The sternal brace: a novel osteopathic diagnostic screening tool to rule out cardiac chest pain in the emergency department

Garrett Gianneschi*, DO, Sarthak Patel, MD and Patrick Hinfey, MD

Abstract

Context: Chest pain is one of the most common emergency medicine complaints in the United States, yet no reliable physical examination finding exists to help differentiate cardiac chest pain (CCP) from noncardiac chest pain (non-CCP).

Objectives: This is a diagnostic accuracy study of the sternal brace, a novel physical examination maneuver to rule out cardiac-related chest pain from non-CCP.

Methods: We performed this double-blind prospective diagnostic accuracy pilot study on 34 adults in the Newark Beth Israel emergency department with a chief complaint of chest pain. We utilized the Numerical Rating Scale 0–10 (NRS) to quantify chest pain severity before and after the maneuver. Eligible for inclusion were adults over 18 years old who were able to provide written informed consent. We performed the sternal brace on all consenting adults meeting these criteria, and the researchers were blinded between test results and final diagnosis. Cardiac ischemia in the US with a disease prevalence of 0.029 was utilized.

Results: A total of 34 patients were included, of whom 11 had a final diagnosis of cardiac-related chest pain. The cutoff value was a decrease in pain severity of 2 or greater between pretest and posttest. Sensitivity was 81.8 % (95 % confidence interval [CI], 48.2–97.7 %); specificity 34.8 % (95 % CI, 16.4–57.3 %), the positive predictive value was 3.6 % (95 % CI, 0.1–20.3 %), and the negative predictive value was 98.4 % (95 % CI, 66.8–100.0 %).

Conclusions: The sternal brace is a good screening test because if a person with chest pain has an NRS that decreases by 2 or more with the maneuver, then there is a 98.5 % chance that the chest pain is noncardiac, given the prevalence of cardia ischemia. In addition, if the disease is present, then it is 81.8 % likely that their NRS will not decrease by more than 2.

Keywords: cardiac; cardiac ischemia; chest pain; sternal brace

Chest pain is a concerning symptom because it can indicate a serious medical condition such as cardiac ischemia. Chest pain accounts for 2.0–9.6 % of all admissions to the emergency department (ED) and up to 20–30 % of medical admissions [1, 2]. In the United States alone, there are approximately 7.16 million visits annually to the emergency room with chest pain, and most of these are of noncardiac etiology [3]. In a 1998 study of 1001 ED patients admitted with chest pain, 42 % were diagnosed with ischemic heart disease, whereas 58 % were diagnosed with non-CCP [4].

Given the high prevalence of noncardiac etiologies in chest pain, it is important to develop a means to more quickly and easily differentiate cardiac chest pain (CCP) from other causes of chest pain. The physical examination technique under consideration is the sternal brace (also known as the Scali sign, named for Victor Scali, DO, the emergency medicine doctor who taught the technique to this author).

In a PubMed search of the various physical signs for diagnosis of chest pain (aside from the respiratory auscultation of various pulmonary causes of chest pain), there was no mention of techniques that were similar to the sternal brace. There is a well-known physical examination finding for costochondritis and other musculoskeletal chest wall syndromes: the presence of tender areas along the anterior and posterior thorax, as noted in Bate’s Guide [5]. However, a 2009 review article by Proulx and Zryd [6] found tender areas served little value in diagnosing chest pain.
Therefore, there is a need to refine physical examination findings to help guide diagnosis.

The main hypothesis is that the sternal brace can become a diagnostic screening tool to rule out CCP from non-CCP. The intended use of this study is to develop a screening method to rule out CCP from more benign etiologies of chest pain when advanced diagnostic equipment is not available, whether in ED triage or out in the field.

**Instructions for sternal brace**

1. The operator stands on either side of the patient, facing the patient.
2. The operator rests their palm along the patient’s sternum, with their fingertips pointing superiorly.
3. The operator’s other palm rests along the spinal vertebra opposite the sternum, roughly T3–T7, with their fingertips pointed superiorly.
4. The operator adds mild compression of the sternum and spine between the two hands, and then asks the patient to breathe out slowly. The operator continues to slightly compress the two hands toward each other following the sternum and spine. The patient does not need to strain to force out extra breath.
5. At the end of expiration, the operator should ask the patient to breathe in while compressing the thoracic cage a bit harder to immobilize the chest wall excursion.
6. If the pain is not cardiac in origin, then the pain should decrease by more than 2.

### Methods

**Study design**

This is a double-blind, prospective diagnostic accuracy test pilot study of the sternal brace as performed in the ED of Newark Beth Israel in Newark, New Jersey on a convenience sample of participants with a chief complaint of chest pain. The study was registered and IRB-approved with Newark Beth Israel, IRB#2021.14. The cohort was 34 chest pain patients enrolled over 8 months from September 2021 through May 2022. Each enrollee was managed by a team of two researchers. Researcher 1 (R1), initials GG, identified the possible participants, consented enrollees with written informed consent prior to testing, and then performed the test and recorded the result. Later, Researcher 2 (R2), initials SP, would determine whether the chest pain was likely cardiac or noncardiac based on chart review and the final diagnosis of the attending physician as written in the ED note. R1 was blinded from the final diagnosis retrieved by R2, who was blinded from the test result recorded by R1. The clinical course was not influenced by enrolling in the study.

In practice, a patient would come to the Newark Beth Israel ED for a chief complaint of chest pain, and be triaged by the triage nurse. The chief complaint would then be displayed on the tracking board for the staff. R1 would intermittently check the tracking board to scout for chief complaints of “chest pain.” Once a potential participant was identified, then R1 would record the patient’s age and medical record number. R1 would approach the patient, consent and enroll the patient in the study, and perform the test as soon as possible. A pretest NRS score from 0-10 was obtained for the primary chest pain complaint. The sternal brace was performed, and a posttest NRS score was obtained. All eligible patients with a chief complaint of chest pain were approached, informed about the study, and potentially enrolled. This was a convenience sample of adults with chest pain, and the subjects were enrolled when the researcher was present in the ED. The test was performed and recorded while the test performer was blinded to all other diagnostic test results. R1 performed the test without interfering with normal management protocols. Ideally, the test was to be performed as soon as triage was complete and before all other diagnostic testing performed; however, given the urgency of a chief complaint of chest pain, that was not always viable. Final diagnosis was retrieved months after the ED visit by R2.

### Participants

Participants were patients coming to the ED for a chief complaint of chest pain, as documented by the triage nurse. The inclusion criteria were age 18 years old and above, with a chief complaint of chest pain. The exclusion criteria were patients unwilling or unable to provide written informed consent.

### Test methods

Pretest and posttest NRS scores were obtained and compared with the final diagnosis. The final diagnosis was the final decision of the attending physician as written in the ED note for that visit. The adverse events from the reference standards were reported. Tests that were hindered or indeterminate were not included in the study.

### Data analysis

The final diagnoses retrieved by R2 were then divided into two groups: CCP and non-CCP. Diagnostic test values were

Table 1: The sensitivity and 1-specificity of each NRS test result based on its ability to differentiate CCP from non-CCP.

<table>
<thead>
<tr>
<th>NRS change</th>
<th>1-Specificity (x)</th>
<th>Sensitivity (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.57</td>
<td>0.73</td>
</tr>
<tr>
<td>2</td>
<td>0.65</td>
<td>0.82</td>
</tr>
<tr>
<td>3</td>
<td>0.74</td>
<td>0.82</td>
</tr>
<tr>
<td>4</td>
<td>0.83</td>
<td>0.82</td>
</tr>
<tr>
<td>5</td>
<td>0.87</td>
<td>0.91</td>
</tr>
<tr>
<td>6</td>
<td>0.91</td>
<td>1</td>
</tr>
</tbody>
</table>

CCP, cardiac chest pain; non-CCP, noncardiac chest pain; NRS, numerical rating scale.
calculated utilizing MedCalc and Diagnostic Test Calculator [7, 8]. Various cutoff values of pretest/posttest decrease in chest pain were plotted for specificity and sensitivity as well as the receiver operating characteristic (ROC) curve that was generated and is shown in Table 1 and Figure 1, respectively. A decrease in chest pain of 2 was considered to be the best choice to study. Therefore, the test will be considered positive for cardiac etiology if the sternal brace does not reduce the NRS score by 2. A test will be considered negative if the sternal brace reduces the NRS by 2 or more. It may be counterintuitive to consider little to no decrease in chest pain as a positive test; therefore, Figure 2 was added to reiterate and clarify this idea.

Cardiac ischemia in the US disease prevalence of 0.029 [9] was utilized for posttest probabilities of positive predictive value (PPV), negative predictive value (NPV), and accuracy.

\[
\text{PPV} = \frac{\text{sensitivity} \times \text{prevalence}}{\text{sensitivity} \times \text{prevalence} + (1 - \text{specificity}) \times (1 - \text{prevalence})}
\]

\[
\text{NPV} = \frac{\text{specificity} \times (1 - \text{prevalence})}{(1 - \text{sensitivity}) \times \text{prevalence} + \text{specificity} \times (1 - \text{prevalence})}
\]

\[
\text{Accuracy} = \text{sensitivity} \times \text{prevalence} + \text{specificity} \times (1 - \text{prevalence})
\]

Figure 1: Receiver operating characteristic (ROC) curve plotting the sensitivity and specificity of each NRS score. A decrease in NRS of 2 was chosen to differentiate between cardiac and noncardiac.

Figure 2: If the sternal brace has little effect on chest pain (i.e., NRS decreases by 0 or 1), then the test is considered positive and more likely to be cardiac. If the sternal brace has a good effect (i.e., NRS decreases by 2 or more), then the test is negative and less likely to be cardiac.

Figure 3: Equations (1)–(3): PPV, NPV, and accuracy with prevalence included in each equation [7].

Results

A total of 34 patients were included in this study. Results obtained from the Newark Beth Israel ED in consenting adults between the age of 22 and 85 years old with a mean age of 48 ± 15 and a median age of 45.5. Race and gender data were not collected, yet demographics likely fell along the lines of
Flow Chart and Diagnostic Test Table for NRS of 2 Cutoff Value

![Flow Chart](image)

**Table 2:** List of all diagnostic test values for the sternal brace at an NRS change of 2.

<table>
<thead>
<tr>
<th>Compiled Diagnostic Test Values</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>34</td>
</tr>
<tr>
<td>Prevalence in US</td>
<td>2.9%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>81.8%</td>
</tr>
<tr>
<td>Specificity</td>
<td>34.8%</td>
</tr>
<tr>
<td>PPV (w/prevalence)</td>
<td>36.5%</td>
</tr>
<tr>
<td>NPV (w/prevalence)</td>
<td>98.5%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>36.2%</td>
</tr>
<tr>
<td>Positive LR</td>
<td>1.25</td>
</tr>
<tr>
<td>Positive LR, posterior probability (odds)</td>
<td>37.0%</td>
</tr>
<tr>
<td>Negative LR</td>
<td>0.52</td>
</tr>
<tr>
<td>Negative LR, posterior probability (odds)</td>
<td>20.0%</td>
</tr>
</tbody>
</table>

CI, confidence interval; LR, likelihood ratio; NPV, negative predictive value; NRS, numerical rating scale; PPV, positive predictive value.

Newark's Weequahic neighborhood demographics: 46% male, 54% female; 91.9% African American, 5.0% Hispanic, and 3.1% other races [10]. The clinical characteristics were not recorded except for age, medical record number, sternal brace test results, and final diagnosis.

To predict CCP, a cutoff value was a decrease in pain severity of 2 or greater between pretest and posttest NRS scores. A flow chart and diagnostic test table for this value are shown in Figure 4.

Utilizing this cutoff value and prevalence yielded the following: Sensitivity 81.8% (95% confidence interval [CI], 48.2–97.7%); specificity 34.8% (95% CI, 16.4–57.3%); PPV 3.6% (95% CI, 0.1–20.3%); and NPV of 98.4% (95% CI, 66.8–100.0%). There was accuracy of 36.2% (95% CI, 20.4–54.4%) [9]. There was a positive likelihood ratio of 1.25 (95% CI, 0.8 to 1.9) with posterior probability (odds) at 37% (95% CI, 29–47%); therefore, approximately 1 in 2.7 with a positive test are sick. We have a negative likelihood ratio of 0.52 (95% CI, 0.13 to 2.06) with posterior probability (odds) at 20% (95% CI, 6–50%); therefore, approximately 1 in 1.2 with a negative test are well [9]. A full list of compiled diagnostic test values is shown below in Table 2.

**Adverse events**

No serious adverse events were reported. Two patients experienced an increase in chest pain, one by an increase in NRS of 1 and the other by an increase in NRS of 2.

**Discussion**

The physiologic basis and mechanism of the sternal brace is not known; however, the authors theorize that the maneuver relieves the dysfunction of the innermost/internal intercostal muscle. These muscles were chosen because they are located both medially and laterally in the chest wall. Similarly in this study, chest pain location could be located anywhere along the midline sternum or as far lateral as the axillary line. It is less likely to be the transversus thoracis because it does not extend laterally, or the external intercostals, which are not located medially.

The innermost/internal intercostals are muscles for expiration. Chest pain is often exacerbated by inhalation, which stretches the innermost/internal intercostals [5]. When the maneuver compresses the chest wall, then the chest wall is put into an exhalation position and the length of the innermost/internal intercostals is reduced. Then, the patient’s attempt to actively expand the rib cage makes the innermost/internal intercostals reciprocally inhibited and not allowed to lengthen because of the operator’s opposing force keeping their length shortened. Therefore, this could then be considered a counterstain technique or a facilitated position-release technique.

The sternal brace study is important for a number of reasons.
(1) There are few physical examination findings to separate CCP from the more common causes of chest pain. Therefore, the sternal brace adds a valuable perspective to the diagnosis.

(2) The high NPV lends itself to triaging patients in a busy ED or with emergency medical services in the field.

(3) The examination is quick, painless, and easy enough that it can be taught to many different levels of healthcare workers.

(4) Chest pain can be psychologically distressing for patients and detrimental to their mental health, which is a reassuring sign of pain relief could be beneficial.

(5) This could be a helpful screening tool when more advanced equipment is not readily available.

Finally, this is an osteopathic technique that has been adapted into a diagnostic physical examination finding. There are many such osteopathic techniques that are underutilized by the medical profession as a whole that may provide better therapeutic and diagnostic techniques.

Study limitations including sources of potential bias, statistical uncertainty, and generalizability are reported here. The demographic of Newark, New Jersey is not representative of the United States as a whole. We had a small sample size of 34 patients because of limited time availability for recruitment. Because this was a convenience sample, a wide age range was recruited, which may confound the data because CCP is highly unlikely in the younger cohort. Race and gender were not collected because this was a proof-of-concept pilot study. Determining CCP was purely based on the final diagnosis of the ED attending during that ED visit without the consideration of laboratory work, other testing, and further hospital course; these would have been valuable to corroborate the final diagnosis. CCP possibly had a higher prevalence in this study because those patients highly suspicious for cardiac issues tend to have a longer ED course and therefore a higher chance of the study team recruiting them. Additionally, more benign forms of chest pain, including musculoskeletal chest wall syndromes and gastroesophageal reflux disease (GERD), may be underrepresented; presumably these more benign forms of chest pain would be discharged more quickly and therefore are less likely to be recruited in this convenience sample. However, it is possible that those patients with more severe symptoms were less amenable to consenting to an experimental study in the first place.

In future studies, we recommend: (1) a more thorough corroboration of the final diagnosis in the ED visit; (2) an increase in sample size; (3) a cohort study of the effect of the sternal brace on known CCP patients; (4) utility of the sternal brace in triaging patients with a chief complaint of chest pain; and (5) better categorization of non-CCP.

Conclusions

The primary objective was to assess the sternal brace as a screening tool. Therefore, with a sensitivity of 81.8% and an NPV of 98.5%, this test would be a good, quick screening tool to rule out CCP. Therefore, if a person with chest pain has an NRS that decreases by 2 or more with this maneuver, then there is a 98.5% chance that the chest pain is noncardiac, given its prevalence. Also, if the disease is present, then it is 81.8% likely that their NRS will not decrease by more than 2. This test did not perform well in other diagnostic measures; it had poor specificity, poor PPV, and poor accuracy.

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Research ethics: The local Institutional Review Board deemed the study exempt from review.

Informed consent: Informed consent was obtained from all individuals included in this study, or their legal guardians or wards.

Author contributions: The authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Competing interests: None declared.

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Data availability: The raw data can be obtained on request from the corresponding author.

References