

# Management of blunt cerebrovascular injuries at a Canadian level 1 trauma centre: Are we meeting the grade?

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**Background:** Untreated blunt cerebrovascular injuries (BCVIs) are associated with high rates of death and disability due to stroke. We assessed alignment of clinical practice at our centre with current recommendations for management of BCVIs and examined rates of new and recurrent in-hospital stroke.

**Methods:** We retrospectively reviewed the BC Trauma Registry to identify all adult (age > 18 yr) patients with trauma with BCVIs at the largest level 1 trauma centre in British Columbia, Canada, from Apr. 1, 2013, to Mar. 31, 2018. We evaluated the registry, hospital databases and patient charts to assess alignment with guidelines for early initiation of appropriate antithrombotic therapy and follow-up imaging, and to ascertain short-term outcomes.

**Results:** A total of 186 patients met the inclusion criteria. Just over half of BCVIs (97 [52.2%]) were Biffi grade 1–2. The majority of patients were treated with acetylsalicylic acid monotherapy (144/162 [88.9%]) or low-molecular-weight heparin (2/162 [1.2%]). Although guidelines recommend repeat imaging at 7–10 days to reassess the injury and guide duration of therapy, only 61/171 patients (35.7%) underwent repeat imaging within 7 days. Neuroimaging within 3 months after injury showed brain infarction in 29 patients (15.6%).

**Conclusion:** Antithrombotic therapy was initiated in the majority of eligible patients with BCVIs, but completion of follow-up imaging and documentation of clear outpatient care plans were suboptimal. This finding shows the need for routine multidisciplinary management to facilitate standardization of care for this complex population.

**Contexte :** Les traumatismes vasculaires cervicaux fermés (TVCF) non traités sont associés à des taux élevés de mortalité et d'invalidité par suite d'un défaut de vascularisation. Nous avons évalué la concordance entre la pratique clinique à notre centre et les recommandations actuelles pour la prise en charge des TVCF et mesuré les taux d'AVC perhospitaliers nouveaux et récurrents.

**Méthodes :** Nous avons procédé à une revue rétrospective auprès du BC Trauma Registry pour recenser tous patients adultes (> 18 ans) victimes de TVCF dans le plus grand centre de traumatologie de niveau 1 de la Colombie-Britannique, au Canada, entre le 1<sup>er</sup> avril 2013 et le 31 mars 2018. Nous avons consulté le registre, les bases de données de l'hôpital et les dossiers des patients pour vérifier la conformité avec les lignes directrices en ce qui concerne l'instauration rapide du traitement antithrombotique approprié et les épreuves d'imagerie de contrôle, et pour connaître l'issue à court terme de ces traumatismes.

**Résultats :** En tout, 186 patients répondaient aux critères d'inclusion. À peine plus de la moitié des cas de TVCF (97 [52,2 %]) étaient de grade Biffi 1–2. La majorité des patients ont reçu de l'acide acétylsalicylique en monothérapie (144/162 [88,9 %]) ou de l'héparine de bas poids moléculaire (2/162 [1,2 %]). Même si les lignes directrices préconisaient des épreuves d'imagerie de contrôle dans les 7–10 jours pour réévaluer la situation et orienter la durée du traitement, seulement 61 patients sur 171 (35,7 %) ont eu droit à de tels contrôles dans les 7 jours. Les épreuves d'imagerie cérébrale dans les 3 mois suivant le traumatisme ont montré des signes d'infarctus cérébral chez 29 patients (15,6 %).

**Conclusion :** Un traitement antithrombotique a été amorcé chez la majorité des patients admissibles présentant un TVCF, mais les contrôles d'épreuves d'imagerie et la préparation de plans de traitement post-hospitaliers clairs ont laissé à désirer. Cette observation rappelle qu'il faut une prise en charge multidisciplinaire pour mieux standardiser les soins chez cette population complexe.

**T**raumatic blunt injury to the carotid or vertebral vessels carries a high risk of death or disability due to stroke. Although blunt cerebrovascular injuries (BCVIs) were previously thought to be rare, the reported prevalence in patients who have experienced trauma is 1%–3%, which suggests a higher ascertainment rate as routine vascular imaging for patients with trauma becomes more common.<sup>1</sup> Blunt cerebrovascular injuries are associated with ischemic brain infarcts, which occur at higher rates among patients not treated with antithrombotics.<sup>2,3</sup> Associated mortality may be as high as 11%–22%, depending on the degree of vascular injury.<sup>4,5</sup> Prompt diagnosis and initiation of antithrombotic therapy for stroke prevention is critical in the management of BCVI, as up to 80% of patients develop neurologic symptoms of ischemia within the first 10–72 hours after injury.<sup>6</sup>

In the past decade, the recognition of BCVIs in patients with trauma has increased owing to more routine use of vascular imaging alongside implementation of standardized screening and diagnostic criteria for BCVI.<sup>7,8</sup> However, the management of BCVI remains controversial. Several studies support the use of both acetylsalicylic acid (ASA) and therapeutic heparin.<sup>9–11</sup> In response to the growing recognition of BCVI among patients with trauma and the lack of consensus with regard to management, the Eastern Association for the Surgery of Trauma developed clinical practice guidelines to consolidate current evidence and streamline patient care.<sup>1,7</sup> In 2018, an updated set of best practices was published, integrating more recent data and higher-quality studies.<sup>8</sup>

Guideline-aligned practice may standardize practice patterns and improve quality of care. At our institution, the stroke neurology service is consulted for patients diagnosed with BCVI and gives recommendations for antithrombotic therapy, follow-up imaging and clinical follow-up. The trauma service enacts management plans while considering the overall direction of care and contextualizing each treatment within the larger scope of the patient's comorbidities and concomitant injuries. Variability in the BCVI treatment pathway has been noted at our institution; hence, the aim of this study was to assess local practice as it aligns with current practice guidelines, and to determine potential practice gaps. We also examined associations between management and patient in-hospital outcomes.

## METHODS

### *Patient selection*

In this retrospective study, we used the BC Trauma Registry, overseen by Trauma Services BC (TSBC), to identify patients who presented or were transferred to the largest level 1 trauma centre in the province of

British Columbia, Canada, from Apr. 1, 2013, to Mar. 31, 2018, with a diagnosis of BCVI. Approvals to access the data sets for the purpose of this study were granted by TSBC.

Inclusion and exclusion criteria were defined by the study team before conducting a search of the registry. Inclusion criteria were as follows: diagnosis of unilateral or bilateral carotid or vertebral artery injury on initial computed tomography angiography (CTA), where injury of the artery was defined as intimal tear, dissection, pseudoaneurysm, occlusion or transection of the vessel. Patients had to be more than 18 years of age and have been admitted to the trauma service. Penetrating traumatic injuries were excluded.

### *Study variables*

We extracted patient demographic characteristics, injury severity scores, injury type and mechanism of injury from the TSBC registry. We reviewed electronic health records to collect outcome measures. We used initial trauma physician and nursing records, as well as the prehospital or interfacility transfer notes, to ascertain important signs and symptoms, and risk factors as described in the expanded Denver screening criteria.<sup>12</sup> We reviewed clinical imaging reports to determine the Biffl grade of each BCVI.<sup>13</sup> Biffl grades 1 and 2 were collapsed into a single group, mainly owing to ambiguity in classification of low-grade injuries in radiology reports and similar treatments within the management algorithm. Patients with multiple BCVIs were placed into the group corresponding to their highest Biffl grade injury.

We extracted treatment recommendations from specialty service consultation notes and reviewed the daily pharmacy medication administration records to document the timing and administration of treatments.

We searched CareConnect, an integrated provincial electronic health record, up to Dec. 31, 2019, to document the timing of follow-up imaging after the initial diagnosis of BCVI. We reviewed discharge summaries to assess clear documentation of the BCVI, as well as appropriate follow-up instructions.

### *Outcomes*

The primary outcome was practice consistent with current guidelines for BCVI management as outlined by the Eastern Association for the Surgery of Trauma<sup>1,7</sup> and the updated guidelines proposed by Brommeland and colleagues.<sup>8</sup> The former guidelines recommend treatment of BCVI with ASA or heparin, whereas Brommeland and colleagues<sup>8</sup> suggest 24–48 hours of low-molecular-weight heparin at antithrombotic dosages (50–100 IU/kg), followed by a transition to low-dose ASA daily. For follow-up imaging, both guidelines suggest CTA within 7–10 days.

In addition, based on newer evidence, the updated guidelines suggest an additional follow-up scan at 3 months for higher-grade injuries to reassess vessel healing.<sup>8</sup> Secondary outcomes were presence of clear follow-up plans in discharge documentation and incidence of stroke in untreated patients.

### Statistical analysis

We conducted descriptive statistics using Microsoft Excel 16.16.7. Continuous variables were expressed as means and standard deviations (SDs), and categorical variables were expressed as frequencies and percentages.

## RESULTS

Over the study period, 196 patients were identified in the trauma registry for review, of whom 186 met the inclusion criteria. Roughly one-third of the patients (59 [31.7%]) were female; the mean age was 49 (SD 20) years (Table 1). The most common causes of injury were motor vehicle or motorcycle collision ( $n = 79$  [42.5%]) and fall from a height ( $n = 55$  [29.6%]). Ninety-seven patients (52.2%) had low-grade BCVIs (Biffl grade 1–2), 26 (14.0%) had grade 3 BCVIs, and 63 (33.9%) had grade 4 BCVIs.

The most common expanded Denver screening criteria were all cervical spine fracture patterns ( $n = 94$  [50.5%]), severe traumatic brain injury with a Glasgow Coma Scale score less than 6 ( $n = 39$  [21.0%]) and upper rib fracture ( $n = 38$  [20.4%]) (Table 2). The mean number of criteria present per patient was 1.74 (SD 1.56) for grade 1–2 injuries, 1.77 (SD 1.18) for grade 3 injuries and 1.67 (SD 1.16) for grade 4 injuries.

**Table 1. Characteristics of patients with blunt cerebrovascular injuries stratified by Biffl grade**

Characteristic	Biffl grade; no. (%) of patients*		
	1–2 $n = 97$	3 $n = 26$	4 $n = 63$
Age, mean $\pm$ SD, yr	44.4 $\pm$ 20.2	44.7 $\pm$ 17.4	55.2 $\pm$ 18.5
Injury Severity Score, mean $\pm$ SD	28.4 $\pm$ 14.5	30.3 $\pm$ 13.0	26.9 $\pm$ 18.0
Gender			
Male	63 (65)	17 (65)	47 (75)
Female	34 (35)	9 (35)	16 (25)
Mechanism of injury			
Motor vehicle collision	36 (37)	7 (27)	17 (27)
Motorcycle collision	6 (6)	7 (27)	6 (10)
Pedestrian accident	16 (16)	2 (8)	6 (10)
Fall from height	25 (26)	6 (23)	24 (38)
Other†	14 (14)	4 (15)	10 (16)

SD = standard deviation.  
\*Except where noted otherwise.  
†Includes all-terrain vehicle accidents, bicycle accidents, snow sport accidents, assaults, axial load injuries, surfing accident and crush injuries.

## Outcomes

### Primary

Almost all patients (184 [98.9%]) received CTA to diagnose the BCVI; of the remaining 2 patients, 1 had magnetic resonance imaging and 1 had magnetic resonance angiography. Fifteen patients died or were transitioned to palliative care. Repeat CTA was performed within 7 days in 61 (35.7%) of the remaining 171 patients (Table 3). Of the 149 patients with a hospital stay of 7 days or longer, 81 (54.4%) had a follow-up scan before discharge. Two-thirds of eligible patients (112/171 [65.5%]) had follow-up imaging to reassess the BCVI within 3 months after injury.

Within 48 hours after injury, 20 patients had died, were transitioned to palliative care or had absolute contraindications to antithrombotic treatment (i.e., active hemorrhage requiring intervention or resuscitation, or high risk of bleeding into a critical site, including intracranial and intraspinal due to injuries such as severe intracranial hemorrhage and spinal epidural hematomas). Among the remaining 166 patients, no antithrombotic treatment was initiated in 4 patients (2.4%) despite the apparent absence of contraindications, antithrombotic therapy was initiated within 48 hours in 128 patients (77.1%), and, in 24 patients (14.5%) with coexisting brain or solid-organ injuries, antithrombotic

**Table 2. Extended Denver screening criteria present stratified by Biffl grade**

Criterion	Biffl grade; no. (%) of patients		
	1–2	3	4
<b>Signs or symptoms of BCVI</b>			
Potential arterial hemorrhage from neck, nose or mouth	3 (3)	3 (3)	0 (0)
Expanding cervical hematoma	0 (0)	1 (3)	1 (3)
Focal neurologic deficit (TIA, hemiparesis, vertebrobasilar symptoms, Horner syndrome)	13 (3)	6 (3)	13 (3)
Neurologic examination findings incongruous with head CT findings	1 (3)	0 (0)	0 (0)
Ischemic stroke on CT or MRI	6 (3)	3 (3)	9 (3)
<b>Risk factors for BCVI in setting of high-energy-transfer mechanism</b>			
Displaced midface fracture (Le Fort II or III)	2 (3)	1 (3)	0 (0)
Mandible fracture	6 (3)	4 (3)	1 (3)
Complex skull fracture, basilar skull fracture or occipital condyle fracture	20 (3)	5 (3)	8 (3)
Severe traumatic brain injury with GCS score < 6	25 (3)	2 (3)	12 (3)
Cervical spine fracture, subluxation or ligamentous injury at any level	44 (3)	6 (3)	44 (3)
Clothesline-type injury or seat belt abrasion with significant swelling, pain or altered level of consciousness	3 (3)	2 (3)	0 (0)
Scalp degloving	3 (3)	0 (0)	1 (3)
Thoracic vascular injury	22 (3)	8 (3)	7 (3)
Upper rib fracture	24 (3)	5 (3)	9 (3)

BCVI = blunt cerebrovascular injury; CT = computed tomography; GCS = Glasgow Coma Scale; MRI = magnetic resonance imaging; TIA = transient ischemic attack.

**Table 3. Frequency of follow-up computed tomography angiography stratified by Biffl grade\***

	Biffl grade; no. (%) of patients		
	1–2 <i>n</i> = 92	3 <i>n</i> = 26	4 <i>n</i> = 53
Timing of CTA			
Within 7 d	33 (36)	13 (50)	15 (28)
Within 30 d	19 (21)	4 (15)	5 (9)
Within 90 d	10 (11)	3 (12)	10 (19)
> 90 d	8 (9)	0 (0)	6 (11)
Received follow-up scan during hospital stay†	49/84 (58)	14/19 (74)	18/46 (39)
No CTA	22 (24)	6 (23)	17 (32)

CTA = computed tomography angiography.  
\*Fifteen patients who died or were transitioned to palliative care are excluded.  
†Includes only patients with a length of stay of 7 days or more.

**Table 4. Timing of treatment initiation and medical treatment modality stratified by Biffl grade**

Timing and modality	Biffl grade; no. (%) of patients		
	1–2	3	4
<b>Timing of treatment initiation</b>			
Within 48 h of diagnosis	64 (66)	18 (69)	46 (73)
Delayed (> 48 h)			
With contraindications	13 (13)	6 (23)	5 (8)
Without contraindications	8 (8)	0 (0)	2 (3)
Untreated			
Owing to contraindications*	5 (5)	1 (4)	0 (0)
Despite no contraindications	2 (2)	1 (4)	1 (2)
Owing to death/palliative care	5 (5)	0 (0)	9 (14)
<b>Medical treatment modality/regimen</b>			
ASA			
Low-dose (81 mg)	74 (76)	18 (69)	40 (63)
Loading dose (325 mg), then low-dose	1 (1)	3 (12)	4 (6)
Alternative dosage (e.g., 160 mg)	2 (2)	1 (4)	1 (2)
Warfarin with heparin bridge	1 (1)	1 (4)	0 (0)
Warfarin with heparin bridge + ASA	0 (0)	0 (0)	2 (3)
Low-molecular-weight heparin (therapeutic)	2 (2)	0 (0)	0 (0)
Clopidogrel	1 (1)	0 (0)	3 (5)
Clopidogrel + ASA	4 (4)	1 (4)	3 (5)
Untreated	12 (12)	2 (8)	10 (16)

ASA = acetylsalicylic acid.  
\*Includes active hemorrhage requiring intervention or resuscitation, and high risk of bleeding into a critical site, including intracranial, intraspinal or retroperitoneal.

**Table 5. Timing and setting of stroke within 3 months of initial diagnosis stratified by Biffl grade**

Timing/setting of stroke	Biffl grade; no. (%) of patients		
	1–2 <i>n</i> = 7	3 <i>n</i> = 8	4 <i>n</i> = 14
Present at time of arrival	6 (86)	3 (38)	9 (64)
While receiving treatment for BCVI	0 (0)	3 (38)	1 (7)
While untreated for BCVI because of contraindications	1 (14)	2 (2)	4 (29)

BCVI = blunt cerebrovascular injury.

therapy was initiated once it was deemed safe to do so (Table 4). Initiation of antithrombotic was delayed in 10 patients (6.0%) despite no clear contraindication.

A total of 144/162 patients (88.9%) received ASA, at a dosage of 81–325 mg, and 2 patients (1.2%) were treated with therapeutically dosed low-molecular-weight heparin (Table 4). The remaining 16 patients (9.9%) received therapeutic unfractionated heparin bridging to warfarin with or without ASA (*n* = 4), or clopidogrel with or without ASA (*n* = 12).

**Secondary**

Of the 186 patients, 29 (15.6%) (7 with Biffl grade 1–2 injuries, 8 with grade 3 injuries and 14 with grade 4 injuries) experienced an ischemic infarct within 3 months of their injury. The stroke developed within the first 7 days of BCVI diagnosis in 28 patients. Eighteen patients (62%) had infarcts visible on initial imaging, 4 strokes (14%) occurred during antithrombotic therapy for BCVI, and 7 strokes (24%) occurred in patients who were not receiving anti-thrombotics owing to contraindications (Table 5). The strokes that occurred during active antithrombotic therapy were all in patients with polytrauma who had Injury Severity Scores between 14 and 41, all of whom were receiving ASA monotherapy at the time of the stroke. Seventeen patients (59%) were asymptomatic or unexaminable, with ischemic infarcts incidentally identified on initial imaging, and 12 (41%) had symptomatic ischemic events.

Four patients, 1 with Biffl grade 3 BCVI and 3 with Biffl grade 4 BCVI, underwent an endovascular intervention (stenting, endarterectomy, thrombectomy with stenting, and coiling).

For 149 patients (80.1%) (75 with Biffl grade 1–2 BCVIs, 23 with grade 3 injuries and 51 with grade 4 injuries), the discharge and death summaries included BCVI as a separate injury on the problem list. Clear instructions regarding follow-up imaging and cessation or continuation of antithrombotic treatment were included in the discharge summary for 133/164 patients (81.1%) (77 with Biffl grade 1–2 BCVIs, 21 with grade 3 injuries and 35 with grade 4 injuries).

**DISCUSSION**

In this retrospective single-centre review of management of patients with BCVIs, antithrombotic management was in keeping with current recommendations. However, there was considerable variability in follow-up care plans in this patient population. This is an identified opportunity to harmonize follow-up vascular imaging and multidisciplinary clinical care by developing a treatment pathway combining in-hospital and outpatient best practices.

Guideline-facilitated diagnosis of BCVI relies on the implementation of screening criteria to identify patients at high risk needing further evaluation with gold-standard



diagnostic imaging, namely, CTA of the cervical carotid and vertebral arteries. The recent extension of the Denver screening tool to include all patients with cervical spine fractures and upper rib fractures was particularly relevant in the present study, as these injuries were among the most common Denver criteria present in our patient population. However, given that 18 patients had brain infarcts on initial imaging (presumably secondary to their concurrent BCVI, given that no patients had infarcts determined to be long-standing and thus likely to have preceded the injury), it could be argued that all patients with major blunt mechanisms should have vascular imaging as part of their baseline radiologic assessment.<sup>14</sup> Concerns about unnecessary radiation exposure and overtriaging are arguments against adopting such a liberal screening strategy. However, given the finding that BCVI is associated with new ischemic events early after presentation,<sup>6</sup> together with evidence from the non-traumatic stroke literature that abnormal vascular imaging is associated with risk of recurrent ischemic events within the first 24 hours after presentation,<sup>15</sup> recognition of BCVI and prompt initiation of antithrombotic treatment could potentially further reduce the risk of later BCVI-associated stroke.

In the present study, the majority of eligible patients were prescribed ASA monotherapy or therapeutic low-molecular-weight heparin during their hospital course. However, antithrombotic treatment was initiated within 24–48 hours in only 90% of those without contraindications to treatment.<sup>8</sup> The strong preference for ASA over low-molecular-weight heparin is reflective of local practice patterns, with anticoagulation being reserved for patients with BCVI with intraluminal thrombus (although there is an absence of evidence in the literature to support this strategy). Other non-guideline-aligned strategies included use of unfractionated heparin, in some cases with bridging to warfarin. Although therapeutic reasoning was not documented consistently, the use of unfractionated heparin, which can be stopped and reversed, over low-molecular-weight heparin may reflect practitioner concerns with regard to bleeding risk. The prescribing of warfarin reflects the practitioner's preference for longer-term anticoagulation, to be reassessed in the outpatient setting.

There were minor variations between stroke care provider recommendations, with very few patients receiving a loading dose of ASA before initiation of daily low-dose ASA. There is evidence from the non-traumatic stroke literature suggesting that the practice of giving a baseline loading dose of ASA is associated with improved outcomes,<sup>16</sup> and good evidence that early initiation of dual antiplatelet therapy with ASA and clopidogrel, or ASA and ticagrelor is superior to ASA alone for secondary prevention.<sup>17–19</sup> However, the value of these strategies for stroke prevention in the BCVI population is unknown.<sup>10</sup> In the present study, stroke care providers more often recommended higher initial dosages of ASA or dual-antiplatelet

therapy in patients with higher-grade injuries, which suggests extrapolation from the nontraumatic stroke literature with higher-risk BCVI grades. Four patients had strokes while receiving ASA monotherapy. All had polytrauma with higher-grade injuries, and, thus, it is possible that more aggressive antithrombotic therapy was precluded owing to concerns about bleeding risk.

In our cohort, there were 30 patients who had concomitant injuries delaying or preventing antithrombotic treatment, nearly one-quarter of whom developed a new infarct. This group illustrates a therapeutic dilemma in the management of patients with BCVI with concomitant brain or solid-organ injuries, namely, balancing the benefits of stroke prevention against the risks of bleeding. Recent evidence suggests that antithrombotic treatment in such cases does not increase the risk of bleeding complications, including new or worsening intracerebral hemorrhage.<sup>10,20</sup> Further discussion is warranted among trauma specialists and neurosurgeons to clarify patients at higher risk in whom early antithrombotic therapy may still be cautiously initiated.

Recommendations for repeat imaging at 7–10 days and at 3 months are clearly outlined in the clinical guidelines as a means of ruling out false-positive findings on initial CTA, and examining vessel healing and determining duration of antithrombotic therapy.<sup>1,7,8</sup> At our centre, only one-third of patients had repeat imaging within 7–10 days, and more than one-quarter did not have any repeat imaging. Since these follow-up investigations help to guide duration of antithrombotic therapy, consistent follow-up could reduce the likelihood of late bleeding complications associated with prolonged antithrombotic therapy.<sup>21</sup> Some physicians opted to repeat CTA at 1 month and 3 months instead of 7 days. There is no clear evidence to suggest that the alternative time frame is inferior; however, evidence suggests that repeat imaging at 7–10 days, especially in patients with low-grade injuries, often changes management.<sup>22</sup> In addition, a potential cause of the suboptimal rates of repeat imaging is the lack of appropriate documentation of the treatment algorithm in 29% of discharge summaries. In British Columbia, the challenge of accessing neuroimaging and outpatient services from remote communities underscores the need for clear communication to general practitioners responsible for the follow-up care of patients with trauma.

Our findings identify 2 meaningful targets for improvement, both requiring a collaborative multidisciplinary effort between the trauma and neurology services. First, antithrombotic therapy should be initiated within 24–48 hours of diagnosis in patients with isolated BCVIs.<sup>8</sup> In patients with concomitant traumatic brain or solid-organ injuries, multidisciplinary discussion is needed to determine which patients may safely tolerate more aggressive timelines for initiating antithrombotic treatment. Second, there is a need for a routine pathway that arranges

appropriate follow-up imaging and clinical follow-up to facilitate decision-making regarding duration of anti-thrombotic treatment, with clear associated documentation and communication on hospital discharge.

Adherence to practice guidelines can be improved. This may be achieved through multidisciplinary education to promote awareness of BCVI management guidelines, and the development of a treatment pathway and preprinted order set that initiates evidence-based patient care and recommendations to ensure a clearer trajectory through the hospital system for patients with BCVIs. The creation of this algorithm at our institution will require a holistic approach that involves engagement and commitment of relevant leaders from trauma surgery, neurology, radiology, primary care and allied health services. Last, given possible regional differences in the management of patients with BCVIs across trauma systems in Canada, further research and consensus statements to standardize and guide the care of this vulnerable population are required.

### Limitations

Limitations of this study include its retrospective design, inclusion of a single centre and small sample. Reliance on appropriate initial vascular imaging to identify cases of BCVI may have resulted in ascertainment bias. Ascertainment bias may also apply to completion of follow-up outpatient imaging, as we adjudicated this centrally through the provincial electronic medical record (CareConnect) and it is possible that technical challenges may have prevented some reports from being uploaded. Still, given the observed low rates of guideline-recommended follow-up imaging at our institution, an action plan to improve quality of care is needed. Finally, detailed information on decision-making regarding choice of antithrombotic timing and agent for individual patients, as well as patient compliance with medication regimens, was inconsistently documented, which prevented us from rigorously analyzing these data.

### CONCLUSION

Antithrombotic therapy was initiated in the majority of eligible patients with BCVIs, but completion of follow-up imaging and documentation of clear outpatient care plans were suboptimal. Measures to improve awareness of and adherence to guidelines for BCVI management could include a multidisciplinary working group to develop a treatment pathway and algorithm for improved quality of care.

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