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Regional Implementation of a Pediatric Cardiology Chest Pain Guideline Using SCAMPs Methodology

**AUTHORS:** Gerald H. Angoff, MD, David A. Kane, MD, Niels Giddins, MD, Yvonne M. Paris, MD, Adrian M. Moran, MB, Bch, Victoria Tantengco, MD, Kathleen M. Rotondo, MD, Lucy Arnold, MD, Olga H. Toro-Salazar, MD, Naomi S. Gauthier, MD, Estella Kanevsky, MS, Ashley Renaud, RN, Robert L. Geggel, MD, David W. Brown, MD, and David R. Fulton, MD

Department of Pediatrics, Dartmouth-Hitchcock Medical Center, Geisel School of Medicine at Dartmouth, Lebanon, New Hampshire; Department of Pediatrics, UMass Medical Center, University of Massachusetts Medical School, Worcester, Massachusetts; Department of Pediatrics, Fletcher Allen Health Care, University of Vermont Medical School, Burlington, Vermont; Department of Pediatrics, Baystate Medical Center, Springfield, Massachusetts; Department of Pediatrics, Tufts University School of Medicine, Boston, Massachusetts; Department of Pediatrics, Maine Medical Center, Portland, Maine; Department of Pediatrics, Hasbro Children’s Hospital, Warren Alpert Medical School at Brown University, Providence, Rhode Island; Department of Pediatrics, Harvard Vanguard Medical Associates, Boston, Massachusetts; Department of Pediatrics, Connecticut Children’s Medical Center, University of Connecticut, Hartford, Connecticut; Department of Pediatrics, Division of Pediatric Cardiology, Boston Children’s Hospital, Boston, Massachusetts; and Department of Pediatrics, Harvard Medical School, Boston, Massachusetts

**KEY WORDS**

chest pain, pediatric cardiology, SCAMPs, clinical practice guideline

**ABBREVIATIONS**

BCH—Boston Children’s Hospital
ECG—electrocardiogram
NECCA—New England Congenital Cardiology Association
PPV—positive predictive value
SCAMPs—Standardized Clinical Assessment and Management Plans
SDFs—SCAMP data forms

Dr Angoff helped to design the study, drafted the initial manuscript, coordinated monthly discussions regarding the Standardized Clinical Assessment and Management Plans process for all centers, and completed the final manuscript as submitted; Dr Kane helped to conceptualize and design the study, participated in monthly site discussions, and edited the draft; Drs Giddins, Paris, Rotondo, Arnold, and Toro-Salazar helped to design the study, participated in monthly site discussions, and edited the draft; Drs Moran and Tantengco participated in monthly site discussions and edited the draft and approved the final manuscript as submitted; Dr Gauthier participated in monthly site discussions and edited the final manuscript as submitted; Ms Kanevsky designed

(Continued on last page)
Chest pain in children is a common reason for referral in both academic and community pediatric cardiology practice. The evaluation is often resource intensive and costly despite the low incidence of cardiac pathology ranging from 0% to 5%.1–15 This low incidence has been documented in the emergency setting as well as ambulatory care.14 Many previous reports on pediatric chest pain have been observational and lack guideline recommendation. We have designed and reported on a quality improvement tool termed Standardized Clinical Assessment and Management Plans (SCAMPs), which guides care of patients with a single presenting symptom or condition according to an algorithm designed by clinicians that improves outcomes, narrows practice variability, and reduces unnecessary testing.15–17 Although sharing some similarities to clinical practice guidelines, SCAMPs differ by mandating data acquisition, analyzing the data on a recurring basis, and altering the SCAMP based on the analysis. Providers are permitted to divert from the pathways, although they are requested to explain the reasons for the action taken potentially offering new insight into the management of the clinical problem. Our previous experience has demonstrated a decrease in practice variation and a marked reduction in unnecessary resource utilization compared with historic controls.17

The New England Congenital Cardiology Association (NECCA) is an organization of 16 academic and community-based practices with 115 member physicians representing all 6 New England states. NECCA was formed in 2009 with a mission to improve continuously the quality, safety, effectiveness, availability, and cost of care for children and adults with known or suspected congenital or acquired heart disease of childhood. Care delivery settings vary from small independent private practices with no academic affiliation to a large, tertiary care academic center.

SCAMP studies to date have been reported from Boston Children’s Hospital (BCH), the core academic center where the methodology was developed. The likelihood for success in implementing the SCAMP process outside the academic center is untested. In this study, we report results of a chest pain SCAMP implemented in concert at BCH and NECCA sites and compare the results from the varied NECCA practices with those of BCH. Analysis of the data reflects on sound clinical practice, the benefits of the SCAMPs approach, and efficacy of broad regional implementation.

METHODS

We developed a SCAMP algorithm for pediatric chest pain using history, physical examination, and electrocardiogram (ECG) to suggest when further diagnostic testing is indicated using methodology previously developed and described.15–17 This algorithm is designed to identify cardiac causes of chest pain while effectively using resources in the outpatient cardiology practice setting. The algorithm was used to analyze the combined patient population and to compare outcomes of those seen at BCH and NECCA sites. Over a 2-year period, representatives from NECCA and BCH reviewed the SCAMP data elements, discussed plausible findings, shared strategies, and, based on feedback, refined the guideline. The guideline was updated before and subsequent to this study but not during the study. In this fashion, providers participated in both the development and implementation of the SCAMP.

Patient Selection

Ambulatory patients between 7 and 21 years of age presenting to a pediatric cardiology practice for a first-time evaluation of the principal complaint of chest pain were enrolled. Those for whom chest pain was a secondary symptom were not included. A total of 109 providers participated in the study, 35 of whom practiced at NECCA sites. Patients were enrolled from July 2010 to December 2011 at BCH and from October 2010 to December 2011 at NECCA sites. Children with known heart disease were excluded. All patient data were de-identified. Activity at the NECCA sites was facilitated, tracked, and coordinated through monthly conference calls that limited site process variation. The institutional review boards at BCH and at participating NECCA sites evaluated the project and waived review designating the SCAMP methodology as quality improvement.

Data Collection and SCAMP Algorithm

We collected demographic and clinical characteristics for each patient, including description of the chest pain, associated symptoms, focused past medical and family history, pertinent physical examination findings, and ECG interpretation (Table 1). Data were collected on SCAMP data forms (SDFs) completed by the provider at the time of the initial visit (see Supplemental Information). SDFs were sent from all sites to a project coordinator at BCH where data were collated and analyzed. The intent was to complete the evaluation at a single visit. Patients who returned after being discharged were evaluated using SDFs documenting interval history and the same data set.

Chest pain history included relationship to exertion, syncope, radiation, changing position, or fever. Past medical history targeted conditions increasing risk of pathologic chest pain to include systemic arthritis/vasculitis, a hypercoagulable state, or prolonged immobilization. Family history documented first-degree relatives with sudden or unexplained death, cardiomyopathy, or a hypercoagulable state. Pertinent physical examination
findings included a pathologic murmur, gallop, friction rub, increased second heart sound intensity, distant heart sounds, peripheral edema, painful or swollen extremities, tachypnea, or fever.

Positive findings from history, physical examination, or ECG listed in Table 2 were indications for echocardiography.

Fever (oral >38.4°C) was the indication for a chest x-ray. Exercise stress testing, ambulatory ECG (Holter) monitoring, and event recorder monitoring were not included as appropriate tests in the algorithm based on previous study, but were tracked as part of the adherence and outcome analysis.

**TABLE 2 Indications for Echocardiography**

<table>
<thead>
<tr>
<th>Historical Factors</th>
<th>Examination Findings</th>
<th>ECG Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest pain early in exercise</td>
<td>RR&gt; 40</td>
<td>Right ventricular hypertrophy</td>
</tr>
<tr>
<td>Chest pain at peak exercise</td>
<td>Temperature &gt;38.4°C</td>
<td>Left ventricular hypertrophy</td>
</tr>
<tr>
<td>Exertional syncope</td>
<td>Ill-appearing</td>
<td>ST segment change &gt; 2 mm</td>
</tr>
<tr>
<td>Radiation* or increase with supine position</td>
<td>Painful/swollen extremities</td>
<td>Low QRS voltage</td>
</tr>
<tr>
<td>Chest pain associated with fever (&gt;38.4°C)</td>
<td>Noninnocent murmur</td>
<td>PR segment depression</td>
</tr>
<tr>
<td>History hypercoagulable state</td>
<td>Distant heart sounds</td>
<td>S1,Q3, inverted T3</td>
</tr>
<tr>
<td>History arthritis/vasculitis</td>
<td>Gallop</td>
<td>QTc &gt; 470 ms</td>
</tr>
<tr>
<td>History immobilization?</td>
<td>↑ Pulmonic component of S2</td>
<td></td>
</tr>
<tr>
<td>Familial sudden unexplained death</td>
<td>Pericardial friction rub</td>
<td></td>
</tr>
<tr>
<td>Familial cardiomyopathy</td>
<td>Peripheral edema</td>
<td></td>
</tr>
<tr>
<td>Familial hypercoagulable state</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*To back, jaw, left arm or left shoulder.*

**Test Interpretation**

ECG interpretation was based on SDF documentation. Positive criteria are listed in Table 2. ECGs were interpreted by the pediatric cardiologist at the time of the visit.

Echocardiography, exercise testing, Holter, and event monitor results were obtained from the SDF documentation. Testing was generally obtained at the time of or soon after the initial visit. Tests performed before pediatric cardiology consultation that deviated from the guideline were noted. Diagnoses considered potential cardiac causes of chest pain included anomalous coronary origins, cardiomyopathy, myocarditis, pericarditis, pulmonary hypertension, aortic dissection, and pulmonary embolism. Mitral valve prolapse was excluded as a likely cause of chest pain. Echocardiogram interpretation was performed at the patient evaluation sites. A core echocardiography laboratory was not used.

**Analysis**

Adherence, Practice Variation, and Resource Utilization

We assessed adherence to the SCAMP algorithm in terms of testing performed or not performed in accordance with the protocol. Practice variation for diagnostic testing was tracked and analyzed. All patients had at least 1 cardiology clinic visit. An ECG was recommended at all visits. Resource utilization for echocardiograms, exercise stress tests, Holter monitors, and event monitors was compared between the BCH and the combined NECCA sites.

**Statistical Analysis**

Descriptive statistics were reported with counts and percentages as well as means and SDs. χ² tests were used to calculate P values for evaluating the difference between the BCH and NECCA sites. Sensitivity and positive predictive
value (PPV) were computed to test the effectiveness of ECGs and echocardiograms. Calculations used a 2-sided test and all statistical analyses were completed by using SAS version 9.3 (SAS Institute, Inc, Cary, NC).

RESULTS

Patient Population
A total of 1016 patients (1025 visits) were enrolled; 61% at BCH and 39% at NECCA sites. Average age at initial visit was 13.1 years (± 3.4). A total of 1007 patients were seen for a single visit and 9 patients (0.9%) for a second visit. Repeat visit frequency did not differ between BCH and NECCA sites.

Initial Evaluation

History and Physical Examination
Elements of history and physical examination are summarized in Table 1. Chest pain was the chief complaint by design. Many patients had multiple symptoms. Chest pain was described as principally at rest in 51.3%, pleuritic in 32.2%, and at peak exercise in 33.7% of patients. Syncope, exertional syncope, and fever were infrequent symptoms, whereas palpitations and exertional dyspnea were common. Asthma was noted in 20.3% of the patients who were seen for their initial visit. Other elements of past medical history contributed little. Significant family history elements were rarely elicited. Of 117 patients with a pertinent family history, 83.6% had a normal echocardiogram, 15.5% had an incidental abnormality, and 1 patient was diagnosed with pericarditis. Physical examination abnormalities were rare. Reproducible chest pain on palpation was present in 116 patients (11.4%).

Testing by Recommendation Status

Adherence for both BCH and NECCA sites was high. An ECG was obtained for 98.4% of patients, short of the design goal of 100%. Of the echocardiograms obtained at all sites, 84% were in accord, whereas 16% were at variance with the SCAMP recommendation. There was no significant difference between the adherence to echocardiography recommendations at BCH and NECCA (81.7% vs 85.7%). However, NECCA sites were significantly more likely to have echocardiograms performed when not recommended compared with BCH (24.0% vs 11.3%, P < .001). Exercise testing and ambulatory monitoring, not recommended in the SCAMP algorithm, were performed at similar infrequent rates at both at NECCA and BCH sites (Fig 1).

ECG Findings

ECG abnormalities were infrequent and minor. Of 1000 ECGs, 85 (8.5%) were abnormal on initial evaluation. Common findings included left ventricular hypertrophy (14, 1.4%), right ventricular hypertrophy (10, 1.0%), and borderline right or left ventricular hypertrophy (18, 1.8%). The 2 patients with a cardiac cause of chest pain had an abnormal ECG (sensitivity 100% and PPV 2.4%). The patient with pericarditis showed ST elevation, whereas the patient with anomalous coronary artery origin had left ventricular hypertrophy.

Chest X-Ray Findings

Chest x-rays were done for 86 patients (8.5%), of which 5 (0.5%) were abnormal. Of these, 3 were done in accordance with the algorithm. Two of the 3 showed pneumonia. Other findings were unrelated to the cause of chest pain.

Echocardiogram Findings

Echocardiography was performed as recommended in 423 patients (41.6%), when not recommended in 81 (8.0%), and was abnormal in 48 (9.5%) of all studies (Table 3). In 2 instances, the echocardiogram findings explained the chest pain (0.5% of the recommended tests, 0.4% overall). One patient presenting with fever, pleuritic chest pain, and dyspnea had acute pericarditis with pericardial and pleural effusions. The second, presenting with exertional chest pain at early and peak exercise, had anomalous origin of the right coronary artery from the left coronary sinus with an interarterial course. Echocardiograms done without SCAMP recommendation found no causes for the chest pain. Incidental findings were relatively common (Table 3). More were discovered on echocardiograms that were not recommended (18.5%), than on the recommended studies (7.3%, P < .002) due in part to abnormal physical findings that did not trigger a SCAMP’s recommended test but drove the provider decision (Table 3). Considerably more echocardiograms were done before the cardiology consultation at NECCA sites compared with BCH. A total of 90 (17.9%) of the echocardiograms were ordered before the...
visit. Of these, 85 (16.9%) were at NECCA sites and 5 (1.0%) at BCH (Table 3). This differential resulted from referring providers ordering echocardiograms before the cardiology visit and contributes to the higher incidence of not recommended echocardiograms performed at NECCA sites (Fig 1). The sensitivity for detecting a cardiac cause of chest pain by echocardiography was 100%, and the PPV was 4.2%.

**SCAMP Deviation Analysis**

Deviations from the SCAMP algorithm were compiled from SDF data (Table 4). The most common reasons for echocardiograms performed when not recommended included parental or referring provider insistence, non-first-degree relatives with congenital heart disease, other medical illness, and abnormal physical examination findings suggesting unrelated cardiac disease. The primary reason for echocardiograms not done when recommended was assessment by the provider that the chest pain was non-cardiac in nature.

Based on history, findings, and clinical judgment, study providers performed a number of additional tests outside the SCAMP recommendations (Table 4). Exercise testing and rhythm monitoring were most frequently done. Reasons for adding exercise testing included exertional dyspnea, dizziness, palpitations, and decreased exercise capacity. Rhythm monitoring was performed primarily for palpitations. Exercise testing and ambulatory monitoring, not recommended in the SCAMP guideline, was performed infrequently and at similar rates for BCH and NECCA sites (Fig 1). These tests did not reveal any clinically relevant abnormalities.

**Final Diagnoses**

Final diagnoses were the clinical impression of the consulting cardiologist. Noncardiac chest pain was described...
for 97.0% of the patients. Two patients (0.2%), as noted, had a cardiac cause for chest pain, 1 with pericarditis and 1 with anomalous origin of the right coronary artery from the left coronary sinus. Other diagnoses were pending or not submitted. Musculoskeletal chest pain was the most frequent diagnosis made by providers (32.9%), with most undiagnosed (54.6%). Pulmonary disease was relatively frequent (6.3%). By initial patient history, 20.3% reported asthma.

Return Visit
Nine patients (0.9%) returned for repeat evaluation after being discharged after the initial evaluation. The primary reasons for return were recurrent symptoms in 7 (77.8%) and family request in 5 (55.6%). No cardiac cause for chest pain was found at these repeat encounters despite increased testing. Follow-up ECGs and echocardiograms were all normal and providers concluded that the patients had noncardiac chest pain.

DISCUSSION
This study has several implications for quality improvement. It affirms that chest pain in children is rarely due to cardiac disease. It validates the SCAMP methodology for creating an efficient and cost-effective approach for evaluating a common complaint in a heterogeneous biologically variable population. It shows that this approach can be implemented regionally among community practice and academic center environments and substantiates the value of the collaborative SCAMP development model in producing a guideline that will be successfully and widely adopted.

A cardiac cause of chest pain was found in 2 cases (0.2%), of which 1 was occult. This case, an anomalous right coronary origin, was identified by echocardiography appropriately performed based on the exercontinual component of the chest pain history. Acute pericarditis, the second case, presented with typical history, examination, and ECG findings. By previous reports, most pediatric patients with chest pain caused by myocarditis, pericarditis, pulmonary embolism, or cardiomyopathy present to the emergency department. The outpatient cardiology department is the setting where rare congenital coronary anomalies are typically identified. Specifying echocardiography as the diagnostic test of choice is based on its ability to identify coronary anomalies. This SCAMP shows that the indication for diagnostic studies can be limited and keyed to presenting symptoms, focused history, cardiac physical findings, and ECG abnormalities. Exercise testing and rhythm monitoring, excluded from the algorithm based on previous study, provide no clear diagnostic benefit. Chest x-ray in the absence of febrile illness was not beneficial. The great majority of patients can be seen, evaluated, and discharged with a single visit. Patients returning after discharge because of persistent symptoms had additional testing but no change in diagnosis. The most common cause of chest pain in this population was musculoskeletal. Notably, pulmonary disease was relatively common by initial history and on final diagnosis.

Improving resource utilization while preserving beneficial clinical outcomes is a core benefit of SCAMPS. In this study, exercise testing, ambulatory monitoring, and repeated follow-up visits were greatly reduced. Friedman et al., in a retrospective study of chest pain evaluation in children, reported exercise testing in 28% and ambulatory monitoring in 17%, which compares to 4.0% and 5.7% in the current study (Fig 1).

Echocardiography was performed frequently based on the SCAMP (504 patients, 49.8%). It identified the 2 patients whose cause of chest pain was cardiac. It also identified incidental findings that added unrelated complexity. Incidental findings were more common on echocardiography performed in deviation from the guideline. Many of these studies were obtained based on history or physical examination findings, although not indicated based on the SCAMP protocol. The NECCA sites were significantly more likely to perform such echocardiograms compared with BCH, probably in part because of constraints on a referral community practice imposed by referring provider and family requests that may be more acceptably deferred at the core academic institution. The higher incidence of echocardiogram studies performed before cardiology consultation at NECCA sites where referring physicians can obtain an echocardiogram without cardiologist review supports this view. Many of these studies would not have been performed under the SCAMP. The overall recommended echocardiography rate in this study was 41.6%. This is similar to the rate of 43% published by Friedman et al for their historical retrospective group. Continued iterative improvements in the criteria for triggering an echocardiogram can provide further resource utilization reductions. Education of providers in the results of this study is an additional mechanism for improved utilization.

It is conceivable that not all patients with a cardiac cause of chest pain were identified. On the other hand, no disease was found in those who returned with persisting symptoms. In a retrospective study of 3700 patients, ages 7 to 23 years seen in a cardiology clinic for chest pain over 10 years, Saleeb et al addressed this concern by searching the US National Death Index and Social Security Death Index for their study patients and found no deaths from a cardiac cause in those discharged from care.

The SCAMP methodology used for this study was essential to both the implementation and result. The methodology is inductive, flows from analysis
of clinical practice, and is suited for study of a heterogeneous biologically variable population.15–17 This approach contrasts with randomized controlled clinical studies that require a homogeneous population that would limit variability or “biological noise.”18 The iterative analysis of SCAMPs data and design can overcome the limits of observation studies for practice guideline development. The chest pain SCAMP is based on collaborative provider input. This aspect has the advantage of being both reflective of the care provided and inclusive of the providers delivering that care. The success of the regional collaboration represented in this study further supports the feasibility of the methodology. Both the development of the SCAMP and its implementation included the core institution, BCH, and the extended 8-state New England region represented by NECCA. The SCAMPs approach is scalable across the full range of practice delivery settings from small private practice to academic centers, increasing its value for guideline development and clinical patient management. Communication, coordination, and consistent implementation may be barriers in multisite studies. As a clinically based quality improvement activity, SCAMPs was readily accepted by the providers involved who incorporated the guideline into their patient care workflow. The monthly conference calls helped to standardize workflows, reduce variation, and maintain active participation. This study demonstrates the value of SCAMPs for dissemination and implementation of practice guidelines. Clinical practice guidelines have been proposed with increased frequency as a means to reduce variation, improve resource utilization, and improve outcomes in clinical care. Translation of research into clinical care, however, has been poor, controversial, or at best highly variable. The reasons offered are diverse, and include behavioral and operational barriers to include decreased awareness, adoption, adherence, buy-in and supportive organizational culture.20–26 Even with awareness, providers will often use clinical judgment at the point of patient care rather than research-based recommendations.27 The SCAMPs approach to quality improvement largely avoids these shortcomings. Providers help create the guideline, provide feedback from its use, participate in periodic data analysis, and have ownership of data, all critical to change management in medical environments.24–29 The resulting guideline is more likely to be broadly implemented in both community and academic practice and achieve the elusive dual goal of outcomes improvement and optimal resource utilization.

CONCLUSIONS

Using SCAMPs methodology, we have demonstrated that chest pain in children is rarely caused by heart disease and can be evaluated in the ambulatory setting efficiently and effectively using minimal resources. The methodology can be implemented regionally across a wide range of clinical practice settings and its approach can overcome a number of barriers often limiting clinical practice guideline implementation.

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Address correspondence to David R. Fulton, MD, Cardiology Outpatient Services, Department of Cardiology, Children’s Hospital Boston, 300 Longwood Ave, Boston, MA 02115. E-mail: david.fulton@cardio.chboston.org

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