Clinical and radiological outcomes following traumatic Grade 1 and 2 vertebral artery injuries: a 10-year retrospective analysis from a Level 1 trauma center

Clinical article

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Object. Screening of blunt vertebral artery (VA) injuries has increased since research has shown that they occur at a higher incidence than originally reported. Grade 1 and 2 injuries are the most common form of blunt VA injury. Proper screening, management, and follow-up of these injuries remain controversial. In this report, imaging, progression, treatment, and outcomes of Grade 1 and 2 blunt VA injuries were analyzed to better define their natural history and to establish a rational management plan based upon their risk of progression and cerebral infarct.

Methods. A retrospective review of all blunt traumatic carotid artery and VA injuries from December 2003 to April 2013 was performed. For the purposes of this report, focus was given to Grade 1 and 2 VA injuries. Grade 1 injuries were defined as a vessel lumen stenosis of less than 25%, and Grade 2 injuries were defined as vessel lumen stenosis between 25% and 50%. Demographic information, radiological imaging, number of images performed per individual, length of radiological follow-up, radiological outcome at the end of follow-up, treatment provided, and documentation of stroke or transient ischemic attack were recorded.

Results. One hundred eighty-seven Grade 1 and 2 VA injuries in 143 patients were identified. Of these 143 patients, 120 with 152 Grade 1 or 2 blunt VA injuries were available for follow-up. The mean duration of follow-up was 40 days. Repeat imaging showed that 148 (97.4%) Grade 1 or 2 blunt VA injuries were stable, improved, or resolved on final follow-up imaging. Seventy-nine patients (66%) were treated with aspirin, whereas 35 patients (29%) received no treatment. The remaining patients were treated with other antiplatelet agents or anticoagulant medication. Neuroimaging demonstrated 2 cases (1.7%) with posterior circulation infarcts that were believed to be related to their blunt VA injuries, both of which occurred during the initial hospitalization and within the first 4 days after injury.

Conclusions. Although follow-up imaging showed progressive worsening without radiological improvement in only a small number of patients with low-grade blunt VA injuries, these findings did not correlate with adverse clinical outcome. The posttraumatic cerebral infarction rate of 1.7% may be overestimated, and the use of acetylsalicylic acid or other antiplatelet or anticoagulant medication did not correlate with radiological changes or rate of cerebral infarction. While these data suggest the possibility that these low-grade VA injuries may not require treatment or follow-up, future prospective studies are needed to make conclusive changes related to management.

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Key Words • blunt cervical vascular injury • vertebral artery injury • cerebral infarction • vascular disorders

Screening of blunt vertebral artery (VA) injuries has increased since research has shown that these injuries are more prevalent than originally reported. Increased screening for blunt VA injuries has led to increased detection in 0.7% of patients with blunt trauma. Grade 1 and 2 vascular injuries are the most common form of blunt VA injury. Management of these injuries remains heavily debated, but antiplatelet or anticoagulant medications tend to be first-line treatments. Endovascular treatment or vessel sacrifice is not generally indicated for low-grade blunt VA injury. A majority of Grade 1 and 2 blunt VA injuries are likely to spontaneously improve, but there is concern that emboli originating from these low-grade injuries may pose a potential risk for cerebral infarction. Imaging, progression, and outcomes of Grade 1 and 2 blunt VA injuries were analyzed to gain a better understanding of the natural history of these injuries and to establish a rational management plan based upon their progression and risk of infarct.
Low-grade blunt vertebral artery injury

Methods

Study Population

After obtaining Institutional Review Board approval, a retrospective review of a prospectively maintained database of all traumatic carotid artery and VA injuries was conducted at our Level I Trauma Center (Parkland Memorial Hospital, Dallas, Texas). For the purposes of this report, attention was focused on the Grade 1 and 2 VA injuries. These 2 injury subsets were documented separately, but evaluated together during final analysis as we identified a similar progression between them. While we suspect that higher-grade injuries carry the potential to behave differently compared with lower-grade injuries, our aim for this Parkland Carotid and Vertebral Artery Injury Survey project was to categorize and report on these injuries separately, namely by Grades 1–2 and Grades 3–4. Additionally, as we are not yet certain whether carotid artery injuries behave similarly to VA injuries, we further separated these 2 vascular entities for the purposes of comparative analysis and reporting, all of which we will look forward to documenting in future papers.

Injury Definitions

Screening for blunt cerebrovascular injuries at our institution occurs through a modification of the Denver Criteria. Any patient found to have cervical spine fractures of the vertebral body, pedicle, or transverse process, basilar skull fractures involving the carotid canal or petrous bone, LeFort II or III fractures, Glasgow Coma Scale score less than 7 without obvious cerebral injury on head CT, and/or near hanging/strangulation with a ligature mark/contusion, receives a screening cervical CT angiogram to rule out a vascular injury.

Grade 1 injuries are defined as a vessel lumen stenosis of less than 25%. Grade 2 injuries are defined as a stenosis of the vessel lumen between 25% and 50%. Grade 3 injuries (defined as stenosis of the vessel greater than 50%, or the development of a pseudoaneurysm), Grade 4 injuries (vessel occlusion), and Grade 5 injuries (complete transection of the artery) were not included in this current analysis. Our department of neuroradiology made all initial reports of the presence and grade of cervical vascular injury. A staff neurosurgeon then confirmed the injury and decided on the desired follow-up and treatment. Only blunt injuries were evaluated. Any vascular injuries secondary to penetrating trauma were not included in this analysis.

Clinical Data

Data including age, sex, mechanism of injury, presence or absence of a cervical fracture, and other traumatic injuries within the proximity of the neck (such as occipital condylye fracture, first rib fracture, and others) were recorded. Radiological imaging was reviewed (such as CT angiography and digital subtraction angiography), as was the number of images performed per individual, and length of time between imaging and radiological outcomes at the end of follow-up. The treatment provided was recorded (such as antiplatelet, anticoagulant, no treatment, and others). The incidence of stroke as confirmed by clinical presentation and neuroimaging was recorded.

Results

From December 2003 through April 2013, there were 537 blunt cervical vascular injuries at our institution. This included 241 (45%) carotid artery and 296 (55%) VA injuries. From this cohort, there were 187 Grade 1 or 2 blunt VA injuries in 143 patients. These injuries comprised 35% of all blunt cervical vascular injuries and 63% of all VA injuries. Of these 143 patients, 120 were available for follow-up and were analyzed further in this current study. This left 152 Grade 1 or 2 blunt VA injuries available for final analysis. There were 35 left, 53 right, and 32 bilateral blunt VA injuries. Of the 23 patients who were excluded, 6 died of other trauma-related injuries and 17 were lost during follow-up. Seventy-nine (66%) of the 120 patients evaluated were male patients. The mean patient age was 36.1 years (range 14–87 years).

The mechanism of injury was motor vehicle collision (MVC) in 80 patients (67%), fall in 23 patients (19%), and motorcycle collision in 9 patients (8%). Other less common mechanisms included assault, all-terrain vehicle accidents, and motor-pedestrian collisions in the remaining 8 patients (7%). In the MVC group, 58% of the patients were reportedly restrained within their vehicle and 72% were involved in vehicular collision without rollover.

Sixty-two patients (52%) had a single-sided Grade 1 or 2 blunt VA injury, while 58 patients (48%) presented with multiple cervical vascular injuries (an additional ipsilateral and/or contralateral blunt VA injury, and/or a blunt carotid artery injury). The distribution of other vascular injuries is shown in Table 1. Cervical fractures were present in 85 patients (71%), and in those with a cervical fracture, the transverse foramen was involved in 43% of cases.

Repeat imaging showed that 148 (97.4%) of the 152 injuries identified as Grade 1 or 2 blunt VA injury were ultimately identified as stable, improved, or resolved, as determined by the final follow-up imaging evaluation (Table 2). Specifically, 20% (29 injuries) remained unchanged, 10% (15 injuries) improved to various degrees, and 70% (99 injuries) completely resolved on final follow-up imaging. There were 9 Grade 1 or 2 blunt VA injury cases (6%) that were considered unstable, as defined by a worsening grade of injury determined by the first follow-up imaging evaluation (Table 3). In this unstable group of 9 Grade 1 and 2 blunt VA injuries, 2 showed subsequent improvement of their injury, and in 3 cases the injury completely resolved at final follow-up. Only 4 cases (2.6% of the total follow-up group) demonstrated progressive worsening of their vascular injury without subsequent radiological improvement (Table 3).

During follow-up, 69 patients (58%) received only 1 follow-up CT angiogram (2 CT angiograms total; Table 4), with the majority of these cases (86%) undergoing imaging again between 7 and 10 days after the initial documented injury. Of these injuries receiving only 1 follow-up image between 7 and 10 days, 69% had resolved in that time frame, 15% had remained stable, 14% had improved, while the remainder (1 case) progressed from a Grade 1 to a Grade 2 injury. The remaining 51 patients had more
than 1 follow-up image. The reason for obtaining multiple repeated images in this group appeared to be the presence of multiple vascular injuries in nearly all cases, with a higher than Grade 2 injury of either the carotid artery or VA included in this majority. There was great variability in both the number of and the timing in between sequential images in this latter group, with an average time to last follow-up image of 79 days. Seventy-five percent of patients in this group received their first follow-up imaging scan between 7 and 10 days, and at that time point 40% of the Grade 1 and 2 blunt VA injuries were identified as stable, 19% were improved, 32% were resolved, and 8% progressed to a worsened grade. The details of injury progression within the 7- to 10-day timeline are summarized in Table 4. The mean overall time of radiological follow-up across all groups was 40 days (range 7–291 days).

Seventy-nine patients (66%) were treated with acetylsalicylic acid (ASA) alone, 3 were treated with heparin and later transitioned to warfarin, 1 was treated with warfarin alone, 1 was treated initially with ASA and then transitioned to heparin and subsequently to ASA and clopidogrel, and 1 was treated with clopidogrel alone. Thirty-five patients (29%) were not treated with any medications, due to other injuries precluding treatment with antiplatelet or anticoagulant medications. In the 79 patients who received ASA, 72 (91%) with 99 injuries had stable, improved, or resolved blunt VA injuries determined by the first follow-up imaging. Of the 7 patients treated with ASA whose injuries progressed to a higher grade, 3 stabilized at the higher Grade, 1 improved from the higher grade, and 3 completely resolved (Table 3). The 3 patients who were initially started on heparin treatment and transitioned to warfarin had stable Grade 1 or 2 blunt VA injuries, and the patient treated initially with ASA and subsequently with heparin with transition to ASA and clopidogrel worsened on initial follow-up imaging (the reason for the alteration in medication), and remained unchanged at the higher grade on further imaging. One of the 35 patients who did not receive medical treatment demonstrated an unstable injury on first follow-up imaging at 1 week, but showed subsequent improvement to a Grade 1 injury on final imaging at 6 months. The other 34 patients who did not receive treatment had stable, improved, or resolved injuries on final imaging. The distribution of individual injuries and respective treatments are reviewed in Tables 2 and 3. In all cases in which clinic follow-up records were available and there was resolution of the vascular injury, the treatment medication was discontinued. In those cases in which the injury remained present at the last available follow-up record, the treatment medication was recommended to be continued.

Computed tomography angiography was used as the initial imaging modality in 99.2% of cases. The number of CTAs performed per patient is depicted in Fig. 1. The average number of images performed in relation to isolated and/or combined injuries is depicted in Table 5. There were 118 patients (98%) who received 2 or more CT angiograms per patient. Digital subtraction angiography (DSA) was performed in 8.3% of cases (10 patients) and was used as an initial imaging modality in only 1 case (0.8%). In those receiving DSA, 60% (6 patients) had this procedure performed only once. The use of DSA was noted to occur most prevalently during the early portion of this study, specifically between the years 2003 and 2005. The use of this imaging modality tapered significantly through 2008, after which time its use was noted in only 1 case (in 2012), in which the low-grade blunt VA injury was associated with bilateral high-grade carotid artery injuries.

Four patients were identified as having posttraumatic cerebral infarcts. These infarcts were suspected either radiographically or confirmed on follow-up imaging. One of these 4 patients was treated initially with ASA and then transitioned to heparin and subsequently to ASA and clopidogrel.

### TABLE 1: Distribution of blunt VA and carotid artery injuries in relation to Grade 1 and Grade 2 blunt VA injury

<table>
<thead>
<tr>
<th>Grade</th>
<th>Blunt VA Injury</th>
<th>Blunt Carotid Artery Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ipsilateral</td>
<td>Contralateral</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

### TABLE 2: Radiological progression of stable and unstable Grade 1 and 2 blunt VA injuries in 120 patients

<table>
<thead>
<tr>
<th>Original Grade</th>
<th>Worsened Grade</th>
<th>Final Outcome</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>resolved</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>stable Grade 2</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>stable Grade 3</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>improved to Grade 1</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>improved to Grade 1</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>stable Grade 3</td>
<td>other*</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>stable Grade 3</td>
<td>ASA</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>resolved</td>
<td>ASA</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>resolved</td>
<td>ASA</td>
</tr>
</tbody>
</table>

* In these 4 cases, there was documented worsening of injury without subsequent improvement.
† A case initiated on ASA and then transitioned to heparin and subsequently to ASA and clopidogrel.

### TABLE 3: Progression of 9 unstable injuries and treatment

<table>
<thead>
<tr>
<th>Original Grade</th>
<th>Worsened Grade</th>
<th>Final Outcome</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>resolved</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>stable Grade 2</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>stable Grade 3</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>improved to Grade 1</td>
<td>ASA</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>improved to Grade 1</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>stable Grade 3</td>
<td>other*</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>stable Grade 3</td>
<td>ASA</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>resolved</td>
<td>ASA</td>
</tr>
</tbody>
</table>

* Patient treated initially with ASA and then transitioned to heparin and subsequently to ASA and clopidogrel.
Low-grade blunt vertebral artery injury

Two cases (1.7% of the follow-up group) had posterior circulation infarcts that were believed to be related to their blunt VA injury. The first patient was an 18-year-old man with an isolated Grade 1 blunt VA injury that progressed to a Grade 2 injury on follow-up imaging. He was involved in an MVC, sustained a C-2 hangman-type cervical fracture involving bilateral transverse foramen, and was treated with ASA for the vascular injury. A new, asymptomatic hypodensity within the right cerebellar hemisphere was observed on a routine head CT scan on hospital Day 2. No MRI was performed in this case. This patient underwent 2 additional follow-up head CT scans while an inpatient, which showed this hypodensity to be stable. The second patient was a 63-year-old woman who had an isolated Grade 1 blunt VA injury that resolved on follow-up imaging at 1 week. She also was involved in an MVC, sustained multiple orthopedic injuries, including a C-2 hangman-type cervical fracture involving bilateral transverse foramen, and was treated initially with ASA for her vascular injury. In this case, due to clinical manifestations on hospital Day 4 (new onset confusion and receptive aphasia), MRI was performed demonstrating scattered supra- and infratemporal posterior circulation infarcts. Her medical management was changed to a heparin drip with subsequent transition to ASA and clopidogrel. Her symptoms resolved and she was discharged home in normal neurological condition on hospital Day 13. This later case did involve a complicated prior medical history, including prior cerebral infarctions and radiological evidence of old cerebellar lacunar infarcts. She had also undergone midbasilar artery stent placement earlier that year, as well as partial coiling of a basilar apex aneurysm (which was also found to contain a small thrombus on vascular imaging).

These 2 cases represent a 1.7% incidence of suspected blunt VA injury-related cerebral infarct in the Grade 1–2 blunt VA injury group. If this later case was determined to be unrelated to the blunt VA injury secondary to the aforementioned posterior circulation disease, the incidence of posttraumatic cerebral infarction in this low-grade blunt VA injury group decreases to 0.8%.

**Discussion**

Blunt cerebrovascular injury research since the 1990s has led to an increase in screening protocols and treatment strategies for this injury. Disagreement exists regarding the appropriate screening, treatment, and follow-up of these injuries. Common parameters for screening include patients who have symptomatic ischemic injuries and patients who are asymptomatic with Le Fort II/III fractures, cervical spine fractures, Horner’s syndrome, foramen lacerum fractures, neck soft-tissue injury, or unexplained ischemic events. There have also been case reports of blunt cerebrovascular injury diagnosis from more benign torsion injuries ranging from yoga to “bottoms-up” drinking.

At our institution, trauma patients meeting criteria for blunt VA injury screening receive a CT angiogram. Although DSA is considered a gold standard for cerebral vascular imaging, CT angiography has become the preferred imaging modality for screening these traumatic vascular injuries. Digital subtraction angiography has a higher sensitivity and specificity, but requires highly trained professionals, time, financial cost, and comes with potential complications (approximately 3.5% rate of procedure-related complications, including 0.3%–1% risk of ischemic stroke). Furthermore, Bendszus et al. found that 23% of patients undergoing DSA demonstrated silent diffusion weighted imaging changes on MRI after DSA.

As our data indicated only 2 patients had cerebral infarcts involving the posterior circulation (<2% of the study cohort), the use of DSA in screening evaluation and follow-up in these particular injuries is a less optimal modality and carries the potential risk of creating an increased false positive rate of stroke and MRI changes in this population. Although CT angiography has slightly less sensitivity and specificity, it is much quicker, safer, and less expensive.
from blunt VA injury was eliminated by the use of ASA.20 sel injuries, Miller et al. determined that ischemic stroke by blunt VA injury. In a similar cohort of patients and ves- grades and found only 1 case of ischemic stroke caused included both carotid artery and VA injuries of various
injuries is the risk of cerebral infarction; however, reports
any other convincing correlation between musculoskeletal
imaging may not be entirely necessary because only 2.6%
of the Grade 1 and 2 blunt VA injuries (4 cases) were
determined to be truly unstable as evidenced by progressive radiological worsening without subsequent improvement. These results are not dissimilar to past studies. Biffl et al. evaluated the progression of blunt cerebrovascular in-
jury in a sequential DSA study examining both vertebral and carotid artery injuries together as a cohort.8 In this study, DSA was performed immediately upon admission and then again 7–10 days after admission, and more than 90% of Grade 1 blunt cerebrovascular injuries and 50%
of Grade 2 blunt cerebrovascular injuries were stable or spontaneously resolved. Our study demonstrated that a slightly larger percentage (97.4%) of these injuries were
ultimately stable, improved, or resolved, but our patients
were comparatively followed for a slightly longer duration overall, so these vascular injuries had a potentially longer time to heal.

Cervical fracture injuries were present in 71% of the
Grade 1 and 2 blunt VA injuries, with 42% of these cases involving the transverse foramen. This high correlation between cervical fracture and blunt VA injury has also been established in previous papers.20,23,26 We did not find any other convincing correlation between musculoskeletal injuries in the proximity of the neck and rate of blunt VA injury.

The greatest concern about Grade 1 and 2 blunt VA injuries is the risk of cerebral infarction; however, reports have suggested the risk of ischemic stroke may be quite low. Griessenauer et al. investigated the outcomes of 112 patients with blunt cerebrovascular injuries.12 This study included both carotid artery and VA injuries of various grades and found only 1 case of ischemic stroke caused by blunt VA injury. In a similar cohort of patients and ves-
sel injuries, Miller et al. determined that ischemic stroke from blunt VA injury was eliminated by the use of ASA.20 Griessenauer et al. concluded that most ischemic strokes will occur before initial screening with CT angiography and treatment with an antiplatelet medication, indicating that follow-up imaging will not aid in preventing most is-
chomic strokes.12 In the Biffl et al. series, in those who suffered a posttraumatic stroke, 90% of infarctions were noted prior to any medical treatments, 9% were identi-
fied while individuals were taking ASA, and 1% occurred while taking heparin.8 A previous study from our institu-
tion by Eastman et al. examined 26 patients with either blunt carotid artery injuries or blunt VA injuries and found a stroke rate of 3.8% (1/26). The cerebral infarction in this study was identified in a patient with a Grade 3 blunt VA injury. There were no strokes in the 12 Grade 1 or 2 blunt VA injury cases (4 Grade 1 and 8 Grade 2).10 Our study identified 4 cases of ischemic stroke as determined by posttraumatic neuroimaging. Two of these cases were not believed to be related to the vascular injuries studied and were not analyzed further. There were 2 (1.7%) of 120 cases with posttraumatic infarcts in the posterior circula-
tion believed to be related to the blunt VA injury. Of the 2
patients with posterior circulation infarcts, both were tak-
ing ASA prior to documenting the infarct, and 1 of these patients had significant preinjury posterior circulation dis-
case. No other patient in the medical treatment groups and none of the 36 patients who received no medical treatment had documented posttraumatic cerebral infarcts.

The progression of injury does not appear to be af-
fected by any specific medical treatment. Cothren et al. evaluated 422 patients with blunt cerebrovascular injury, with 130 of those patients having a Grade 1 or 2 blunt VA injury.9 The majority of patients in this cohort (49%)
were treated with heparin, 23% were treated with either ASA or a combination of ASA and clopidogrel, and 28% were untreated. This study concluded that there was no reliable way to alter the progression of injury. Our study found similar results, in that the progression of injury was not altered by any specific treatment or absence of treat-
ment. To date, there have been no promising studies to
indicate specific methods to alter the progression of these injuries, although there have been studies evaluating the effect of different supplements on progression such as vitamin E, which has shown experimental promise in pre-
vending progressive stenosis in arterial injuries.15,18,27 No patient in this study who demonstrated a progression of their injury to a higher grade required stent placement or coil embolization. In a retrospective study of blunt VA injury performed by Biffl et al., stent placement for any grade of blunt VA injury was not recommended, because this angiographic modality of treatment carried a higher morbidity than treatment with medicine alone.5

The major limitation of this study was its retrospec-
tive design. A prospective study is needed to implement various treatment strategies to verify appropriate follow-
up protocols. Although some studies have suggested that CT angiography overestimates vascular injury in these blunt traumatic cases,12,20,23,28 we used this imaging mo-
dality in the majority of cases due to the comparative ease,
accessibility, and safety associated with this procedure compared with DSA, especially in critically ill patients with multiple trauma. Use of CT angiography may have then produced a falsely elevated incidence rate of vascular
injury at our center. Because these low-grade injuries reflect a smaller percentage of vessel diameter disruption, a falsely elevated rate of improvement on follow-up imag-

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**TABLE 5: Number of CT angiograms received and average follow-up duration per group**

<table>
<thead>
<tr>
<th>Blunt VA Injury Group</th>
<th>Mean No. of CT Angiograms</th>
<th>Mean Follow-Up (days)</th>
<th>No. of Patients</th>
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<tbody>
<tr>
<td>unilateral</td>
<td>2.4</td>
<td>34.6</td>
<td>62/120</td>
</tr>
<tr>
<td>bilateral</td>
<td>2.6</td>
<td>50.3</td>
<td>31/120</td>
</tr>
<tr>
<td>w/ blunt carotid artery injury</td>
<td>3.0</td>
<td>51.9</td>
<td>27/120</td>
</tr>
</tbody>
</table>

Furthermore, many studies have established CT angiogra-
phy as a better imaging modality than DSA.4,21,24,28 Other imaging techniques such as duplex Doppler ultrasono-
graphy have been tried and found not to be as sensitive or specific as DSA or CT angiography.17,21 At our center, CT angiography is currently used for the initial screening and follow-up of these vascular injuries. Our recent follow-up protocol has been to image injuries at 1 week, 1 month, 3 months, 6 months, and then yearly as long as the injury is still present. Our study suggests that frequent follow-up imaging may not be entirely necessary because only 2.6% of the Grade 1 and 2 blunt VA injuries (4 cases) were determined to be truly unstable as evidenced by progressive radiological worsening without subsequent improvement.

In the Biffl et al. series, in those who suffered a posttraumatic stroke, 90% of infarctions were noted prior to any medical treatments, 9% were identified while individuals were taking ASA, and 1% occurred while taking heparin.8 A previous study from our institution by Eastman et al. examined 26 patients with either blunt carotid artery injuries or blunt VA injuries and found a stroke rate of 3.8% (1/26). The cerebral infarction in this study was identified in a patient with a Grade 3 blunt VA injury. There were no strokes in the 12 Grade 1 or 2 blunt VA injury cases (4 Grade 1 and 8 Grade 2).10 Our study identified 4 cases of ischemic stroke as determined by posttraumatic neuroimaging. Two of these cases were not believed to be related to the vascular injuries studied and were not analyzed further. There were 2 (1.7%) of 120 cases with posttraumatic infarcts in the posterior circula-
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Low-grade blunt vertebral artery injury

...ing may also be reflected in this study as compared with older studies that used DSA, especially if there was a potential overestimation of initial injury.

Due to the dynamic nature of our study population, and at times following multiple vascular injuries simultaneously, we experienced a large variability in our follow-up duration, which does limit our ability to conclusively define timing as it relates to the healing of these low-grade VA injuries. However, that limitation does not diminish the fact that the majority of these injuries (97.4%) proved to be stable and have an overall low posttraumatic infarct rate (1.7%). Another limitation of this retrospective study is that we cannot be entirely sure that some clinically silent strokes were not missed, but we can offer that all individuals included in this study did undergo follow-up evaluations, and thus we are certain that all clinically apparent strokes were both identified and recorded. While this data across the past 10 years at our institution yielded valuable information, the data involving low-grade VA injuries alone did not afford us much ability for statistical analysis; however, once all of the data across all of the cervical vascular injuries have been analyzed, we look forward to the ability to offer a well-powered analysis across all grades of blunt vertebral and carotid artery injuries, specifically as it relates to the stroke risk in the setting of treatment, timing, vessel, and grade.

Conclusions

Results of this study suggest that Grade 1 and 2 blunt VA injuries have a generally benign course, with a cerebral infarction rate of 1.7%, which may be overestimated. Follow-up imaging showed progressive worsening of the vascular injury without subsequent radiological improvement in 2.6% of cases; however, this finding did not correlate with adverse clinical outcome. The use of ASA or other antiplatelet or anticoagulant medication in these low-grade blunt VA injuries did not appear to correlate with radiological injury stability, nor with a decreased rate of cerebral infarction, and thus suggests that in individuals with Grade 1 or 2 VA injuries, the use of these medications may not provide a difference in the progression of injury nor eliminate the small but present risk of cerebral infarction. That said, each clinician should balance the individual risks and benefits of treatment in this category of vascular injury. The time and cost allotted for follow-up imaging deserves attention as continued imaging in this particular subset of vascular injury may prove entirely necessary. Follow-up protocols should be amended, but further prospective studies are needed to make conclusive changes as it relates to management.

As we continue this Parkland Carotid and Vertebral Artery Injury Survey study from our institution, we look forward to presenting our entire experience of cervical vascular injuries in sectioned categories as discussed above. After we conclude reporting on all grades of carotid artery and VA injuries, we will at that time consider our plans for prospective research on this topic in an effort to more specifically define which injuries require follow-up and which injuries benefit from treatment.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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