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Clinical Decision Tool Reviews

Review of the Modified Denver Criteria for Blunt Cerebrovascular Injury (BCVI)

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Abstract

Blunt cerebrovascular injury (BCVI) is an uncommon but potentially devastating complication of blunt trauma that is frequently clinically occult. The Modified Denver Criteria provides a practical, evidence-based framework for identifying trauma patients who warrant CT angiography (CTA) screening. This review summarizes the evidence supporting the development and validation of the Modified Denver Criteria and their current role in clinical practice.. While contemporary studies have highlighted opportunities to further expand screening, the Modified Denver Criteria remains the most widely validated and commonly implemented tool for selective BCVI screening and supports earlier diagnosis and treatment when applied alongside clinical judgment.

I. How to Use

When to Use

Use the Modified Denver Criteria during the initial evaluation of patients with blunt trauma to identify those at increased risk for blunt cerebrovascular injury (BCVI) who may benefit from vascular imaging. The criteria are intended for use in emergency departments and trauma centers following a primary and secondary survey, particularly in patients with presentations due to high-energy mechanisms, cervical spine injuries, basilar skull fractures, severe facial fractures, unexplained neurologic deficits, or other injury patterns associated with carotid or vertebral artery injury.

The Modified Denver Criteria are designed to identify patients who warrant CT angiography (CTA) of the neck for detection of BCVI before the onset of ischemic neurologic complications. They should be applied in conjunction with a comprehensive trauma assessment and institutional screening protocols.

Pearls / Pitfalls

The Modified Denver Criteria remain the most widely adopted screening tool for BCVI and are incorporated into numerous trauma center protocols and professional society guidelines. Compared with earlier screening criteria, the Modified Denver Criteria broaden the spectrum of injury patterns associated with BCVI and have substantially increased injury detection through more liberal use of CTA.

Despite their widespread adoption, the Modified Denver Criteria are not perfectly sensitive. Several retrospective studies have demonstrated that a meaningful proportion of BCVIs occur in patients who do not meet Modified Denver Criteria, prompting some trauma centers to adopt expanded screening protocols or universal CTA imaging among patients undergoing cervical spine imaging. Individuals and institutions should consider local patient populations, imaging resources, and trauma volumes when determining their screening strategy.

The Modified Denver Criteria identify patients who should undergo vascular imaging, but does not diagnose BCVI. A negative CTA in a patient with persistent neurologic findings concerning for BCVI may warrant repeat imaging or catheter directed angiography depending on clinical suspicion and institutional practice.

As CTA technology has improved, so has diagnostic accuracy; however, false-positives remain possible, particularly for low-grade vertebral artery injuries. Imaging findings should always be interpreted within the clinical context and, when appropriate, reviewed with radiology or vascular specialists.

As already discussed, the Modified Denver Criteria should complement, not replace, clinical judgment. Absence of Modified Denver Criteria should not reassure clinicians when suspicion remains high. Patients with unexplained neurologic deficits, concerning mechanisms, or

evolving symptoms may still warrant CTA despite not meeting formal criteria.

Why Use

Blunt cerebrovascular injury (BCVI) is an uncommon but potentially devastating consequence of blunt trauma. Without treatment, BCVI may result in thromboembolic stroke hours to days after injury, often in initially asymptomatic patients. Early identification through targeted screening allows initiation of antithrombotic therapy when appropriate, significantly reducing the risk of stroke and improving neurologic outcomes.

The Modified Denver Criteria provide a practical, evidence-based framework for selecting trauma patients who are most likely to benefit from screening with CTA while promoting standardized evaluation across trauma systems. Their widespread validation and incorporation into national trauma guidelines have made them the preferred screening criteria at many Level I and Level II trauma centers.

II. NEXT STEPS

Advice

The Modified Denver Criteria are intended to identify patients at increased risk for blunt cerebrovascular injury (BCVI) who warrant vascular imaging and should not be used as a substitute for clinical judgment. Patients with concerning neurologic findings following blunt trauma including focal or lateralizing neurologic deficits, neurologic findings incongruous with head CT findings, transient ischemic attack, amaurosis fugax, Horner syndrome, or evidence of cerebral infarction, should undergo prompt cerebrovascular imaging regardless of whether formal screening criteria are met. Conversely, meeting screening criteria does not confirm BCVI and requires definitive evaluation with CT angiography (CTA) or other appropriate vascular imaging.

The criteria have not been validated to determine treatment decisions, predict stroke risk after diagnosis, or guide duration of antithrombotic therapy. Once BCVI is identified, subsequent management should be individualized based on injury grade, associated traumatic injuries, bleeding risk, and multidisciplinary consultation.

Management

Patients meeting any single Modified Denver Criteria should undergo CTA of the neck as the preferred initial test for BCVI. Modern multidetector CTA has become the imaging modality of choice because of its widespread availability, rapid acquisition, and high diagnostic accuracy.

When BCVI is diagnosed, injuries should be classified using the Biffl grading system to guide prognosis and management. In the absence of contraindications, early initiation of antithrombotic therapy, with either antiplatelet or anticoagulant therapy, has consistently been associated with a significant reduction in ischemic stroke and mortality. Higher-grade injuries, enlarging pseudoaneurysms, vessel occlusion with ongoing ischemia, or injuries not amenable to medical therapy may require endovascular intervention or surgical consultation.

Repeat vascular imaging is commonly performed to assess for healing or progression, particularly for lower-grade injuries, although follow-up protocols vary among institutions.

Critical Actions

Clinicians should maintain a high index of suspicion for BCVI in patients with high-risk blunt trauma mechanisms or injury patterns, as neurologic deficits may not develop until hours or days after the initial injury. Early recognition and timely CTA imaging are critical because stroke is frequently preventable when BCVI is identified before cerebral ischemia occurs.

The Modified Denver Criteria are a screening tool, not a diagnostic or management algorithm. Clinical judgment should always supersede the criteria when concern for BCVI remains high despite the absence of formal screening criteria. Likewise, treatment decisions should be based on imaging findings, injury severity, associated injuries, and multidisciplinary trauma management rather than the screening criteria alone.

III. EVIDENCE

The Modified Denver Criteria were developed to improve identification of blunt cerebrovascular injury (BCVI), an uncommon but potentially devastating complication of blunt trauma. Early studies demonstrated that many BCVIs were clinically occult until patients developed ischemic stroke symptoms, prompting investigators at Denver Health to identify injury patterns associated with carotid and vertebral artery injury and develop a selective screening strategy.

Subsequent refinement of the original Denver Criteria resulted in the Modified Denver Criteria, which expanded the number of injury patterns and clinical findings that warrant vascular imaging. These modifications increased screening sensitivity while maintaining a practical approach that could be incorporated into routine trauma evaluation. The Modified Denver Criteria are now among the most widely adopted BCVI screening criteria and are incorporated into trauma protocols worldwide.

Numerous retrospective and prospective studies have validated the association between the Modified Denver Criteria and BCVI. Although no screening tool identifies every injury, implementation of protocolized screening

with CT angiography (CTA) has consistently increased BCVI detection compared with symptom-based diagnosis alone. Earlier diagnosis has, in turn, enabled prompt initiation of antithrombotic therapy, which has been associated with substantial reductions in stroke and BCVI-related morbidity.

As multidetector CT technology has improved, CTA has become the preferred imaging modality for evaluating suspected BCVI because of its rapid acquisition, widespread availability, and excellent diagnostic performance. Despite these advances, debate remains regarding the optimal screening strategy. Several contemporary studies have demonstrated that some patients with BCVI do not meet Modified Denver Criteria, leading some trauma centers to adopt expanded screening protocols or universal CTA screening for selected blunt trauma populations.

Professional society guidelines, including those from the Eastern Association for the Surgery of Trauma (EAST), support screening patients with recognized risk factors using CTA of the neck. Concerning findings include severe facial or skull-base fractures, cervical spine fractures or ligamentous injuries, severe traumatic brain injury or diffuse axonal injury with low GCS, near-hanging with anoxic brain injury, and significant neck soft-tissue injury. Following diagnosis, injury severity is typically classified using the Biffl grading system to guide treatment and follow-up. Early antithrombotic therapy, when not contraindicated, remains the cornerstone of management and has consistently been associated with reduced stroke risk.

Although the Modified Denver Criteria have become the standard screening tool at many trauma centers, they should be viewed as an adjunct to—not a replacement for—clinical judgment. Patients with unexplained focal neurologic deficits or persistent concern for BCVI should undergo vascular imaging regardless of whether formal screening criteria are met.

Foundational Evidence: Original Denver Data

In a prospective 7-year study at a Level I trauma center, Cothren et al. evaluated 13,280 blunt trauma patients and used a predefined screening protocol based on associated injury patterns and neurologic signs or symptoms to identify risk for BCVI. Risk factors included Le Fort II/III fractures, basilar skull fracture with carotid canal involvement, cervical spine fracture, diffuse axonal injury with GCS ≤ 6, and near-hanging with anoxic brain injury. Through this structured screening approach, 643 patients underwent angiography, and 114 were found to have blunt carotid artery injury (overall incidence 0.86% of all trauma admissions), demonstrating that these injuries are substantially more common than once believed.[1] Historically, as referenced in prior literature cited in this study, more than 90% of BCVI cases were only diagnosed after neurologic symptoms occurred, meaning the majority were previously missed when clinicians relied on symptoms alone.[1]

The clinical consequences of missed or untreated BCVI were profound: 46% of patients who did not receive anticoagulation developed an ischemic neurologic event, compared to 0% of the 73 asymptomatic patients who were promptly anticoagulated, an outcome consistent across heparin, LMWH, and antiplatelet therapy.[1] However, treatment was not randomized, and patients who did not receive anticoagulation included those with contraindications to therapy or neurologic symptoms preceding diagnosis; therefore, it cannot be determined whether earlier detection and anticoagulation would have prevented these poor outcomes. Stroke-related mortality in the cohort reached 32% (6 of 19 patients), and the average onset of neurologic symptoms occurred within a "latent window" of approximately 50–77 hours post-injury, reinforcing that early identification before symptom onset is time-critical for preventing stroke.[1] These findings reinforced that BCVI is frequently clinically occult and may only be detected through intentional screening. Early diagnosis and prompt treatment may substantially reduce morbidity and mortality, providing the foundational rationale for screening tools such as the Modified Denver Criteria.

Why Screening Criteria Became Necessary

Building on this work, Biffl et al. analyzed patients undergoing angiography for suspected BCVI and identified independent predictors of carotid and vertebral artery injury, including Glasgow Coma Scale ≤6, petrous bone fracture, diffuse axonal brain injury, and Le Fort II/III fractures.[2] In patients with a high-risk mechanism (hyperextension, hyperflexion, or direct blow) and at least one of these predictors, the risk of carotid injury was approximately 41%, and about 39% of patients with cervical spine fracture had a vertebral artery injury.[2] These findings supported the development and refinement of the Denver, Modified Denver, and Expanded Denver Criteria, which formalized the use of mechanism and injury-based screening to select trauma patients for cerebrovascular imaging rather than relying on neurologic symptoms alone.

Modern Validating Evidence

More recent multicenter and population-level studies confirm that BCVI is both more common and more clinically significant than earlier estimates suggested, with reported incidence ranging from ~1% of all blunt trauma patients up to 2.7% in centers using liberal or universal CTA imaging protocols.[3-5] Left untreated, BCVI carries reported stroke rates of 9–11% and mortality of 16–27%, underscoring the high stakes of missed injury.[5] Importantly, contemporary work shows that reliance on Den-

ver-based criteria alone will still miss a meaningful subset of patients: in one multi-institution cohort, 30–35% of BCVIs would have been missed by the Denver and Expanded Denver Criteria compared with a liberalized CTA approach,[3] and in another series 16% of BCVI patients had none of the Expanded Denver risk factors, meaning they would not have been screened under guideline-only strategies.[5] A universal screening protocol found that 23% of patients with grade ≥3 BCVI (clinically significant injuries) lacked any established screening criteria.[4] Despite these limitations, Denver-based predictors remain the most validated framework for risk stratification, and once BCVI is identified, treatment is impactful. In one universal-screening cohort, 83% of patients received antiplatelet or anticoagulation therapy, with only 4% bleeding complications, 3% progression, and 8% stroke, supporting the clinical value of detecting BCVI early and justifying the use of structured tools such as the Modified Denver Criteria to guide imaging decisions.[4]

Formula

The Modified Denver Criteria identify patients who should undergo CTA screening for BCVI based on the presence of specific signs, symptoms, or high-risk injury patterns following blunt trauma. The criteria are intended to guide imaging decisions and should not be used to diagnose BCVI or determine treatment.

The Modified Denver Criteria for BCVI are met when a patient presents with one or more of the following injury patterns:

Modified Denver Criteria for BCVI
Le Fort II or III fracture
Basilar skull fracture with carotid canal involvement
Diffuse axonal injury with GCS <6
Cervical spine fracture patterns
Near-hanging with anoxic brain injury

FACTS & FIGURES

BCVI occurs in approximately 1–3% of patients with blunt trauma when systematic screening protocols are used.

Most patients are initially asymptomatic despite potentially severe vascular injury.

Early diagnosis and antithrombotic therapy substantially reduce the risk of ischemic stroke.

CTA is the preferred initial imaging modality for evaluation of BCVI at most trauma centers.

The Biffl grading system is used to classify BCVI severity after diagnosis.

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