely; 13 cases (25%) were reduced partially; and 19 cases were not reduced (37%) [26]. The majority of cervical spondyloptosis cases resulted in significant neurological impairment prior to traction. Traction was applied for a wide range of time, from 6 h to 20 days, with an average of 6 days needed for cases in which total reduction was achieved [26]. Urgent decompression was prioritized in our report in order to optimize outcome. While the presence of neurological injury, level of cervical spinal cord injury, and age were not shown to be predictors of successful closed reduction [1], cases of neural sparing add a degree of difficulty to deciding at what point it is advisable to convert from a closed to an open approach to preserve neurological function. Nguyen et al. reported another case of C7–T1 spondyloptosis with neural sparing for which cervical traction applied with tongs failed to reduce subluxation, therefore a halo was placed and the following day the patient underwent posterior decompression and reduction of the dislocation with bilateral complete facetectomies at C7 and fusion from C4 to T2, and an anterior C7–T1 fusion was performed through a midline sternotomy [10]. In two cases of C7–T1 spondyloptosis described by Kim et al., early surgical intervention was prioritized, thus closed cervical traction was not attempted. Instead, a posterior open approach and pedicle screws were used to perform a distraction maneuver for reduction of spondyloptosis, and stabilization was achieved with short segment fusion [35].

Lastly, there are three important factors in the case presented that may have contributed to the patient's preserved spinal cord function despite spondyloptosis: (1) a larger than average diameter of the spinal canal, likely congenital in nature, (2) fracture of the posterior elements of C7 and (3) CSF leak. All of these factors may have contributed to a lower intraspinal pressure which conferred little to no injury to the spinal cord. A congenitally narrower cervical spinal canal is an established risk factor for the development of cervical myelopathy [57] and has been shown to be a risk factor for worse outcome in acute spinal cord injury [58]. As also shown by Nguyen et al. [10], fracture of the posterior elements leads to increased spinal canal diameter, which may be protective against spinal cord injury. Finally, CSF release in cervical spine stenosis has been shown to immediately improve intraoperative neuromonitoring signals [59] and CSF diversion in pigs after acute spinal cord injury has demonstrated improved spinal cord perfusion [60]. Reduction in CSF theoretically leads to decreased intraspinal pressure and may ultimately increase spinal cord perfusion in humans as discussed in a recent systematic review [61].

CONCLUSIONS

The case presented here and a review of prior reports of successful reduction of cervicothoracic spondyloptosis in patients with complete or near-complete neural sparing suggests closed cervical traction may be attempted with the use of neuromonitoring and intraoperative fluoroscopy after each successive addition of weight. A preoperative CT angiogram is warranted to determine

Table 1. Summary of studies reporting traumatic cervicothoracic spondyloptosis.

Authors, Year	Age (years)	Gender	Level	Presenting AIS Grade
Alharbi et al. [25]	56	M	C7/T1	E
Ng et al. [1]	22	M	C7/T1	A
Khelifa et al. [26]	19	M	C5/6	A
	30	M	C5/6	A
Lachance et al. [27]	88	F	C1/2	E
	68	M	C1/2	D
Sakti et al. [28]	16	M	C5/6	B
Kwun et al. [2]	25	M	C5/6	A
Rokaya et al. [29]	22	M	C4/5	A
Fattahi et al. [30]	34	M	C2/3	E
Okoro et al. [50]	18	F	C5/6	A
Haimovich et al. [12]	24	M	C6/7	E
Kumar et al. [11]	40	M	C7/T1	E
Payne et al. [13]	63	M	C7/T1	E
Singh et al. [31]	32	M	C2/3	D
Tsujimoto et al. [32]	69	M	C7/T1	B
	73	M	C7/T1	D
Ahuja et al. [33]	25	M	C1/2	D
Fattahi et al. [34]	18	F	C5/6	A
Kumar et al. [51]	30	F	C6/7	C
Kim et al. [35]	60	M	C7/T1	A
	39	M	C7/T1	D
Mehra et al. [52]	45	F	C6/7	E
Kumar et al. [36]	11	M	C1/2	D
Saleh et al. [37]	2 weeks	M	C4/5	D
Wong et al. [38]	49	F	C5/6	A
Nguyen et al. [39]	63	F	C7/T1	E
Modi et al. [40]	35	M	C6/7	A
	8	M	C7/T1	A
	70	M	C7/T1	A
Nguyen et al. [10]	60	M	C7/T1	E
Ahn et al. [53]	32	M	C7/T1	E
	42	F	C7/T1	E
Munakomi et al. [9]	56	F	C7/T1	E
Oppenlander et al. [41]	73	M	C6/7	A
Padwal et al. [42]	50	F	C6/7	C
	40	M	C7/T1	C
	40	M	C7/T1	D
	45	M	C6/7	E
	64	M	C7/T1	D
	24	M	C6/7	D
	45	M	C6/7	C
	55	M	C6/7	E
Choi et al. [43]	51	M	C6/7	C
Sribnick et al. [44]	20	F	C6/7	A
	37	M	C7/T1	C
	28	F	C6/7	B
Manjila et al. [45]	39	M	C2/3	A
Ramieri et al. [8]	55	F	C6/7	E
Gasco et al. [15]	45	M	C4/5	E

Table 1. continued

Authors, Year	Age (years)	Gender	Level	Presenting AIS Grade
Dahdaleh et al. [14]	61	M	C7/T1	E
	48	F	C6/7	D
	51	M	C7/T1	E
	48	M	C6/7	A
	42	M	C7/T1	C
Keskin et al. [46]	51	F	C6/7	D
Mamindla et al. [7]	46	F	C5/6	D
Tumialan et al. [3]	43	M	C4/5	B
Acikbas et al. [5]	42	M	C7/T1	E
Chadha et al. [47]	35	F	C6/7	A
Srivastava et al. [6]	35	M	C3/4	E
Tumialan et al. [4]	48	M	C7/T1	E
Lee et al. [54]	65	M	C7/T1	D
	72	M	C7/T1	E
Menku et al. [17]	35	M	C6/7	E
Shah et al. [48]	40	M	C7/T1	D
Ozdogan et al. [55]	67	M	C3/4	E
Feigenbaum et al. [49]	15	F	C5/6	A
Bhojraj et al. [56]	8	F	C6/7	C

stability of the vertebrobasilar and carotid vasculature prior to intervention. In the case of failed closed reduction, conversion to an open approach to free the facet joint and facilitate manual reduction is advised. Finally, although successful patient outcomes after cervical spondyloptosis management have been reported, this injury pattern conveys high morbidity and mortality.

DATA AVAILABILITY

All data generated and analyzed during this study are included in the published article.

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AUTHOR CONTRIBUTIONS

Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: BFJ, JAT. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: TFW. Study supervision: TFW.

COMPETING INTERESTS

The authors declare no competing interests. Dr. Witham reported being an Advisory Board Member (unpaid) and stockholder from Augmedics and receiving grants from Gordon and Marilyn Macklin Foundation outside the submitted work.

ETHICAL APPROVAL

Ethical approval was not required by the Johns Hopkins Medicine Institutional Review Board, as the presented work is a medical/educational activity that does not meet the Department of Health and Human Services definition of "research", which is: "a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge."

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41394-023-00604-3.

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