Ischemic Stroke Secondary to Dynamic Vertebral Artery Stenosis: Case Report and Review of the Literature

Mohammed K. Bukhari 1, 2, Saeed A. Alghamdi 3, 1, 2

Abstract

Ischemic stroke secondary to dynamic vertebral artery stenosis or occlusion, also known as "bow hunter’s syndrome," is a rare stroke mechanism. We report a case of a 24-year-old man with multiple hereditary exostoses (MHE) diagnosed at childhood. His first presentation to a neurologist was due to neck pain and clinical syndrome suggestive of ischemia in the vertebrobasilar territory. A therapeutic occlusion was done successfully without complication. Moreover, this stroke mechanism has been reported extensively in the literature in isolation or secondary to many underlying diseases. In total, there are 168 cases reported in the published English literature, in either case reports or small series. In this review, we found that by far, vertebral artery occlusion at the atlanto-axial (C1–2) level dominated most reported cases. The most frequent presentation that led to further investigation was syncope or pre-syncope provoked by head rotation to one side. To our knowledge, there is no previous report of any stroke syndrome related to MHE before our case. In this paper, we report the first case secondary to MHE and review the literature up to date since the first reported case in 1952.

Keywords: ischemic stroke, dynamic vertebral artery stenosis, vertebral artery occlusion, bow hunter syndrome, vertebral artery compression, stroke

Introduction

Strokes in the vertebrobasilar territory are commonly due to diseases affecting the vessels, such as atherosclerosis, penetrating small-vessel disease, or arterial dissection [1]. Conversely, non-traumatic dynamic rotational occlusion of the vertebral arteries causing an ischemic stroke or recurrent transient ischemic attack (TIA) is very rare. In 1978, the term bow hunter’s stroke was introduced to describe this stroke mechanism [2]. Some of the common symptoms that occur with this syndrome with head rotation are dizziness, nystagmus, and syncope [3]. Since there are no guidelines for the diagnosis of this syndrome, clinicians use different imaging modalities such as cerebral angiogram, magnetic resonance angiography, ultrasonography, or computed tomography angiography [3]. Moreover, the treatment for this syndrome is conservative management that includes neck immobilization or invasive treatment like surgical decompression.

We will present a case of a young man with multiple hereditary exostoses (MHE) diagnosed during childhood, presenting with a minor ischemic stroke followed by TIA related to head rotation. His vascular imaging revealed a dynamic severe narrowing of the left vertebral artery on head-turning to the right, with reproducibility of his symptoms. He was treated by endovascular occlusion of the culprit vessel.

Case Presentation

A 24-year-old man with MHE was diagnosed in childhood. His syndrome is the result of a de novo gene mutation and has been associated with multiple exostoses (also known as osteochondroma) mainly involving his extremities. He underwent several surgeries in the past to remove these bony lesions that have caused minor disability and moderate pain. He had no established stroke risk factors and has been otherwise healthy.

His first presentation to a neurologist was two weeks prior to admission. This was when he presented with neck pain and clinical syndrome suggestive of ischemia in the vertebrobasilar territory. He denied any history of trauma or neck manipulation. His main neurological finding at that time was persistent limb ataxia on the left side. His cranial computed tomography (CT) and CT angiography (CTA) reported no parenchymal or vascular abnormality. However, it showed multiple exostoses growing of his vertebrae at C1–C2 level with narrowing of the vertebral canal. MRI with diffusion-weighted images (DWI) showed restricted diffusion in the left cerebellum and right thalamus. He was discharged on aspirin and scheduled for follow-
up. One week after his discharge, he presented to our institution complaining of recurrent isolated spells of loss of vision on the left visual field. His neurological examination showed left superior homonymous quadrantanopsia that lasted only a few hours. On the contrary, the left arm ataxia persisted. Repeat CT of the head showed no evolution of the previous stroke, and CTA demonstrated a left vertebral artery dissection at C2 level. The vertebral exostoses were impinging on the vessel and causing significant narrowing (Figures 1, 2). His neck was immobilized, clopidogrel was added to aspirin, and later he was anticoagulated with fractionated heparin as he continued to experience TIAs manifested by recurrent left quadrantanopsia, left facial numbness, and worsening of limb ataxia on the left while being on dual antiplatelets. A new MRI of the head showed no new infarcts and confirmed the presence of the previously reported restricted diffusion in the left cerebellum and right thalamus (Figures 3, 4). Surgical decompression on his cervical spine was deferred because it was considered a high-risk operation. Thus, the decision was made to perform a cerebral angiogram for consideration of left vertebral artery sacrifice/occlusion. The angiogram confirmed the dynamic nature of the left vertebral artery narrowing with severe stenosis on head-turning to the right (Figures 5, 6). A therapeutic occlusion by a detachable balloon with prior balloon test occlusion was done successfully without any complication. The patient was discharged two days later on aspirin alone. In follow up one year later he continued to be symptom free.

**FIGURE 1:** CT angiography (CTA) axial view shows severe narrowing of the left vertebral artery at C2 level with possible dissection (arrow).
FIGURE 2: CT angiography (CTA) coronal view, shows severe narrowing of the left vertebral artery at C2 level with possible dissection (arrow).
FIGURE 3: MRI of the brain with diffusion-weighted images (DWI) shows small infarctions at the left cerebellum.
FIGURE 4: MRI of the brain with T2 weighted image shows small infarctions at the right thalamus.
FIGURE 5: Cerebral angiogram with head in the neutral position.
Discussion

Vertebral artery dissection is a common mechanism for vertebrobasilar strokes especially in the young population [4]. Other rare mechanisms have been described and one of them is the dynamic occlusion of the vertebral artery on head rotation. In a study of 1108 patients undergoing cerebral angiogram for different indications, rotational occlusion of either vertebral artery happened in 5% of the patients. Not all of them were symptomatic and the most predictive symptoms for positive angiogram were fainting and dimming of vision [5]. Husni et al. found that in 23 symptomatic patients with rotational occlusion of either vertebral artery, the other one would be either hypoplastic (22 patients) or critically narrowed at its origin (one patient) [6].

Probably the first described case was the one by Ford in 1952. He described a patient with syncope, vertigo, and disturbed vision provoked by voluntary head rotation. The proposed mechanism was intermittent obstruction of the vertebral artery due to a defect in the odontoid process and excessive mobility of the second cervical vertebra [7]. In 1978 a paper describing vertebrobasilar stroke caused by a similar mechanism in a man while practicing archery introduced the term "bow hunter’s stroke," which was later adopted in most similar reports in the literature [2]. Many case reports or small series have been published since then, describing patients with different vertebrobasilar stroke syndromes sharing the same mechanism related to head rotational movement. We will list and summarize the findings of those cases published in English at Medline since the case of Sorensen [2] in 1978 (Table 1). In total, there are 168 cases reported in the English literature, in either case reports or small series. In this review, we chose to include only the cases that documented dynamic and symptomatic occlusion of the vertebral artery by cerebral angiogram. Only one case that did not respect this criteria and CTA was the only study performed is included [8]. Although some papers proposed a definition that would only include cases with vertebral artery occlusion at the atlanto-axial level, we thought differently as some other reviewers did and included cases where the vessel was involved at lower cervical or even higher (cranio-cervical junction) levels.

In this review, we found that by far, vertebral artery occlusion at the atlanto-axial (C1-2) level dominated most reported cases 100 out of 168 (59.52%). The remaining reports describe cases where the vessel...
occlusion happened at the lower cervical spine level, except two reports that described occlusion due to obstruction at cranio-cervical junction [9,10]. The most frequent presentation that led to further investigation was syncope or pre-syncope provoked by head rotation to one side. Conservative management with antiplatelet or anticoagulant therapy and sometimes with neck immobilization was the option in 23.21%. Only 3.6% of them failed this approach and required some intervention with either fusion or decompressive surgery. In those where the outcome of treatment was reported during follow-up 144 cases out of 168 (85.7%), the surgical intervention by either fusion or decompressive surgery was favorable compared to conservative therapy. Moreover, recurrent symptoms occur in 5%, and stroke happening in 2.4%. We should not draw firm conclusions from this comparison given that most of the literature on this subject is coming from the surgical field and the potential for publication bias is high. Endovascular interventions were only reported in nine cases. The cases treated with endovascular stent are five [11-15]. Moreover, there are four cases treated with coil embolization [16-19].

Many different etiologies were reported causing the external compression of the vertebral artery. Instability or subluxation of the cervical uncovertebral joint at different levels due to degenerative spine disease, rheumatoid arthritis, or trauma was the most common [8,20-25]. Traumatic fracture of the atlas was reported in one case [26]. Some of the other etiologies include longus colli muscle hypertrophy [27], disc herniation [28], occipital bone osseous anomaly [9,10], thick fibrous band [29], cervical vertebra osseous anomalies [30,31], tortuosity in the V1 segment [11], osteophyte formation [32-37], schwannoma [38], congenital bilateral C2 transverse foramina stenosis [39], thyroid cartilage compression [40], facet hypertrophy at C4-5 and associated spondylolisthesis [41], and congenital C2-C3 fusion [42].

Hereditary multiple exostoses (HME) is a genetic bone disease characterized by the development of benign bone tumors and exostoses [osteochondromas] growing off the metaphysis of long bones. It is caused by a mutation in the EXT1 or EXT2 genes, which are both tumor suppressor genes. Most cases are inherited in autosomal dominant trait, and sporadic cases are less often [43]. The most common level for spinal involvement in HME is at C2 level. Neurological complications of this disease are all related to tissue compression by the enlarging exostoses. Nerves, roots, and spinal cord compression have been reported [44]. We will list and summarize the findings of all published cases in English at Medline since the case of Sorensen in 1978 (Table 1). Therefore, to our knowledge, there is no previous report of any stroke syndrome related to HME before our case.

| Author                  | Year | No. of cases | Sex | Age | Presentation                        | Side | Level       | Imaging                          | Treatment                      | Follow up | Prognosis |
|-------------------------|------|--------------|-----|-----|-------------------------------------|------|-------------|---------------------------------|--------------------------------|-----------|-----------|
| Sorensen [2]            | 1978 | 1            | M   | 39  | Lateral Medullary syndrome          | RV   | C1-C2       | Cerebral angiogram               | Conservative                   | 2 w       | Good      |
| Kojima et al [27]       | 1985 | 1            | M   | 64  | Rotational Syncope                 | RV   | C3-C7       | Cerebral angiogram               | Surgical decompression         | 1.5 yrs   | Good      |
| Yang et al [40]         | 1985 | 2            | M   | 58  | Episodic blindness & Paroxysms     | L    | All C1-C2   | Cerebral angiogram               | All Cerebral angiogram          | Both 6 m  | Good      |
| Shintaku et al [42]     | 1986 | 1            | M   | 37  | Bilateral Cervical strokes          | LV   | C1-C2       | Cerebral angiogram               | Surgical decompression         | 2 yrs     | Good      |
| Hanakita et al [31]     | 1988 | 3            | F   | 53  | Rotational Vertigo & Syncope       | LV   | All C1-C2   | Cerebral angiogram               | All Surgical decompression      | 2 yrs     | Good      |
| Fox et al [40]          | 1988 | 1            | F   | 33  | Tinnitus, syncope                  | L    | C1-C2       | Cerebral angiogram               | Surgical decompression         | 6 m       | Good      |
| Motomizu et al [44]     | 1996 | 1            | M   | 70  | Rotational vertigo and Syncope     | L    | All C1-C2   | 3D CTA & Intraventricular angiogram | C1-2 fixation                   | N/A       | Good      |
| Mollerus et al [31]     | 1997 | 17           | F   | 61  | 7 vertigo & Dizziness 5 syncpe 1 numbness | 5 RV | All C1-C2   | 3D CTA & Intraventricular angiogram | 8 fusion at C1-2 9 Surgical decompression | Variable  | Variable  |
| Kawaguchi et al [29]    | 1997 | 1            | M   | 56  | Rotational blindness               | TV   | C4-C5       | Cerebral angiogram               | Surgical decompression         | N/A       | Good      |

In the decompression arm, 2 had recurrent symptoms, and 1 had cerebellar infarction.
| Authors           | Year | Gender | Age | Symptoms                      | Site | Imaging Tests                          | Procedure                          | Duration | Outcome |
|------------------|------|--------|-----|-------------------------------|------|---------------------------------------|-------------------------------------|---------|---------|
| Matsuyama et al  | 1997 | M      | 71  | Vertigo Syncope               | LV   | C1-C2 3D CTA & Cerebral angiogram    | C1-2 fusion                        | N/A     | Good    |
| Kim et al        | 1999 | N/A    | N/A | Vertigo Paresthesia           | BV   | R C5-G & L C1-2 Cerebral angiogram   | C5-6 fusion                        | N/A     | Good    |
| Shirasu S        | 1999 | M      | 53  | Vertigo and fainting          | LV   | Atlas Cerebral angiogram, 3D CTA, and CT. | Surgical-Decompression              | N/A     | Good    |
| Seki et al        | 1999 | M      | 39  | Rotational Syncope            | RV   | C1-C2 3D CTA & Cerebral angiogram   | Conservative                        | N/A     | N/A     |
| Seki et al        | 2001 | M      | 47  | Rotational Syncope            | LV   | C1-C2 Cerebral angiogram             | Surgical-decompression              | 6 m     | Good    |
| Vales et al       | 2002 | M      | 56  | Rotational Syncope            | LV   | C4-C5 Cerebral angiogram & TCD      | Decompression                       | 6 w     | Good    |
| Horinaka et al   | 2002 | M      | 85  | Rotational Syncope            | RV   | C1-C2 Cerebral angiogram & TCD      | Conservative                        | N/A     | N/A     |
| Tominaga et al   | 2002 | M      | 34  | Recurrent strokes             | LV   | CVJ Cerebral angiogram               | Surgical-decompression              | N/A     | Good    |
| Shimizu S        | 2003 | F/M    | 54  | Vertigo and fainting          | LV   | C1-C2 Cerebral angiogram and doppler ultrasonography | C1-C2 posterior fixation with decompression. | N/A     | N/A     |
| Nishida et al     | 2005 | M      | 54  | Rotational Syncope            | LV   | C1-C2 Cerebral angiogram             | Surgical-decompression              | 2 yrs   | Good    |
| Iguchi et al      | 2006 | M      | 45  | Rotational syncope            | RV   | C2-C3 Cerebral angiogram & TCD      | Conservative                        | N/A     | Good    |
| Velat et al       | 2006 | M      | 50  | Rotational syncope            | LV   | C5-G Cerebral angiogram              | Surgical-decompression              | 4 w     | Good    |
| Bulsara et al     | 2006 | M      | 55  | Rotational syncope            | RV   | C5-G 3D CTA & Cerebral angiogram    | Obstructive and foraminal decompression | 6 w     | Good    |
| Whitmore et al    | 2007 | M      | 87  | Rotational syncope            | LV   | C1-C2 Cerebral angiogram & TCD      | Surgical-decompression              | 6 m     | Good    |
| Tsuchiya et al    | 2008 | M      | 59  | Rotational syncope            | BV   | R C6 L C6 Cerebral angiogram & TCD  | C5-7 fusion                        | N/A     | Good    |
| Kim et al         | 2008 | M      | 60  | Rotational dizziness          | RV   | C2-C3 3D CTA & Cerebral angiogram   | Surgical-decompression              | 1 m     | Good    |
| Male et al        | 2008 | M      | 48  | Rotational syncope            | LV   | C4-C5 Cerebral angiogram             | Dissectomy and fusion               | N/A     | Good    |
| Sugita et al      | 2009 | M      | 56  | Rotational syncope            | RV   | C1-C2 Cerebral angiogram             | Standing dizziness in LV            | 6 m     | Good    |
| Liu et al         | 2009 | M      | 12  | R thalamic stroke             | RV   | CVJ Cerebral angiogram               | Surgical-decompression              | 6 m     | Good    |
| Natello et al     | 2009 | M      | 76  | Rotational syncope            | RV   | C4-G Cerebral angiogram              | Standing RV intrasellar             | N/A     | Good    |
| Chough et al      | 2010 | F      | 71  | Rotational vertigo            | LV   | C1-C2 Cerebral angiogram             | C1-2 fusion                        | N/A     | Good    |
| Sabo et al        | 2010 | M      | 7   | Recurrent strokes             | LV   | C1-C2 Cerebral angiogram & TCD      | Vert Thrombus                       | C1-2 fusion | Good    |
| Last Name et al | Year | Sex | Age | Symptoms | Imaging | Treatment | Outcome | Duration |
|----------------|------|-----|-----|----------|---------|-----------|---------|----------|
| Geiser et al   | 2010 | M   | 15  | Recurrent strokes | RV | C1-C2 | 3D CTA & Cerebral angiogram | Conservative then Surgical decompression | 3 m | Good |
| Sato et al     | 2010 | M   | 66  | Recurrent strokes | RV | C1-C2 | 3D CTA & Cerebral angiogram and TCD | Conservative | 1 y | Recurrent asymptomatic stroke |
| Yoshimura et al | 2011 | M   | 64  | Rotational syncope, vertigo, and diplopia | BV | R: C3-C4 L: C1-C2 | 3D CTA & Cerebral angiogram | Conservative then dissection and fusion at C3-4 | 3 m | Good |
| Dankibanti et al | 2011 | 4 M | 69  | Mean | 3 LV 1 RV | N/A | dynamic digital subtraction angiography (DSA) | All stent placement in V2 and 1 had another V1 stent. | Mean 6 m | All good |
| Saka et al     | 2011 | M   | 16  | Recurrent strokes | LV | C1 | 3D CTA & Cerebral angiogram | Coil embolization of the left VA | 10 m | Good |
| Lee et al      | 2012 | F   | 18  | Cerebellar stroke | LV | C1-C2 | CTA | Surgical decompression followed by Conservative | N/A | Both good |
| Anderekken et al | 2012 | F   | 86  | Rotational vertigo, vomiting, and syncope | LV | C5-C6 | CTA, MRA, and ultrasound | Surgical decompression | 6 m | Good |
| Verma et al    | 2012 | M   | 47  | Neck pain | RV | C1-C2 | MRA & Cerebral angiogram | Conservative | N/A | N/A |
| Feijen et al   | 2012 | M   | 70  | Recurrent strokes | LV | C1-C2 | Cerebral angiogram | C1-2 fusion | N/A | Good |
| Cornélia et al | 2012 | 5 F | 24  | Vertigo, blurred vision, syncope, and tinnitus | 3 LV 2 BV | All C1-C2 | All Cerebral angiogram | 3 Surgical decompression 3 Fusion | 1 for 7 m | All Good |
| Dargon et al   | 2012 | M   | 53  | Rotational syncope | BV | R: C4-C5 L: C1-C2 | TCD & Cerebral angiogram | Surgical decompression of RV | 6 m | Good |
| Ding D [4]     | 2013 | F   | 43  | Rotational pre-syncope and syncope | LV | C4-C5 | Cerebral angiogram and CTA | Surgical decompression | N/A | Good |
| Ge [2]         | 2013 | 2 F | 30 42 | Rotational vertigo, dizziness, right upper extremity tingling, numbness, and syncope. | 2 LV | C1-C1-C2 | CT angiography and Cerebral angiogram | 2 Surgical decompression | 2 N/A | 2 Good |
| Pioli I [60]   | 2013 | M   | 27  | Rotational vertigo and dizziness | RV | C6-C7 | MRA and dynamic angiogram | Cervical arthrodiesis. | 15 m | Good |
| Inamae et al   | 2013 | M   | 22  | Cerebellar stroke | RV | C1-C2 | CTA & Cerebral angiogram | C1-2 fusion | 9 m | Good |
| Fleming et al  | 2013 | M   | 54  | Rotational syncope, vertigo, and tinnitus | BV | C4-C5 | CTA & Cerebral angiogram | Surgical decompression of BV and fusion | 3 m | Good |
| Anane-Madick T | 2013 | M   | 16  | Right sided numbness, dysphagia, and right peripheral visual field loss | RV | C1 | CTA, Cerebral angiogram, and MRA | Conservative then surgical decompression then coil embolization in the RV. | 3 m | Good but with some residuals |
| Choi et al     | 2013 | S F | Mean | 6 RV 6 LV | All C1-C2 | Central Angiogram | 10 Conservative 2 Fusion | M r | 10 good 2 strokes |
| Zeid et al     | 2014 | S F | 58  | Rotational syncope, vertigo, and diplopia | 3 RV 3 LV | C1-C2 & C5-C7 | Central Angiogram | 2 Conservative 2 Surgical decompression | Mean 9 m | All good |
| Author | Year | N | Gender | Age | Symptoms | Imaging | Treatment | Follow-up | Outcome |
|--------|------|---|--------|-----|----------|---------|-----------|-----------|---------|
| Anaizi AN | 2014 | 1 | F | 68 | Persistent nystagmus, disorientation, loss of balance, and occasional loss of consciousness. | MRI, MRA, and intraoperative fluorescent angiography. | Surgical removal of ventral osteophyte then, decompression and mobilization of left vertebral artery. | 2 m | Good |
| Sehur J | 2014 | 1 | M | 27 | Near syncope, tunnel vision, somnolence, and roaring in the ears. | Duplex ultrasonography, CTA, formal dynamic angiogram, and MRA. | Conservative. | N/A | Good |
| Ikeda DS | 2014 | 1 | M | 44 | Continued positional tinnitus, vertigo, nausea, and stroke. | CT, MRI, standard and dynamic diagnostic cerebral arteriography. | Surgical decompression. | 3 m | Good |
| Selen MG | 2014 | 1 | F | 37 | Vertigo, tightness in the right occipital region of her head, headaches | CT, MRI, standard and dynamic diagnostic cerebral arteriography. | Surgical decompression. | 15 m | Good |
| Takeshima Y | 2014 | 1 | F | 18 | Headache. | 3D CTA and MRI. | Left-side Southwick-Robinson anteromedial approach, followed by an anterior cervical disectomy and fusion. | 22 m | Good |
| Buchanan GC | 2014 | 1 | M | 35 | Dizziness, extremity weakness. | MRI, CTA, and cervical and vertebrobasilar angiography, and CT. | Surgical decompression and fusion. | 6 m | Good |
| Sasahara S | 2015 | 1 | M | 45 | Rotation vertigo, visual blurring, nystagmus, and tunnel vision. | MRI, CTA, and digital subtraction angiography. | Surgical decompression and fusion. | 24 m | Good |
| Schielke S | 2015 | 1 | M | 60 | Near syncope, nausea, vertigo, and unsteadiness of gait. | CTA and MRA. | Lateral Southwick-Robinson anteromedial approach, followed by an anterior cervical disectomy and fusion. | 1 yrs | Good |
| Yamazaki Y | 2015 | 1 | M | 45 | Dizziness, vertigo, headache, and tinnitus. | MRI, MRA, dynamic angioangiography, and digital subtraction angiography. | Surgical decompression and fusion. | N/A | N/A |
| Ravindra VM | 2015 | 3 | 1 F | Mean 52 | Syncope, dizziness, dysphagia, and right arm weakness. | 1-CTV 1 Right PICA 2 V3 3 V4 4 RICA 5 V1-5 V2 | MRI, MRA, CTA, and ultrasound. | 1 y | Good |
| Jost GF | 2015 | 2 | 1 M | Mean 51 | Syncope, loss of vision, dizziness, and fainting spells. | MRI and dynamic angiography. | Surgical decompression and fusion for both. | 6 m N/A | Minor symptom. Neck pain and stiffness. |
| Healy AT | 2015 | 1 | M | 58 | Persistent cervicalgia, persistent nystagmus, and vertigo. | MRI, CT, Doppler ultrasound, and dynamic vascular angiography. | Laminectomy and fusion from C2–C6 bilaterally. | 1 y | Good |
| Okawa M | 2015 | 1 | F | 31 | Dizziness, headache, and vomiting. | MRI, MRA, and 3D CTA. | Surgical decompression. | 1 m | Good |
| Takeshima H | 2015 | 1 | M | 40 | Dizziness, headache, and vomiting. | CT, MRI, and angiography. | Decompression with conservative therapy. | N/A | Good |

2021 Bukhari et al. Cureus 13(12): e20167. DOI 10.7759/cureus.20167
| Reference | Year | Age | Gender | Diagnosis | Imaging Modalities | Treatment | Outcome |
|-----------|------|-----|--------|-----------|-------------------|------------|---------|
| Thomas B [16] | 2015 | 60 | M | Recurrent transient ischemic attacks | 3D CTA, CTA, MRI, dynamic angiogram | Conservative then endovascular coil embolization | Good |
| Nguyen HS [18] | 2015 | 52 | M | Recurrent transient ischemic attacks | 3D CTA, MRI, dynamic angiogram and MR | Surgical decompression of the vertebral artery | Good |
| Chaudhry NA [18] | 2016 | 1 | F | Mean 17.5 | 3D CTA, C5-C6 C4-C6 | Conservative then endovascular coil embolization | Good |
| Kageyama H [86] | 2016 | 17.5 | M | Partial visual field defect and visual disturbance | MRI, MRA, X-ray angiography | Posterior fixation both | Good |
| Ariyoshi T [87] | 2016 | 62 | M | Rotational vertigo and pre-syncope | Ultrasound, Digital subtraction angiography and 3D CTA | Conservative | N/A | N/A |
| Brinjikji W [88] | 2016 | 60 | M | Rotational vertigo, tinnitus, blurred vision, left hemisbody numbness, and occasional syncope | CT, CTA, digital subtraction angiography | Surgical decompression | N/A | Good |
| Felbaum DR [89] | 2017 | 50 | M | Rotational vertigo, neck pain, and near-syncopal episodes | MRI, dynamic x-rays, CTA, and Digital subtraction angiography | Instrumentation from C2 to T2 | 1 yrs | Good |
| Buch VP [90] | 2017 | 38 | M | Rotational dizziness and pre-syncope | CT, CTA, MRI, digital subtraction angiography | Surgical decompression | N/A | Good |
| Lee T[91] | 2017 | 71 | M | Rotational vertigo, neck pain, and syncope | C4-C5 | Surgical decompression | 1 yrs | Good |
| Hamada S [92] | 2017 | 71 | M | Rotational dizziness and loss of consciousness | C5-C6 | Surgical decompression and removal of the bony mass | 6 m | Good |
| Motiei-Langroudi R [11] | 2017 | 61 | M | Rotational lightheadedness | MRI, CTA, and digital subtraction angiography | Conservative then stent | 3.5 m | Good |
| Bert AF [93] | 2017 | 56 | M | Rotational vertigo, nausea, and diplopia | C4-C5 | Endovascular deconstruction | 6 m | Good |
| Simkin CT [94] | 2017 | 59 | M | Rotational dizziness | C1 | MRI, CTA, and digital subtraction angiography | Conservative then surgical decompression | 6 m | Good |
| Yaghi H [95] | 2017 | 74 | M | Ischemic embolic stroke, vertigo, and visual deficit | C4-C5 | Digital subtraction angiography, CTA, and dynamic imaging | Conservative then surgical decompression | 8 m | Good |
| Klahnra H [96] | 2017 | 83 | F | Dizziness | C1 | CTA, and MR | Conservatively | N/A | N/A |
| Johnson SA [97] | 2017 | 42 | M | Transient right hemiparesis and right-sided vision loss | C4-C5 | Digital subtraction angiography, CTA, and dynamic imaging | Conservative then surgical decompression | 8 m | Good |
| Godfard A [98] | 2017 | 41 | M | Rotational dizziness | C2 | CTA and MRI | Conservatively | N/A | N/A |
| Name          | Age | Gender | Presentation | Imaging | Treatment | Duration | Outcome |
|---------------|-----|--------|--------------|---------|-----------|----------|---------|
| Bergl PA      | 62  | M      | Rotational dizziness | LV, C7 | CTA, angiography, and MRA | Surgical fixation and fusion | N/A     |
| Iida Y         | 65  | M      | Dizziness and downbeat nystagmus | LV, C3-C4 | MRI, MRA, and Digital subtraction angiography | Surgical decompression and fusion | N/A     |
| Albertson AJ   | 84  | F      | Vertigo and postural instability | LV, C1 | X-ray, CT, CTA, MRI, and MRA | Discharge | N/A     |
| Lukashnikov V  | 34  | M      | Dizziness and loss of consciousness | LV, C1 | CTA, and CT neuronavigation | Surgical decompression | 6 m     |
| Schuerman V     | 80  | M      | Dizziness and loss of consciousness | LV, C3 | CTA, MRI, and dynamic cerebral angiography | Surgical decompression and fusion | Several months     |
| Ng S           | 70  | M      | Dizziness, vertigo, fainting, and syncope | LV, C3-C4 | Dynamic CTA, TCD, and Digital subtraction angiography | Surgical decompression | 8 m     |
| Jorde JN       | 24  | M      | Rotational preyncope and disorientation | LV, C1-C3 | MRA, CTA, MRI, and dynamic X-rays | Conservative | 3 m     |
| Komeda T       | 36  | M      | Rotational preyncope and loss of consciousness | LV, C1 | MRI, CTA | Surgical inferior retrobulbar decompression | 4 y     |
| Cornelius AY   | 48  | M      | Blurring of vision and syncope | LV, C6-C7 | MRI, MRA, CT, TCD, and CTA | Surgical decompression | 4 m     |
| Cai DZ         | 40  | M      | Rotational preyncope | LV, C3-C4 | CTA and MRA | Cervical dissection and fusion | 4 m     |
| Kothe KE       | 54  | M      | Nausea, vomiting, vertigo | LV, C1-C2 | Compression by the posterior arch of the atlantoaxial ligament | Laryngoplasty | 2 m     |
| Koo P          | 65  | M      | Transient right-sided weakness and loss of consciousness | LV, C1-C2 | MRI and 3D CTA | Surgical decompression and fusion | 1 m     |
| Gerik S        | 36  | M      | Rotational dizziness | LV, C1-C2 | MRI and 3D CTA | Surgical decompression and fusion | 1 y     |
| Park JH        | 55  | M      | Recurrent vertigo and syncope | LV, C4-C5 | MRI, CT, dynamic angiography, and CTA | Surgical decompression and fusion | N/A     |
| Mori M         | 43  | F      | Rotational mid/sidest pain, dizziness, and vertigo | LV, C6-C7 | Doppler ultrasonography, MRI, angiography, 3D CTA, and MRA | she underwent tumor resection with facetectomy and fusion | 6 m     |
| Hernandez RN   | 49  | F      | Vague neck pain and severe vertigo, nausea, and near syncope | LV, C1-C2 | MRI and CTA | Surgical decompression and fusion | 6 m     |
| Cohen N        | 2   | F      | Transient episode of left-side weakness | LV, C1-C2 | Central angiogram and CT | Conservative | N/A     |
| Takeda K       | 56  | M      | Visual blurriness, dizziness, and nausea | LV, C1-C2 | MRA, CTA, and cervical digital subtraction angiography | Endovascular occlusion of the culprit left VA by coil embolization | 9 m     |
TABLE 1: Summary of all cases of bow hunter’s syndrome reported in the English literature since the first case described by Sorensen in 1978.

| Authors | Year | Age | Sex | Symptoms | Vascular Imaging | Surgical Procedures | Outcome |
|---------|------|-----|-----|----------|------------------|---------------------|---------|
| Bando K | 2020 | 13  | F   | Transient visual disturbance, hypoesthesia, and paralysis of the left side of the body. | LV C1-C2 | MRI, MRA, and X-ray | C1-C2 surgical fusion | 8 m | Good |
| Qashqari H | 2020 | 6  | F   | Headache and fluctuating right-sided weakness. | BV C1-C2 C2-C3 | MRA and Dynamic angiogram | Conservative | 2 y | Stable |
| Shi C | 2020 | 19 | M   | Dizziness, binocular blackness, and disturbance of consciousness. | RV C2 | MRI and Dynamic CTA | Conservative | N/A | Good |
| Yasuyuki Nomura | 2020 | 47 | F   | Rotational vertigo, nausea, nystagmus, and dullness of the right arm. | RV N/A | MRI, MRA, and 3D-CT | Conservative | N/A | Good |
| Montano M | 2021 | 79 | F   | Rotational pre-syncope, lightheadedness, a ringing in her ears, and darkening of her vision. | LV C4-C5 | CTA, Dynamic provocative cerebral angiography, and MRI | Cervical spine decompression at C4-5 with anterior cervical disectomy and fusion, but he is now on conservative treatment | N/A | N/A |

$ Reported immediate outcome in all cases and further follow up in few of them.

* Only 12 out of 21 in the report were typical cases.

The stroke mechanism in our patient is interesting because either vascular injury in the form of vertebral artery dissection or dynamic stenosis of the vessel on head rotation could explain his symptoms. However, more likely both mechanisms have been responsible for his clinical course, with the initial stroke being related to the dissection and the later TIA’s on head-turning related to the dynamic stenosis of the narrow and compromised vertebral artery.

Conclusions

Although rare, vertebrobasilar stroke can be caused by dynamic vascular occlusion or stenosis. The hallmark of this presentation is that head turning provokes symptoms. Once suspected, dynamic angiography should be done to confirm the diagnosis. Hereditary multiple exostoses can be associated with different neurological complications and ischemic stroke is one of them, which we believe that our case is the first one to report.

Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Caplan LR: Dissections of brain-supplying arteries. Nat Clin Pract Neurol. 2008, 4:34-42. 10.1038/ncpneuro0683
2. Sorensen BF: Bow hunter’s stroke. Neurosurgery. 1978, 2:259-61. 10.1227/00006123-19780500-00013
3. Go, G, Hwang SH, Park IS, Park H: Rotational vertebral artery compression: bow hunter's syndrome. J Korean Neurosurg Soc. 2015, 53:424-5. 10.5340/jkns.2015.53.4.245
4. Ferro JM, Massaro AR, Mat JL: Aetiological diagnosis of ischaemic stroke in young adults. Lancet Neurol. 2010, 9:1085-96. 10.1016/s1474-4422(10)70251-9
5. Sakaguchi M, Kitagawa K, Hougaki H, et al.: Mechanical compression of the extracranial vertebral artery during neck rotation. Neurology. 2005, 61:845-7. 10.1212/01.wnl.0000178081.12097.ae
6. Husni EA, Storer J: The syndrome of mechanical occlusion of the vertebral artery: further observations. Angiology. 1967, 18:106-16. 10.1177/000331976701800205
7. Ford FR: Syncpe, vertigo and disturbances of vision resulting from intermittent obstruction of the vertebral arteries due to defect in the odontoid process and excessive mobility of the second cervical vertebra. Bull Johns Hopkins Hosp. 1953, 91:168-73.
8. Shetty SR, Shankaraiah BA, Hegde T, Nagaraiah RK: Bow hunter's stroke - a rare presentation of CV junction anomaly: case report. Neurol India. 2012, 60:520-1. 10.4103/0003-3197-105204
9. Tominaga T, Takahashi T, Shimizu H, Yoshimoto T: Rotational vertebral artery occlusion from occipital bone anomaly: a rare cause of embolic stroke. Case report. J Neurosurg. 2002, 97:1456-9. 10.3171/jns.2002.97.6.1456
10. Lu DC, Gupta N, Mummaneni PV: Minimally invasive decompression of a suboccipital osseous prominence causing rotational vertebral artery occlusion. Case report. J Neurosurg Pediatr. 2009, 4:191-5. 10.3171/2009.3.PEDS08270
11. Motiei-Langroudi R, Griesensauer CJ, Alturki A, Adeeb N, Thomas AJ, Ogilvy CS: Bow hunter's syndrome from a tortuous T1 segment vertebral artery treated with stent placement. World Neurosurg. 2017, 98:878. 10.1016/j.wneu.2016.11.067
12. Sugiu K, Agari T, Tokunaga K, Nishida A, Date I: Endovascular treatment for bow hunter's syndrome: case report. Minim Invasive Neurosurg. 2009, 52:193-5. 10.1055/s-0029-1230501
13. Natello GW, Carroll CM, Katwal AB: Rotational verteobasilar ischemia due to vertebral artery dynamic stenoses complicated by an ostial atherosclerotic stenosis. Vasc Med. 2009, 14:265-9. 10.1177/1358863X08099707
14. Kan P, Srivatsan A, Johnson JN, Chen SR: Republished: Rotational carotid insufficiency: an unusual cause of bow hunter's syndrome. J Neurointerv Surg. 2019, 11:i99. 10.1136/neurintsurg-2018-014210.rep
15. Dardkerhani MZ, Thompson MC, Lazzaro MA, Taqji MA, Zaidat OO: Vertebral artery stenting for the treatment of bow hunter's syndrome: report of 4 cases. J Stroke Cerebrovas Dis. 2012, 21:908. 10.1016/j.jstrokecerebrovasdis.2011.09.006
16. Thomas B, Barreau X, Pointillart V, Siboni I, Renou P: Endovascular embolization of a nondominant vertebral artery compressed by an osteophyte to prevent recurrence of vertebrobasilar infarctions. J Stroke Cerebrovas Dis. 2015, 24:e257-9. 10.1016/j.jstrokecerebrovasdis.2015.03.035
17. Tanaka K, Steinfort B: Rare cause of bow hunter's syndrome due to an aberrant course of a vertebral artery. BMJ Case Rep. 2019, 12:10.1136/ber-j-2019-229584
18. Anene-Maidoh TI, Vega RA, Fautheree GL, Reavey-Cantwell JF: An unusual case of pediatric bow hunter's stroke. Surg Neurol Int. 2015, 4:148. 10.4103/2152-7806.121647
19. Sakamoto Y, Kimura K, Ichiji Y, Iwagana T, Toi H, Matsubara S, Uno M: An embolic bow hunter's stroke associated with anomaly of cervical spine. Neurology. 2011, 77:1405-4. 10.1212/01.wnl.0000387313.52152.99
20. Fujiiwara H, Kaito T, Makino T, Yonenobu K: An unusual case of pediatric bow hunter's stroke caused by a severe facet hypertrophy of C1-2 and bilateral suboccipital bony anomaly: case report. J Neurosurg Pediatr. 2009, 4:191-5. 10.3171/jns.2009.4.3.191
21. Kawaguchi T, Fujita S, Hosoda K, Shibata Y, Iwakura K, Iwakura M, Tamaki N: Bow hunter's stroke associated with an aberrant course of both vertebral arteries on CT angiography. J Vasc Surg. 2013, 58:1076-9. 10.1016/j.vasc.2013.01.079
22. Kimura T, Sako K, Tohyama Y, Hodozuka A: Bow hunter's stroke caused by simultaneous occlusion of both vertebral arteries. Acta Neurochir (Wien). 1999, 141:895-6. 10.1007/s007010050394
23. Saito K, Hirano M, Taoka T, et al.: Arterial-to-arterial embolism with a mobile mural thrombus due to rotational vertebral artery occlusion. J Neuroimaging. 2010, 20:284-6. 10.1177/1052081509343373
24. Shimizu S, Yamada M, Takagi H, Fujii K, Kan S: Bow hunter's stroke caused by an aberrant course of the vertebral artery--case report. Neurol Med Chir (Tokyo). 2008, 48:90-4. 10.1136/neurintsurg-2018-014210.rep
25. Kojima N, Tanami N, Fujita K, Matsumoto S: Vertebral artery occlusion at the narrowed ‘scalenevertebral angle’: mechanical vertebral artery occlusion in the distal first portion. Neurosurgery. 1985, 16:672-4. 10.1227/00006123-198505000-00017
26. Vates GE, Wang KC, Bonovich D, Dowd CF, Lawton MT: Bow hunter stroke caused by cervical disc herniation. Case report. J Neurosurg. 2002, 96:90-3. 10.3171/spi.2002.96.1.0090
27. Dargot PT, Liang CW, Kohal A, Dogan A, Barnwell SL, Landry GJ: Bilateral mechanical rotational vertebral artery occlusion. J Vasc Surg. 2015, 61:1076-9. 10.1016/j.vasurg.2012.12.044
28. Tsutsui S, Ito M, Yasumoto Y: Simultaneous bilateral vertebral artery occlusion in the lower cervical spine manifesting as bow hunter's syndrome. Neurol Med Chir (Tokyo). 2008, 48:90-4. 10.1136/neurintsurg-2018-014210.rep
29. Greiner HM, Abruzzo TA, Kabbouche M, Leach JL, Zeccaurolo M: Rotational vertebral artery occlusion in a child with multiple strokes: a case-based update. Childs Nerv Syst. 2010, 26:1669-74. 10.1007/s00381-010-1299-3
30. Bulsara KR, Velaz DA, Villavicencio A: Rotational vertebral artery insufficiency resulting from cervical spondylosis: case report and review of the literature. Surg Neurol. 2006, 65:625-7. 10.1016/j.surneu.2005.08.016
31. Chough CK, Cheng BC, Welch WC, Park CK: Bow hunter's stroke caused by a severe facet hypertrophy of C1-
6. Dynamic vertebral artery stenosis at the cranio-cervical junction—a management algorithm based on a
Cornelius JF, George B, N'dri Oka D, Spiriev T, Steiger HJ, Hänggi D: dissection
Yamaguchi Y, Nagasawa H, Yamakawa T, Kato T: degenerative spinal disorder syndrome associated with bony abnormalities of the C7 vertebra
Lee V, Riles TS, Stableford J, Berguer R: Insights Case Rep. 2010, 3:1-4.
Saito K, Hirano M, Taoka T, et al.: with an ultrasonic bone curette to treat bow hunter's syndrome
Kim K, Isu T, Morimoto D, Kominami S, Kobayashi S, Teramoto A: 6569.2006.00040.x
Iguchi Y, Kimura K, Shibazaki K, Iwanaga T, Ueno Y, Inoue T: of extracranial vertebral artery compression in bow hunter's brain ischemia caused by neck rotation
Kamouchi M, Kishikawa K, Matsuo R, Yasumori K, Inoue T, Okada Y, Ibayashi S: 10.1097/000071134.200112.0037
Matsuyama T, Morimoto T, Sakaki T: vertebral artery in the treatment of bow hunter's stroke
Seki T, Hida K, Akino M, Iwasaki Y: vertebrobasilar insufficiency causing stroke
Hanakita J, Miyake H, Nagayasu S, Nishi S, Suzuki T: symptomatic positional occlusion of the vertebral artery. Case report
Yang PJ, Latack JT, Gabrielsen TO, Knake JE, Gebarski SS, Chandler WF: osteochondroma
Pannier S, Legeai-Mallet L: Hereditary multiple exostoses and enchondromatosis
Qashqari H, Bhathal I, Pulcine E, et al.: vertebrobasilar insufficiency causing stroke
Karle WE, Buniel MC, Lutsep HL, Hamilton BE, Nesbit GM, Schindler JS: Thyroid cartilage compression causing stroke. Laryngoscope, 2019, 129:E445-8. 10.1002/lary.27837
Montano M, Alman K, Smith MI, Boghosian G, Enochs WS: Bow hunter’s syndrome: a rare cause of vertebralbasilar insufficiency. Radiol Case Rep. 2021, 16:867-70. 10.1016/j.radcr.2021.01.041
Qashqui H, Bhatal I, Puline E, et al.: Bow hunter syndrome: a rare yet important etiology of posterior circulation stroke. J Clin Neurosci. 2020, 78:418-9. 10.1016/j.jocn.2020.04.110
Kamatani S, Legesi-Mallet L: Hereditary multiple exostoses and enchondromatosis. Best Pract Res Clin Rheumatol. 2008, 22:45-54. 10.1016/j.berh.2007.12.004
Tian Y, Yuan W, Chen H, Shen X: Spinal cord compression secondary to a thoracic vertebrae osteochondroma. J Neurosurg Spine. 2011, 15:252-7. 10.3171/2011.3.SPINE10484
Yang PI, Latack JF, Gabrielson TO, Knake JE, Gebarski SS, Chandler WF: Rotational vertebral artery occlusion at C1-C2. AJNR Am J Neuroradiol. 1985, 6:96-100.
Shimizu T, Waga S, Kojima T, Niwa S: Decompression of the vertebral artery for bow-hunter’s stroke. Case report. J Neurosurg. 1988, 69:127-31. 10.3171/jns.1988.69.10127
Hanakita J, Miyake H, Nagayasu S, Nishi S, Suzuki T: Angiographic examination and surgical treatment of bow hunter’s stroke. Neurosurgery. 1988, 25:228-32. 10.1227/00006123-198806000-00018
Fox MW, Piegrass DG, Bartleson JD: Anterolateral decompression of the atlantoaxial vertebral artery for symptomatic positional occlusion of the vertebral artery. Case report. J Neurosurg. 1995, 83:737-40. 10.3171/jns.1995.83.4.0737
Morimoto T, Kaido T, Uchiyama Y, Tokunaga H, Sakati T, Iwasaki S: Rotational obstruction of nondominant vertebral artery and ischemia. Case report. J Neurosurg. 1996, 85:507-9. 10.1016/j.jns.1996.85.5.0507
Matsuyama T, Morimoto T, Sakati T: Comparison of C1–2 posterior fusion and decompression of the vertebral artery in the treatment of bow hunter’s stroke. J Neurosurg. 1997, 86:619-25. 10.3171/jns.1997.86.4.0619
Matsuyama T, Morimoto T, Sakati T: Usefulness of three-dimensional CT for bow hunter stroke. Acta Neurochir (Wien). 1997, 139:265-6. 10.1007/BF01844765
Sakai K, Tsutsui T: Bow hunter’s stroke associated with atlantooccipital assimilation--case report . Neurol Med Chir (Tokyo). 1999, 39:696-700. 10.2176/ncm.39.696
Seki T, Hida R, Akino M, Iwasaki Y: Anterior decompression of the atlantoaxial vertebral artery to treat bow hunter’s stroke: technical case report. Neurosurgery. 2001, 49:1474-6. 10.1097/00006123-200112000-00037
Horowitz M, Jovin T, Balarz J, Welch W, Kassam A: Bow hunter’s syndrome in the setting of contralateral vertebral artery stenosis: evaluation and treatment options. Spine (Phila Pa 1976). 2002, 27:E495-8. 10.1097/00007632-200210000-00015
Kamouchi M, Kishikawa K, Matsuo R, Yasumori K, Inoue T, Okada Y, Ibayashi S: Ultrasonographic detection of extracranial vertebral artery compression in bow hunter’s brain ischemia caused by neck rotation. Cerebrovasc Dis. 2005, 16:305-9. 10.1159/000071134
Netuuka D, Benes V, Mikulik R, Kuba R: Symptomatic rotational occlusion of the vertebral artery -- case report and review of the literature. Zentralbl Neurochir. 2005, 66:217-22. 10.1055/s-2005-856660
Iguchi Y, Kimura K, Shibazaki K, Iwana T, Ueno Y, Inoue T: Transcranial doppler and carotid duplex ultrasonography findings in bow hunter’s syndrome. J Neuroimaging. 2006, 16:278-80. 10.1111/j.1552-6569.2006.00040.x
Kim K, Isu T, Morimoto D, Kominami S, Kobayashi S, Teramoto A: Anterolateral vertebral artery decompression with an ultrasonic bone curette to treat bow hunter’s syndrome. Acta Neurochir (Wien). 2008, 150:301-3. 10.1007/s00701-008-1491-8
Saito K, Hirano M, Taoka T, et al.: Juvenile bow hunter’s stroke without hemodynamic changes. Clin Med Insights Case Rep. 2010, 5:1-4.
Lee V, Riles TS, Stableford J, Berguer R: Two case presentations and surgical management of bow hunter’s syndrome associated with bony abnormalities of the C7 vertebra. J Vasc Surg. 2011, 53:1581-5. 10.1016/j.vasurg.2010.11.095
Anderegg L, Arnold M, Andres RH, Raabe A, Reinert M, Gealla J: Bow hunter’s stroke due to prominent degenerative spiral disorder. Clin Neuroradiol. 2012, 22:555-8. 10.1007/s00626-012-0154-9
Yamaguchi Y, Nagasawa H, Yamakawa T, Kato T: Bow hunter’s syndrome after contralateral vertebral artery dissection. J Stroke Cerebrovasc Dis. 2012, 21:916. 10.1016/j.jstrokecerebrovasdis.2012.04.003
Cornelius JF, George B, N'dri Oka D, Spiriev T, Steiger HJ, Hänggi D: Bow-hunter’s syndrome caused by dynamic vertebral artery stenosis at the cranio-cervical junction—a management algorithm based on a systematic review and a clinical series. Neurosurg Rev. 2012, 35:127-35. 10.1007/s10143-011-0543-4
Ding D, Mehta GU, Medel R, Liu KC: Utility of intraoperative angiography during subaxial foramen
transversarium decompression for bow hunter’s syndrome. Interv Neurol. 2015, 19:240-4. 10.1177/15910199150190215

65. Pitohl I, Ramirez M, Saló G, Ros AM, Blanch AL: Symptomatic vertebral artery stenosis secondary to cervical spondylosis. Spine (Phil Pa 1976). 2015, 38:E1505-5. 10.1097/BRS.0b013e31825441a9

66. Choi KD, Choi JH, Kim JS, et al.: Rotational vertebral artery occlusion: mechanisms and long-term outcome. Stroke. 2013, 44:1817-24. 10.1161/STROKEAHA.113.001219

67. Zaidi HA, Albuquerque FC, Chowdhry SA, Zabramski JM, Ducruet AF, Spetzler RF: Diagnosis and management of bow hunter’s syndrome: 15-year experience at barrow neurological institute. World Neurosurg. 2014, 82:735-8. 10.1016/j.wneu.2014.02.027

68. Anzai AN, Sayyah A, Berkowitz M, McGraill K: Bow hunter’s syndrome: the use of dynamic magnetic resonance angiography and intraoperative fluorescent angiography. J Neurosurg Spine. 2014, 20:71-7. 10.3109/20728651.2013.9.SPINE121019

69. Sarkar J, Wolfe SQ, Ching BH, Kellicut DC: Bow hunter’s syndrome causing verteobasilar insufficiency in a young man with neck muscle hypertrophy. Ann Vasc Surg. 2014, 28:1032.e1-e10. 10.1016/j.avsg.2013.06.038

70. Ikeda DS, Villelli N, Shaw A, Powers C: Bow hunter’s syndrome unmasked after contralateral vertebral artery sacrifice for aneurysmal subarachnoid hemorrhage. J Clin Neurosci. 2014, 21:1044-6. 10.1016/j.jocn.2013.10.005

71. Safaí MG, Tālan J, Malek AM, Hwang SW: Spontaneous atraumatic vertebral artery occlusion due to physiological cervical extension: case report. J Neurosurg Spine. 2014, 20:278-82. 10.3109/20728651.2013.12.SPINE15653

72. Park SH, Kim SJ, Seo JD, Kim DH, Choi H, Choi KD, Kim JS: Upbeat nystagmus during head rotation in rotational vertebral artery occlusion. J Neurol. 2014, 261:1213-5. 10.1007/s00415-014-7528-5

73. Takeshima Y, Nishimura F, Park YS, Nakase H: Fusion surgery for recurrent cerebellar infarctions due to bilateral atlantoaxial rotational vertebral artery occlusion. Spine (Phil Pa 1976). 2014, 39:E860-5. 10.1097/BRS.0000000000000541

74. Buchanan CC, McLaughlin N, Lu DC, Martin NA: Rotational vertebral artery occlusion secondary to adjacent-level degeneration following anterior cervical disectomy and fusion. J Neurosurg Spine. 2014, 20:714-21. 10.3109/20728651.2013.8.SPINE13452

75. Yamaguchi S, Horie N, Tsunoda K, et al.: Bow hunter’s stroke due to stretching of the vertebral artery: a case report. NMC Case Rep J. 2015, 3:1-11. 10.3171/2015.1.FOCUS14791

76. Schellaut S, Verhasselt S, Carpentier K, Moke L: Subaxial rotational vertebral artery syndrome: resection of the uncinate process and anterior fusion can be sufficient!: case report and review of the literature. Neurosurg Focus. 2015, 38:E6. 10.3171/2015.4.SPINE15493

77. Yamaoa Y, Ichikawa Y, Morita A: Evaluation of rotational vertebral artery occlusion using ultrasound facilitates the detection of arterial dissection in the atlas loop. J Neuroimaging. 2015, 25:647-51. 10.1111/jon.12174

78. Ravindra VM, Niel JA, Mazur MD, Park MS, Coulwdwell WT, Tausky P: Motion-related vascular abnormalities at the craniovertebral junction: illustrative case series and literature review. Neurosurg Focus. 2015, 38:E6. 10.3171/2015.1.FOCUS14826

79. Jost GF, Dailey AT: Bow hunter’s syndrome revisited: 2 new cases and literature review of 124 cases . Neurosurg Focus. 2015, 38:E7. 10.3171/2015.1.FOCUS14791

80. Healy AT, Lee BS, Walsh K, Bain MD, Krishnayan A: Bow hunter’s syndrome secondary to bilateral dynamic vertebral artery compression. J Clin Neuroradiol. 2015, 22:209-12. 10.1016/j.jocn.2014.05.027

81. Okawa M, Amamoto T, Abe H, Yoshimura S, Higashi T, Inoue T: Wake-up stroke in a young woman with rotational vertebral artery occlusion due to far-lateral cervical disc herniation. J Neurosurg Spine. 2015, 23:166-9. 10.3109/20728651.2013.14.SPINE14593

82. Takekawa H, Suzuki K, Yoshimura S, et al.: Recurrent juvenile ischemic stroke caused by bow hunter’s stroke: revealed by carotid duplex ultrasonography. J Med Ultrasound (Paris). 2015, 42:437-40. 10.1007/s10396-015-0611-y

83. Wu R, Watanabe Y, Sakaguchi M, Tanaka H, Tomiyama N: Right cerebellar infarction due to ipsilateral neck-rotation-induced right vertebral artery compression and occlusion, demonstrated by CT angiography. Radiol Case Rep. 2015, 10:1025. 10.2484/rcr.v10i1.1025

84. Nguyen HS, Doan N, Eckardt G, Pollock G: Surgical decompression coupled with diagnostic dynamic intraoperative angiography for bow hunter’s syndrome. Surg Neurol Int. 2015, 6:147. 10.4103/2152-7806.165173

85. Chowdhry NS, Ambekar S, Elhammady MS, Riley JP, Pradilla G, Nogueira RG, Ahmad FU: Combined use of intraoperative indocyanine green and dynamic angiography in rotational vertebral artery occlusion. J Clin Neurosci. 2016, 30:152-4. 10.1016/j.jocn.2015.10.005

86. Kageyama H, Yoshimura S, Iida T, Shirakawa M, Uchida K, Tomogane Y, Miyaji Y: Intraoperative indocyanine green and dynamic angiography in rotational vertebral artery occlusion due to compression of a persistent first intersegmental vertebral artery variant: case report. J Neurosurg Spine. 2017, 26:199-202. 10.3101/20728651.2016.SPINE163

87. Lu T, Chinnadurai P, Anaya-Ayala JE, Diaz OM: DynaCT angiography for the diagnosis of bilateral bow hunter’s syndrome. Interv Neuroradiol. 2017, 23:73-8. 10.1177/1591019916673221

88. Haimoto S, Nishimura Y, Hara M, et al.: Surgical treatment of rotational vertebral artery syndrome induced by spinal tumor: a case report and literature review. NMC Case Rep J. 2017, 4:101-5. 10.3171/2015.10.005
118. Cai DZ, Roach RP, Weaver JP, McGillicuddy GT, Mansell ZM, Eskander JP, Eskander MS: Neurosurg. 2018, 119:358-61.
119. Cornelius JF, Slotty PJ, Tortora A, Petridis AK, Steiger HJ, George B: Osteophyte of the atlas: case report.
120. Kameda T, Otani K, Tamura T, Konno S: Do not look the other way.
121. Albertson AJ, Kummer TT: Bilateral bow hunter’s syndrome mimicking a classic seizure semiology.
122. Lukianchikov V, Lovi I, Grin A, Kordonskiy A, Polunina M, Krylov V: Minimally invasive surgical treatment for vertebral artery compression in a patient with one-sided ponticulus posticus and ponticulus lateralis.
123. World Neurosurg. 2018, 117:97-102. 10.1016/j.wneu.2018.06.002
124. Schunemann V, Kim J, Dornbos D 3rd, Nimjee SM: Compression of the subaxial vertebral artery: surgical technique of anterolateral decompression.
125. Jung S, Boetto J, Favier V, Thouvenot E, Costalat V, Lonjon N: Secondary to anomalous entrance into transverse foramen.
126. Johnson SA, Ducruet AF, Bellotte JB, Romero CE, Friedlander RM: Rotational vertebral artery dissection secondary to anomalous entrance into transverse foramen. World Neurosurg. 2017, 108:998.e1-5. 10.1016/j.wneu.2017.09.086
127. Bergl PA: Provoked dizziness from bow hunter’s syndrome. Am J Med. 2017, 130:e575-8. 10.1016/j.amjmed.2017.04.024
128. Iida Y, Murata H, Jobkura K, Higashida T, Tanaka T, Tateishi K: Bow hunter’s syndrome by nondominant vertebral artery compression: a case report, literature review, and significance of downbeat nystagmus as the diagnostic clue. World Neurosurg. 2018, 111:367-72. 10.1016/j.wneu.2017.12.167
129. Albertson AJ, Kummer TT: Bow hunter’s syndrome mimicking a classic seizure semiology.
130. Lukianchikov V, Lovi I, Grin A, Kordonskiy A, Polunina M, Krylov V: Minimally invasive surgical treatment for vertebral artery compression in a patient with one-sided ponticulus posticus and ponticulus lateralis.
131. World Neurosurg. 2018, 117:97-102. 10.1016/j.wneu.2018.06.002
132. Schunemann V, Kim J, Dornbos D 3rd, Nimjee SM: C2-C5 anterior cervical arthrodensis in the treatment of bow hunter’s syndrome: case report and review of the literature. World Neurosurg. 2018, 118:284-9. 10.1016/j.wneu.2018.07.129
133. Ng S, Boetto J, Favier V, Thouvenot E, Costalat V, Lonjon N: Bow hunter’s syndrome: surgical vertebral artery decompression guided by dynamic intraoperative angiography. World Neurosurg. 2018, 118:290-5. 10.1016/j.wneu.2018.07.152
134. Jadeja N, Nalleballe K: Pearls & Oy-sters: bow hunter syndrome: a rare cause of posterior circulation stroke: do not look the other way. Neurology. 2018, 91:329-31. 10.1212/WNL.0000000000006069
135. Kameda T, Otani K, Tamura T, Konno S: Beauty parlor stroke syndrome due to a bone fragment from an osteophyte of the atlas: case report. J Neurosurg Spine. 2018, 28:389-94. 10.3171/2017.7.SPINE17226
136. Cornelius JF, Slotty PJ, Tortora A, Petridis AK, Steiger HJ, George B: Bow hunter’s syndrome caused by compression of the subaxial vertebral artery: surgical technique of anterolateral decompression. World Neurosurg. 2018, 119:558-61. 10.1016/j.wneu.2018.08.122
137. Cai DZ, Roach RP, Weaver JP, McGillicuddy GT, Mansell ZM, Eskander JP, Eskander MS: Bow hunter’s syndrome in a patient with a right hypoplastic vertebral artery and a dynamically compressible left vertebral artery. Asian J Neurosurg. 2018, 13:153-5. 10.4103/1793-5482.181129
138. Çevik S, Katar S, Hanmomgu H: C1-C2 transverse foramen decompression by anterolateral approach as an alternative treatment in bow hunter’s syndrome. Asian J Neurosurg. 2018, 15:411-3. 10.4103/ajns.AJNS.338.16
139. Park BH, Ihn YK, Hong JT: Significance of provocative perfusion computed tomography for evaluation of bow hunter syndrome. World Neurosurg. 2019, 121:1-5. 10.1016/j.wneu.2018.09.107
140. Hernandez RN, Wippinger C, Navarro-Ramirez R, et al.: Bow hunter syndrome with associated pseudoaneurysm. World Neurosurg. 2019, 122:53-7. 10.1016/j.wneu.2018.10.102
141. Cohen NT, Harras DB, Diah YA, Pearl MS, Murnick IG: Atlanto-occipital ligament calcification: a novel imaging finding in pediatric rotational vertebral artery occlusion. Pediatr Radiol. 2020, 50:137-41. 10.1007/s00247-019-05435-5
142. Bandi K, Okazaki T, Mure H, Koriy M, Takagi Y: A juvenile case of bow hunter’s syndrome caused by atlantoaxial dislocation with vertebral artery dissecting aneurysm. World Neurosurg. 2020, 137:393-7. 10.1016/j.wneu.2020.02.041
143. Shi C, Wang L, Dou Y, Yang F, Qiao Y, Zhang H: Dynamic CT angiography of the head and neck in the diagnosis of bow hunter’s Syndrome: a case report. Radiol Case Rep. 2020, 15:2275-7. 10.1016/j.radcr.2020.08.022
144. Nomura Y, Toi T, Ogawa Y, Oshima T, Saito Y: Transitional mystagmus in a bow hunter’s syndrome case report. BMC Neurol. 2020, 20:455. 10.1186/s12883-020-02009-3