Case Series:
Non-traumatic Causes of Brown-sequard Syndrome: A Case Series and Clinical Update With Systematic Review

Vaner Köksal1*, Mahmoud Osama2, Mohammed Ali Alvi3

1. Department of Neurosurgery, Samsun Health Practices and Research Center, University of Samsun, Samsun, Turkey
2. Faculty of Medicine, Zagazig University, Zagazig, Egypt
3. Mayo Clinic Neuro-Informatics Laboratory, Mayo Clinic, Rochester, Minnesota, USA

* Corresponding Author:
Vaner Köksal, MD.
Address: Department of Neurosurgery, Samsun Health Practices and Research Center, University of Samsun, Samsun, Turkey
Tel: +90 (505) 5212361
E-mail: vanerkoksal@hotmail.com

Abstract

Background and Importance: Brown-Sequard Syndrome (BSS) is a rare neurological condition resulting from a hemisection injury to or unilateral compression on the spinal cord. The common causes of BSS that are amenable to be treated surgically can be divided into traumatic and non-traumatic injuries. Traumatic injuries are often reported as the main cause of BSS. However, non-traumatic injuries of the spinal cord are more seen in recent years. This study aims to classify and update surgically treatable causes of BSS.

Case Presentation: Retrospective data of 17 patients operated for BSS between 2008 and 2020 were included. The long-term outcomes of these patients were evaluated. In addition, a comprehensive search in PubMed, Scopus, and CINAHL was conducted for the retrieval of all relevant studies.

Results: Magnetic Resonance Image (MRI) of our patients revealed Cervical Disc Herniation (CDH), spinal canal stenosis with cervical spondylosis, epidural hematoma, and ossification of the posterior longitudinal ligament. The postoperative outcomes of our cases ranged from partial to complete recovery. While the patients with acute epidural hemorrhage achieved complete recovery after surgery, neurological deficits in the other patients, especially those with severe cervical spinal canal stenosis, persisted despite adequate surgical decompression. The systematic literature review revealed that CDH is the most common non-traumatic surgically treatable cause of BSS, followed by spinal cord herniation and spinal epidural hematoma.

Conclusion: Non-traumatic injuries of the spinal cord accompanied by narrowed cervical spinal canal pathologies are prominent surgically treatable causes of BSS. Contrary to the definition made 100 years ago, BSS can occur spontaneously due to underlying pathologies rather than major traumatic injuries.
1. Background and Importance

Brown-Sequard Syndrome (BSS), first described in 1846 by Charles-Edouard Brown-Séquard, is a rare neurological syndrome that evolves due to a hemisection injury to or unilateral compression on the spinal cord. As a result of interruption of both ascending spinothalamic and descending corticospinal tracts, a constellation of symptoms and signs appears, including ipsilateral loss of motor function (presenting as hemiplegia or hemiparesis), proprioception, vibration, and fine touch sensation, and contralateral loss of temperature and pain sensation. In addition, there is an ipsilateral loss of all sensations and motor functions at the level of the lesion [1]. Etiologies of BSS include surgically treatable (traumatic and non-traumatic injuries) and medically treatable causes. Traumatic injuries were often reported as the main surgical causes of BSS. However, non-traumatic etiologies have been more frequent in recent years, as reported in the literature. Non-traumatic etiologies have been more frequent in recent years, as reported in the literature. Surgical interventions performed for these pathologies have a great impact on the prognosis of patients. Herein, we present a case series of surgically treatable non-traumatic causes of BSS along with a systematic review of the literature. We aimed to raise awareness that there are more non-traumatic causes of BSS. This work has been reported with preferred items for systematic review and meta-analysis PRISMA guidelines which is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses [7].

2. Case Presentation

Seventeen patients were admitted to our clinic in the Department of Neurosurgery, University of Health Sciences-Samsun Health Practices and Research Center, Samsun, Turkey, between 2008 and 2020. They presented the aforementioned clinical picture of BSS. The patients consisted of 12 men (70.6%) and 5 women (29.4%). The age of the patients ranged from 48 to 85 years (mean= 65 years). The etiologies of BSS in these patients as revealed by cervical Magnetic Resonance Image (MRI) were as follows: 6 cases were produced by CDH alone (35.3%), 5 patients by OPLL (29.4%), 1 patient by spinal canal stenosis with cervical spondylosis (5.9%), 3 patients by epidural hematoma (17.6%), and 2 patients by cervical spinal stenosis (11.8%) (Table 1; Figure 1). All patients with disc herniation and spinal canal stenosis denied any history of major traumas. In most patients, the symptoms were observed during their daily activities. Few of them had a history of minor traumas in the form of falling at the same level [8]. Written consent was taken from the patients for performing the appropriate surgical intervention. According to the diagnosis, the patients underwent the following surgical interventions: anterior cervical discectomy for CDH, anterior oblique corpectomy for OPLL, posterior hemilaminectomy for epidural hematoma, and total posterior laminectomy for spinal stenosis and some cases of CDH (Table 1). In addition to

Highlights

- An update on the Brown-Sequard Syndrome (BSS) described a century ago is considered.
- Contrary to popular belief, major traumas are not the most common cause of BSS today.

Plain Language Summary

In our aging process, we can usually notice the change in our neck spine too late. In particular, it may not give any symptoms due to long-term compression of the spinal cord tissue. As with lumbar hernia, complaints of numbness in the hands or arms may occur first without experiencing pain complaints. For these reasons, the patient may not have any complaints until the neck spinal cord is compressed. Challenging physical activities in our daily life can easily affect the previously narrowed cervical spine, and a severe clinical picture may begin. This article has tried to emphasize the typical—characteristics of such patients.
Figure 1. Case 2: A: T2 sagittal MRI shows a hypointense lesion occupying a space in the spinal canal between C5-7; Section B: T1 sagittal MRI shows a hyperintense intradural lesion indicating presence of bleeding (epidural hematoma); C: T2 axial MRI displays a hypointense lesion for a typical epidural hematoma. Case 5: D: T2 sagittal MRI demonstrates a narrow spinal canal and hypertrophied Posterior Longitudinal Ligament (PLL); E: Computed Tomography (CT) section shows OPLL between C5-7; F: T2 axial MRI shows severe stenosis in the left half of the cervical spinal canal; Case 8: G: T2 sagittal MRI shows a hyperintense lesion for acute C2-3 Cervical Intervertebral Disc Herniation (CIDH) and edema in the Spinal Cord (SC); H: T2 axial MRI demonstrates CIDH in front of the right foramen; J: Narrow spinal canal diameter in the right side C5-6. Case 15: K: T2 sagittal MRI shows narrowing and myelomalacia in the SC; L: CIDH or OPLL filling the left side of the spinal canal; M: A CT section shows a calcified CIDH. BSS occurred in these 4 patients without major trauma. The patients were presented to the emergency room with BSS after a daily activity, especially case 5 and 15. It is understood that the anatomical change narrows the cervical spinal canal in the chronic processes. The spinal tracts tolerate until the last moment. In all cases, there were no apparent painful radicular complaints in their background.

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In our cases, we systematically performed a comprehensive literature search in PubMed, Scopus, and CINAHL for retrieval of all relevant case series and case reports that reported surgically-treatable causes of BSS with the way of management and postoperative outcome for the past 20 years according to PRISMA guidelines [9], using the following keywords: “Brown-Sequard”, “Brown-Séquard”, “surgery”, “surgical intervention”, “operation”, “surgical approach”, “neurosurgery”, “case report”, “report”, and “case series”. The search results were checked for duplication, then underwent screening.

3. Results

Our patients were followed up for 2 to 3 years; their long-term outcomes post-operatively ranged from partial to complete recovery, as shown in Table 1. Four cases completely recovered, whereas 13 showed incomplete recovery in the form of sensory and motor deficits. In our cases, complete recovery was mainly associated with patients with acute CDH and epidural hematoma, whereas incomplete recovery was mainly associated with OPLL, lateral stenosis, calcified CDH, and spinal stenosis. Moreover, our patients’ outcomes showed that late surgical treatment after the occurrence of BSS did not have enough benefit, and poor neurological conditions persisted. The comprehensive search in the aforementioned databases yielded 482 case series and reports. Of these, 75 articles were excluded for deduplication, 97 articles because of title and abstract screening, and 157 articles because of full-text screening for reporting cases treated medically and conservatively. Finally, 153 articles were included for qualitative synthesis as demonstrated by the PRISMA flow chart (Figure 2) for estimating the frequency of each surgically treatable cause of BSS for the past 20 years. Of these 153 articles, 52 reported major traumatic injuries, and 101 reported micro- or non-traumatic injuries (Table 2). CDH was the most common surgically treatable non-traumatic cause for the past 20 years (frequency=28), followed by SCH (frequency=27).

### Table 1. The demographic data of our 17 patients

| Case No. | Patient (Age/Sex) | Diagnosis | Surgical Intervention | Outcome |
|----------|------------------|-----------|-----------------------|---------|
| 1        | 57/M C3/C4/C5 cervical spondylosis and stenosis | Posterior total laminectomy | IR |
| 2        | 85/F C4/C5/C6 Rt-sided epidural hematoma | Posterior hemilaminectomy | IR |
| 3        | 56/M C7/T1/T2 epidural hematoma | Posterior hemilaminectomy | IR |
| 4        | 60/M C3/C4 acute Lt-sided CDH | Anterior cervical discectomy | CR |
| 5        | 67/M C4/C5/C6 OPLL + stenosis | Anterior oblique corpectomy | IR |
| 6        | 54/F C4/C5 acute Lt-sided CDH | Anterior cervical discectomy | CR |
| 7        | 81/M C5/C6 calcified CHD | Anterior cervical discectomy | IR |
| 8        | 64/M C2/C3 acute Rt-sided CDH | Anterior cervical discectomy | CR |
| 9        | 78/F C6/C7 - T1 epidural hematoma | Posterior hemilaminectomy | CR |
| 10       | 48/F C5/C6 acute CDH | Anterior cervical discectomy | IR |
| 11       | 59/M C4/C5/C6 OPLL + lateral stenosis | Anterior oblique corpectomy | IR |
| 12       | 69/M C3/C4/C5/C6 OPLL + lateral stenosis | Anterior oblique corpectomy | IR |
| 13       | 70/M C3/C4/C5 calcified CDH + OPLL | Posterior total laminectomy | IR |
| 14       | 68/M C5/C6 acute CDH | Anterior cervical discectomy | IR |
| 15       | 67/F C5/C6/C7 calcified disc + stenosis | Anterior cervical discectomy | IR |
| 16       | 58/M C4/C5/C6 CDH + spinal stenosis | Posterior total laminectomy | IR |

CR: Complete Recovery; IR: Incomplete Recovery; M: Male; F: Female
micro- or non-traumatic epidural hematoma (frequency=14), and Intramedullary Spinal Cord Metastasis (ISCM) (frequency=6) (Figure 3, Table 2). Males were affected more often than females (males=59 cases; females=42 cases). The ages of the patients reported in these studies ranged from 7 to 86 years (mean=50 years; 95%CI: 47 to 53) (Figure 4, Table 2).

4. Discussion

Surgically treatable etiologies of BSS

BSS may occur due to spontaneous non-traumatic causes, major traumatic injuries, or some infectious diseases. Many of these causes require conservative treatment, such as medical or rehabilitation therapy, and the others require surgical intervention. In recent years, BSS frequently occurs due to micro- or non-traumatic injuries, such as CDH, SCH, epidural hematoma, OPLL, cervical canal stenosis, and benign and metastatic tumors, as noticed in our cases. We classified surgically treatable causes of BSS into two categories based on our case series and a comprehensive search in the literature: major traumatic injuries and micro- or non-traumatic injuries (Figure 5). Major traumatic injuries result from direct injuries to the spinal cord, including stab injuries (accounting for 26% of spinal cord injuries) [10], blunt traumas [11], gunshot [12], penetrating glass injuries [13], cervical vertebral dislocation, acute traumatic cervical disc herniation, and traumatic vertebral fracture. Major traumatic injuries are usually accompanied by Horner’s syndrome when traumas involve the cervical region [14] and usually require urgent surgical intervention for spinal cord decompression, removal of foreign objects, repair of the affected area, and preservation of the spinal
cord in its correct position. On the other hand, micro- or non-traumatic injuries result from trivial traumas, physical activities, or hyperextension [8]. The definitive diagnostic tool for such cases is MRI, which demonstrates the etiology and extension of the lesion. Micro- or non-traumatic injuries have been reported more frequently than before for the past 20 years. Based on the results from 153 case reports, there are 19 different surgically treatable non-traumatic etiologies that can result in BSS. CDH constitutes most of these causes as found in our cases [15, 16], followed by SCH, spinal epidural hematoma, ISCM, and benign tumors (Figure 5). CDH occurs mainly due to minor traumatic events (the main cause of herniation) or develop progressively over a long period of time [17]. In addition to disc herniation, SCH has been also reported as a surgically treatable non-traumatic cause of BSS occurring as a result of pre-existing dural defects, unrecognized traumatic events, surgical intervention (iatrogenically), or rarely, congenital defects. However, this clinical entity was not present in our patients. Spinal epidural hematoma comes in the third place among non-traumatic causes of BSS. It may
occur spontaneously or evolve secondarily due to minor traumas, vascular malformation, hemorrhagic diseases [18], anticoagulant therapy, hypertension, or pregnancy. The fourth most common non-traumatic cause of BSS is tumors, which can be classified into primary and metastatic. Primary tumors include cavernous hemangioma, schwannoma, meningioma and osteochondroma [19, 20]. Secondary metastasis from remote sites includes malignant mesothelioma [21], colonic carcinoma [22], squamous cell carcinoma of the maxillary sinus [23], and gastric adenocarcinoma [24], leading to intramedullary spinal cord metastasis. Spinal canal stenosis with cervical spondylosis and OPLL are forms of degenerative conditions that develop over the years and affect the vertebral column and surrounding ligaments [14]. Cervical spinal stenosis is the commonest form of spinal canal stenosis developing mainly from spinal canal stenosis with cervical spondylosis and OPLL and therefore requires surgical intervention for dilatation of the spinal canal and release of any compression on the spinal cord. BSS is produced by these conditions mainly due to compression on the spinal cord by bone spurs and degenerated intervertebral disc herniation [25]. Overlap between some spinal canal pathologies is common in real life such as CDH, spinal canal stenosis with cervical spondylosis, and OPLL. Time of surgical intervention plays a vital role and has a great impact on the postoperative outcome; the earlier the intervention, the better the prognoses and postoperative outcomes. Therefore, most non-traumatic injuries have good prognosis after early surgical interventions and patients achieve complete recovery, except for ISCM and calcified CDH that carry moderate to bad prognosis [21, 26]. Other surgically treatable non-traumatic causes of BSS that have been reported rarely include neurenteric cyst, cervical synovial cyst, ganglion cyst, spinal arteriovenous fistula, intramedullary abscess, intramedullary tuberculosis, and regional kyphosis (Figure 3).

Figure 5. This figure demonstrates surgically treatable and medically treatable etiologies of BSS

Overview of medically treatable etiologies of BSS

Non-surgical causes of BSS are treated conservatively without a need for surgical intervention. They include spinal cord ischemia and infarction, many infectious diseases, such as varicella virus infection, treated with acyclovir and steroid [27, 28], and neurodegenerative dis-
Table 2. The non-traumatic surgical causes of BSS reported for the past 20 years since 2002

| Study            | Year | Patient (Age/Sex) | Diagnosis                                  | Surgical Approach                                                                 | Outcome     |
|------------------|------|-------------------|--------------------------------------------|----------------------------------------------------------------------------------|-------------|
| Ding et al. [33] | 2019 | 49/M              | C6/C7 Spontaneous CDH                      | C6/7 discectomy; C6 corpectomy                                                   | CR          |
| Neale et al. [34]| 2019 | 61/F              | T4 ISCH                                    | T3/T4 laminectomy and medial facetectomy                                         | IR          |
| Gomez et al. [35]| 2019 | 20/F              | T4/T5 ISCH                                 | Posterior approach                                                               | IR          |
| Tyagi et al. [36]| 2019 | 72/M              | T4/T5 ISCH                                 | T3 to T5 laminectomy                                                             | IR          |
| Mathais el al. [37]| 2018 | 78/M              | C4 to T5 SSEH, prevailing in C5-C6         | C3 to C7 Posterior cervical laminectomy                                          | CR          |
| Patel et al. [38]| 2018 | 51/M              | C3 to C5 SEEH                              | bilateral spinous process C4 laminectomy; Rt C3 and C5 hemilaminectomy           | IR          |
| Zeng et al. [39] | 2018 | 57/M              | C4/C5 Spontaneous CDH; C5/C6/C7 spondylosis| Subtotal ACCF                                                                    | CR          |
| Du et al. [40]   | 2018 | 16/F              | T3/T4 intraspinal thoracic osteochondroma  | Transpedicular approach + tumour excision                                        | CR          |
| Kida et al. [41] | 2018 | 67/F              | C3/C4 recurrent cervical neurenteric cyst   | Anterior approach                                                                | CR          |
| Ghali et al. [42]| 2018 | 66/F              | T5/T6 ISCH                                 | T5/T6 laminectomy                                                               | CR          |
| O'Neill et al. [43]| 2017 | 49/F              | C4/C5 ISCM from thyroid carcinoma          | C4/C5 cervical laminoplasty + resection of the ISCM                              | CR          |
| Lee et al. [44]  | 2017 | 50/F              | C1/C2 instability (falling from a ladder)  | C1/C2 arthrodesis with screws and rods.                                          | IR          |
| Baudracco et al. [45]| 2017 | 45/F              | C4/C5 spontaneous CDH                      | C4/C5 Anterior cervical corpectomy and fusion                                    | CR          |
| Baldvinsdottir et al. [46] | 2017 | 67/M              | T6/T7 extramedullary cavernous haemangioma | posterior laminectomy + en bloc excision                                         | CR          |
| Alkhamees et al. [47]| 2016 | 50/F              | T3 ISCH                                    | Laminectomy + medial durotomy                                                    | IR          |
| Delgado et al. [48]| 2016 | 33/F              | T7/T8 ISCH                                 | T7/8 laminectomy                                                                | CR          |
| Porto et al. [49]| 2016 | 86/M              | C4/C5 CHD; C3/C4 severe cervical stenosis  | C3 to C5 ACDF                                                                   | IR          |
| Aiyer et al. [50]| 2016 | 50/M              | C3 Spinal cord herniation + Pseudomeningocoele | C2-4 posterior cervical approach                                                  | CR          |
| Guan et al. [51] | 2015 | 53/M              | C4/C5 calcified CDH; C5 posterior vertebral osteophyte. | CS subtotal vertebrectomy and anterior reconstruction                           | IR          |
| Ju et al. [52]   | 2015 | 33/F              | T3/T4 ISCH                                 | T3 total laminectomy                                                             | CR          |
| Noguera et al. [53]| 2015 | 43/M              | C7/T1 intramedullary neurocysticercosis cyst | C6/C7/T1 laminectomy                                                            | CR          |
| De Souza et al. [54]| 2014 | 66/F              | T4 ventral spinal cord herniation          | T4 laminectomy                                                                  | IR          |
| Ramdasi et al. [55]| 2014 | 28/M              | T2/T3 thoracic osteochondroma              | T2/T3 laminectomy                                                               | CR          |
| Wittw et al. [56]| 2014 | 36/M              | T8/T9 Thoracic disc herniation             | Posterior surgical decompression and resection of the intradural disc             | IR          |
| Yamamoto et al. [57]| 2014 | 62/M              | C3 ISCM from Sarcomatoid Malignant Mesothelioma | C3 laminectomy; C4/C6 laminoplasty                                              | IR          |
| Kim et al. [58]  | 2014 | 64/M              | C7/T1 extradural cervical synovial cyst; C4/C5/C6 osteophytes | C5/C6 laminoplasty; C7 laminectomy                                              | IR          |
| Kulkarni et al. [59]| 2013 | 65/F              | C3 to C5 epidural hematoma (minor trauma; sudden voluntary hyperextension of the neck) | C3/C4/C5 Open-door laminoplasty                                                  | CR          |
| Bulsara et al. [60]| 2013 | 51/F              | C6 spinal arteriovenous fistulae           | C5/C7 laminectomies; partial CS/6 facetectomy                                   | CR          |
| Sinha et al. [61]| 2013 | 44/F              | C2 to C5 intramedullary abscess (Streptococcus milleri) | C3/C5 laminectomy                                                               | IR          |
| Ko et al. [62]   | 2013 | 30/M              | T2-T3 SSEH                                 | Laminectomy + hemotoma evacuation                                                | CR          |
| Study            | Year | Patient (Age/Sex) | Diagnosis                              | Surgical Approach                                                                 | Outcome |
|------------------|------|-------------------|----------------------------------------|-------------------------------------------------------------------------------------|---------|
| Seon et al. [63] | 2013 | 65/M              | C3/C4/C5 Spontaneous epidural hematoma  | C3 to C5 hemilaminectomy + hematoma evacuation                                      | IR      |
| Yoon et al. [64] | 2012 | 59/F              | C3 to C6 Spontaneous epidural hematoma  | C3 to C6 hemilaminectomy + hematoma evacuation                                      | CR      |
| Yokoyama et al. [65] | 2012 | 63/M              | C3/C4 CDH + C4 to C7 severe canal stenosis | Decompression posterior cervical laminoplasty                                     | CR      |
| Roy et al. [66]  | 2012 | 65/F              | C3-C4 SSEH                             | C3-C5 laminoplasty                                                                | CR      |
| Lee et al. [67]  | 2012 | 32/M              | C4-C5 facet area Cervical Os-teochondroma (history of trivial trauma) | C4-C5 hemilaminectomy                                                              | IR      |
| Aydin et al. [68] | 2011 | 52/F              | T4-T5 and T5-T6 ISCH                  | Laminectomy                                                                        | IR      |
| Kansal et al. [69] | 2011 | 45/M              | C5/6 CDH                              | C5/6 anterior discectomy                                                          | IR      |
| Urrutia et al. [70] | 2011 | 51/M              | C6–C7 CDH                             | C6 corpectomy                                                                     | CR      |
| Jost et al. [71]  | 2010 | 54/M              | Regional kyphosis and large swollen paraspinal muscles impinging on the spinal cord (after posterior cervical decompression) | C4/C5 ACDF                                                                       | CR      |
| Choi et al. [72]  | 2009 | 31/M              | C3-C4 CDH                             | C3-C4 microsurgical right-sided Smith-Robinson approach (through a transverse incision) | IR      |
| Choi et al. [72]  | 2009 | 66/F              | C5 to C7 CDH                          | C5 to C7 ACDF                                                                     | CR      |
| Laghmari et al. [73] | 2009 | 79/M              | C4-C5 CDH                             | C4-C6 ACCF                                                                         | CR      |
| Kim et al. [74]   | 2009 | 28/M              | C3-C4 CDH                             | C3-C4 ACDF                                                                        | CR      |
| Ulivieri et al. [75] | 2009 | 35/M              | T9-T10 spinal cord herniation         | T9-T10 thoracic laminectomy                                                        | IR      |
| Marshman et al. [76] | 2009 | 48/F              | T8 ISCH                               | T8 laminectomy                                                                     | CR      |
| Riaz et al. [77]  | 2009 | 63/M              | C4 to C6 SSEH                         | C5-C6 laminectomy                                                                 | CR      |
| Han et al. [78]   | 2009 | 7/M               | C7 Osteochondroma                     | C6/C7 partial hemilaminectomy + removal of the tumor                                | CR      |
| Selviaridis et al. [79] | 2009 | 51/M              | T2–T3 SSCH                            | T2–T3 laminectomy                                                                  | CR      |
| Crowley et al. [80] | 2008 | 74/M              | T1-T2 ISCM from bladder carcinoma     | Laminectomies + subtotal resection                                                  | IR      |
| Uhl et al. [81]   | 2008 | 50/M              | T2-T3 ISCH                            | T2-T3 dorsal foraminotomy                                                          | IR      |
| So et al. [82]    | 2008 | 42/F              | C4 to C7 epidural hematoma (neck extension) | C3 to C7 laminoplasty                                                            | CR      |
| Sayer et al. [83] | 2008 | 46/M              | C3/C4 CDH                             | ACFD + iliac crest bone graft                                                      | CR      |
| Riaz et al. [84]  | 2007 | 52/M              | C6-C7 SSEH                            | C6-C7 laminectomy                                                                  | CR      |
| Noudel et al. [85] | 2007 | 12/F              | T11 intramedullary spinal cord cavernous angioma | T10 to T12 laminotomy                                                              | IR      |
| Payer et al. [86] | 2007 | 50/M              | C6 to T8 Intradural pleural malignan nt mesothelioma | T4–T6 laminectomy; T5 costo-transverso-pediculectomy; T5 corpectomy | IR      |
| Lee et al. [87]   | 2007 | 56/M              | C5-C6 CDH                             | Anterior cervical foraminotomy                                                     | CR      |
| Lee et al. [87]   | 2007 | 47/M              | C5-C6 CDH                             | Anterior cervical foraminotomy                                                     | CR      |
| Lee et al. [87]   | 2007 | 45/M              | C5-C6 CDH                             | Anterior cervical foraminotomy                                                     | CR      |
| Chen et al. [88]  | 2007 | 61/F              | C4-C5 ossification of the ligamentum flavum | C3 to C7 laminectomy                                                              | CR      |
| Cheng et al. [89] | 2006 | 58/M              | C6–C7 Ganglion cyst                    | C6–7 laminectomy + total removal of the cyst                                       | CR      |
eases, such as multiple sclerosis. Spinal cord ischemia, usually followed by infarction, occurs due to diminished blood supply to the spinal cord. The causes of blood supply cessation include compression on the blood vessels supplying the spinal cord by tumors or hernias, circulating thrombi, or iatrogenically following endovascular embolization of vertebral hemangioma [29-32]. The treatment is usually conservative with anticoagulation and antiplatelets [31].

5. Conclusion

Surgically treatable non-traumatic causes of BSS are more frequent than major traumatic injuries in recent years, as reported in the literature. CDH has been reported as the commonest surgically treatable non-traumatic surgical cause of BSS, followed by SCH, spinal epidural hematoma, ISCM, benign tumors, OPLL, and spinal canal stenosis with cervical spondylosis. Regarding the postoperative outcomes of our patients, the cases with acute epidural hemorrhage achieved complete recovery after surgery, whereas neurological deficits in the other cases, especially those with severe cervical spinal canal stenosis, persisted despite adequate surgical decompression.

Ethical Considerations

Compliance with ethical guidelines

Ethics approval Consent to participate written informed consent was obtained from the patients for publishing this article accompanied by the MRI images. Consent for publication Written informed consent was obtained from the patients for publishing this article accompanied by the MRI images.

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Authors' contributions

Data Collection: Mahmoud Osama, Vaner Köksal, Mohammed Ali Alvi; Data Analysis and Interpretation: Mahmoud Osama, Vaner Köksal, Mohammed Ali Alvi; Drafting the article: Mahmoud Osama, Vaner Köksal, Mohammed Ali Alvi; Critically revising the article: Mahmoud Osama, Vaner Köksal, Mohammed Ali Alvi; Reviewing submitted version of manuscript: Mahmoud Osama, Vaner Köksal, Mohammed Ali Alvi; Approving

| Study | Year | Patient (Age/Sex) | Diagnosis | Surgical Approach | Outcome |
|-------|------|-------------------|-----------|-------------------|---------|
| Ellger et al. [90] | 2006 | 59/F | T2 ISCH | T2 posterior hemilaminectomy; T3 partial hemilaminectomy | IR |
| Sani et al. [91] | 2005 | 75/F | C3 to C7 severe canal stenosis | Cervical laminectomy | IR |
| Kim et al. [92] | 2005 | 72/F | T8-T9 Thoracic subpial intramedullary schwannoma | T8-T9 osteoplastic laminotomy | CR |
| Rivas et al. [93] | 2004 | 49/M | T6-T7 SSCH | T6-T7 laminectomy | IR |
| Mastronardi et al. [94] | 2004 | #/M | C5-C6 CDH | ACDF | IR |
| Chang et al. [95] | 2003 | 50/M | T7-T8 neurenteric cyst | Thoracic laminectomy | CR |
| Kobayashi et al. [96] | 2003 | 64/M | C5-C6 CDH spondylosis | C5-C6 ACDF | CR |
| Kobayashi et al. [96] | 2003 | 39/M | C2-C3 CDH spondylosis | C2-C3 ACDF | CR |
| Sagiuchi et al. [97] | 2003 | 48/M | T7-T8 ISCH + calcified CDH | T7-T8 laminectomy | CR |
| Abe et al. [98] | 2003 | 17/M | Cervical kyphosis secondary to neurofibromatosis (flattened spinal cord) | ACDF | CR |
| Cellerin et al. [99] | 2002 | 53/M | T8–T9 ISCH | T8–T9 laminectomy | IR |
| Cellerin et al. [99] | 2002 | 37/F | T4–T5 ISCH | T4–T5 costotransversectomy | CR |

Abbreviations: CR: Complete Recovery; IR: Incomplete Recovery; ACCF: Anterior Cervical Corpectomy and Fusion; ACDF: Anterior Cervical Discectomy and Fusion; ISCH: Idiopathic Spinal Cord Herniation; ISCM: Intramedullary Spinal Cord Metastasis; SSCH: Spontaneous Spinal Cord Herniation; SSEH: Spontaneous Spinal Epidural Hematoma.
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Conflict of interest
The authors have no conflict of interest to declare.

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