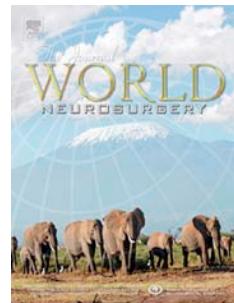


# Accepted Manuscript

Traumatic subarachnoid hemorrhage originating from mid-cervical arterial injury

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PII: S1878-8750(15)00793-7

DOI: [10.1016/j.wneu.2015.06.045](https://doi.org/10.1016/j.wneu.2015.06.045)

Reference: WNEU 2997

To appear in: *World Neurosurgery*

Received Date: 16 April 2015

Revised Date: 19 June 2015

Accepted Date: 20 June 2015

Please cite this article as: Kim B-J, Kim S-H, Lim D-J, Ha S-K, Traumatic subarachnoid hemorrhage originating from mid-cervical arterial injury, *World Neurosurgery* (2015), doi: 10.1016/j.wneu.2015.06.045.

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1 CASE REPORT

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3 **Traumatic subarachnoid hemorrhage originating from mid-cervical arterial injury**

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1    **Abstract**

2

3    *Background* Subarachnoid hemorrhage (SAH) occasionally originates from extracranial arteries, and SAH caused by  
4    cervical trauma is even rarer.

5    *Case* A 17-year-old male was admitted to our emergency department following a bike accident; he was drowsy and  
6    showed left hemiparesis. Initial brain computed tomography (CT) showed subarachnoid hemorrhage (SAH) into the  
7    cervicomedullary cistern. A 4-h follow-up brain CT revealed heavy bleeding into the basal cistern. Because CT  
8    angiography did not show any vascular injury, we performed imaging studies of the cervical spine. Magnetic  
9    resonance imaging (MRI) revealed a blood clot located ventral to the C4–C5 level of the spinal cord without any  
10   flow void. The patient's condition deteriorated over time, and he was accordingly referred for surgery.  
11   Intraoperatively, a thick subarachnoid hematoma ventral to the spinal cord was observed. The hematoma was  
12   removed and hemostasis by bipolar cauterization was performed for bleeding from a small branch of the anterior  
13   spinal artery. Postoperatively, the weakness of the lower extremity improved considerably.

14   *Conclusion* In pediatric patients with SAH of unexplained origin, we suggest that the cervical region be considered  
15   as the bleeding focus; in such cases, surgical evacuation of bleeding can save some patients.

16

17   **Key Words**

18   Traumatic subarachnoid hemorrhage, Angio-negative, Juvenile spine, Mid-cervical injury, Anterior spinal artery

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1 **Introduction**

2 Traumatic subarachnoid hemorrhage (SAH) is commonly caused by craniofacial trauma. However, the etiology of  
 3 traumatic SAH remains unknown (19). In a few cases, the hemorrhage originates from extracranial arteries, and  
 4 SAH caused by cervical injury is even rarer (2, 14). There are sporadic reports describing SAH caused by cervical  
 5 trauma, and some authors have described cases associated with upper cervical trauma (8, 16). Although Romano et  
 6 al. presented a case report of spontaneous spinal SAH without any vascular anomaly (17), most SAH cases caused  
 7 by cervical trauma have been associated with dural arteriovenous fistulae (1, 4, 12, 13) or injury to the extracranial  
 8 vertebral artery (VA) (3, 9, 10, 18).

9 In younger pediatric patients, unlike in adult patients, the cervical spinal cord can undergo great tensile force  
 10 without an obvious fracture or ligament injury owing to the elasticity of the spine. Here, we present a rare case of  
 11 traumatic SAH originating from a mid-cervical lesion without any fracture or vascular anomaly.

12

13 **Case report**

14 A 17-year old male presented to our emergency room following a bike accident. The patient was drowsy and  
 15 showed left hemiparesis. Brain computed tomography (CT) showed facial bone fractures and SAH, predominantly  
 16 bleeding into the cervicomедullary cistern (**Figure 1A-B**). Although the patient had no definite interval change, we  
 17 obtained a 4-h follow-up brain CT scan, which showed a thick SAH clot in the basal cistern (**Figure 2A**). CT  
 18 angiography failed to detect any vascular injury. The next day, the patient developed left hemiplegia. Since a repeat  
 19 brain CT scan showed no definite changes as compared to the previous images, we performed cervical spine  
 20 magnetic resonance imaging (MRI). MRI showed a thick intradural hematoma compressing the spinal cord ventrally  
 21 from the mid-cervical to the retroclival area (**Figure 2B-D**). No findings indicating vascular anomalies, such as flow  
 22 void, were observed. The patient then underwent surgery. Because the hematoma was causing severe compression of  
 23 the spinal cord at the C4–C5 level, total C3–C5 laminectomy was performed. The epidural space showed no  
 24 pathological findings; therefore, the dura was incised in the midline. After arachnoid dissection, the right dentate  
 25 ligaments were retracted and a thick subarachnoid hematoma was identified in the ventral portion of the spinal cord  
 26 (**Figure 3A**). The hematoma was removed, and active bleeding was observed from a small branch of the anterior  
 27 spinal artery (ASA); this was meticulously controlled by means of bipolar cautery. On further exploration, no  
 28 enlarged vessels or angiomas were found. Postoperatively, the weakness of the lower extremity considerably  
 29 improved (from grade 0/5 to grade 4/5) (**Figure 3B**). Follow-up digital subtraction angiography (DSA) was  
 30 performed and no vascular abnormality was noted; 2-week follow-up MRI showed an edematous spinal cord  
 31 (**Figure 3C**). Two months postoperatively, the patient presented with severe headache and gait disturbance. Follow-  
 32 up brain MRI revealed the development of hydrocephalus. Therefore, a ventriculoperitoneal shunt was placed;

1 subsequently, the symptoms subsided. After 1 month of rehabilitation, the patient was discharged. At 2-year follow-  
2 up, the neurological function was noted to have considerably improved, except for left arm weakness (shoulder  
3 abduction grade: 1/5, elbow flexion grade: 2/5, and hand grasp: 4/5).

4

## 5 Discussion

6 We have described our experience with an extremely rare case of a patient with an extensive SAH filling the basal  
7 cisterns due to facial trauma originating from a mid-cervical lesion without any vascular abnormality. Surgery was  
8 performed to evacuate the hematoma compressing the spinal cord, and the bleeding ventral spinal artery was  
9 cauterized. Most reports concerning traumatic SAH cases of extracranial origin have described the rupture of pre-  
10 existing vascular anomalies in the cervical spine (8). However, in our case, CT angiography, DSA, and cervical MRI  
11 failed to show any pre-existing vascular anomaly or VA injury.

12 The VA has been frequently found to be involved in SAH in trauma patients who have no pre-existing anomalies.  
13 Owing to the anatomical course of the VA, which runs through the transverse foramen of the cervical spine and  
14 eventually enters the intracranial space after turning around the atlas, cervical fractures and dislocation can result in  
15 VA dissection (6). In a necropsy study of 17 patients, Harland et al showed that in the majority of cases, SAH caused  
16 by upper cervical trauma originated from VA injury (8). In the present case, we initially suspected VA dissection due  
17 to the pattern of intracranial SAH and the patient's history of trauma. However, CT angiography showed no  
18 abnormal findings in the VA or its surrounding structures and no fracture in the cervical spine. After identification of  
19 the bleeding from the mid-cervical artery during the emergency operation, we realized that the intracranial SAH  
20 could have originated from the cervical portion of the artery. Postoperatively, we performed a follow-up DSA study.  
21 However, DSA also showed no vascular abnormality.

22 Surgical evacuation of a hematoma arising from the ventral spinal cord is a challenging procedure. However, after  
23 incising the dentate ligaments, the ventral portion of the spinal cord can be approached more easily. Intraoperatively,  
24 we identified active bleeding at the ventral portion of the mid-cervical spinal cord in our patient, suggesting the  
25 involvement of a small branch of the ASA. Based on previous literature, the ASA, even in traumatic cases, is known  
26 to be prone to ischemic syndrome, termed as "ASA syndrome" (5, 7). In our patient, the 2-week postoperative MRI  
27 showed an edematous spinal cord and intramedullary white spot, which suggested ischemic injury (Figure 3C).  
28 However, the patient did not show the characteristic features of ASA syndrome. Therefore, we assumed that the MRI  
29 findings were indicative of a minor ischemic spinal cord injury, caused by hematoma compression combined with  
30 injury of a small branch of the ASA, rather than of the main trunk of the ASA.

31 According to previous studies, in juvenile patients, high-velocity trauma can cause damage to the spinal cord

1 without fracturing the bony structures because the elasticity of the cervical spine allows intersegmental displacement  
2 and rearrangement of the cervical spine (15). This phenomenon may provide a clue to the pathomechanism of the  
3 injury to the ASA branch without an obvious fracture or dislocation in our patient. Anatomically, the ASA arises  
4 from the VA and courses along the anterior median fissure. Then, it gives rise to several small branches, which run  
5 into the intervertebral foramina. The main trunk of the ASA is embedded in the median fissure of the spinal cord and  
6 is relatively mobile; in contrast, the radicular artery runs through the neural foramen and is relatively fixed. We  
7 considered that in our patient, a small branch of the ASA suffered damage at the junction between the main ASA  
8 trunk and the radicular artery during traumatic acceleration-deceleration owing to the elasticity of the juvenile spine.

9 It is widely accepted that some patients develop severe deformities after multi-level cervical laminectomies and  
10 require subsequent fusion operation (11). Previous studies have suggested that the patient's age at the time of  
11 operation is related to the risk of iatrogenic post-laminectomy deformity (11, 20). In the present case, our patient  
12 was 17 years old; no instability was observed on the preoperative X-ray or MRI. Yasuoka et al. reported that among  
13 patients aged 15–24 years, the post-laminectomy kyphosis rate was 6%, which is considerably lower than the  
14 corresponding rate (46%) in patients aged <15 years (20). We considered that in our patient, cervical instrumentation  
15 would not provide significant benefit against fusion-related risk in an adolescent patient in whom the spine is still  
16 growing. At 2-year follow-up, no laminectomy-induced complications, including axial pain or deformity, were  
17 observed in our patient; however, careful follow-up in the long term is recommended, considering the potential of  
18 late development of deformities.

19 In traumatic SAH patients with unexplained neurological deficits, MRI of the cervical spine is essential (21). MRI  
20 provides valuable information in cases of patients with head trauma, such as the location and extent of hematomas  
21 and the existence of cord injury or vascular anomalies; this information is highly helpful in planning surgery. In the  
22 case of our patient, the MRI showed a subarachnoid hematoma located at the C4–C5 segment that was severely  
23 compressing the spinal cord on the ventral side. Therefore, we planned evacuation of the blood clot at the C4–C5  
24 level and, consequently, found the origin of the hemorrhage. In traumatic SAH patients who show unexplained  
25 bleeding, even in cases of SAH located in the cervicomedullary cisterns, we suggest that the cervical region be  
26 considered the bleeding focus. Early surgical evacuation of bleeding can save patients in such cases.

27

## 28 Conclusion

29 To the best of our knowledge, this is the first report describing traumatic SAH originating from mid-cervical  
30 arterial injury. Our patient did not show any pre-existing vascular anomaly or VA injury. We suggest that in pediatric  
31 cases, injury to the mid-cervical vessels of the spinal cord can occur even without bony fracture. Our experience

1 demonstrated that surgical evacuation of the mid-cervical SAH with meticulous hemostasis led to a fair clinical  
2 result.

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1    **Figure legends**

2    **Figure 1.** (A) Initial brain computed tomography shows panfacial bone fractures and subarachnoid hemorrhage in  
3    the cervicomedullary cistern. (B) A small epidural hematoma is observed at the fractured left temporal area and a  
4    small intraventricular hematoma is observed in the fourth ventricle, with no definite hematoma in the basal cistern.

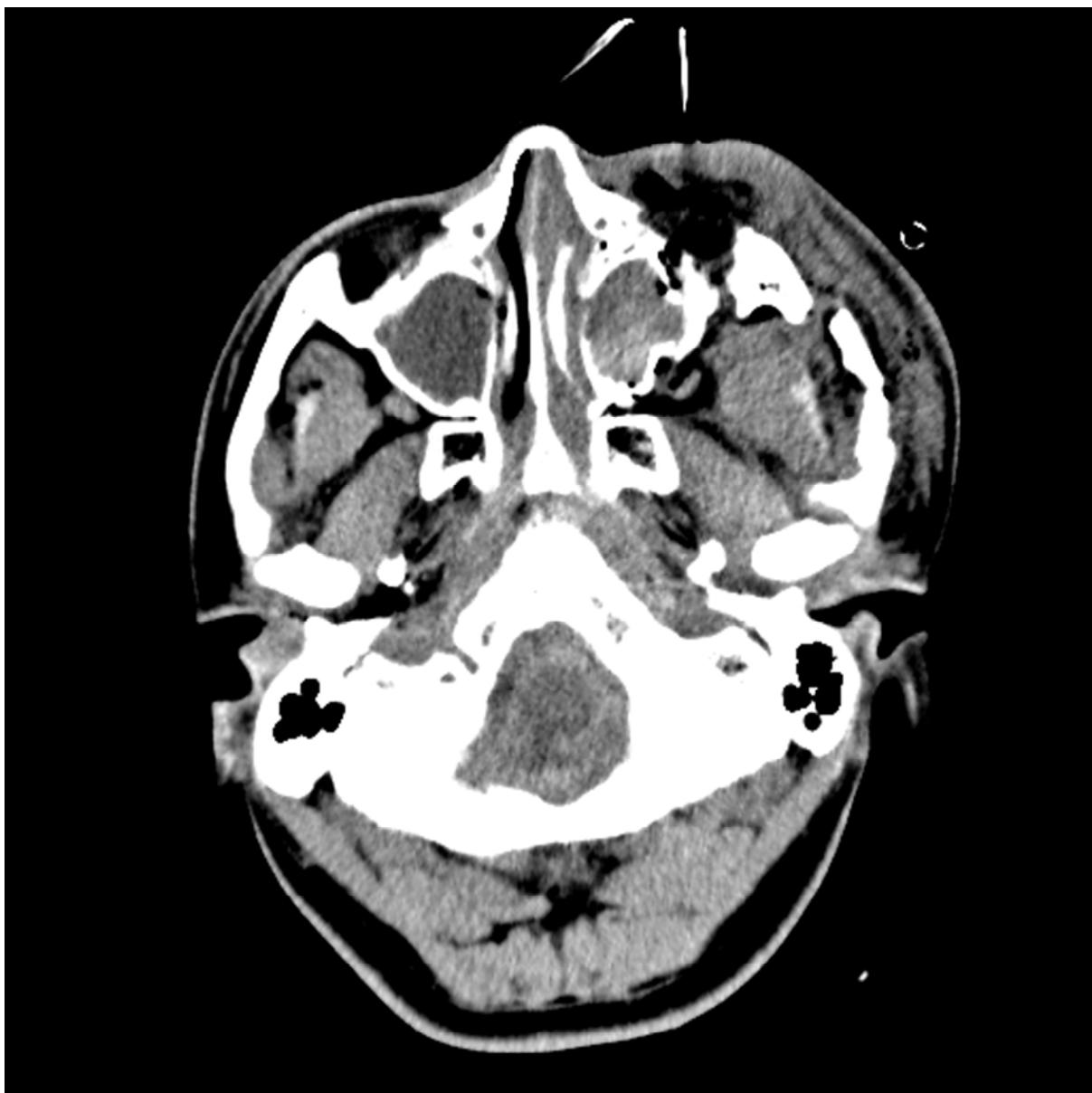
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6    **Figure 2.** (A) Four-hour follow-up brain computed tomography shows thick subarachnoid hemorrhage into the basal  
7    cistern with worsening of the left frontal contusion and epidural hematoma. (B-D) Cervical spine magnetic  
8    resonance imaging shows subarachnoid hematoma severely compressing the spinal cord at the ventral side at the  
9    C4-C5 level, which extends to the basal cistern.

10

11    **Figure 3.** (A) Intraoperatively, a thick subarachnoid hematoma was identified at the ventral portion of the spinal  
12    cord. (B) Postoperative computed tomography shows a properly decompressed spinal cord and remnant hematomas  
13    spreading along the subarachnoid space to the basal cistern. (C) MRI obtained 2 weeks postoperatively shows an  
14    edematous spinal cord and a hyperintense intramedullary spot.

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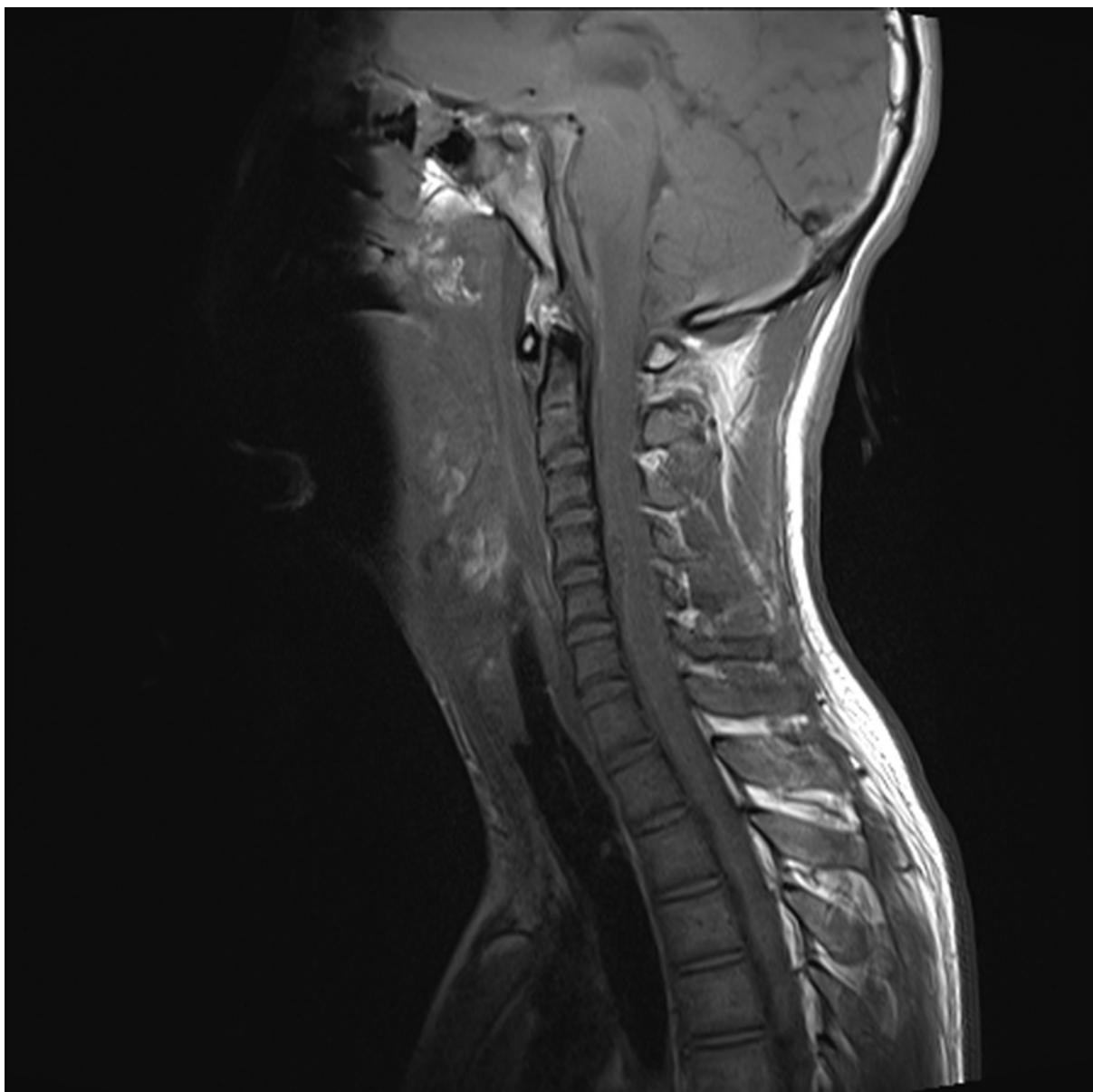
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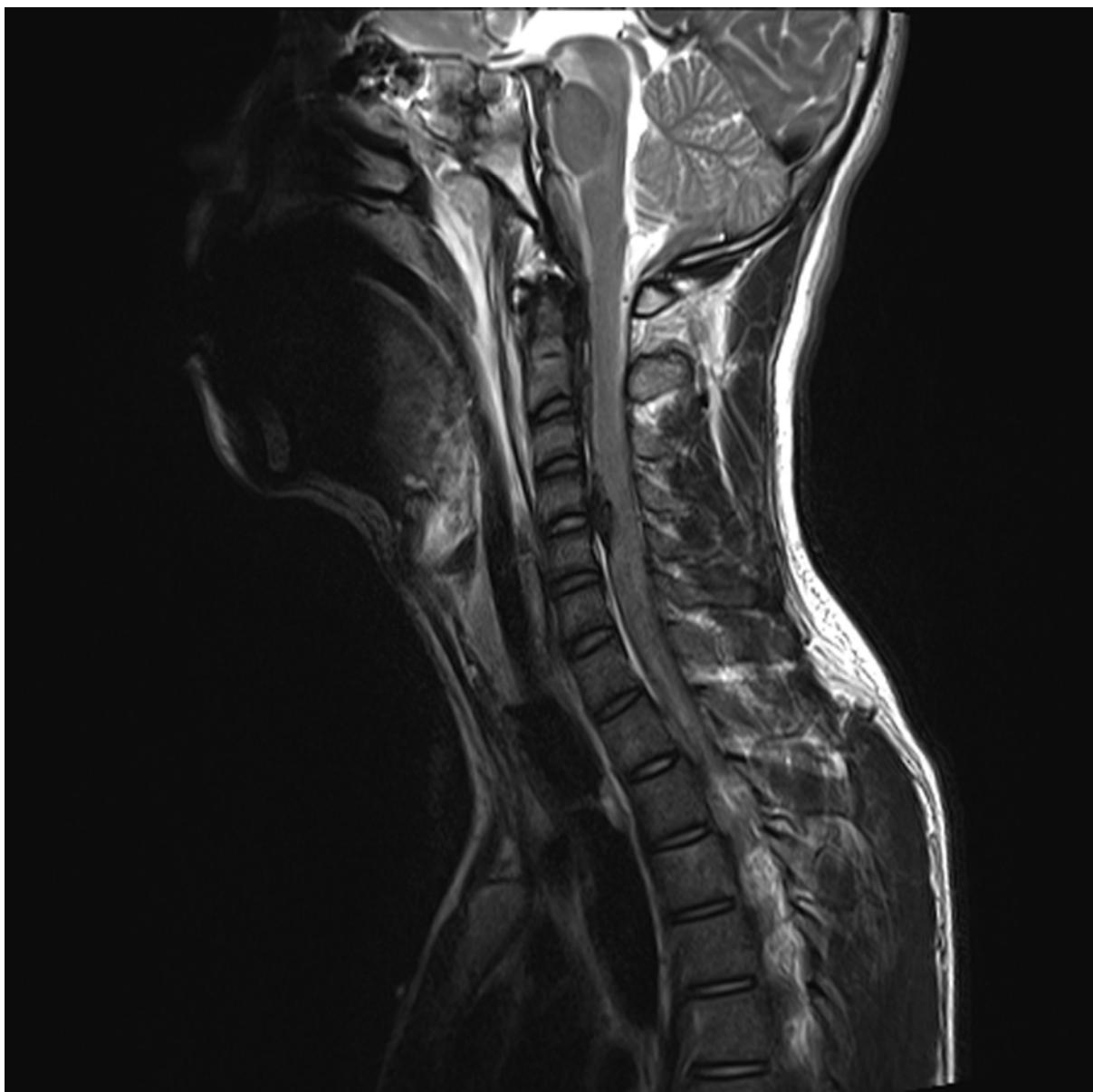
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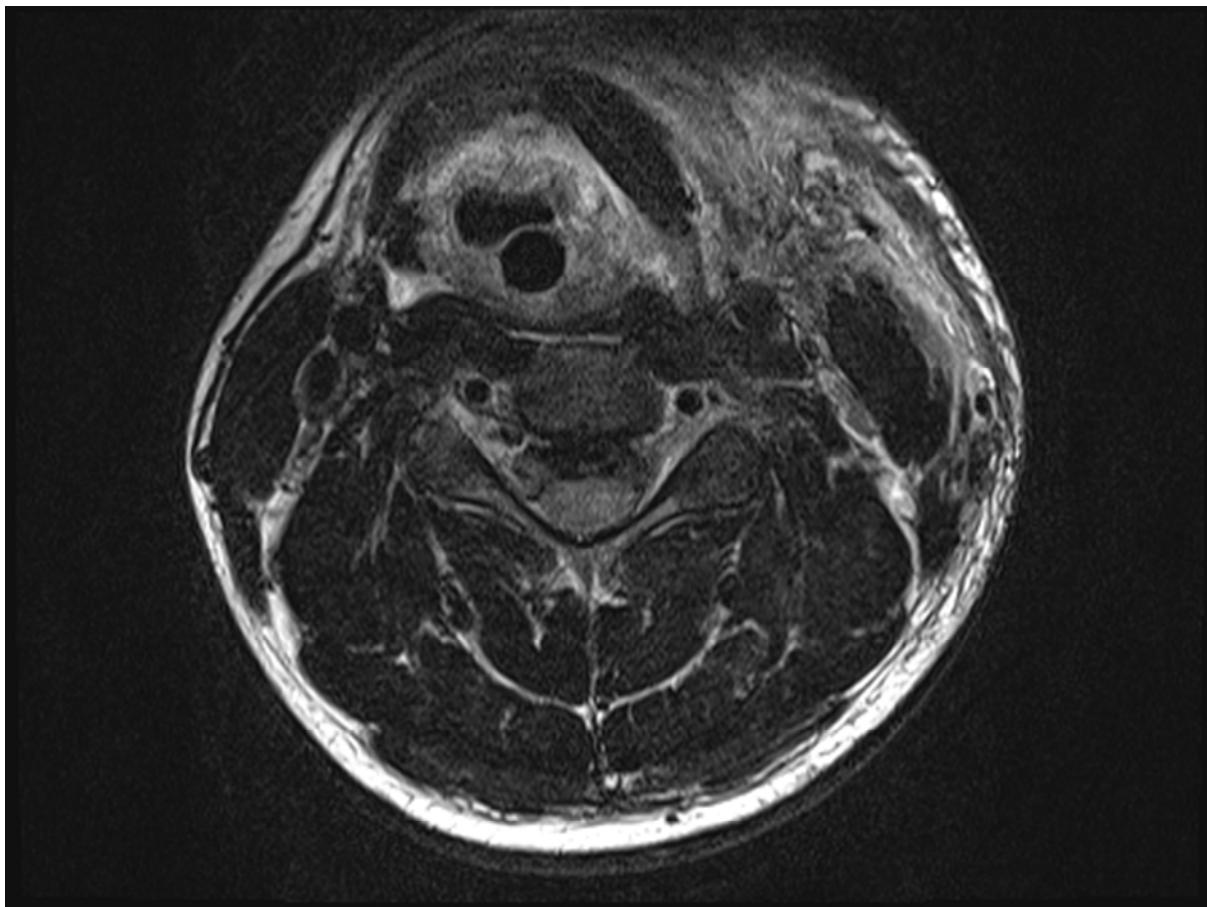
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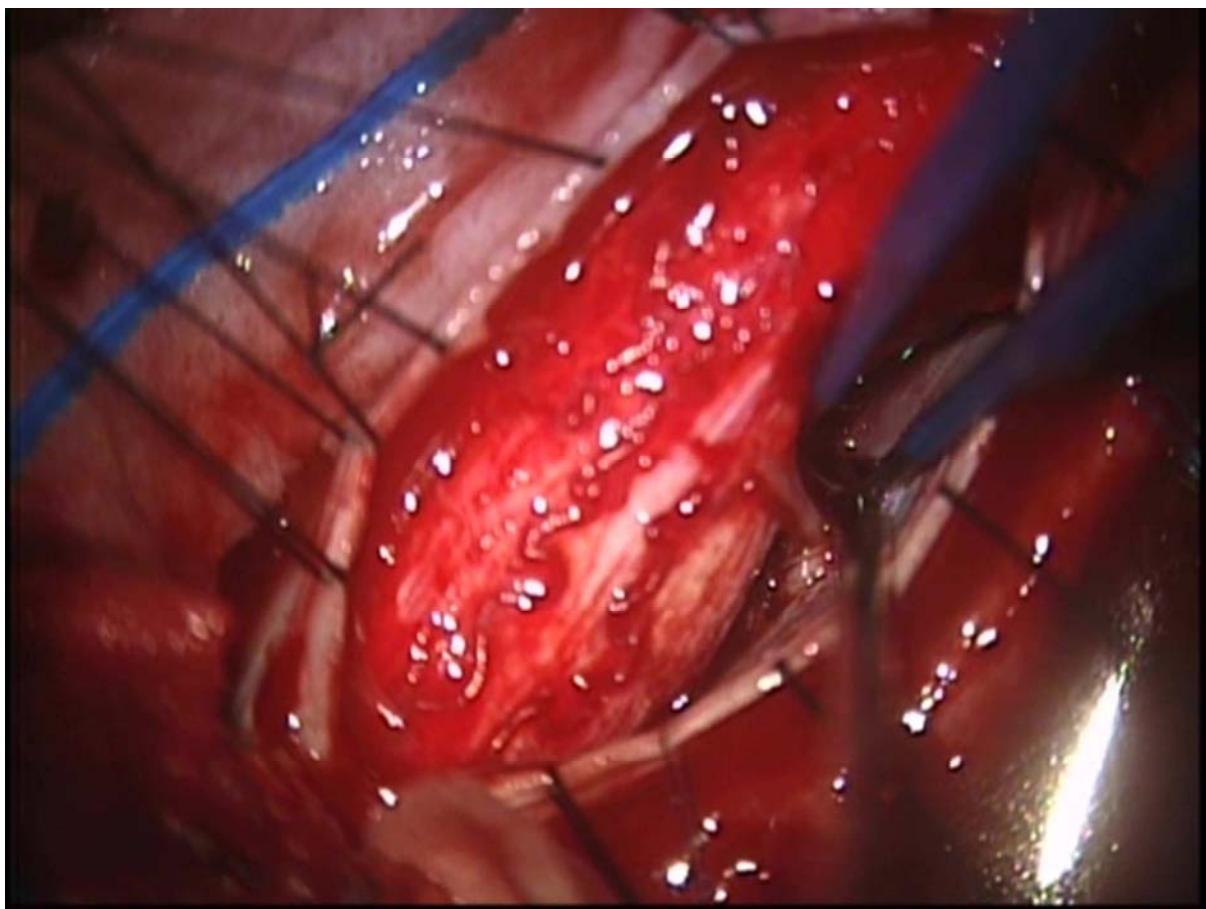
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- We report an extremely rare case describing traumatic SAH originating from mid-cervical arterial injury without any vascular abnormality.
- We evacuated the hematoma compressing the spinal cord from the ventral side, and cauterized the active bleeding from the small branch of ASA.
- We suggest that high-velocity trauma can cause injury to the spinal artery without fracturing the bony structures, particularly in juvenile patients.