

Early repeat imaging is not warranted for high-grade blunt cerebrovascular injuries

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BACKGROUND:	The current management for blunt cerebrovascular injuries (BCVIs) includes repeat imaging 7 days to 10 days after initial diagnosis. This recommendation, however, has not been systematically evaluated. The purpose of this study was to evaluate the impact of early repeat imaging on treatment course. We hypothesized that a minority of patients with high-grade injuries (Grades III and IV) have complete resolution of their injuries early in their treatment course and hence repeat imaging does not alter their therapy.
METHODS:	Our prospective BCVI database was queried from January 1, 1997, to January 1, 2013. Injuries were graded according to the Denver scale. Injuries, treatment, and imaging results were analyzed. BCVI healing was defined as a complete resolution of the injury.
RESULTS:	During the 16-year study, 582 patients sustained 829 BCVIs; there were 420 carotid artery injuries and 409 vertebral artery injuries. The majority (78%) received antithrombotic therapy. For the 296 carotid artery injuries (70%) with repeat imaging, there was complete healing of the injury in 56% of Grade I, 20% of Grade II, 5% of Grade III, and 0% of Grade IV injuries. For the 255 vertebral artery injuries (62%) with repeat imaging, there was a resolution of the injury in 56% of Grade I, 17% of Grade II, 14% of Grade III, and 3% of Grade IV injuries. For BCVIs overall, there was healing documented in 56% of Grade I, 18% of Grade II, 8% of Grade III, and 2% of Grade IV injuries.
CONCLUSION:	Injury grade of BCVIs is associated with the healing rate of the injury. While approximately half of Grade I BCVIs resolved, only 7% of all high-grade injuries healed. Early repeat imaging may not be warranted in high-grade BCVI; the vast majority of injuries do not resolve. The cost, radiation, and transport risk of early repeat imaging should be weighed against the potential treatment impact for individual patients. (<i>J Trauma Acute Care Surg.</i> 2014;77: 540–545. Copyright © 2014 by Lippincott Williams & Wilkins)
LEVEL OF EVIDENCE:	Therapeutic/care management study, level IV.
KEY WORDS:	Blunt cerebrovascular injury; carotid artery injury; vertebral artery injury; trauma; antithrombotics.

Blunt cerebrovascular injuries (BCVIs) are diagnosed in approximately 1% of the blunt trauma population but up to 2.7% of the patients with an Injury Severity Score (ISS) greater than 15.¹ The majority of BCVI patients exhibit a latent period, which allows timely diagnosis and treatment before neurologic sequela.^{2,3} The screening protocols originally developed by the Memphis⁴ and Denver⁵ groups and recently modified by the Denver group^{2,6,7} identify the most high-risk patients for diagnostic imaging. The current management algorithms for patients with BCVI include repeat imaging 7 days to 10 days after initial diagnosis.^{2,8} This practice was initially recommended on the basis of frequent healing of low-grade (Grade I and II) injuries and the occasional decision to use endovascular therapy for Grade III injuries.⁹ However, this recommendation has not been systematically evaluated. Furthermore, the role of endovascular therapy for high-grade lesions continues to be debated in the literature. While some centers advocate that endovascular therapy remains pivotal in the management of high-grade injuries,¹⁰ our evaluation to date suggests that the vast majority of injuries may be managed with antithrombotic therapy alone.^{11,12} If endovascular therapy is not used during the initial hospitalization, the need to reimaging patients simply to plan for endovascular stenting is not necessary. The purpose of this study was to evaluate the impact of early repeat imaging of BCVI on the treatment course. We hypothesized that the majority of patients with high-grade injuries (Grades III and IV) do not have resolution of their BCVI early in their treatment course and hence repeat imaging is premature.

PATIENTS AND METHODS

Denver Health Medical Center is a state-certified and American College of Surgeons–verified Level I regional trauma center and an integral teaching facility of the University of Colorado School of Medicine. BCVI identification is based on an established institutional screening algorithm.² Patients sustaining BCVI from January 1, 1997, to January 1, 2013, were

reviewed from our prospective database. The type of BCVI, initial antithrombotic management, and repeat imaging results were analyzed. Injuries were graded according to the Denver scale: Grade I (<25% luminal stenosis), Grade II (\geq 25% luminal narrowing), Grade III (pseudoaneurysm), Grade IV (occlusion), and Grade V (transection).¹² For this study, high-grade BCVI were defined as Grade III and Grade IV injuries. Each injury was considered unique for the purpose of our analysis.

Antithrombotic therapy was initiated at the discretion of the trauma attending physician using either an anticoagulation protocol^{13,14} or antiplatelet agents. Low molecular weight heparin and subcutaneous heparin in doses administered for venous thromboembolism prophylaxis were not considered treatment. BCVI healing was defined as a complete resolution of the injury on repeat imaging; the overall percentage of complete healing was calculated for each injury grade as was any change in grade of BCVI. In an attempt to delineate the rationale for lack of repeat BCVI imaging, patients without in-hospital follow-up radiographic studies were subdivided by type of BCVI, time to discharge, outcome (discharge vs. death), and cause of death. An arbitrary time of 10 days was used for this analysis in concert with the standard dictum that follow-up imaging should occur 7 days to 10 days after initial injury. Data are presented as mean \pm SEM. Statistical analysis was performed using SAS for Windows (SAS Institute, Cary, NC). The Colorado Multi-Institutional Review Board, our university based institutional review board, approved this study.

RESULTS

During the 16-year study, 582 patients sustained 829 BCVIs (Table 1). The majority of patients (63%) were men, with a mean age of 37 ± 0.7 years, and a mean ISS of 27 ± 0.8 (Table 2).

Early Repeat Imaging

Of the 829 injuries, 551 (66%) had repeat imaging; mean time to initial follow-up imaging was 11 ± 0.9 days (range,

TABLE 1. BCVI Classified by Location and Grade

Grade	BCVIs		
	CAI (n = 420)	VAI (n = 409)	Total (n = 829)
I	224	198	422
II	78	80	158
III	96	45	141
IV	10	83	93
V	12	3	15

1–220 days). For BCVIs overall, there was healing documented on repeat imaging in 56% of Grade I injuries, 18% of Grade II injuries, 8% of Grade III injuries, and 2% of Grade IV injuries (Table 3). Change to a higher grade of injury was observed in 10% of Grade I injuries, 27% of Grade II injuries, and 2% of Grade III injuries. Forty-seven patients with Grade I and II injuries progressed to a Grade III injury. There was stability in injury grade on repeat imaging in 34% of Grade I injuries, 36% of Grade II injuries, and 83% of Grade III injuries.

Of the 829 injuries, there were 420 carotid artery injuries (CAIs); 296 CAIs (70%) had an early repeat imaging (Table 4). There was complete healing of the injury in 56% of Grade I injuries, 20% of Grade II injuries, 5% of Grade III injuries, and 0% of Grade IV injuries. Conversely, 10% of Grade I injuries, 29% of Grade II injuries, and 1% of Grade III injuries changed to higher-grade injuries. Of the 255 vertebral artery injuries (VAIs) (62%) with repeat imaging, there was a resolution of the injury in 56% of Grade I injuries, 17% of Grade II injuries, 14% of Grade III injuries, and 3% of Grade IV injuries (Table 5). Progression to a higher grade of injury occurred in 10% of Grade I injuries, 25% of Grade II injuries, and 3% of Grade III injuries.

Approximately half (56%) of Grade I BCVIs fully healed, while only 7% of all Grade III and IV injuries healed. Of those injuries that resolved with no antithrombotic treatment, 90% (28 of 31) were Grade I injuries.

Of those patients without repeat imaging, the mean hospital stay was 13 ± 1.1 days. The majority (62%) of asymptomatic BCVI patients without repeat imaging were discharged or died

TABLE 2. Patient Demographics (n = 582)

Mean age, y	37 (range, 1–83)	
Sex		
Male	366	63%
Female	216	37%
Injury mechanism		
Motor vehicle collisions	267	46%
Falls	75	13%
Auto-pedestrian	52	9%
Motorcycle collisions	46	8%
Associated injuries		
Head	291	50%
Spine	267	46%
Chest	226	39%
Extremity	186	32%
Abdomen	104	18%
Pelvis	81	14%

TABLE 3. Results of Repeat Imaging for All BCVIs, Stratified by Grade of Injury

All BCVIs With Repeat Imaging Performed (n = 551)				
Initial Grade of Injury	Grade of Injury on Repeat Imaging*	Treatment	No Treatment	Total Healed
Grade I (n = 291)	0	135	28	56%
	I (no change)	80	18	
	II	8	1	
	III	14	6	
Grade II (n = 104)	0	19	0	18%
	I	17	3	
	II (no change)	35	2	
	III	22	5	
Grade III (n = 108)	0	7	2	8%
	I	2	0	
	II	5	0	
	III (no change)	72	18	
Grade IV (n = 42)	0	1	0	2%
	I	2	0	
	II	5	0	
	III	3	0	
	IV (no change)	30	1	

*Classification as Grade 0 on repeat imaging indicates that the original BCVI has healed and no residual injury is identified.

10 days or less after admission; 46% of the patients were discharged on hospital Day 7 or earlier. Of the 54 patients with asymptomatic CAI, 28 were discharged and 8 died within 10 days. One death of the eight was attributed to either traumatic brain injury (TBI)-related herniation or BCVI-related hemispheric stroke with edema and herniation; the remaining patients were not related to BCVI-related stroke (4 TBIs, 1 multiple-organ failure, 1 sepsis). Of the 16 patients with combined CAI and VAI, 2 were discharged and 6 died within 10 days of admission; all deaths were caused by TBI. Of the 99 patients with asymptomatic VAI, 58 were discharged and 2 died within 10 days of admission; the 2 deaths were caused by adult respiratory distress syndrome and a necrotizing soft tissue infection.

Treatment and Outcomes

The majority of patients received antithrombotic therapy for their injuries; of the 829 BCVIs, 648 (78%) were treated. BCVI-related neurologic sequelae were identified in 85 patients; these patients had neurologic symptoms or had computed tomography and/or magnetic resonance imaging results consistent with stroke (Fig. 1). Of the 85 patients, 2 patients appropriately treated with systemic heparin demonstrated neurologic findings. Of the 85 patients, 83 were not treated with antithrombotic agents and sustained a transient ischemic attack or stroke; 39 patients presented to the ED with symptoms of neurologic ischemia, 38 patients had contraindications to antithrombotics or were on subtherapeutic treatment, and 6 patients experienced stroke after endovascular therapy. Mean time to stroke was

TABLE 4. Results of Repeat Imaging Stratified by Grade of CAI

CAIs With Repeat Imaging Performed (n = 296)				
Initial Grade of Injury	Grade of Injury on Repeat Imaging*	Treatment	No Treatment	Total Healed
Grade I (n = 159)	0	69	20	56%
	I (no change)	41	12	
	II	3	1	
	III	8	4	
Grade II (n = 56)	0	11	0	20%
	I	7	1	
	II (no change)	19	2	
	III	11	4	
Grade III (n = 73)	0	3	1	5%
	I	2	0	
	II	3	0	
	III (no change)	50	13	
Grade IV (n = 3)	0	0	0	0%
	I	0	0	
	II	0	0	
	III	0	0	
	IV (no change)	3	0	

*Classification as Grade 0 on repeat imaging indicates that the original BCVI has healed and no residual injury is identified.

42 ± 8 hours; for those patients without symptoms within 2 hours of injury, the mean time to neurologic symptoms or identification of stroke on imaging was 70 ± 11 hours. Death in 18 patients (21%) was attributed to their BCVI-related stroke.

DISCUSSION

The purpose of this study was to evaluate the impact of early repeat imaging of BCVI on treatment course. For all BCVIs, the grade of injury is associated with the healing rate; while almost half of Grade I injuries resolve, only 7% of Grade III and IV injuries resolved. This analysis confirmed our hypothesis that the majority of patients with high-grade injuries do not have resolution of their BCVI early in their treatment course; hence, repeat imaging is premature.

Radiologic imaging for BCVI in high-risk patients is a standard part of the evaluation of a trauma patient. Early diagnosis of BCVI and appropriate treatment almost universally prevent stroke.^{2,10} Historically, part of the patient's management was repeat imaging at 7 days to 10 days. This was performed for two reasons. First, the dynamic nature of some BCVIs has been previously described. A percentage of BCVIs seem to completely heal within the first 2 weeks, and for those that resolve antithrombotic, treatment can be stopped. In our early study of 114 patients with BCVI, follow-up arteriography was performed within 10 days in all patients.⁹ Grade I and Grade II injuries frequently changed, with 57% of Grade I and 8% of Grade II injuries healing completely, allowing cessation of treatment.

Progression to pseudoaneurysm formation was seen in 8% of Grade I and 43% of Grade II lesions, prompting interventional treatment. A subsequent study by our group compiling 10 years of experience demonstrated similar findings with Grade I and II injuries having a 20% to 50% incidence of healing.³ Edwards et al.¹⁵ reported similar rates of change on repeat imaging of BCVI; 72% of Grade I injuries healed, 30% of the Grade II lesions improved, and the majority of Grade III lesions remained the same or enlarged, prompting treatment with endovascular stents. This study confirms these previously reported healing rates.

The second rationale for early repeat imaging, as alluded to earlier, involved the role of endovascular stenting for high-grade lesions. Initially promoted for these complex lesions,¹⁴⁻¹⁸ enthusiasm for endovascular treatment of BCVIs has waned in recent years. Some recent investigations have suggested that antithrombotic treatment is effective, while routine stenting entails increased costs and potential risk for stroke and does not seem to add benefit.^{11,12} In our institution, stenting is reserved for the rare patient with symptoms due to narrowing or a markedly enlarging pseudoaneurysm;¹¹ therefore, repeat imaging to determine the need for endovascular intervention is not necessary. So although approximately 10% of Grade I and 25% of Grade II BCVIs worsen on early repeat imaging, there is not a change in the antithrombotic treatment of these patients. If, however, endoluminal therapy for high-grade injuries and pseudoaneurysms is routine in one's practice, early repeat imaging at 7 days to 10 days may have a more central role. For the medical management of patients with BCVI, studies to date indicate that

TABLE 5. Results of Repeat Imaging Stratified by Grade of VAI

VAIs With Repeat Imaging Performed (n = 255)				
Initial Grade of Injury	Grade of Injury on Repeat Imaging*	Treatment	No Treatment	Total Healed
Grade I (n = 132)	0	66	8	56%
	I (no change)	39	6	
	II	5	0	
	III	6	2	
Grade II (n = 48)	0	8	0	17%
	I	10	2	
	II (no change)	16	0	
	III	11	1	
Grade III (n = 35)	0	4	1	14%
	I	0	0	
	II	2	0	
	III (no change)	22	5	
Grade IV (n = 39)	0	1	0	3%
	I	2	0	
	II	5	0	
	III	3	0	
	IV (no change)	27	1	

*Classification as Grade 0 on repeat imaging indicates that the original BCVI has healed and no residual injury is identified.

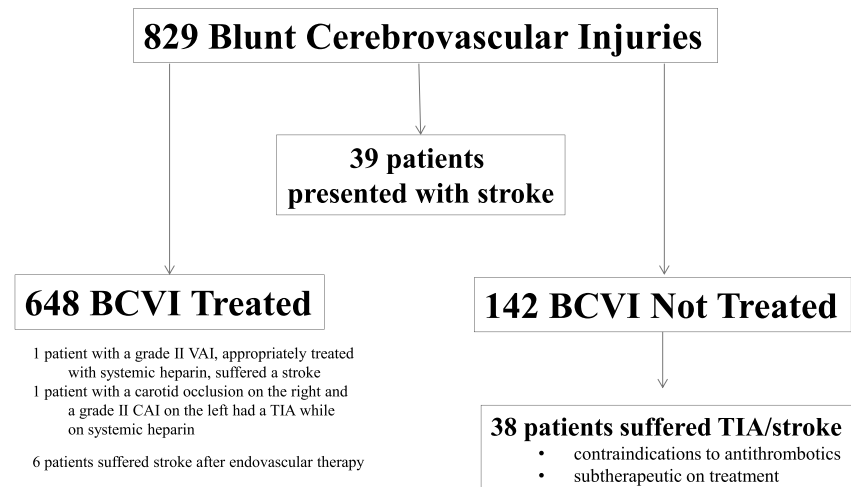


Figure 1. Outcomes stratified by treatment for patients with BCVI.

anticoagulation and antiplatelet agents seem to have equivalent outcomes for the treatment of asymptomatic patients with BCVI.^{3,10,19}

Despite these previous findings, current management algorithms do not reflect the opportunity for BCVI grade-based decision making on repeat imaging. This study is the largest analysis to date on the role of early repeat imaging. Healing of the injury seems to be associated with BCVI grade. For all BCVIs, more than half of Grade I injuries healed. However, with increasing grade of injury, fewer injuries healed for both CAI and VAI. With so few Grade III and IV BCVIs showing resolution on repeat early imaging, one should question the role of repeat imaging early in the patient's hospital course. This is particularly true for any patient that requires either anticoagulation or antiplatelet agents for other injuries or illnesses. For example, in a patient with multiple injuries on lifelong aspirin for his or her comorbid cardiac history, repeating a computed tomography angiography (CTA) to evaluate his or her Grade I CAI is not necessary. Whether this injury resolves or persists, the patient will remain on antiplatelet therapy regardless. Similarly, for the patient who develops an early postinjury pulmonary embolism managed with systemic heparin, repeat CTA of his or her vertebral artery pseudoaneurysm is unnecessary; the patient will remain on anticoagulation, and only the rare patient will require endovascular stenting for such an injury. Using the data provided by this analysis, the clinician can individualize the decision for early repeat imaging based on the healing rates for each individual grade and type of BCVI. These data can be used in concert with the patient's medical comorbidities and current physiology to determine if repeat imaging will truly impact treatment plans. The cost, radiation, and transport risk of early repeat imaging may not warrant a change in management.

Interestingly, there were some BCVIs that resolved without treatment. Of those injuries that healed without antithrombotics, 90% were Grade I injuries. One might conclude that these BCVIs were, in fact, not actual injuries but rather postinjury vasospasm. Although this is possible, delineating which Grade I injuries are vasospasm versus real intimal disruptions or narrowings is problematic. Stroke rate for Grade I BCVI is reported to be between 6% and 8%.⁹ In our experience to date, a BCVI-related stroke

experienced by 14 patients was caused by a Grade I injury. In fact, one patient with a Grade I injury documented on admission CTA subsequently experienced a stroke when not anticoagulated because of associated TBI; the patient was subsequently heparinized, and on repeat CTA performed per protocol, the Grade I injury had completely healed. All Grade I BCVI should be treated until healing is documented.

For patients that do not undergo early repeat imaging, we obtain a CTA at 3 months after injury to determine whether antithrombotic therapy can be discontinued and if another treatment (e.g., stenting) is needed. Although optimal therapy has not been conclusively determined in the literature, we use systemic heparin during the acute postinjury phase, transitioning to aspirin 325 mg near the time of discharge. If the CTA performed at 3 months does not document healing of the vessel, it is reasonable to provide ongoing treatment, since delayed stroke can occur and has been reported as long as 14 years after injury.²⁰ For some patients, however, the risk of the imaging examination may be greater than simply continuing antithrombotic therapy.

This study does have limitations. Follow-up imaging was performed in the majority but not all of the patients. Although these "missing" data could potentially affect the results, our observed healing rates are in concert with other results to date.^{15,21} Of those patients without repeat imaging, almost half were discharged on Day 7 or earlier. For the remainder, we cannot ascertain from the database the reason for the lack of repeat imaging or whether these patients were already on chronic antithrombotic therapy or had other indications for systemic anticoagulation. Conclusions in this study, therefore, are drawn on repeat imaging of 551 BCVIs.

CONCLUSION

Injury grade of BCVI is associated with the healing rate of the injury. While approximately half of Grade I BCVIs resolved, only 7% of all high-grade injuries healed. Since antithrombotic treatment is discontinued only in those patients with documented complete BCVI healing, few patients with high-grade injuries will have a change in management. For patients on lifelong antithrombotic treatment for other medical illnesses,

repeat imaging during their hospital course is unwarranted. For all other patients, the cost, radiation, and transport risk of early repeat imaging should be weighed against the potential treatment impact for the individual. Repeat imaging may not be warranted in high-grade BCVIs as the minority of injuries resolve. Management algorithms should be updated to reflect this important decision point in the patient's care rather than arbitrarily mandating repeat imaging at 7 days to 10 days.

AUTHORSHIP

C.C.B. provided the study design. C.C.B., W.L.B., and A.E.W. performed the data collection/analysis/interpretation. C.C.B. drafted the manuscript. W.L.B., E.E.M., F.M.P., R.T.S., K.M.B., A.E.W., and G.J.J. performed critical review.

DISCLOSURE

The authors declare no conflicts of interest.

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