Screening for blunt cardiac injury: An Eastern Association for the Surgery of Trauma practice management guideline

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BACKGROUND: Diagnosing blunt cardiac injury (BCI) can be difficult. Many patients with mechanism for BCI are admitted to the critical care setting based on associated injuries; however, debate surrounds those patients who are hemodynamically stable and do not otherwise require a higher level of care. To allow safe discharge home or admission to a nonmonitored setting, BCI should be definitively ruled out in those at risk.

METHODS: This Eastern Association for the Surgery of Trauma (EAST) practice management guideline (PMG) updates the original from 1998. English-language citations were queried for BCI from March 1997 through December 2011, using the PubMed Entrez interface. Of 599 articles identified, prospective or retrospective studies examining BCI were selected. Each article was reviewed by two members of the EAST BCI PMG workgroup. Data were collated, and a consensus was obtained for the recommendations.

RESULTS: We identified 35 institutional studies evaluating the diagnosis of adult patients with suspected BCI. This PMG has 10 total recommendations, including two Level 2 updates, two upgrades from Level 3 to Level 2, and three new recommendations.

CONCLUSION: Electrocardiogram (ECG) alone is not sufficient to rule out BCI. Based on four studies showing that the addition of troponin I to ECG improved the negative predictive value to 100%, we recommend obtaining an admission ECG and troponin I from all patients in whom BCI is suspected. BCI can be ruled out only if both ECG result and troponin I level are normal, a significant change from the previous guideline. Patients with new ECG changes and/or elevated troponin I should be admitted for monitoring. Echocardiogram is not beneficial as a screening tool for BCI and should be reserved for patients with hypotension and/or arrhythmias. The presence of a sternal fracture alone does not predict BCI. Cardiac computed tomography or magnetic resonance imaging can be used to differentiate acute myocardial infarction from BCI in trauma patients. (*J Trauma Acute Care Surg*. 2012;73: S301–S306. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Blunt cardiac injury; practice management guidelines; trauma; echocardiogram; troponin.

In 1998, the first Eastern Association for the Surgery of Trauma (EAST) Practice Management Guideline (PMG) for screening of blunt cardiac injury (BCI) was completed and published.[1] The EAST PMG committee reviewed research published since the original guideline to formulate new recommendations based on this recent literature.

STATEMENT OF THE PROBLEM

Diagnosing BCI can be difficult. Many patients with cardiovascular compromise from BCI are already admitted to the critical care setting based on their associated injuries, but much debate surrounds those patients who are hemodynamically stable on initial evaluation and do not otherwise require a higher level of care. It thus becomes crucial to determine what tests and diagnostic studies are required to safely rule out BCI, to allow for safe discharge home or admission to a nonmonitored setting. The decision to screen for BCI is clinician dependent because there are no standard criteria. Attempts have been made to identify specific injuries that might be highly associated with BCI, such as sternal fracture, but no such association has been demonstrated. In general, the literature supports that patients with any significant blunt trauma to the anterior chest should be screened.

PROCESS

A computerized search of the National Library of Medicine MEDLINE database was undertaken using the PubMed Entrez interface. English-language citations were queried during the period of March 1997 through December 2011 using the primary search strategy: [((*myocardial injury OR myocardial contusion*) AND (*traumatic OR trauma*)) OR (*heart injuries*)] AND *humans* NOT (*case reports OR letter OR comment OR news*).

Review articles, autopsy studies, and investigations of indirect myocardial injury after trauma were excluded. The PubMed Related Articles algorithm was also used to identify

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additional articles similar to the items retrieved by the primary strategy. Of approximately 599 articles identified by these two techniques, those dealing with either prospective or retrospective studies examining BCI were selected, composing of 27 institutional studies evaluating diagnosis and management of adult patients with suspected or proven blunt cardiac trauma. Each article was reviewed by two members of the BCI workgroup. Data were collated, and a consensus was obtained for the final recommendations of this practice management guideline update (Table, Supplemental Digital Content 1, at http://links.lww.com/TA/A202).

A separate search strategy was used to identify relevant radiology articles using the search ([*blunt*] AND [*cardiac*] AND [*injury*]). Because major changes in imaging technology have been widely adopted in the last 5 years, 2005 was chosen as a starting point. This yielded 13 articles, 3 of which examined radiologic diagnostic studies. The bibliographies of these articles were then hand searched to yield recent literature regarding utility of diagnostic imaging.

ASSESSMENT OF SCIENTIFIC EVIDENCE

The scientific evidence assessment methods outlined by the EAST PMG committee should be applied when classifying the articles identified for review.[2] For purposes of practice management guidelines for trauma, the data will be classified as follows:

Class I: Prospective randomized controlled trials—the criterion standard of clinical trials. Some may be poorly designed, have inadequate numbers, or suffer from other methodological inadequacies.

Class II: Clinical studies in which the data were collected prospectively and retrospective analyses that were based on clearly reliable data. Types of studies so classified include observational studies, cohort studies, prevalence studies, and case-control studies.

Class III: Studies based on retrospectively collected data. Evidence used in this class indicates clinical series, database or registry review, large series of case reviews, and expert opinion.

ESTABLISHING THE RECOMMENDATIONS

Level 1

The recommendation is convincingly justifiable based on the available scientific information alone. This recommendation is usually based on Class I data; however, strong Class II evidence may form the basis for a Level 1 recommendation, especially if the issue does not lend itself to testing in a randomized format. Conversely, low-quality or contradictory Class I data may not be able to support a Level 1 recommendation.

Level 2

The recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert opinion. This recommendation is usually supported by Class II data or a preponderance of Class III evidence.

Level 3

The recommendation is supported by available data, but adequate scientific evidence is lacking. This recommendation is generally supported by Class III data. This type of recommendation is useful for educational purposes and in guiding future clinical research.

RECOMMENDATIONS

We first attempted to address previously determined recommendations and whether there was additional scientific evidence to support each one, move it to a different level, or eliminate it altogether. We then reviewed the literature to assess whether new recommendations could be made. Changes from the original guideline are noted accordingly.

Level 1

1. An admission electrocardiogram (ECG) should be performed on all patients in whom BCI is suspected (no change).

Level 2

1. If the admission ECG reveals a new abnormality (arrhythmia, ST changes, ischemia, heart block, and unexplained ST changes), the patient should be admitted for continuous ECG monitoring. For patients with preexisting abnormalities, comparison should be made to a previous ECG to determine need for monitoring (updated).
2. In patients with a normal ECG result *and* normal troponin I level, BCI is ruled out. The optimal timing of these measurements, however, has yet to be determined. Conversely, patients with normal ECG results but elevated troponin I level should be admitted to a monitored setting (new).
3. For patients with hemodynamic instability or persistent new arrhythmia, an echocardiogram should be obtained. If an optimal transthoracic echocardiogram cannot be performed, the patient should have a transesophageal echocardiogram (updated).
4. The presence of a sternal fracture alone does not predict the presence of BCI and thus should not prompt monitoring in the setting of normal ECG result and troponin I level (moved from Level 3).
5. Creatinine phosphokinase with isoenzyme analysis should not be performed because it is not useful in predicting which patients have or will have complications related to BCI (modified and moved from Level 3).
6. Nuclear medicine studies add little when compared with echocardiography and should not be routinely performed (no change).

Level 3

1. Elderly patients with known cardiac disease, unstable patients, and those with an abnormal admission ECG result can safely undergo surgery provided that they are appropriately monitored. Consideration should be given to placement of a pulmonary artery catheter in such cases (no change).

2. Troponin I should be measured routinely for patients with suspected BCI; if elevated, patients should be admitted to a monitored setting and troponin I should be followed up serially, although the optimal timing is unknown (new).
3. Cardiac computed tomography (CT) or magnetic resonance imaging (MRI) can be used to help differentiate acute myocardial infarction (AMI) from BCI in trauma patients with abnormal ECG result, cardiac enzymes, and/or abnormal echo to determine need for cardiac catheterization and/or anticoagulation (new).

SCIENTIFIC FOUNDATION

Electrocardiogram

Five studies evaluated the utility of ECG in diagnosis of BCI. One study determined that a normal ECG effectively ruled out BCI. This is consistent with the findings of the first BCI guideline.[3] Fulda et al.[4] determined that initial ECG is the best single overall predictor of BCI.

A recent study by Nagy et al.[5] evaluated which patients required evaluation for BCI following blunt chest trauma. They concluded that patients with abnormal ECG result or cardiac failure following blunt chest trauma should be admitted to a monitored bed, as 6 of 22 of the patients with BCI ultimately required treatment.

Four studies determined, however, that a normal ECG alone does not rule out significant BCI.[4,6–8] One study used transesophageal echocardiography to diagnose BCI, which was defined as a wall motion abnormality or dilation of the cardiac chambers.[6] Only 59% of the patients who had significant findings on transesophageal echocardiogram (TEE) presented with an abnormal ECG result. In the study of Fulda et al., 24% of the patients with a mechanism for BCI had a normal ECG result at admission, and 41% of these patients developed a clinically significant abnormality. Salim et al.[8] and Velmahos et al.[7] found that a small but significant number of patients in their studies also presented with normal ECG result, but were later diagnosed with BCI.

There have been attempts to use specialized types of ECG to improve the predictive value of this modality. Because the right ventricle is believed to be the more likely injured cardiac chamber in BCI, Walsh et al.[9] assessed the ability of V4R (right-sided ECG) to aid the diagnosis of BCI. Forty-five patients with blunt chest trauma and 40 unmatched controls were compared with standard 12-lead ECG and right precordial leads. The authors concluded that patients with a significant mechanism and physical findings of blunt chest trauma were more likely than controls to have an abnormal 12-lead ECG result; they were not more likely to have abnormalities in V4R. Right-sided ECG was not helpful in diagnosing BCI. Fulda et al.[4] examined the role of signal-averaged ECG and found it to be of no benefit.

Echocardiogram

In the first BCI guideline, multiple studies showed that routine transthoracic echocardiogram is not useful as a primary screening modality but rather as a diagnostic test for patients who have unexplained hypotension or arrhythmias. Recent studies are consistent with this determination.[4,5,7,10–13]

The literature also supports reserving echocardiogram for symptomatic patients even with significant mechanism of injury. Specifically, patients with isolated sternal fracture do not need screening for BCI.[10,11]

CARDIAC ENZYMES

Creatinine Phosphokinase

Four studies assessed the utility of creatinine phosphokinase and its isoenzyme CK-MB. They determined that CK-MB was not useful for diagnosing BCI, as was suggested by the original guideline.[4,6,14,15]

Swaanenburg et al.[14] obtained CK, CK-MB, troponin I, and troponin T levels and compared patients based on the presence or absence of thoracic injury. They determined that CK-MB, CK-MB/CK total ratio, CK-MB mass, and CK-MB mass/CK total ratio were not useful in detecting myocardial damage after blunt chest trauma.

Another study of hemodynamically stable patients with BCI after blunt chest trauma evaluated the prognostic value of cardiac troponin I (cTnI), cardiac troponin T (cTnT), CK, CK-MB, and their ratios.[15] Neither CK nor CK-MB was able to differentiate those with BCI from those without.

Troponin

Initial studies indicated that troponin was not helpful in the diagnosis of BCI, and thus, it was not recommended in the first set of EAST BCI recommendations. Swaanenburg et al.[14] obtained troponin I and troponin T at admission and 24 hours later and compared patients based on the presence or absence of thoracic injury. The study found that cTnI and cTnT were more reliable than the CK biomarkers, but if initial values were negative, the repeat analysis at 24 hours was necessary to help diagnose myocardial damage. Of the patients with blunt thoracic trauma, only three were determined to have BCI, and this subgroup was not further clarified. This study did not determine to evaluate patients with BCI but rather evaluated patients with blunt thoracic trauma and compared them with patients without blunt thoracic trauma.

Another study of hemodynamically stable patients with BCI after blunt chest trauma evaluated the prognostic value of cTnI, cTnT, CK, CK-MB, and their ratios.[15] Because of the low sensitivity of cTnT (12%) and cTnI (23%), neither provided an improved method of diagnosis of BCI.

One study of severe trauma patients evaluated patients with BCI diagnosed by abnormal ECG result and subcategorized patients based on magnitude of troponin I elevation (greater or less than 2 μg/L) and duration of elevation (very transient, ≤12 hours; transient, ≤36 hours; and sustained, ≥36 hours). This study determined that patients with sustained elevations had a greater likelihood of coronary injury, but elevated troponin levels had no prognostic value for BCI. Of note, the level of elevated troponin I for this study was greater than that for other studies.[7,8]

Collins et al.[3] conducted a prospective study that evaluated the usefulness of serum troponin (cTnI) levels to evaluate cardiac injury. This study found that positive cTnI had a

low positive predictive value. Furthermore, they found that a negative ECG result alone ruled out BCI. In this study, they also found that if the ECG result was abnormal but the cTnI level was normal, a BCI was ruled out. Patients with both abnormal ECG result and abnormal cTnI level should be admitted with telemetry monitoring.

In a study by Rajan et al.[16] a cTnI less than 1.05 μg/L drawn immediately upon evaluation or at 6 hours in the asymptomatic patient ruled out BCI. The authors concluded that a cTnI greater than 1.05 μg/L necessitated further workup. Neither CK total or CK-MB were helpful in predicting BCI.

Further studies specifically targeting BCI rather than all comers for thoracic injury seem to show that a small, but important, group of patients may present with a normal ECG result and clinically significant cardiac injury that is identified early only with the addition of troponin. In a 2001 prospective study by Salim et al.,[8] patients with significant blunt thoracic trauma were evaluated with ECG at admission and 8 hours as well as cTnI at admission, 4 hours, and 8 hours. Of the 19 patients (16.5%) with significant BCI, all were admitted to the intensive care unit for associated injuries. The negative predictive value (NPV) for BCI improved from 95% with ECG alone to 100% for ECG and cTnI combined. The authors concluded that patients with both a normal ECG result and normal cTnI level at admission and no other injuries requiring admission could be safely discharged home without further monitoring.

When the same population was combined with more patients by Velmahos et al.,[7] their prospective study determined that a negative troponin and normal ECG results ruled out BCI, but a normal ECG result alone could not rule out BCI. The incidence of significant BCI in their study was 13%, which they defined as cardiogenic shock, arrhythmia requiring treatment, posttraumatic structural defects, or unexplained hypotension. Importantly, 5 of 67 patients with normal initial ECG result had a positive result for troponin and clinically significant BCI defined by hypotension, arrhythmia, decreased cardiac index, and/or need for treatment. An abnormal cTnI level was defined as greater than 1.5 ng/mL. All patients with significant BCI required admission to the intensive care unit for associated injuries. Forty-one patients with normal ECG result and troponin level at admission and 8 hours, but significant mechanism, were admitted for 1 day to 3 days of observation. None of these patients developed clinically significant BCI. The authors determined that the NPV of normal ECG result and normal cTnI level was 100%. They concluded that patients with normal ECG result and normal cTnI level at admission were at no risk of developing subsequent cardiac instability requiring intervention and could be safely discharged without further monitoring.

An additional study evaluating the role of troponin T and signal-averaged ECG prospectively evaluated patients with chest wall injuries; patients received daily ECG, signal-averaged ECG, and serial troponin T levels as well as creatinine phosphokinase (CK-MB).[4] A troponin T level of 0.02 μg/L or greater was considered elevated. Patients with preexisting cardiac disease were excluded from the study, as were patients discharged in less than 48 hours. This study determined that, while ECG is the single best predictor of BCI, the best combined predictors of the development of clinically significant disease are ECG and troponin.

These more recent studies show that ECG alone is not sufficient to definitively rule out BCI, which is a major change from the previous EAST PMG. This recommendation is based on data from four studies representing more than 500 prospectively studied patients, taking into account the overlap from the studies of Salim et al. and Velmahos et al. and not counting them twice. Most of the studies show that the addition of troponin I increases the NPV to 100%. When looking at a 5% difference combining ECG and troponin, the effect may seem relatively small; however, this represents an inexpensive way (certainly less expensive than a day in the hospital) to allow safe discharge, as well as being a way to identify patients who potentially need further workup to prevent harm. When the risk is low (a blood test) and the benefit is relatively high (no missed diagnosis and decreased length of stay), the potential effect is more significant and thus represents a stronger recommendation.

One recent study looked at the use of troponin I in the pediatric trauma population, finding that it was elevated in 27%. Elevation was associated with higher injury severity and interventions, although the degree of elevation was not indicative of the degree of injury. Furthermore, peak troponin I did not correlate with abnormalities on cardiac echo and was not useful in detecting cardiac injury. No recommendations can be made for this population.[17]

STERNAL FRACTURE

Five studies evaluated the relationship of sternal fracture to BCI. Four of those studies concluded that sternal fracture was not a marker for BCI.

Sadaba et al.[18] evaluated 37 patients with isolated sternal fracture. Of those patients with a normal chest radiograph and normal ECG results, none exhibited any signs or symptoms of BCI. They concluded that isolated sternal fracture is not a marker for BCI and these patients could be safely discharged if they had a normal chest radiograph and normal ECG results.

In a retrospective review of 100 patients, 67 of whom had isolated sternal fractures, the incidence of BCI was 4%, which was diagnosed by ECG.[10] Echocardiography did not add to the ability to diagnose BCI and was not recommended as a screening tool in the evaluation of patients with isolated sternal fractures.

In a second retrospective review of 50 patients with diagnosis of sternal fracture, of the 30 patients with isolated sternal fracture, only 1 patient (3%) had a BCI.[11] This patient had a normal echocardiogram result, with myocardial contusion diagnosed by ECG. No clinical intervention was needed. Because this was a retrospective study, no information was available regarding any hemodynamic instability as a result of the BCI. While the authors recommended that an echocardiogram be used for patients with sternal fracture and moderate (Injury Severity Score [ISS], 6–15) or severe (ISS > 16) injury, no clinically actionable abnormalities were identified on any of the abnormal echocardiography results. Thus, in a

patient with isolated sternal fracture, the diagnostic algorithm should remain the same as in other patients with suspected BCI.

In a study that assessed cardiovascular injury associated with sternal fracture, the authors found that sternal fracture either with or without a retrosternal hematoma was not a marker for BCI.[19]

A final study retrospectively examining the relationship between sternal fractures and BCI determined that patients with isolated sternal fractures, in the absence of hemodynamic instability, could be safely discharged without further workup.[20] Management of patients with sternal fracture should be directed at the management of associated injuries.

MULTIDETECTOR CT/MRI

Previously, the utility of helical CT was compared with TEE for diagnosis of blunt cardiac injuries and associated injuries such as valvular damage.[12] Both modalities had similar ability to identify surgically acute thoracic aortic injury. In a select group of ninety-five patients in this prospective study, multiplane TEE was compared with helical chest CT for the diagnosis of traumatic cardiovascular injury. Of the four patients with "myocardial contusion," all were diagnosed by TEE, and none were diagnosed by helical chest CT. Helical chest CT at that time (2001) was considered unreliable in identifying BCI and its associated cardiac injuries.

MRI has been used in the past to diagnose significant cardiac disease, including impending cardiac rupture and valvular compromise. Most studies involve case reports and anecdotal evidence. The potential benefit is in being able to distinguish direct traumatic cardiac disease from ischemic peritraumatic disease arising from coronary artery disease that would warrant further interrogation with cardiac catheterization, thus sparing the former group an unnecessary intervention. This modality requires a stable patient and is associated with a relatively greater cost than other imaging modalities. The quality of MRI is also more variable from institution to institution.[21,22]

CT technology has changed markedly since the first EAST BCI guideline. Multidetector CT (MDCT) became available around 2002, becoming widely adopted by 2005. The advent of MDCT with ECG-gated capabilities promises to give new sensitivity and specificity to the diagnosis of BCI. The ability to accurately distinguish types of injury to the myocardium seems to be approaching that of MRI, in a much faster and less expensive way. Formerly hampered in resolution by patient motion and increased cardiac activity via tachycardia, current scanners are much faster and can be gated to take images only in diastole, with immediate reconstruction of the combined images.[22–25] CT can identify very small pericardial effusions, pericardial tears, and rarer entities such as cardiac luxation, characterized by displacement of the heart to the left, entrapment of the left atrium and ventricle, and pneumopericardium. A combined modality with MDCT Angiography shows coronary anatomy and can gauge myocardial function and perfusion.[26–28] Differentiation between BCI and AMI must be established to determine whether to proceed with cardiac catheterization or anticoagulation that would be helpful in AMI but potentially harmful in BCI, especially in the setting of associated traumatic injury.

FUTURE INVESTIGATION

To advance our understanding of BCI diagnosis, future studies should address the role of troponin in ruling out BCI. Specifically, questions remain as to whether troponin I or troponin T is the more appropriate test, the timing of the test, if the test needs to be repeated, or whether a single value is adequate. Furthermore, the literature still has ambiguity as to what value constitutes a positive troponin. This information will advance our ability to provide cost-efficient workup for BCI and allow us to safely discharge patients without the danger that they will subsequently develop clinically significant sequelae of BCI that requires treatment.

Changes in our ability to detect and differentiate myocardial injury, particularly in our aging population, offers a potential for change in practice as well. Further studies are needed to assess the sensitivity and specificity of MDCT in the trauma population and to identify those patients who might benefit from cardiac CT.

SUMMARY

The diagnosis of BCI remains challenging but should be considered in those patients with significant mechanism of injury and in those who respond poorly to resuscitative efforts. To date, no single test is able to rule in or rule out BCI. The challenge remains to identify those with clinically significant BCI while limiting costly workup for patients with low risk of hemodynamic instability from BCI. Many of the patients in the articles reviewed who were diagnosed with BCI requiring intervention were admitted to the intensive care unit for associated injuries. What is still not clear from the literature is how much testing needs to be completed to determine that a patient can be safely discharged without further monitoring.

ECG remains the most commonly recommended tool for initial diagnosis of BCI. Less clear is the role that troponin should play in addition to ECG in the diagnostic workup, although it seems that this may allow for safe discharge or admission to a regular ward. A normal ECG result has an excellent NPV, in most studies being greater than 95%. Some studies, however, indicate that the addition of troponin I will increase the NPV to 100%, which could potentially decrease overall costs should that allow for more discharges and avoidance of intensive care unit stay.

The marked advancements in CT technology in the last decade will likely change our ability to differentiate traumatic from ischemic injury in our patients, particularly in a high-risk, aging population. Because traumatic injury is superimposed on preexisting morbidities, this distinction becomes increasingly important as the treatment algorithm is markedly divergent between AMI and BCI.

AUTHORSHIP

All authors collected, analyzed, and interpreted the data. K.C., C.V., J.B., B.C., S.K., F.L., D.N., A.S., B.T., and E.H. critically revised the

manuscript. K.C. and E.H. designed the study. K.C., C.V., and E.H. conducted the literature search and wrote the manuscript.

DISCLOSURE

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