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Iatrogenic spinal cord injury with tetraplegia after an elective non-spine surgery with underlying undiagnosed cervical spondylotic myelopathy: Literature review and case report

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ABSTRACT

Cervical spondylotic myelopathy (CSM) can predispose to acute spinal cord injury and post-operative quadriparesis during non-spine procedures, although few accounts of this phenomenon exist within the literature. To the best of our knowledge, there are only 18 cases reported in the literature including ours with spinal cord injury following elective non-spine surgery with undiagnosed CSM. Due to multifactorial pathophysiology, the maintenance of cervical cord neutrality is not sufficient to ensure that these patients will not sustain cord injury intraoperatively as this solely addresses the role of static factors. Vigilance to factors affecting cord perfusion and vascular compromise, such as the mean arterial pressure (MAP), is imperative. Additionally, further studies should evaluate the role of positioning in the myelopathic patient and whether the steep Trendelenburg position, commonly used in robotic surgeries, contributes to spinal cord venous congestion and resultant cord ischemia in these patients given their baseline stenotic canal. This review illustrates the importance of having a heightened awareness of this common degenerative condition in our aging patient population, often a forgotten underlying medical comorbidity.

1. Introduction

Cervical spondylosis (CS) is a chronic degenerative process of the cervical spine that occurs during the ordinary course of aging [1]. CS leads to intervertebral disc herniation, osteophyte formation, and ligament hypertrophy, which may eventually cause compression of the spinal cord and lead to cervical spondylotic myelopathy (CSM) [1]. In individuals older than 55 years, CSM is the most common type of spinal cord dysfunction and the most common cause of acquired spastic tetraparesis seen in later life [1,2]. Many patients with CSM are asymptomatic or have only mild symptoms such as loss of fine control of the hands, sensory disturbances, gait imbalance, and/or urinary difficulties [1,2]. CS diagnosis frequently results from incidental findings on X-ray or MRI.

Spinal cord injury (SCI) and acute neurological deterioration can occur in patients with underlying CSM. The lack of obvious symptomatology paired with the diffuse and sometimes severe nature of bony and ligamentous changes in this population places these patients at higher risk for SCI following minor injuries such as a fall. SCI can also occur due to iatrogenic causes; however, it is a rare complication of surgery when the procedure does not involve the spine. Cases of SCI after non-spine surgery in patients with diagnosed CSM and chronically compressed cords have been well reported on. [3]. However, there is less acknowledgment of the iatrogenic SCI that occurs in patients with undiagnosed CSM.

To the best of our knowledge, there are only 18 cases reported in the literature, including ours, with SCI following elective non-spine surgery in patients with undiagnosed CSM (Table 1) [4–18]. Most of these cases were post-operatively attributed to pre-existing CS in which the spinal cord was vulnerable to damage caused by prolonged neck extension during intubation and surgical positioning.

In this paper, we would like to bring attention to the importance of possible neurologic deterioration in the setting of underlying CSM in our aging population and its anesthetic considerations, to discuss the possible mechanisms for neurological worsening, and to provide guidance in future decision-making in the form of an algorithm.

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Table 1

Literature review of spinal cord Injury with tetraplegia after an elective surgery with underlying undiagnosed CSM. *A/G- age/gender, Preop Sx- preoperative symptoms, MAP- mean arterial pressure, LOS- length of surgery in minutes, Postop sx- postoperative symptoms, Preop ASIA: preoperative American Spinal Injury Association score, Postop ASIA: postoperative American Spinal Injury Association score, NR- not reported, N- No, PE- physical exam, WNL- within normal limit, C-spine- Cervical spine, HE- hyperextension, NI- no issues, TP- tetraplegia, MRI- magnetic resonance imagining, POD- post operative day, BUE-bilateral upper extremity, BLE- bilateral lower extremity, CS- cervical spondylosis, I&M w/- induced and maintained with, GA- general anesthesia, ADI- atlas-dens interval, IPR- inpatient rehabilitation, ACDF- anterior cervical discectomy and fusion, ACCF- anterior cervical corpectomy and fusion.*

No.	Author	A/G	Comorbidity	Known CS, preop Sx, PE	Procedure	Position	Intubation	Intraop	Anesthesia	MAP	LOS	Postop sx, preop ASIA	MRI timing & finding	Treatment	Follow up, recovery, postop ASIA	Mechanism
1	Whiteson et al 1997 [4]	NR	NR	N, N, NL	Dental extraction	C-spine HE	NR	NI	NR	NR	NR	TP, ASIA NR	NR, advanced spondylosis and spinal stenosis	NR	NR	Passive hyperextension
2	Pastor Tomás et al [5]	NR	NR	NR	Stapedectomy for otosclerosis	NR	NR	NR	NR	NR	NR	TP, ASIA NR	POD1, C6-C7 acute herniated disk w/ ischemia	NR	8 months, unchanged, ASIA NR	NR
3	Fujioka et al [6]	63/M	CAD, ESRD on HD, DM, HTN, TIA	N, N, WNL	CABG	Supine, neck extension	NI	NI, pressers used	I&M w/ midazolam, ketamine, propofol,-fentanyl	> 60 - mm Hg	355	TP, ASIA B	POD4, C4-C6 stenosis with high signal changes	Edaravone, radical scavenger and IPR	3 months, improved, ASIA C	Positioning: neck extension, hypotension
4	Naja Zohar et al [7]	61/M	CAD	N, N, WNL	CABG	Supine, neck extension	NI	NI	I&M w/ midazolam, propofol, fentanyl vecuronium	60–-70	240	TP, ASIA A	POD0, C3-C6 congenital cervical stenosis w/ disk herniation and cord compression and edema	Urgent ACDF on POD013, 14	6 weeks, significant improvement and revealed a partial Brown-Sequard syndrome, ASIA NR Died at 5 months: from bowel perforation and respiratory failure	Positioning: neck extension
5	Hirose et al 2005 [8]	65/M	CAD, DM, HTN, PVD, Stroke	N, N, WNL	CABG	NR	NI	NI	GA	NR	NR	TP, ASIA A	POD 2, large C7-T1 disc herniation cord compression and edema	Urgent C6-T1 ACDF with C7 corpectomy on POD 2	4 weeks, unchanged, ASIA A	Neck positioning during intubation
6	Hwang et al 2008 [9]	63/M	DM, HTN, MVP, MR, Afib, CKD, PUD, CS	Y, N, WNL	CABG and valves repair	Supine, neck extension	NI	NI, pressor used	I&M w/ fentanyl, etomidate, pancuronium, isoflurane.	60-80 - mm Hg	NR	TP, ASIA NR	POD3, C4-C7 disk herniation with cord compression and edema	Steroid, IPR	6months, regained full motor power in all limbs except for some deficit in fine movements of the left hand, ASIA NR	Neck positioning and fluctuations in perfusion
7	Mercieri et al 2009 [10]	54/M	ESRD on HD for 27 years	N, Y: some cervical pain, WNL	Total Parathyroidectomy	Supine, neck extension	NI	NI	I&M w/ propofol, fentanyl, cis-atracuriu, sevoflurane, fentanyl	NR	300	TP, ASIA B	POD2, severe CS at C3-C6 with canal stenosis and cord compression worse at C5-C6	C6-T1 ACDF w/ C5 corpectomy	NR, only modest improvement, ASIA NR	Prolonged neck extension

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Table 1 (*continued*)

No.	Author	A/G	Comorbidity	Known CS, preop Sx, PE	Procedure	Position	Intubation	Intraop	Anesthesia	MAP	LOS	Postop sx, preop ASIA	MRI timing & finding	Treatment	Follow up, recovery, postop ASIA	Mechanism
8		47/M	Chronic IgA glomerulonephritis, ESRD on HD for 26 years	N, Y: non-specific pain around the shoulders, WNL	Subtotal Parathyroidectomy	Supine, neck extension	NI	NI	I&M w/ propofol, fentanyl, cis-atracuriu, sevoflurane, fentanyl	NR	240	TP, ASIA C	POD0, C3-C7 CS w/ marked canal stenosis and cord compression	C3-C7 ACDF w/ C4–C6 corpectomy	NR, unchanged ASIA C	Prolonged neck extension
9	Gorur et al 2010 [11]	62/M	Unstable angina, coronary angioplasty and stenting, HTN	N, Y; numbness in both arms, WNL	CABG	Supine, neck extension	NI	NI	I&M w/ fentanyl, propofol, pancuronium	NR	NR	TP, ASIA NR	POD1, C6-C7 herniated disk w/ cord ischemia	Surgery (unspecified)	NR, gradually improved, POD 10 walk with crutches and BUE 3 to 4 of 5, ASIA D	Positioning and neck extension
10	Carron et al 2010 [12]	42/M	Wolf–Parkinson–White syndrome, HTN	N, N, WNL	Total thyroidectomy	Supine, neck extension	NI	NI	I&M w/ propofol, fentanyl, rocuronium, desflurane	NR	90	TP, ASIA A	POD0, C2-C5 ventral cord compression with edema due to spinal meningioma	Emergent C2–C5 decompressive laminectomy	NR, tracheostomy POD5 with unchanged exam and discharged to IPR on POD 18, ASIA A	Spinal meningioma and the neck hyperextension
11	Kudo et al 2011 [13]	71/F	Gastric cancer	N, Y; BUE numbness, WNL	Retinopexy for retinal detachment	NR	NI	SBP drop below 90 and used pressor	I&M w/ propofol, ketamine, rocuronium, remifentanil	NR but SBP was 85-140 mm Hg	NR	TP, ASIA NR	POD0, C3-C7 CS with cord compression and edema	Conservative	NR, muscle weakness gradually improved and completely recovered by the following morning, ASIA E	Hypotension, GA
12		72/F	DM, HTN	N, Y: mild progressive BLE weakness and pain, WNL	L1-L5 posterior lumber vertebral fusion	Pron	NI	NI	I&M w/ propofol, ketamine, rocuronium, remifentanil	NR	300	Weak spontaneous breath, TP, ASIA NR	POD, C3-T2 CS with spontaneous fusion of C4–5 causing cord compression	Conservative	NR, muscle strength completely recovered 2 h after extubation,ASIA E	GA
13	Li et al 2013 [15]	77/M	DM,HTN, chronic hepatitis B, and ESRD on HD (6 years)	N, N, WNL	CABG	Supine, neck extension	NI	NI	I&M w/ fentanyl, etomidate, rocuronium	NR	360	TP, ASIA B	POD4, C3-C7 CS with marked canal stenosis and cord compression	C3-C6 laminectomies without improvement on POD5, C4-C7 ACDF on POD10	6 months, no improvement, ASIA B Tracheostomy for long-term mechanical ventilator support, died of pneumonia 6 months later	Prolonged neck extension

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Table 1 (*continued*)

No.	Author	A/G	Comorbidity	Known CS, preop Sx, PE	Procedure	Position	Intubation	Intraop	Anesthesia	MAP	LOS	Postop sx, preop ASIA	MRI timing & finding	Treatment	Follow up, recovery, postop ASIA	Mechanism
14	Agarwal et al 2013 [15]	7/M	Sleep-disordered breathing and recurrent tonsillitis	N, after event they find that; pt has difficulty climbing stairs and lifting heavy objects, persistent mild neck pain, on exam: muscle wasting with mild weakness of all four limbs and hyper-reflexia and bilateral extensor plantar response	Elective adenotonsillectomy	Rose position (head extension with a roll placed underneath the shoulders)	Using laryngoscopy, NI	NI	I&M w/ fentanyl, thiopental, atracuriu, isoflurane	NR	40	No spontaneous breathing, TP, ASIA NR	POD1, C-spine XR: increased anterior ADI measuring 12 mm & decreased posterior ADI measuring 12 mm. MRI w/ cord compression with edema at craniovertebral junction and upper cervical spine	Posterior cervical fusion, time not reported	7 months, slow but complete, recovery of motor power, ASIA E	Atlanto-axial subluxation, intubation and position
15	Clancy et al 2014 [16]	65/M	DM, HTN, HLD	N, N, WNL	CABG	Supine, neck extension	NI	NI	GA	NR	NR	TP, ASIA A	POD0, C5-C7 CS with cord compression with edema and myelomalacia	ACDF, time and level not reported	NR, unchanged and discharge to IPR, ASIA A	Prolonged neck extension
16	Xiong et al 2015 [17]	60/F	CS	Y, Y: neck pain, WNL	Subtotal thyroidectomy	NR	NR	NI	GA	NR	100	TP, ASIA NR	POD0, CS with intervertebral disc herniation and cord compression	Emergent ACCF, time NR	NR, motor function improved dramatically, able to walk and muscle strength returned to grade 4/5 within 1 week and grade 5/5 within 3 months, with only slight numbness in her left index finger, ASIA E	Klippel–Feil syndrome, neck extension
17	Shim et al 2017 [18]	68/M	Parotid tumor, HTN, DM, stable angina	N, N,WNL	Parotidectomy	Supine, neck extension	NI	NI	I&M w/ pentothal sodium, 2% lidocaine, rocuronium, sevoflurane, N2O	NR but SBP 110–90 mm Hg	300	Urinary retention, TP, ASIA NR	NR, C3-C6 CS with cord compression and myelomalacia	Steroid, emergent C4-C6 laminoplasty on POD0	6 months, patient can walk but has a little difficulty maintaining balance, and there is no urinary retention, ASIA NR	Prolonged neck extension
18	Our case	68/M	Carpal tunnel syndrome, hypertension, COPD, CS, prior cervical, and lumbar spine surgeries	Y, Y, limited cervical ROM, +ve Hoffmann's	Robotic-assisted inguinal hernia repair	Supine in 30∘ of Trendelenburg and neutral position of the head and neck	NI	NI	I&M w/ propafol, lidocaine rocuronium, sevoflurane	Mid 70 s mm Hg for 75 - minutes	210	TP, ASIA B	POD0, CS worse at C6-C7 with cord compression and signal change	MAPs goal > 85 × 5 days, steroid, C6-C7 ACDF	4 weeks, excellent recovery with motor strength 4 to 4+ throughout and was able to walk, ASIA D	Relative hypotension, steep Trendelenburg?

2. Case presentation

A 68-yr-old male underwent robotic-assisted inguinal hernia repair. His medical history was significant for carpal tunnel syndrome, hypertension, chronic obstructive pulmonary disease (COPD), CS, and a prior C4-C5 ACDF. His systolic and diastolic blood pressures were 140–150 mm Hg and 60–80 mm Hg, respectively, with baseline mean arterial pressures (MAPs) 90–100 mm Hg.

At the time of pre-operative evaluation, he reported neck pain, bilateral upper extremity paresthesia, and progressively worsening gait imbalance necessitating a cane for ambulation. Physical exam elicited slightly decreased cervical extension, full strength in all extremities with sensation intact throughout, and 2+ deep tendon reflexes (DTR) in the upper and lower extremities bilaterally with a positive Hoffman's sign. Spinal imaging was not available for review prior to the procedure. Neurosurgery was not consulted preoperatively.

The patient voluntarily placed his head and neck into a position of ease once on the operating table. Following a standard intravenous induction, intubation was performed via a C-Mac video laryngoscope without any further neck extension. After positioning the patient into 30 degrees of Trendelenburg, a neutral positioning of the head and neck was reconfirmed. He remained in the Trendelenburg position for 135 min. Maintenance of anesthesia was achieved with sevoflurane, a known vasodilatory agent. As part of the standard American Society of Anesthesiologist (ASA) guidelines, non-invasive blood pressure (NIBP) monitoring was utilized. A baseline MAP of 92 mm Hg was recorded. The MAP fell below 80 mm Hg during the procedure, and the lowest recorded MAP was 73 mm Hg. His MAP was maintained at approximately 78 mm Hg for the last 75 min of the operation. The surgery was uneventful. He was extubated without any issues, and vital signs remained stable after being transferred to the recovery area.

Once he had fully emerged from anesthesia, he was found to have new-onset tetraparesis (4/5 strength in his bilateral upper extremities and 1/5 strength in his bilateral lower extremities). He also experienced a new-onset sensory level deficit in the region of the right T4 dermatome. His rectal sensation was preserved. Additionally, he was hyperreflexic with 3 + DTR throughout and a positive Hoffman's sign bilaterally. Physical exam was thus consistent with American Spinal Injury Association Impairment Scale (AIS) type B injury. Given his known history of cervical spine stenosis and exam consistent with cervical spinal cord injury, there was high concern for cord compression that had occurred during the perioperative period. He underwent an emergent MRI and transfer to the intensive care unit (ICU) for monitoring and maintenance of MAP $>$ 85 mm Hg to ensure cord perfusion and prevent secondary injury. MRI of the cervical spine confirmed severe cervical cord stenosis with cord compression and T2-weighted cord signal changes at C6-C7. (Fig. 1).

The decision was made for urgent single level ACDF at C6-C7 to decompress the spinal cord. He was intubated with anesthesia and maintained in in-line traction with a hard cervical collar to avoid further cord injury. MAPs were maintained above 85 mm Hg intraoperatively, and surgery was uneventful. The patient tolerated the procedure without any further complication.

After extubation, the patient was transferred to the ICU for close observation and MAP goal was maintained > 85 mm Hg for five days. He received 48 h of intravenous methylpredisone. The patient showed improvement in his neurological exam and X-rays were satisfactory with adequate decompression of the spinal canal (Fig. 1). Over the course of the hospital stay, his strength continued to improve. He was discharged to inpatient rehabilitation on postop day nine. At discharge, his exam was consistent with an AIS type D injury. Unfortunately, due to logistical difficulties, the patient was not followed up past discharge.

3. Discussion

3.1. Literature review

We reviewed the literature and to the best of our knowledge, there are only 18 reported cases including ours that describe iatrogenic SCI following elective non-spine surgery with undiagnosed CSM (Table 1) [4–18]. The average age of SCI presentation was 58 years, and the median age was 63 years (range, 7–77 years), which is consistent with the ages for CSM. The outlier was one patient who was seven years old and had underlying myelopathy due to atlantoaxial subluxation [15]. 82% of patients were male, compared to 18% that were female. Each patient had at least one to five associated co-morbidities. Including our case, only 16% were known to have CS prior to surgery [9,17]. Half of the patients, including our patient, were symptomatic with symptoms that included cervical pain, shoulder pain, bilateral upper extremity numbness and upper and lower extremity weakness [10,11,13,15,17]. All patients had a normal physical exam except in two cases [15], ours and one from the literature, in which hyperreflexia was the common finding. All of the patients underwent non-spine surgeries except one patient who underwent L1-L5 posterior lumbar spine fusion [13]. Nine patients (50% of cases) underwent dental or head and neck procedures including dental extraction [4], stapedectomy for otosclerosis [5], total or subtotal thyroidectomy [12,8], total or subtotal parathyroidectomy [10], adenotonsillectomy [15], parotidectomy [18], and retinopexy for retinal detachment [13] while 78% of the other half underwent a coronary artery bypass graft (CABG) [6–9,11,14,16]. Length of surgery (LOS) was only reported in [11] cases with an average of 258 min, ranging between 40 and 355 min.

Surgical positioning was reported in 74% of cases and most of the cases were positioned supine with neck extension [4,6,7,9–12,14–16,18]. Our patient was in a supine Trendelenburg position with 30 degrees of tilt. Neutral position of the head and neck was maintained throughout the procedure. Intraoperative MAPs were only reported in 4 cases (22%), including ours, and ranged from 60 to 80 mm Hg [6,7,9]. All patients presented with acute tetraplegia upon emerging from anesthesia. Pre-op AIS score was only reported in 9 cases including our case, with 44% AIS type A, 44% AIS type B, and 12% AIS type C [6–8,10,12,14,16]. For most of the cases, MRI was obtained on the same day and showed underlying CS due to disc herniation, ligamentous atrophy, and bony osteophytes that resulted in canal stenosis and cord compression with acute signal changes indicating spinal edema.

Postoperative management was reported in 16 cases. Postoperative MAP goals were only reported in our case. A twenty-four to forty-eight hours' steroid course was used only in 3 cases including our own [9,18]. Postoperative follow-up ranged from 4 weeks to 8 months and reported outcomes varied widely between patients, with no improvement in 35% [5,8,10,12,14,16] and some improvement to full recovery in 65% [6,7,9–11,13,15,17,18], of which 64% underwent surgical treatment [7,10,11,15,17,18]. Post-operative AIS score was found in 12 cases including ours: 25% AIS type A, 8% AIS type B, 17% AIS type C, 17% AIS type D, and 48% AIS type E [6,8,10–17]. Our patient improved postoperatively from AIS type B to AIS type D. Of the cases reviewed, two patients died: one at five months due to bowel perforation and respiratory failure [7] and the second due to pneumonia at six months after post-operative tracheostomy for long-term mechanical ventilator support [14]. The reported possible underlying mechanisms for injury were analyzed, and most of these cases were related to pre-existing CS in which the spinal cord was vulnerable to damage. We found that damage was precipitated by prolonged neck extension during intubation in 17% of the cases [8,13,15], surgical positioning with neck extension in 58% of the cases [4,6–12,14–18], hypotension and/or relative hypotension with possible hypoperfusion to the cord in 17% of the cases [6,9,13], and as in our case with possible cord venous congestion which may have resulted in hypoperfusion when in steep Trendelenburg (5%), which is defined by 30–45 degrees of tilt [19].

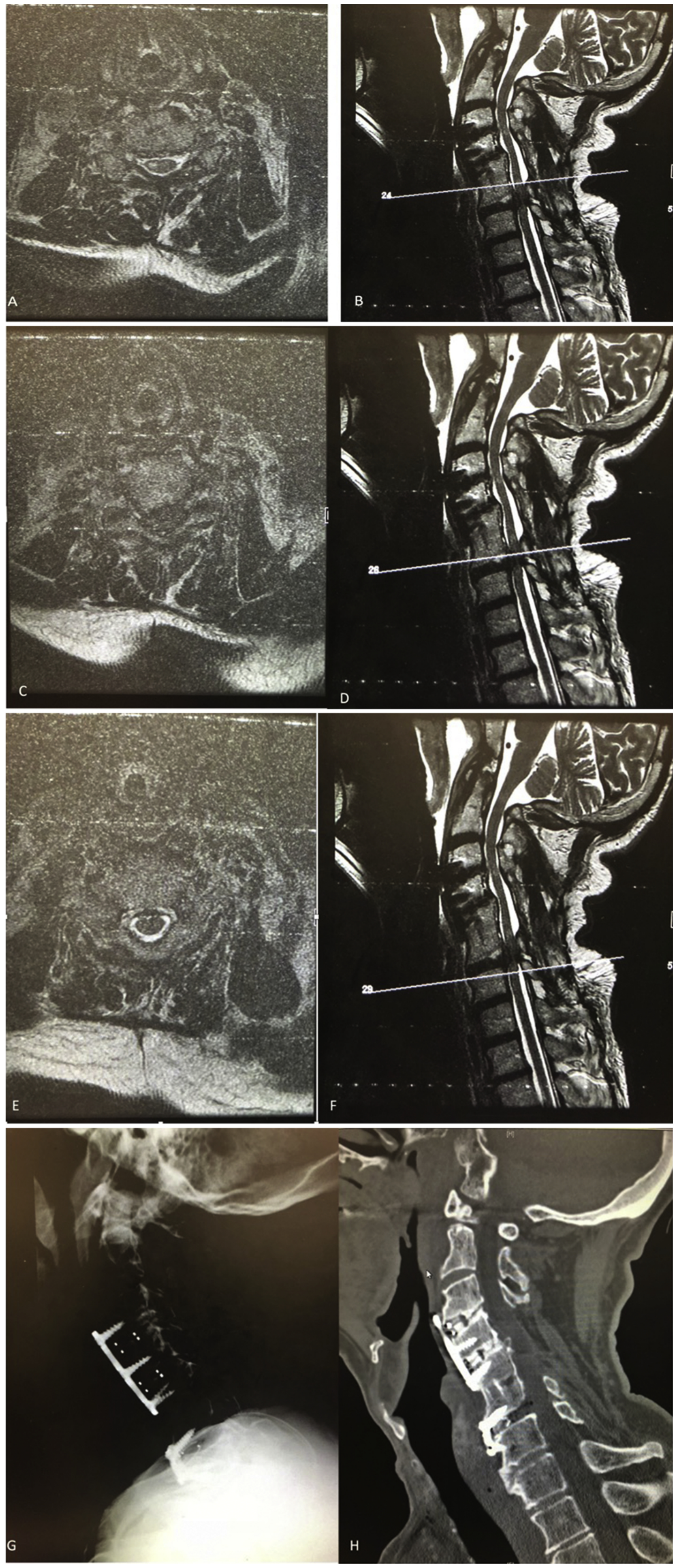

Fig. 1. Preoperative Cervical spine magnetic resonance T2-weighted imaging (A–F) showing severe cervical cord stenosis with cord compression and cord signal change at C6-C7. (A, B) axial and sagittal views above the C6-C7 level, (C, D) axial and sagittal views at the C6-C7 level, and (E, F) axial and sagittal views below the C6-C7 level. Postoperative sagittal views, Cervical spine X-ray (G) and Computed tomography scan (H) showing C6-C7 hardware placement.

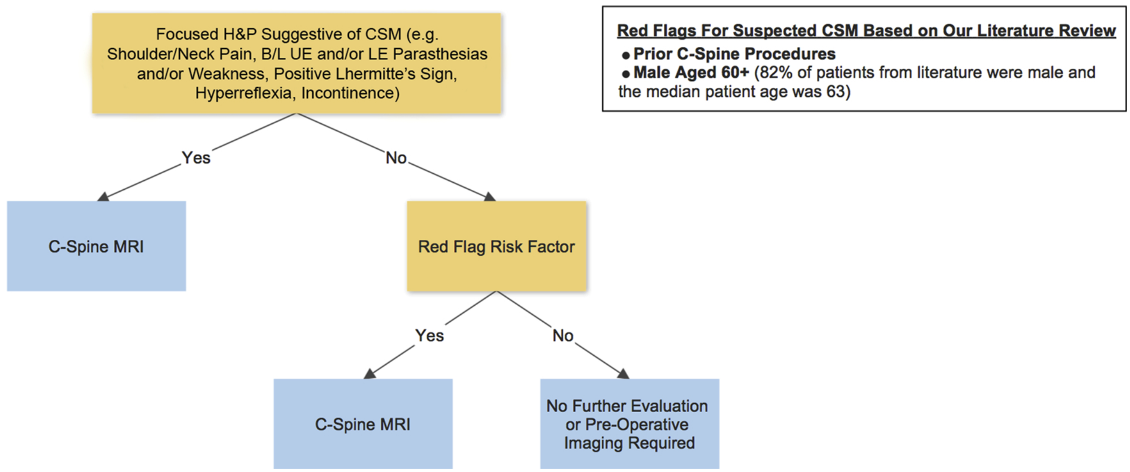

Fig. 2. Our proposed algorithm for determining whether a patient should be pre-operatively imaged for CSM. *C-Spine – Cervical Spine, H&P – History and Physical, CSM – Cervical Spinal Myelopathy, PMHx – Past Medical History, HTN – Hypertension, PSHx – Past Surgical History, B/L – Bilateral, UE – Upper Extremity, LE – Lower Extremity.*

3.2. *Importance of considering undiagnosed cervical myelopathy*

Postoperative tetraparesis is an extremely rare complication of surgery when the procedure does not involve the cervical spine. However, underlying cervical disease increases the risk of such complications. Our aging population has an increasing incidence of underlying cervical disease which must be considered prior to operations. The incidence of cervical stenosis with myelopathy is underreported in the literature, and very few recent manuscripts detail its epidemiology despite its recognized prevalence in our aging population. Data from 2013 estimated the highest incidence of CSM at 28.9 and 15.3 per 100,000 hospital admissions for males and females over age 70, respectively [20]. Most importantly, the authors found that cervical SCI was 1.5 times more likely to occur in individuals with CSM who had not had prior surgical treatment. There should be a high index of suspicion for CS in every aging patient, and while one could argue that prior surgery decreases risk for SCI, we would argue that even more attention should be paid to an individual with prior surgery, as they are at risk of accelerated disc degeneration above or below the construct which places the cord at risk. In the context of our patient who had had a prior ACDF, this data highlights the importance of better preoperative screening.

3.3. *Pathogenesis of acute SCI with regards to cervical myelopathy*

Possible mechanisms proposed to explain the complication of acute SCI include ischemic damage due to overstretching of the spinal cord during extension [21], occlusion of the vertebral arteries resulting from extreme head rotation [22], and direct compression of the spinal cord due to pre-existing cervical stenosis [22]. In chronically compressed cords, the mechanical causes of neurologic deterioration are well recognized, however, the role of relative hypotension and spinal venous congestion resulting in reduced cord perfusion is underestimated in most reports. Legal medical literature has investigated venous drainage and arterial perfusion to the spinal cord with ultrasound technology. When individuals were placed in the Trendelenburg position, regardless of tilt degree, the vertebral veins and internal jugular veins demonstrated slowed velocity and increased diameter suggestive of positional venous congestion [23]. Trendelenburg position has also been shown to cause dilation of the inferior vena cava and decreased venous return, possibly due to external compression by abdominal organs during positional change [24].

Given the physiologic changes that occur with Trendelenburg position, it is important to discuss these in the context of CSM. The spinal cord ischemia induced by chronic CS can result in microinfarcts of the cord as reflected by intraoperative Doppler ultrasonography. In a previous study, when MAPs dropped below 60 mm Hg intraoperatively, ultrasonography demonstrated decreased perfusion through the anterior spinal artery [25], which is responsible for perfusion of nearly two thirds of the spinal cord [26]. In patients with cervical stenosis, the engorgement of spinal venous plexi associated with Trendelenburg positioning leads to an even higher risk for cord ischemia. While inadequate venous drainage is a known cause of more subacute spinal cord infarcts in cervical myelopathy, we hypothesize that given the prolonged surgical time in our patient, this contributed to his more acute injury [27]. Our literature review lends support to this hypothesis, as we found the average LOS to be greater than four hours.

3.4. *Identifying patients with risks of SCI*

As listed in Table 1, comorbidities aside from CS/CSM and proposed surgery play an important role in risk assessment. Individuals with hypertension live at a higher MAP than the average patient which makes intraoperative relative hypotension a more dangerous phenomena compared to a normotensive individual. As in our patient, allowing the MAP to drop to the mid 70 s from his baseline of 90–100 mm Hg put his spinal cord at risk for hypoperfusion, a recognized cause of SCI [28]. We hypothesize that this relative hypotension explains the prevalence of SCI following CABG, which was the operation preformed in nearly 40% (7/18) of the cases reported in the literature. Communication with the anesthesia team is crucial throughout the case to ensure that fluctuations in the patient's vital signs do not place them at risk for complications such as SCI. In addition, end stage renal disease was a common trait throughout the literature in the patients who experienced post operative SCI, likely given their poor bone quality secondary to demineralization and bone remodeling [29]. Lastly, head and neck procedures made up an additional 40% of our data, highlighting the risk that neck position places to the patient with CS and CSM. Minimizing the amount of neck extension and hyperextension places the patient at less risk for acute SCI.

We suggest that a detailed preoperative screening for CSM with history and physical be performed as part of the routine pre-operative assessment conducted by primary care physicians and anesthesiologists, with consideration of a referral to a spine surgeon for further risk-benefit analysis and possible MRI. We have illustrated our algorithm as a flow chart (Fig. 2). We chose MRI as our preferred imaging modality due to its high sensitivity in diagnosing CSM [30].

3.5. Managing the post-operative SCI

In regard to management of post-operative SCI, there should be a low threshold for postoperative MRI of the cervical spine if an individual emerges from anesthesia with a new neurological deficit. In our patient, an MRI performed immediately following emersion from anesthesia confirmed the diagnosis, allowing for early initiation of MAP goals, steroid therapy, and surgical planning. With respect to MAP goals, the most recent literature is summarized in a review that suggests maintaining MAPs greater than 85–90 mm Hg for 5–7 days with pressor classes specific for the region of injury [28]. These recommendations are consistent with our treatment of our patient.

The role of steroids remains controversial within the SCI literature. High dose methylprednisolone initiated within eight hours following injury is the only currently accepted option for treatment [31]. The current recommendation is that if intravenous steroids are initiated within eight hours following injury, then they should be started at a bolus dose followed by a continuous infusion for 48 h; however, if initiated within 3 h, then the total course of treatment need only be 24 h [32]. Contraindications to this therapy include gunshot wounds, age < 13 years old, pregnancy and cauda equina syndrome. In our patient, intravenous methylprednisolone was initiated and maintained for 48 h as the exact time of SCI intraoperatively was unknown.

In regard to surgery, two thirds of the cases in our literature review underwent a surgical procedure to address their SCI during their postoperative course, however the timing and operation performed varied amongst individuals and was not indicated in each case (Table 1). Nearly all patients had postoperative imaging within the first four days following their procedure with the majority undergoing an MRI on the day of their index surgery (Table 1). Surgical interventions varied amongst multilevel laminectomies, ACDF, ACCF, and posterior spinal fusions (PSF). Prior literature has recommended decompression within 72 h of injury; however, more recent data suggests that the operative window may be 24 h [33]. While our patient also underwent urgent surgery, additional research is required to determine the benefits of early surgery, a topic that remains controversial within the neurosurgical community.

Lastly, of importance is the societal consequence of SCI, which affects nearly 12,000 individuals in the United States annually [33]. For the individuals and their families, a SCI can pose a large burden, as lost wages, enormous medical expenses, and long-term care are all factors adding to the patient's recovery from their initial surgery. We strongly recommend that surgeons of all disciplines take note of the increasing prevalence of underdiagnosed CSM in our aging population and screen patients accordingly. We believe such measures can help minimize the burden of SCI on our society.

4. Conclusion

The maintenance of cervical cord neutrality is not sufficient to ensure that patients with spondylotic myelopathy will not sustain cord injury intraoperatively and vigilance to factors affecting cord perfusion and vascular compromise, such as the MAP, is imperative. Future studies should evaluate the role of positioning in the myelopathic patient and the complications associated with surgical positioning such as steep Trendelenburg. This review illustrates the importance of having a heightened awareness of this common degenerative condition in our aging patient population, often a forgotten underlying medical comorbidity. Pre-operative evaluation, a focused neurological exam and referral to spine surgeons for evaluation and clearance for elective non-spine surgery should be considered.

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