*Original Article*

# Vertebral artery occlusion associated with blunt traumatic cervical spine injury

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*Aim:* Vertebral artery injury associated with blunt traumatic cervical spine injury sometimes causes severe cerebellar and brain stem infarction. No treatment guidelines for vertebral artery injury aimed at preventing stroke have been decided. We have conducted endovascular embolization in patients with up to Denver grade IV cerebrovascular injury complicated by unstable cervical spine injury before open reduction and fixation surgery. The purpose of this study was to validate the clinical course of vertebral artery injury and especially endovascular treatment for grade IV patients in our hospital.

*Methods:* Participants comprised of patients diagnosed as having traumatic cervical spine injury in our hospital between January 2015 and April 2018. Among these patients, we selected those with vertebral artery injury and retrospectively examined the background characteristics of the patients, details of treatment, and complications with or without stroke.

*Results:* Traumatic cervical spine injury was diagnosed in 89 patients. Among these patients, 15 (16.7%) showed a complicating vertebral artery injury. Mean age was 62.6 years, and almost 50% of the patients were injured in falls. Three types of cervical spine injury caused vertebral artery injury: subluxation, Jefferson fracture, and fracture involving the foramen transversarium. Vertebral artery injury was classified as grade IV in 12 patients, of whom nine required spinal surgery. All patients who needed spinal surgery underwent endovascular therapy before surgery, and none experienced a stroke.

*Conclusion:* Endovascular embolization of the vertebral artery occlusion in patients with unstable cervical spine injury before open reduction and fixation surgery can be a treatment option to prevent stroke.

**Key words:** Cervical spine fracture, endovascular therapy, grade IV, prevention of stroke, VAI

## INTRODUCTION

VERTEBRAL ARTERY INJURIES (VAI) associated with blunt traumatic cervical spine injuries sometimes causes severe cerebellar and brain stem infarction. Although digital subtraction angiography (DSA) is the gold standard for the diagnosis of blunt cervical vascular injury,[1,2] including VAI, computed tomography angiography (CTA) is widely used as a screening tool for VAI because of its improved performance.[3] The Denver grading system (Table 1) proposed by Biffl *et al*. is widely used to evaluate the morphological characteristics of cervical vascular injuries,[4] and grade IV (vessel occlusion) is a more frequent type of VAI.[5] Previous studies have reported that the mechanism of serious cerebellar and brain stem infarction associated with VAI is the scattering of emboli during open reduction and fixation surgery.[6] Although it is clear that antithrombotic or anticoagulant therapy is the gold standard treatment to prevent stroke with VAI, endovascular embolization of the vertebral artery may be performed in patients who require fixation surgery or who are not eligible for anticoagulation or antithrombotic therapy.[7] However, there is not enough evidence for this treatment strategy. In this study, we

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examined the type of injury, frequency of VAI, and details of treatment in patients with cervical spine injuries and VAI at our hospital. We investigated the long-term prognosis particularly in the patients who required endovascular treatment.

## METHODS

AT OUR HOSPITAL, CTA was performed to evaluate cervical vascular injuries in the all patients with unstable cervical spine injuries and transverse process fractures, a suspected cervical spinal cord injury, and severe traumatic brain injury. Antithrombotic or anticoagulant therapy was the mainstay of treatment for VAI and was introduced as soon as possible for the patients with VAI, considering their physical status, other sites of injury, and the timing of open surgery. In the Denver grade IV VAI patients with unstable cervical spine injury, endovascular embolization was performed before fixation surgery (Fig. 1).

This study included patients with blunt cervical spine injuries who were admitted to the Senshu Trauma and Critical Care Center in Osaka Prefecture between January 2015 and April 2018. Among these patients, we retrospectively reviewed their background characteristics, morphological characteristics, Denver grade, details of treatment, and complications with or without stroke. Patients who were in cardiac arrest on hospital arrival were excluded from the study. In August 2019, we contacted the patients or their family members by telephone and in writing to ask whether the patients had experienced any episodes of suspected stroke after discharge from the hospital.

## RESULTS

### Characteristics of patients with and without VAI

TABLE 2 presents the characteristics of the patients. There were 89 patients with blunt cervical spine injuries during this period, of whom 15 (16.7%) had complications of VAI at 19 sites. The mean age of all patients was 59.7 years, half of them were injured in traffic accidents, and most of the remainder were injured in a fall. The median Injury Severity Score (ISS) was 17, and 66 of the patients suffered severe trauma (ISS of 15 or greater).

**Table 1.** The Denver Grading Scale

| | |
|---|---|
| Grade I | Irregularity of the vessel wall or lumen stenosis <25% |
| Grade II | Intimal flap or lumen stenosis >25% |
| Grade III | Pseudoaneurysm |
| Grade IV | Vessel occlusion |
| Grade V | Complete transection of the artery |

### Details of the 15 patients with VAI

Details of patients with VAI are shown in Table 3. There were 11 cases of unilateral VAI and four of bilateral VAI, for a total of 19 VAI sites. The most frequent cause of VAI was subluxation ($n$ = 8). Cervical spinal cord injury was observed in nine patients. Other causes of VAI were Jefferson fracture ($n$ = 3) and fracture involving the foramen transversarium ($n$ = 4). Fourteen patients were diagnosed as having unstable cervical spine injuries, except for one patient in whom the facet was preserved with a single transverse process fracture.

Of the 15 patients (19 sites) with VAI, 12 patients (14 sites) had grade IV, two had grade I alone, and one had grade II alone. Endovascular embolization was performed in 9 of 12 patients with grade IV VAI (Fig. 2). For patients with bilateral vertebral artery occlusion (cases 11 and 12), bilateral vertebral artery embolization was performed. Endovascular treatment was performed in four patients on the day of admission and in five patients on day after admission.

Internal fixation was given priority in cases in which internal fixation could be performed promptly or halo ring placement was not possible because of skull fracture, whereas in the other cases, external fixation was performed first and internal fixation later.

Three patients with grade IV VAI did not receive endovascular treatment (cases 13, 14, and 15). One patient had a stable cervical spine injury that did not require restorative fixation, so treatment with antiplatelet agents was selected (case 13). Cases 14 and 15 suffered severe disturbance of consciousness when transported and were judged to have a poor neurological prognosis, and they were not treated actively. Case 15 resulted in death in hospital. Excluding case 15, 14 of 15 patients were discharged alive, and none suffered an apparent stroke during hospitalization.

### Long-term outcomes of VAI patients

The prognosis of the 14 patients as of August 2019 is shown in Table 4. One patient (case 5) was a foreign traveler. Therefore, we could not follow his prognosis.

Three patients died after discharge from the hospital, including two with malignant tumor (liver cancer and bladder cancer) and one with gastrointestinal hemorrhage. There were no new strokes in these three patients. The other 10

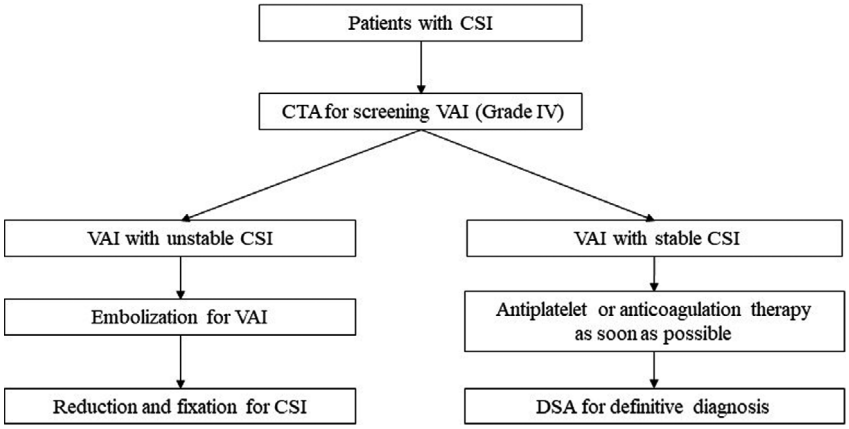


**Fig. 1.** Therapeutic algorithm for cervical spine injury patients with grade IV VAI. Endovascular therapy was performed before spinal surgery for Grade IV VAI patients with unstable cervical spine injury (CSI). VAI patients with stable CSI were treated with pharmacotherapy such as antiplatelet agents or anticoagulants as soon as possible. CTA, computed tomography angiography; DSA, digital subtraction angiography.

**Table 2.** Characteristics of the patients with and without VAI

| Characteristic | VAI | (*n* = 15) | Non-VAI (*n* = 74) |
|---|---|---|---|
| Total (*n* = 89) | | | |
| Mean age (y) | 62.6 (26–81) | 59.1 (2–94) | 59.7 (2–94) |
| Sex | | | |
| Male | 11 | 53 | 64 |
| Female | 4 | 21 | 25 |
| Site of SCI | | | |
| C1 | 2 | 9 | 11 |
| C2 | 2 | 23 | 25 |
| C3 | 2 | 6 | 8 |
| C4 | 3 | 12 | 15 |
| C5 | 7 | 12 | 19 |
| C6 | 7 | 19 | 26 |
| C7 | 1 | 25 | 26 |
| Subluxation | 8 | 16 | 24 |
| Mechanism of injuries | | | |
| Traffic accident | 7 | 38 | 45 |
| Fall | 8 | 33 | 41 |
| Others | 0 | 3 | 3 |
| Complications of SCI | 9 | 29 | 38 |
| Injury Severity Score (median) | 17 | 17 | 17 |

SCI, spinal cord injury; VAI, vertebral artery injury.

patients were observed to have survived without any episodes of suspected stroke. The average follow-up period of the surviving patients was 29.4 months.

## DISCUSSION

ALTHOUGH VAI ASSOCIATED with blunt trauma is estimated to occur in <1% of patients,[5,8–10] VAI is not uncommon in cervical spine injuries, occurring in 7% to 39% of cases.[8,10,11] Blunt cervical vascular injuries are often associated with trauma from a traffic accident. In a previous report of 13 cases with a mean age of 45.0 years at our hospital in 2009, 12 (85.7%) were cases of traffic trauma.[12] Moreover, the number of cases because of fall trauma increased in the present study, and the average age of the patients also increased.

Similar to the increase in falls among the elderly as the mechanism head injury, changes in the mechanism of injury because of aging have been observed in cervical spine injury.

Recently, CTA is being widely used for screening because whole-body CT has become widespread in emergency departments.[13] However, a previous study reported that DSA should be used for diagnosis because there were many false-positive cases with CTA screening.[14] At our hospital, CTA is performed for the screening of patients with suspected cervical injury, and DSA is done for patients with suspected VAI.

Cothren *et al*. found that 93% of blunt cervical vascular injury cases had cervical spine injuries, either a fracture involving the foramen transversarium, subluxation, or a C1–C3 spine fracture.[9] The Advanced Trauma Life Support manual recommends that screening for cervical vascular injury should be done in patients with the above three types of injury.[15] In the present study, the three types of cervical

**Table 3.** Details of the 15 patients with VAI

| Case no. | Age | Sex | Grade | IVR | Type of CSI |
|---|---|---|---|---|---|
| 1 | 50s | M | rt I | None | Subluxation (C6) |
| 2 | 50s | F | rt I | None | Jefferson fracture |
| 3 | 70s | M | rt II | None | Jefferson fracture |
| 4 | 70s | M | rt IV; lt I | Coil | emboli |
| 5 | 60s | F | lt IV | Coil | Subluxation (C4) emboli |
| 6 | 20s | M | lt IV | Coil | Jefferson fracture emboli |
| 7 | 40s | M | rt IV | Coil | Fractures involving transverse foramen (lt C4–C6) emboli |
| 8 | 70s | M | rt IV | Plug | Subluxation (C5) emboli |
| 9 | 60s | M | rt IV | Coil + plug | Subluxation (C5) emboli |
| 10 | 70s | M | rt IV | Coil + plug | Subluxation (C3) emboli<br>Fractures involving transverse foramen (rt C4–C5) |
| 11 | 60s | M | bi IV | Coil | emboli |
| 12 | 50s | M | bi IV | Coil + plug | Subluxation (C5) emboli<br>Subluxation (C5), fractures involving transverse foramen (lt C5–C6) |
| 13 | 80s | F | lt IV | None | Fractures involving transverse foramen (lt C6) |
| 14 | 50s | F | rt IV | None | Fractures involving transverse foramen (rt C6–C7) |
| 15 | 70s | M | rt IV; lt II | None | Subluxation (C6) |

bi, bilateral; Coil emboli, coil embolization; CSI, cervical spine injury; IVR, interventional radiology; lt, left; Plug emboli, vascular plug embolization; rt, right; VAI, vertebral artery injury.

spine injury causing VAI were fracture involving the foreman transversarium, subluxation, and Jefferson fracture. This suggests that searching for VAI is essential in patients with unstable cervical spine injury, and in cases of fracture involving the foreman transversarium, even if the cervical spine injury is stable.

The frequency of complications of stroke in grade IV VAI ranges from 7.1% to 33.3%.[16] Although there is no standard treatment strategy for VAI, several reports suggest that antithrombotic or anticoagulant therapy is effective,[1,7,8] and it is also recommended for patients without a bleeding tendency in the Advanced Trauma Life Support manual.[15] However, there is not sufficient evidence to make standard recommendation as to whether antithrombotic therapy or anticoagulant therapy is superior for preventing stroke caused by VAI.[17]

In Denver grade IV cases, it is important to prevent scattering infarcts when performing open reduction and fixation surgery for cervical spinal injury. Therefore, we perform endovascular embolization for VAI complicated by unstable cervical spinal injury that requires open reduction and fixation. In the nine patients who underwent embolization before reduction and fixation in this study, we confirmed that vertebrobasilar artery blood flow was sufficient by CTA and cerebral angiography. Even in cases of bilateral vertebral artery occlusion (cases 11 and 12), blood flow to the vertebrobasilar artery was sufficiently maintained by the anterior circulation and collateral circulation from the external carotid artery circulation (Fig. 3).

In cases of traumatic vertebral artery occlusion, the degree of function of the collateral circulation is thought to determine whether insufficient vertebrobasilar artery blood flow will occur. Contrastingly, if sufficient blood flow is maintained from the collateral circulation to the vertebrobasilar artery system when the vertebral artery is occluded, embolization of the injured vertebral artery may not result in inadequate blood flow distal to the occlusion.

So far, the treatment strategy of prophylactic embolization in cases of traumatic vertebral artery occlusion has not been established. Indo *et al*. reported that in a study of 23 patients with traumatic vertebral artery occlusion who required cervical surgery in the acute phase, preoperative vertebral artery embolization reduced the risk of postoperative stroke.[18] Fujita *et al*. suggested that prophylactic embolization may be indicated not only in cases of vertebral artery occlusion requiring cervical spine fixation, but also in cases of stenosis requiring fixation and those of embolic infarction not requiring fixation.[19] In our institution, as shown in Figure 1, prophylactic embolization is performed only in cases of occlusions that require cervical spine fixation.

In the present study, we conducted an additional follow-up study to evaluate whether prophylactic embolization prevented stroke. Of the 14 patients who were discharged alive, none of the 13 patients who could be followed had suffered an apparent stroke after discharge. Three of the 13 patients

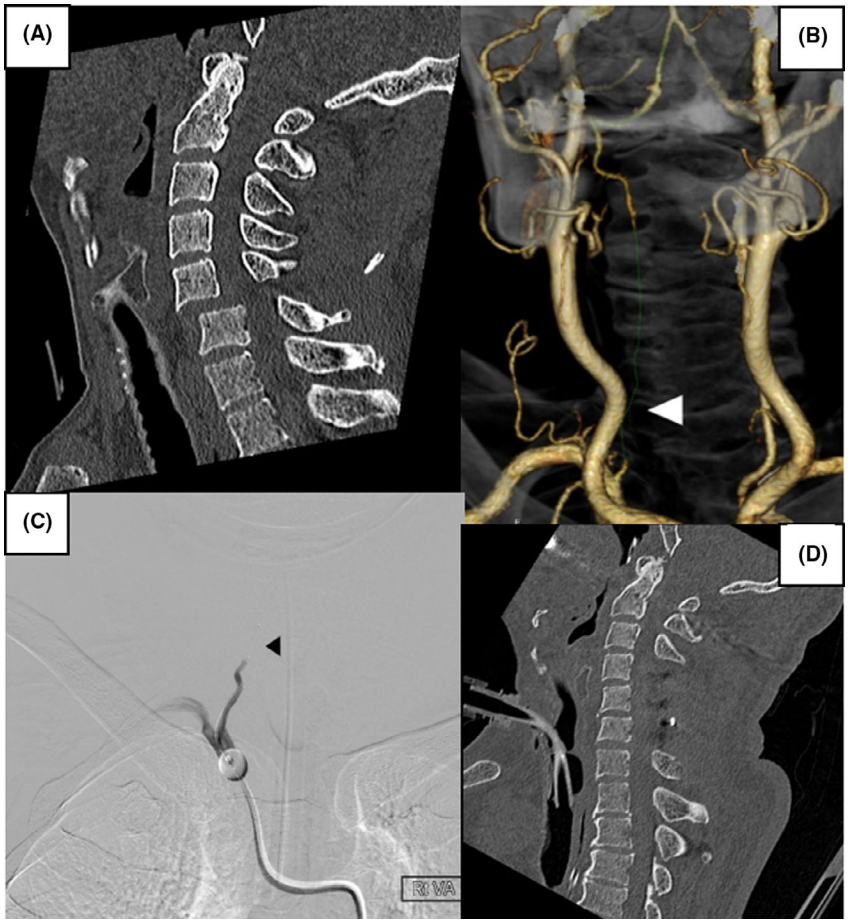


**Fig. 2.** CT and DSA results from case 8. (A) Sagittal plane CT scan of cervical spine before reduction showing forward subluxation fracture of C5. (B) CTA of carotid and vertebral arteries reveals right vertebral artery occlusion (arrowhead). (C) DSA of right vertebral artery embolization by vascular plug (arrowhead). (D) Sagittal plane CT scan of cervical spine after open reduction and fixation. CTA, computed tomography angiography; DSA, digital subtraction angiography.

**Table 4.** Long-term follow-up of the VAI patients

| Case no. | Grade | IVR | Complication of CI | Prognosis | Follow-up period (months) |
|---|---|---|---|---|---|
| 1 | rt I | None | No | Alive | 49 |
| 2 | rt I | None | No | Alive | 26 |
| 3 | rt II | None | No | Alive | 21.5 |
| 4 | rt IV; lt I | Coil emboli | No | Alive | 18.5 |
| 5 | lt IV | Coil emboli | No | Unknown | – |
| 6 | lt IV | Coil emboli | No | Alive | 46 |
| 7 | rt IV | Coil emboli | No | Alive | 38.5 |
| 8 | rt IV | Plug emboli | No | Alive | 16 |
| 9 | rt IV | Coil + plug emboli | No | Alive | 20 |
| 10 | rt IV | Coil + plug emboli | No | Dead | 3.5 |
| 11 | bi IV | Coil emboli | No | Dead | 5 |
| 12 | bi IV | Coil + plug emboli | No | Alive | 16.5 |
| 13 | lt IV | None | No | Dead | 7 |
| 14 | rt IV | None | Yes | Alive | 42 |
| 15 | rt IV; lt II | None | Yes | Dead (in-hospital) | – |

The cerebral infarction seen in cases 14 and 15 had already occurred before arrival at the hospital. bi, bilateral; CI, cerebral infarction; Coil emboli, coil embolization; IVR, interventional radiology; lt, left; rt, right; VAI, vertebral artery injury.

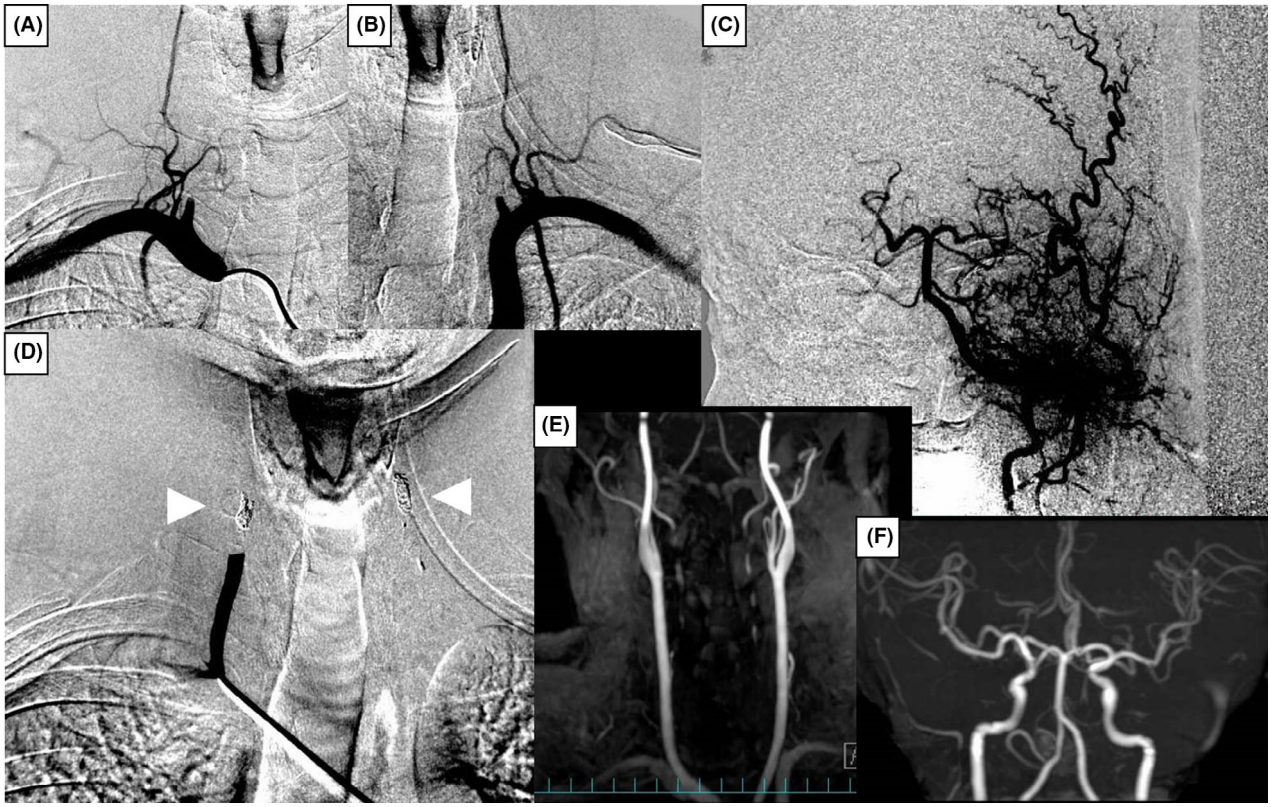


**Fig. 3.** DSA and MRA results from case 12. (A, B) DSA of right and left subclavian arteries reveals bilateral vertebral artery occlusion. (C) Left external carotid artery injection shows flow in the left vertebral artery to basilar artery through collateral circulation. (D) DSA of bilateral vertebral artery embolization by coil and vascular plug (arrowheads). (E, F) Neck and head MRA images after bilateral vertebral artery embolization show normal blood flow in the intracranial posterior circulation. DSA, digital subtraction angiography; MRA, magnetic resonance angiography.

died after discharge, but none of these deaths were related to the onset of stroke. Based on these data, our treatment strategy of preoperative embolization of the occluded vessel, prevention of embolus dispersion, and restorative fixation can be an option to prevent stroke for Denver grade IV patients who are judged to have sufficient blood flow in the intracranial posterior circulation based on neurological and CTA findings.

### Limitations

The limitations of this study are that the morphological changes in the injured vessels and whether the injury was complicated by cerebellar and brain stem infarction were not strictly followed up with CTA or magnetic resonance imaging (MRI). In particular, the presence or absence of cerebellar and brain stem infarction after hospital discharge was confirmed only by telephone and written communication with the patient or family. In addition, the number of cases in this study was small, and multicenter prospective comparative studies will be necessary to establish a treatment strategy for VAI.

## CONCLUSION

ALTHOUGH OUR BASIC treatment is antithrombotic and anticoagulant therapy, we performed prophylactic embolization before cervical spine surgery in the Denver grade IV patients, and no obvious cerebellar and brain stem infarction was observed even after discharge. Treatment strategies for VAI, including for Denver grade IV cases, have not yet been established, and prospective observational studies that include analysis of long-term prognosis are needed.

## DISCLOSURES

Approval of Research Protocol: This study was approved by the ethics committee of our hospital as a retrospective

review and prognostic study of stroke complications (acceptance number: 30-44, 2019-021).
Informed Consent: We disclosed information about this study based on the opt-out approach.
Registry and the registration no. of the study/trial: Not applicable.
Animal Study: Not applicable.
Conflict of Interest: None declared.

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