Effectiveness of Screening for Life-Threatening Chest Pain in Children

WHAT'S KNOWN ON THIS SUBJECT: Chest pain in children is an extremely frequent complaint, with generally benign causes. Referrals to cardiologists are increasing in volume, although the frequency of cardiac causes is exceedingly low.

WHAT THIS STUDY ADDS: This study demonstrates that thorough history assessments, physical examinations, and electrocardiograms can be used effectively in initial screening to determine when higher-level care and testing are needed. This technique allowed for no cardiac deaths over a 10-year period.

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abstract

OBJECTIVE: We sought to determine the incidence of sudden cardiac death among patients discharged from the cardiology clinic with presumed noncardiac chest pain (CP).

METHODS: The records of children >6 years of age who presented to Children's Hospital Boston between January 1, 2000, and December 31, 2009, with a complaint of CP were reviewed for demographic features, clinical characteristics, resource utilization, and presumed diagnosis. Patients were searched for in the US National Death Index and Social Security Death Index.

RESULTS: Data for a total of 3700 patients with CP (median age at evaluation: 13.4 years [range: 7–22.3 years]) were reviewed. The median follow-up period was 4.4 years (range: 0.5–10.4 years), for total of 17 886 patient-years of follow-up data. CP with exertion occurred in 1222 cases (33%), including 15 with associated syncope. A cardiac cause was determined in 37 cases; the remaining 3663 patients (99%) had CP of unknown ($n = 1928$), musculoskeletal ($n = 1345$), pulmonary ($n = 242$), gastrointestinal ($n = 108$), anxiety-related ($n = 34$), or drug-related ($n = 4$) origin. Emergency department visits for CP were documented for 670 patients (18%), and 263 patients (7%) had cardiology follow-up visits related to CP. There were 3 deaths, including 2 suicides and 1 spontaneous retroperitoneal hemorrhage.

CONCLUSION: CP in children is a common complaint and rarely has a cardiac cause. Review of 1 decade of cardiology visits (nearly 18 000 patient years) revealed that no patient discharged from the clinic died as a result of a cardiac condition. *Pediatrics* 2011;128:e1062–e1068

Chest pain (CP) in children is a common complaint in general pediatric clinics, emergency departments, and pediatric cardiology clinics and leads to a fair amount of school and sports absenteeism, as well as patient, parent, and physician anxiety.[1–4] As opposed to adults, for whom CP often signals a cardiac problem, multiple studies have demonstrated that the most common causes of CP among children are benign idiopathic, musculoskeletal, gastrointestinal, pulmonary, or psychogenic, with cardiac causes being quite rare.[2–10] Pantell et al[2] reported that 44% of adolescents were concerned that a heart attack was the cause of their CP, a concept echoed in other studies.[3,8,11] This common misperception by the lay public that CP in children represents similar pathologic conditions, compared with those seen among adults, accounts for the frequency of seeking medical evaluations and the difficulty physicians face in relieving parental concerns. These misperceptions are perpetuated by the tragic, although truly rare, instances of sudden cardiac death among young people, which are broadcast widely by the media.

The purpose of this study was to assess whether any patients evaluated in our clinics for CP and discharged with a presumed diagnosis of noncardiac CP subsequently died as a result of a cardiac condition. Given the high frequency of CP among children and the low incidence of associated cardiac pathologic conditions, our group developed guidelines, in the form of standardized clinical assessment and management plans (SCAMPs), to facilitate appropriate resource utilization and to reduce unnecessary testing while maintaining diagnostic accuracy and potentially improving care.[12–15] Development of the CP SCAMP was based on previous studies that assessed known cardiac causes of CP, as well as resource utilization in assessing CP. Patients enrolled in the SCAMP are re-evaluated continuously, and modifications to the SCAMP are made in accordance with gained knowledge, on an ongoing basis. Given the increases in health care costs and impending health care reform, quality improvement initiatives such as the SCAMP project are vitally important. The results of this study should either support or challenge our current practice of evaluating pediatric CP with the use of the SCAMP.

METHODS

Identification of Subjects

Patients were identified on the basis of International Classification of Diseases, Ninth Revision (ICD-9), discharge billing codes for initial CP assessment (at >6 years of age) in outpatient clinics at Children's Hospital Boston between January 1, 2000, and December 31, 2009. Assessment and documentation were not standardized at the time of this study and were at the discretion of the evaluating cardiologist. Patients were excluded if they had normal cardiac evaluation results for CP at another institution, incomplete records, known significant cardiovascular disease, or extensive cardiac evaluations because of systemic illness or a family history of cardiac disease. The institutional review board for clinical research at Children's Hospital Boston approved the use of patient medical records for this retrospective review.

Chart Review

The medical records were analyzed with respect to demographic features, clinical characteristics, cardiac testing, presumed diagnosis, and follow-up visits. Patients were categorized as having CP predominantly with exertion or rest. Exertional CP was defined as occurring during intense activity, during which the heart rate would be elevated significantly above baseline. Minor activity such as walking or climbing stairs was not considered exertional. Medical history findings considered relevant included inflammatory disorders, malignancies, hypercoagulable state, connective tissue disorders, and asthma. Family history findings considered relevant included sudden unexplained death, pulmonary hypertension, cardiomyopathy, hypercoagulable state, arrhythmia, connective tissue disorders, and congenital heart disease. Additional family history findings recorded included early coronary artery disease. The physical examination results were screened for pathologic murmurs, abnormal second heart sounds, gallops, rubs, and stigmata of connective tissue disease.

Results of electrocardiograms (ECGs) performed for all patients and higher-level testing performed at the discretion of the cardiologist, including echocardiography, cardiac MRI, exercise stress tests (ESTs), sestamibi stress tests, Holter monitoring, and extended loop monitoring, were ascertained. Benign findings, including RSR′/interventricular conduction delay or early repolarization on ECGs, clinically insignificant ectopy in ESTs and rhythm monitoring, and mild tricuspid or pulmonary regurgitation on echocardiograms, were not recorded. Vital status and cause of death were ascertained through queries of both the National Death Index (maintained by the Centers for Disease Control and Prevention; current through December 31, 2008) and the Social Security Death Index (maintained by the US Social Security Administration; current through July 2010).

Statistics

The primary outcome was death related to cardiac causes. Clinical symp-

toms and numbers of cardiac tests were expressed as counts and proportions. Continuous variables were represented by median values and ranges. Data were analyzed by using standard statistical methods, with MS-Excel 2003 (Microsoft, Seattle, WA).

RESULTS

Study Group

Of 4165 patients who were identified initially on the basis of ICD-9 discharge billing codes for CP at the first cardiology clinic visit, 3700 constituted the final cohort. Patients were excluded because of known cardiovascular disease ($n = 164$), miscoding ($n = 123$), incomplete records ($n = 107$), previous extensive cardiac evaluations unrelated to CP ($n = 38$), and second opinions after normal evaluation results ($n = 33$). The median age at the clinic visit was 13.4 years (range: 7–22.3 years), and the median follow-up period after the clinic visit was 4.4 years (range: 0.5–10.4 years), for a total of 17 886 patient-years of follow-up monitoring. Between 235 and 500 patients were evaluated per year, with generally increasing numbers of referrals with time (Fig 1).

Clinical Characteristics

CP occurred predominantly with exertion for 1222 patients (33%), predomi-
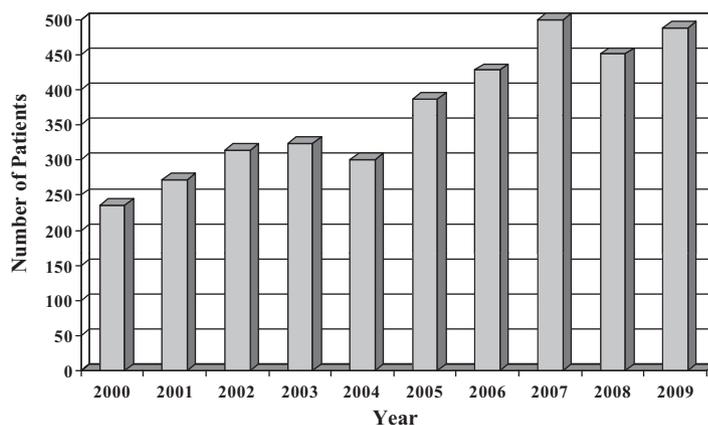
TABLE 1 Medical and Family History Findings

	n (%)
Pertinent medical history findings	
Asthma	565 (15.3)
Gastroesophageal reflux	65 (1.8)
Minor congenital heart disease	42 (1.1)
Inflammatory disorder	39 (1.1)
Connective tissue disorder	16 (0.4)
Hypercoagulable state	15 (0.4)
Depression/anxiety	15 (0.4)
Malignancy	13 (0.3)
SVT	3 (0.08)
Pertinent family history findings[a]	
Congenital heart disease	91 (2.5)
Arrhythmia	77 (2.1)
Cardiomyopathy	15 (0.4)
Sudden death	13 (0.3)
Connective tissue disorder	5 (0.1)
Hypercoagulable state	5 (0.1)
Pulmonary hypertension	1 (0.02)

[a] First-degree relatives only.

nantly at rest for 2072 (56%), and in unknown circumstances for 406 (11%). Accompanying symptoms included palpitations for 828 patients (22%), shortness of breath for 576 (16%), dizziness for 389 (11%), and syncope for 49 (1.3%), including exertional syncope with CP for 15 (0.4%). Emergency department visits for CP before the cardiology clinic visits were documented for 670 patients (18%).

Significant medical and family history findings for first-degree relatives are presented in Table 1. Minor congenital heart disease included hemodynami-

cally insignificant ventricular septal defects ($n = 15$), repaired or small patent ductus arteriosus ($n = 10$), mitral valve prolapse ($n = 4$), small atrial septal defects ($n = 3$), mild pulmonary stenosis ($n = 2$), bicuspid aortic valves ($n = 2$), and unspecified resolved "holes in the heart" that did not require intervention ($n = 6$). Three patients who presented with CP in adolescence had a remote history of supraventricular tachycardia (SVT), without recurrence. Other positive medical history findings included hyperlipidemia that did not require therapy for 34 patients (0.9%), systemic hypertension for 28 (0.8%), and diabetes mellitus for 15 (0.4%).

Among first-degree relatives, arrhythmias included long QT syndrome in 2 cases and ventricular tachycardia in 3 cases; the remaining arrhythmias were of supraventricular origin or were unspecified. The cardiomyopathies consisted of dilated cardiomyopathy ($n = 6$), hypertrophic cardiomyopathy ($n = 5$), left ventricular noncompaction ($n = 2$), arrhythmogenic right ventricular dysplasia ($n = 1$), and unspecified cardiomyopathy ($n = 1$). The causes of sudden death were sudden infant death syndrome ($n = 3$), stillbirth ($n = 2$), and unspecified causes ($n = 8$). Not included in Table 1 are data for 48 families with premature coronary artery disease in first-degree relatives and an additional 151 families with findings for more-distant relatives. Distant relatives also had reported sudden unexplained death in 59 cases (sudden infant death syndrome: $n = 6$; unspecified: $n = 53$), cardiomyopathy in 39, and arrhythmias in 38.

Physical Examination and ECG Findings

Notable physical examination and ECG findings were uncommon and are presented in Table 2. No patients pre-

FIGURE 1
Number of initial cardiology evaluations per year.

TABLE 2 Physical Examination and ECG Findings

	n (%)
Physical examination findings	
Clicks	52 (1.4)
Pectus excavatum or carinatum	42 (1.1)
Pathologic murmurs	31 (0.8)
Abnormal second heart sound	12 (0.3)
Rub	9 (0.2)
Joint hyperlaxity	5 (0.1)
ECG findings	
Left ventricular hypertrophy	93 (2.5)
Abnormal ST segments or T waves	27 (0.7)
Right ventricular hypertrophy	23 (0.6)
Preexcitation	11 (0.3)
Complete right bundle branch block	8 (0.2)
Atrial enlargement	3 (0.08)
Second-degree heart block	1 (0.02)

TABLE 3 Incidental Echocardiographic Findings

	n
Mild dilated aortic root/ascending aorta	27
Mild mitral regurgitation	27
Mitral valve prolapse	27
Mild LV dilation	14
Mild aortic regurgitation	10
Bicuspid aortic valve	10
Mild LV hypertrophy	8
LV hypertrabeculation/noncompaction*	8
Atrial septal defect	6
Mild LV dysfunction	5
Small ventricular septal defect	5
Trivial or mild subaortic stenosis	4
High takeoff of right coronary artery	3
Patent ductus arteriosus	3
Right ventricular dilation (no identified shunt)	3
Small LV aneurysm	2
Mild dilated pulmonary root	2
Tricuspid valve prolapse	2
Peripheral pulmonic stenosis	1
Mild left coronary dilation (no fistula)	1
Mild tethering tricuspid valve leaflet	1
Nonobstructive cor triatriatum	1
Dysplastic pulmonary valve	1
Sinus venosus defect	1

LV indicates left ventricular.
* Normal LV function.

sented to the clinic with documented gallop, fever, arthritis, peripheral edema, or hepatomegaly. Miscellaneous ECG findings included first-degree heart block ($n = 21$) and QTc prolongation that ultimately was considered normal ($n = 12$).

Selective Testing

Echocardiography was performed for 1410 patients (38%), and findings were normal for 1242 (88.1%). Positive findings potentially related to the complaint of CP were detected in 11 cases (0.8%), including a right coronary artery arising from the left sinus with an interarterial course in 3 cases, pericardial effusion in 5 cases (small: $n = 4$; moderate: $n = 1$), moderate left ventricular dysfunction in 1 case with myocarditis, and hypertrophic and dilated cardiomyopathy in 1 case each. The remaining 157 echocardiograms (11.1%) had incidental findings that were unlikely to be related to CP (Table 3), including 2 atrial septal defects, 2 cases of patent ductus arteriosus, and 1 sinus venosus defect that were repaired surgically. Suspicion was raised regarding anomalous coronary arteries for 4 other patients, which were confirmed as normal through cardiac MRI. Cardiac MRI was performed for an additional 23 patients and was confirmatory of echocardiographic diagnoses in all cases except 2, in which right ventricular dilation was noted on cardiac MRI scans and not echocardiograms. Of the 1222 patients with exertional symptoms, echocardiography was performed for 696 (57%).

ESTs were performed for 769 patients (20.8%) and were notable for changes suggesting ischemia in only 1 case (0.1%), which ultimately was considered a false-positive result. The patient presented with exertional CP and palpitations and demonstrated inferior ST segment depressions on the EST, with normal echocardiographic and sestamibi stress test results. The remaining findings were predominantly respiratory, including obstructive and/or restrictive spirometric patterns in 90 cases (11.7%). Hypertension was diagnosed for 6 patients, and 2 patients had notable QTc prolongation, considered normal findings after further evaluation in both cases. One patient presented with CP at rest without additional symptoms and demonstrated abnormal ECG findings, with diffuse ST segment elevations. Echocardiographic results were normal; however, the EST demonstrated poor tolerance, which led to sestamibi scan with suspicion of lateral wall ischemia. The patient was lost to follow-up monitoring. Sestamibi stress tests were performed for an additional 17 patients, and all findings were normal.

Holter monitors were used for 491 patients (13.3%), event recorders for 363 (9.8%), and loop monitors for 242 (6.5%). Cumulatively, the rhythm monitor results were positive for 13 (0.4%) of 3700 patients, diagnosing SVT ($n = 9$), ectopic atrial tachycardia ($n = 1$), nonsustained ventricular tachycardia ($n = 1$), wide complex tachycardia ($n = 1$) not inducible in atrial and ventricular stimulation studies, and significant ventricular ectopy accounting for 42% of beats ($n = 1$), with normal echocardiographic results. All except 2 of the 13 patients complained of palpitations, 1 with left axis deviation on ECGs for whom ectopic atrial tachycardia was diagnosed and 1 with no positive physical examination or ECG findings for whom SVT was diagnosed.

Diagnoses

The presumed causes of CP are demonstrated in Fig 2. Musculoskeletal causes included costochondritis, precordial catch syndrome, trauma, and unspecified chest wall pain. Gastrointestinal causes consisted of gastroesophageal reflux disease, gastritis, esophagitis, and constipation. Asthma dominated the pulmonary causes, which also included pleuritic pain, respiratory infections, and hyperventilation. A cardiac cause was determined for 37 patients (1%). CP for patients with diagnosed pericarditis occurred at rest in all cases and was associated with positional changes or radiation to
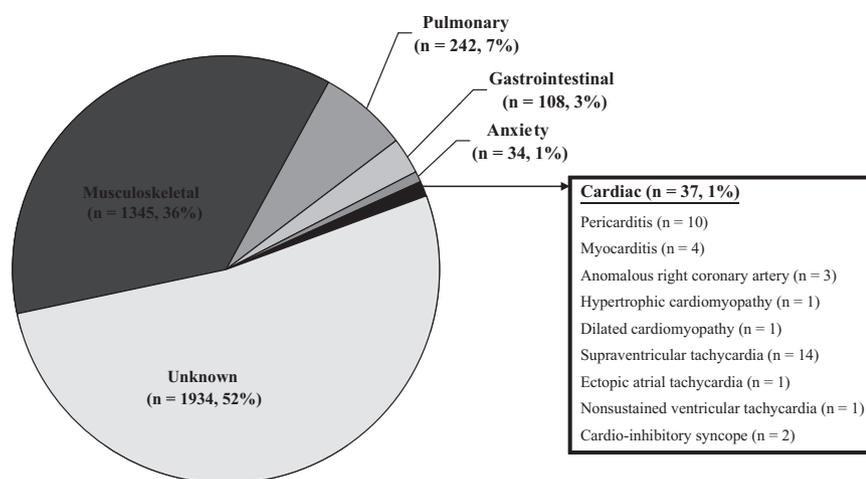
FIGURE 2
Causes of CP.

the jaw (*n* = 3), rub on examination (*n* = 3), ECG changes (*n* = 6), and effusion on echocardiograms (*n* = 4). CP associated with myocarditis also occurred at rest and was diagnosed on the basis of a history of preceding illness (*n* = 4), ectopy on examination (*n* = 2), ECG changes (*n* = 1), and moderate left ventricular dysfunction (*n* = 1) on echocardiogram, which resolved within 1 week. Few cases of myocarditis were detected in the cardiology clinic, because the majority of patients with myocarditis present to the emergency department. Two of 3 patients with anomalous right coronary arteries from the left sinus and an intramural course had CP at rest, associated with cocaine use in 1 case. Results of physical examinations and ECGs were normal in all 3 cases. Echocardiograms were performed because of exertional symptoms, concerns regarding drug-induced ischemia, and unrelated issues for the 3 patients. The first 2 patients have undergone unroofing of the coronary artery, and the third is being monitored. Both patients with cardiomyopathy presented with exertional CP. The patient with dilated cardiomyopathy had an affected uncle, and the patient with hypertrophic cardiomyopathy demonstrated left ventricular hypertrophy and T wave ab-

normalities on an ECG. All except 3 patients (13 [81%] of 16 patients) with tachyarrhythmias presented with exertional CP, and 14 (88%) of 16 patients had associated palpitations. ECG findings were positive for 4 patients (preexcitation: *n* = 3; left axis deviation: *n* = 2), and rhythm monitoring results were positive for 12 (75%) of 16 patients. The final 2 patients with cardioinhibitory syncope presented with longstanding histories of CP at rest and associated palpitations and recurring syncope; both underwent electrophysiological studies and pacemaker placement.

Death Registry Outcomes

In the cohort of 3700 patients, there were 3 deaths (0.1%), none related to cardiac pathologic conditions. Two patients (1 boy and 1 girl) committed suicide at 17 years of age. The boy presented to the clinic at 12 years of age with CP that occurred at rest every 2 to 3 days for ~2 years, without associated symptoms. Echocardiography was performed because of "ongoing concern" and yielded normal results. No additional information on this patient was available. The girl presented to the cardiology clinic 4 months before her suicide, with a history of CP that occurred at rest infrequently over

2 years. She had a known history of anxiety, depression, and bipolar disorder. Her cardiac evaluation results were normal, and no additional information was available. The third patient underwent a cardiac evaluation with normal results 4 years before his death and experienced fatal retroperitoneal bleeding while attending a dance party.

DISCUSSION

CP in children is the cause of tremendous anxiety and resource utilization despite generally benign causes in the vast majority of cases, as demonstrated in this study and in many others.[2–10,13] Fears of sudden cardiac death in both the lay public and medical communities foster activity restrictions, elaborate evaluations, and excessive referrals, which are increasing with time. The estimated incidence of pediatric sudden cardiac death ranges from 0.6 to 6.2 deaths per 100 000, with hypertrophic cardiomyopathy, coronary artery anomalies, and malignant arrhythmias being responsible for the majority of cases and deaths being more common during athletic activities.[16–24] Determining which children are at risk for sudden death is challenging, particularly because there often are no preceding symptoms.

The incidence of cardiac disease in our population of 3700 children presenting with CP was exceedingly low at only 1%. Our study had an intentional ascertainment bias to select for patients not considered to have cardiac disease, because patients for whom cardiac disorders were detected would more likely be assigned diagnostic rather than symptomatic ICD-9 billing codes. Our study serves as a counterpart to the recent report by Kane et al,[12] in which patients were identified in the same decade of study on the basis of billing codes for 9 serious cardiac di-

agnoses associated with sudden cardiac death. Further analysis indicated that only 41 children with serious cardiac diagnoses presented to outpatient cardiology clinics with complaints of CP, which, if included in our study, would increase the incidence of cardiac disease to 2%, not including more-benign diagnoses such as SVT. More importantly, our study demonstrates that those children, who were evaluated in all cases with history assessments, physical examinations, and ECGs and in many cases with other tests and were deemed to have noncardiac disease, remain alive, with no incidents of sudden cardiac death. This finding should be reassuring and underscores the importance of educating the public and medical communities to allay fears and to pursue quality improvement initiatives to limit resource utilization in the evaluation of pediatric CP.

The vast majority of patients identified as having a cardiac cause for their CP had suggestive symptoms (particularly exertional CP), concerning medical or family history findings, abnormal examination results, and/or abnormal ECG findings, which led to further investigation. Positive initial history, physical examination, and ECG findings form the basis of the CP SCAMP currently being implemented in our department. As described previously, the CP SCAMP suggests echocardiography as the diagnostic test of choice in the majority of cases with positive screening results and elimination of echocardiography and other higher-level tests, such as ESTs, for patients with negative screening results. In this cohort of 3700 patients, approximately one-third of patients presented with exertional symptoms, and 1 of 10 patients had other relevant history, physical examination, or ECG find-

ings. If the CP SCAMP were applied to this cohort, then resources would be redistributed to generate potentially higher yields of clinically relevant positive findings and to decrease missed diagnoses, ultimately improving patient care.[13] The CP SCAMP in the hands of pediatric cardiologists would lead to reductions in the costs of care; however, the reductions would be most dramatic with a modified CP SCAMP in the hands of general pediatricians, a project that is currently underway. In theory, >50% of the patients in this group would not necessarily need referral to a cardiologist with effective screening by the generalist.

This study also brings to light a suspected but underreported finding. There were 2 suicides among the cohort of 3700 children. A history of depression and/or anxiety was reported for only 15 patients (0.4%), which likely was a gross underestimate.[25] According to the Injury Surveillance Program at the Massachusetts Department of Public Health, in 2008 there were 44 youth suicides (15–24 years of age) among Massachusetts residents, with a rate of 0.6 cases per 100 000 residents. Practitioners should be aware of somatization of complaints, including CP, in patients with underlying psychiatric illnesses and should screen and refer the patients appropriately.

There are several important limitations to this study. This study was performed as a retrospective review and relied on medical records for data on patient symptoms, history findings, and physical examination findings. This study was performed before initiation of the use of the CP SCAMP and relied on assessments from various providers with different approaches to CP. Patients underwent varied tests, at the providers' discretion. We cannot account for any potentially missed

cardiac diagnoses, including life-threatening diagnoses, that were not manifested during this study. In addition, cardiac diagnoses that lead to significant morbidity are not captured by the death indexes; in review of the entire medical record, however, no such instances were observed among patients who continued to receive care at Children's Hospital Boston. Lastly, we relied on the accuracy of the death registries, which may be incomplete, to capture fatal events. Studies have shown that the National Death Index, which is considered the standard, has 92% to 98% accuracy in detecting known decedents, with similar sensitivity for Internet-based Social Security registries.[26–28] Given the low incidence of sudden cardiac death among children, it is not surprising that no patient was found in either registry to have died as a result of a cardiac cause, and rates of potential misses or near-misses are presumed to be low.

CONCLUSIONS

CP in children is a common complaint with rare cardiac causes and is associated with tremendous anxiety and resource utilization. Review of nearly 18 000 patient-years of data over the span of 1 decade revealed that no patient discharged from the clinic died as a result of a cardiac condition. Future studies should focus on quality improvement initiatives to allay anxiety, to reduce unnecessary referrals, and to validate current practice management strategies for the evaluation of CP, including the use of the CP SCAMP.

ACKNOWLEDGMENTS

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