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ARTICLE

Pediatric Myocarditis: Emergency Department Clinical Findings and Diagnostic Evaluation

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ABSTRACT

OBJECTIVE. The goal was to determine, in children with myocarditis, the frequency of various presenting symptoms and the sensitivity of clinical and laboratory investigations routinely available in the emergency department.

METHODS. We performed a retrospective review of all patients <18 years of age who were diagnosed as having myocarditis at our institution between May 2000 and May 2006 and who initially presented to an emergency department. Patients were categorized as having definite myocarditis (positive endomyocardial biopsy results) or probable myocarditis(diagnosis assigned by a pediatric cardiologist on the basis of history, physical examination, and investigation results in the absence of an endomyocardial biopsy or in the presence of negative biopsy results). All patients were assigned a predominant category of symptoms at presentation on the basis of criteria defined a priori.

RESULTS. There were 16 cases of definite myocarditis and 15 cases of probable myocarditis. The age distribution was nonnormal, with peaks among children ≤3 years and ≥16 years of age. Of 14 patients who were seen by a physician before being diagnosed with myocarditis, 57% were originally diagnosed as having pneumonia or asthma. Thirty-two percent of patients presented with predominantly respiratory symptoms, 29% had cardiac symptoms, and 6% had gastrointestinal symptoms. Although evidence of cardiac dysfunction was frequently present in the form of respiratory distress, only a minority of children had evidence of hepatomegaly or abnormal cardiac examination results. The sensitivities of electrocardiograms and chest radiographs as screening tests were 93% and 55%, respectively. Among laboratory tests studied, aspartate aminotransferase measurement was the most sensitive (sensitivity: 85%).

CONCLUSIONS. Children with myocarditis present with symptoms that can be mistaken for other types of illnesses; respiratory presentations were most common. When clinical suspicion of myocarditis exists, chest radiography alone is an insufficient screening test. All children should undergo electrocardiography. Aspartate aminotransferase testing may be a useful adjunctive investigation.

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Key Words
myocarditis, gastroenteritis, emergency department, diagnosis, aspartate aminotransferase, chest radiograph, electrocardiogram

Abbreviations
ED— emergency department
ECG— electrocardiogram
CI— confidence interval
AST—aspartate aminotransferase

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Myocarditis is a rare, potentially life-threatening, inflammatory disorder of the myocardium. It accounts for nearly one half of all cases of dilated cardiomyopathy in children.[1] However, because children with myocarditis may be asymptomatic, the true incidence is unknown.[2] Myocarditis may be difficult to diagnose because its clinical presentation overlaps with that of other, more-common disorders, such as asthma and gastroenteritis.[3–6] Because the mortality rates for infants and children with myocarditis may be as high as 75% and 25%, respectively,[7] and early initiation of therapy is potentially beneficial, prompt diagnosis is imperative.[8]

The clinical presentation of myocarditis varies from the gradual onset of congestive heart failure to acute cardiovascular collapse.[4] However, some children do not present with symptoms directly referable to the cardiovascular system.[4] The relative frequency of such presentations is unknown. The most common clinical findings in a small case series included tachypnea, intercostal retractions, tachycardia, and grunting.[9] Those symptoms led to 71% of the children being misdiagnosed as having either sepsis or pneumonia/asthma.[9] Alternatively, children may present with nausea and vomiting and may be mistakenly diagnosed as having gastroenteritis. For such children, excessive administration of intravenous fluids may exacerbate the heart failure.[3,4,10] However, the actual frequency of such presentations is unknown. Although it is clearly important to have a high index of suspicion to diagnose myocarditis, clinicians also need to have knowledge regarding the sensitivity of the screening tests readily available to them, to allow for appropriate treatment of these children. To date, the sensitivities of chest radiographs and electrocardiograms (ECGs) in the pediatric population have been inadequately evaluated.[11] The purposes of this study were to determine the relative frequencies of various presenting symptoms in children with myocarditis and to determine the sensitivities of chest radiographs, ECGs, and laboratory investigations in diagnosing pediatric myocarditis.

METHODS

Setting

The Hospital for Sick Children is a tertiary care children's hospital in Toronto, Ontario, Canada. It is the major pediatric academic teaching facility for the University of Toronto and serves patients from a broad demographic spectrum and a geographic region that includes urban, suburban, and rural areas. This study was approved by the institution's research ethics board.

Patient Selection

We performed a retrospective chart review of all children <18 years of age who were diagnosed as having myocarditis at the Hospital for Sick Children between May 1, 2000, and May 1, 2006, and who presented initially to an emergency department (ED). Patients were identified by searching the hospital database for all children who had an *International Classification of Diseases, Ninth Revision, Clinical Modification* discharge diagnostic code corresponding to myocarditis (Appendix). Results were cross-referenced with databases compiled independently by the divisions of cardiology and pathology. We included children who presented to our ED directly and those who were transferred from another institution. Patients were eligible if this was their initial presentation with myocarditis.

Because myocarditis may present as sudden death, we also reviewed available data on children who underwent autopsy at the Hospital for Sick Children and had a diagnosis of myocarditis. These children were identified from the division of pathology database and were diagnosed as having myocarditis on the basis of the presence of lymphocytic infiltrates in the myocardium. Separate research approval was obtained from the Office of the Chief Coroner of Ontario, because many of these autopsies were performed at the request of the Office of the Chief Coroner, with tissue samples supplied by the institutions where the children died.

Definitions and Data Collection

Definite myocarditis was defined as endomyocardial biopsy results consistent with myocarditis, according to the Dallas criteria.[12] Children with probable myocarditis had a diagnosis of myocarditis determined by an attending pediatric cardiologist, on the basis of the clinical history combined with supporting physical examination and investigation results, either in the absence of an endomyocardial biopsy or in the presence of negative biopsy results. Echocardiographic abnormalities were not a requirement. This is in keeping with expert opinion that clinical findings are most commonly used to diagnose myocarditis[13] and with the North American Pediatric Cardiomyopathy Registry definition, which is based on echocardiographic criteria and states that probable myocarditis includes "patients with a physician's diagnosis of cardiomyopathy who did not meet these strict echocardiographic criteria."[14] We chose to include children with negative endomyocardial biopsy results because myocarditis affects the myocardium in a patchy manner and <10% of patients for whom myocarditis is suspected on clinical grounds have positive biopsies when the Dallas criteria are used.[4,15]

All medical charts were reviewed twice by a single investigator (Ms Haladyn), to ensure consistency of data abstraction. Patient demographic characteristics, medical history, vital signs, physical examination results, and laboratory variables were abstracted from an electronic database. When applicable, data were abstracted from correspondence sent from the referring hospital, supplemented by data recorded in the consultation report com-

pleted by the cardiologist at our institution. The results of the initial chest radiograph, ECG, echocardiogram, and endomyocardial biopsy were recorded by using the official report of the appropriate specialist (ie, radiologist for the chest radiograph and cardiologist for the ECG). Electronic database and chart reviews were used to record the laboratory results and disposition data, respectively. All data were collected by using the Hospital for Sick Children's electronic patient chart system. For each variable, the first available result was abstracted for analysis.

We defined 5 ED clinical presentations, namely, respiratory (rhinorrhea, cough, or shortness of breath), gastrointestinal (nausea, vomiting, diarrhea, or abdominal pain), cardiac (chest pain or palpitations), hypoperfusion (lethargy, lightheadedness, dizziness, syncope, or seizure), and Kawasaki-associated. Two investigators (Dr Freedman and Ms Haladyn) independently classified patients exclusively into 1 of the 5 presentations. If assessments were discordant, then a third reviewer (Dr Thull-Freedman) reviewed the medical charts. The final classification was determined on the basis of agreement by 2 of the 3 reviewers.

Chest radiographs were defined as abnormal and associated with myocarditis if cardiomegaly, pulmonary vascular congestion, or pleural effusion was present.[10] ECGs were considered abnormal and associated with myocarditis if one of the following was present: axis deviation, decreased ventricular voltages, ST segment or T wave abnormalities, atrial enlargement, ventricular enlargement, heart block, or an infarction pattern.[7,10] Echocardiographic findings considered to be consistent with myocarditis included increased ventricular end-systolic or diastolic dimensions, reduced shortening or ejection fractions, atrioventricular valve regurgitation, and regional wall motion abnormalities.[11] For laboratory tests, age-appropriate normal values were used.[16]

Statistical Analyses

The primary outcome was the relative frequency of ED-presenting symptom complexes in children with myocarditis. Secondary outcome measures included the sensitivity of clinical examination findings, laboratory investigations, chest radiographs, ECGs, and echocardiograms in diagnosing myocarditis.

For sensitivity calculations, continuous variables were dichotomized into normal or abnormal. Fever was defined as a temperature of >38.0°C measured rectally or tympanically, >37.4°C measured orally, or >36.9°C measured in the axilla.[17] Heart rate, respiratory rate, blood pressure, and laboratory results were categorized on the basis of age-appropriate values.[17]

Dichotomous or discrete variables were analyzed by using frequency tables. Means, medians, SDs, and interquartile ranges were computed for continuous variables. The χ^2 test and t test were used for dichotomous and discrete variables, respectively. When the number of observations expected by chance in any given cell of the contingency table was <5, Fisher's exact test was used. All variables were analyzed to detect differences among those classified as having definite and probable myocarditis, which were reported when indicated. All statistical tests were evaluated at the 5% level of significance.

The 60-month data collection period was expected to generate a sample size that would be sufficient to yield generally stable estimates of the incidence of myocarditis presenting with primarily gastrointestinal symptoms. This symptom complex was selected because it was anticipated to be the least common. For sample size calculations, we hypothesized that the proportion with a gastrointestinal presentation would be 10%. To provide a 95% confidence interval (CI) with a maximal width of 10% and an α value of .05, a minimum of 35 subjects was required. Statistical analyses were performed by using SAS 8 (SAS Institute, Cary, NC) and SPSS for Windows 14.0 (SPSS, Inc, Chicago, IL).

RESULTS

Patients

Over the 5-year period, 236 365 patients were seen in the Hospital for Sick Children ED. A total of 60 potential myocarditis cases were identified in the 3 databases. Chart review revealed that only 31 satisfied study eligibility criteria and the definitions of definite or probable myocarditis. Four patients had previously been diagnosed as having myocarditis, 7 had inadequate documentation of their initial presentation available for review, 17 had a discharge diagnosis other than myocarditis (ie, were inappropriately identified), and 1 was a neonate who did not have an ED visit. Six children presented initially to the Hospital for Sick Children ED, and 5 were transferred for general evaluation; the others were transferred for cardiologist evaluation. Therefore, the prevalence of children presenting with undiagnosed myocarditis (ie, not for cardiologist evaluation) in our institution's ED was 0.5 cases per 10 000 visits.

There were 16 (52%) definite and 15 (48%) probable cases of myocarditis. None of the 15 probable cases underwent biopsy. Patients ranged in age from 21 days to 18 years (median: 8.0 ± 6.4 years), and 20 (65%) were male. The age distribution was found to be nonnormal ($P = .002$), with the majority of patients being either <3 years or 16 to 18 years of age (Fig 1).

Chart reviews detected evidence of an antecedent illness in 24 cases (77%), 83% of which were upper respiratory tract infections. Fourteen patients (45%) had ≥1 previous physician visit; 8 patients were assigned a diagnosis of pneumonia/asthma, 3 patients were diagnosed as having pharyngitis, and 1 child each was diagnosed as having viral illness, urinary tract infection, and anorexia nervosa.

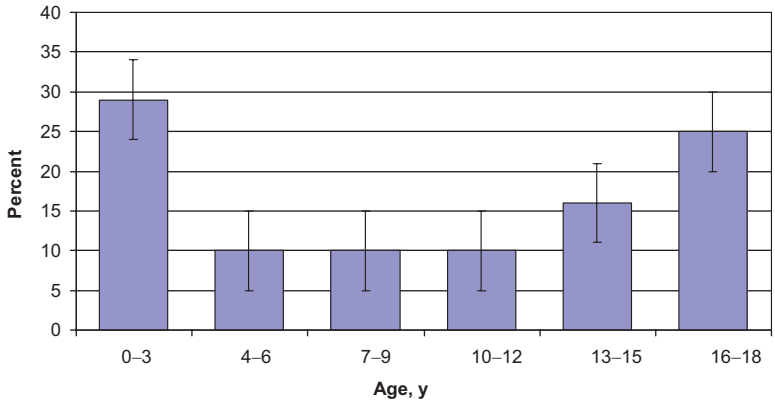

FIGURE 1
Frequency histogram of total myocarditis cases according to age. The total number of cases was 31.

Five patients had a probable cause identified through endomyocardial biopsy. Parvovirus B19 was identified in 2 specimens, enterovirus and coxsackie B were identified in 1 specimen each, and a hypersensitivity reaction was detected in 1 specimen. Of 8 viral swabs performed, 1 was positive for influenza A.

Outcomes

The most common presenting symptom category was respiratory (n = 10 [32%]). Other presentations included cardiac (n = 9; [29%]), hypoperfusion (n = 7; [22%]), Kawasaki-associated (n = 3; [10%]), and gastrointestinal (n = 2; [6%]). The presenting symptom complex was related to age (P = .003). All children who presented with chest pain were >10 years of age; (Table 1) however, only 22% of those children were tachycardic. The other 7 children >10 years of age presented with respiratory (n = 3) or hypoperfusion (n = 4) symptoms. For children <10 years of age, the most common presenting symptom was respiratory distress (7 of 15 children [47%]).

The most common physical examination feature was respiratory distress (Table 2). Although tachycardia was uncommon in older children, it was present in 73% of children <10 years of age. Hepatomegaly was noted in 36% of patients, and abnormal heart sounds or murmurs were auscultated in 32%. Either of these findings was present in 52% of patients.

TABLE 1 **Presenting Symptoms for Pediatric Myocarditis, Grouped According to Age (Total N = 31)**

Clinical Presentation Pattern	n (%)		
	Age of <10 y[a]	Age of ≥10 y[a]	Total
Respiratory	7 (47)	3 (19)	10 (32)
Gastrointestinal	2 (13)	0 (0)	2 (7)
Cardiac	0 (0)	9 (56)	9 (29)
Hypoperfusion	3 (20)	4 (25)	7 (23)
Kawasaki-associated	3 (20)	0 (0)	3 (10)
Total	15 (100)	16 (100)	31 (100)

[a] The clinical presentation pattern was associated significantly with age (P = .003).

Overall, myocarditis was not suspected in 8 cases (26%) before ED disposition. Three children were admitted to the hospital with pneumonia, 2 with Kawasaki disease, 2 with unspecified febrile illnesses, and 1 with status epilepticus. The diagnosis of myocarditis was made for 4 children when they developed worsening respiratory distress, for 2 children when they became hypotensive, for 1 child at autopsy, and for 1 child when an echocardiogram was performed as part of a fever evaluation.

Investigations

Findings suggesting cardiac dysfunction were present in 17 of 31 chest radiographs (sensitivity: 55%; 95% CI: 38%–71%) (Table 3). ECG findings potentially indicative of myocarditis were reported in 93% of cases (95% CI: 78%–99%) (Table 4 and Fig 2). Sixteen patients (55%; 95% CI: 37%–72%) had both an abnormal chest radiograph and an abnormal ECG; 29 (97%; 95% CI: 83%–100%) of 30 children who had both tests performed had an abnormality on either the chest radiograph or the ECG. Cardiomegaly was the most common chest radiograph abnormality. ST or T wave abnormali-

TABLE 2 **Physical Examination Findings Documented in Charting of Initial Physician Encounters (n = 31)**

	n (%)
Respiratory distress/abnormal respiratory examination results/tachypnea[a]	21 (68)
Tachycardia	18 (58)
Lethargy	12 (39)
Hepatomegaly[b]	11 (36)
Abnormal heart sounds/murmur[b]	10 (32)
Fever	9 (30)
Hypotension	7 (23)
Pallor	6 (19)
Peripheral edema/cold or mottled extremities	5 (16)
Cyanosis/hypoxia	3 (10)

Multiple abnormalities were reported per case, if present.
[a] Respiratory distress required documentation in the chart of grunting, respiratory distress, indrawing, or tracheal tug. Abnormal respiratory examination results required documentation in the chart of decreased air entry, crackles, wheeze, or rhonchi.
[b] Findings reported in cardiology consultation notes were included.

TABLE 3 **Chest Radiograph Abnormalities Reported, According to the Likelihood of Myocarditis (Definite Versus Probable) ($n = 31$)**

	n (%)			*P*[a]
	Definite Myocarditis ($n = 16$)	Probable Myocarditis ($n = 15$)	Total ($n = 31$)	
Cardiomegaly	9 (56)	4 (27)	13 (42)	.14
Pulmonary venous congestion	7 (44)	3 (20)	10 (32)	.21
Pleural effusion	5 (31)	3 (20)	8 (26)	.56
Any abnormality	11 (69)	6 (40)	17 (55)	.08

Multiple abnormalities were reported per case, if present.
[a] *P* values compare the likelihood of an abnormality being detected in the definite group, compared with the probable group.

TABLE 4 **ECG Abnormalities Reported, According to the Likelihood of Myocarditis (Definite Versus Probable) ($n = 31$)**

	n (%)			*P*[a]
	Definite Myocarditis ($n = 15$)	Probable Myocarditis ($n = 15$)	Total ($n = 30$)	
ST or T wave abnormalities	9 (60)	11 (73)	20 (67)	.70
Axis deviation	8 (53)	4 (27)	11 (37)	.20
Ventricular hypertrophy	3 (20)	6 (40)	9 (30)	.43
Heart block	5 (33)	2 (13)	7 (23)	.39
Infarction pattern	1 (7)	3 (20)	4 (13)	.60
Decreased ventricular voltage	1 (7)	1 (7)	2 (7)	1.00
Atrial enlargement	1 (7)	1 (7)	2 (7)	1.00
Any abnormality	14 (93)	14 (93)	28 (93)	1.00

Multiple abnormalities were reported per case, if present.
[a] *P* values compare the likelihood of an abnormality being detected in the definite group, compared with the probable group.

ties and axis deviations were the most common ECG findings. For 5 of 6 children with axis deviation, the axis deviation was resolved in follow-up ECGs.

Echocardiograms were performed for 30 patients (97%), and abnormalities consistent with myocarditis were detected in 87% (95% CI: 69%–96%) (Table 5). Myocardial dysfunction was detected more frequently among those with definite myocarditis (100% vs 73%). The only individual for whom an echocardiogram was not performed presented in status epilepticus and was diagnosed as having myocarditis at autopsy. Of the laboratory investigations evaluated, the serum aspartate aminotransferase (AST) level was the most sensitive marker for myocarditis (Table 6). In our group, an elevated value was present in 85% (95% CI: 65%–96%) of samples, including that for the 1 child who had a normal ECG and chest radiograph. The erythrocyte sedimentation rate was ≥10 mm/hour for 57% (95% CI: 34%–78%) of the children for whom it was measured.

Autopsy Cases

A review of autopsy data detected 14 cases of myocarditis. Three of those children met our inclusion criteria and are included in the results given above. Eleven children were seen at other institutions in Ontario, Canada, and had tissue specimens referred to our pathology department. The median age of those subjects was 2.0 years, which was less than for our cases ($P = .08$). Three of those children were known to have had a previous ED visit; 2 were diagnosed as having gastroenteritis and the third a nonspecific viral illness. Predominant symptoms were cardiogenic for 5 children (46%), including 3 children discovered to be lifeless by their caregivers, gastrointestinal for 4 (36%), all of whom had isolated vomiting, and hypoperfusion for 2 (18%). The presentations were not significantly different from those of the patients who did meet our eligibility criteria ($P = .89$).

DISCUSSION

This study examined a series of 31 children diagnosed as having myocarditis at a tertiary care pediatric center. We explored presenting complaints, clinical findings, and ED diagnostic evaluations and found the most common presenting symptoms at the time of ED presentation to be related to the respiratory system. Considering the common nature of respiratory distress, tachypnea, and abnormal respiratory examination results among pediatric ED patients, it is easy to understand why pneumonia and asthma were the most frequent initial diagnoses. However, it is reassuring to know that, when myocarditis is clinically suspected, a chest radiograph, an ECG, and serum AST testing are likely to reveal the correct diagnosis.

Our findings should remind clinicians that pulmonary complaints may be common for children with myocardial dysfunction, whereas cardiac findings may be minimal.[9,18,19] This is in contrast to adult myocarditis data, which list chest pain as the primary complaint in 65% of cases.[20] In our case series, >50% of children were diagnosed as having pneumonia or asthma at their initial physician encounter, and 3 children were admitted to the hospital with presumed pneumonia. A previous case series also identified asthma and pneumonia as common misdiagnoses for children with myocarditis.[9] Given that hepatomegaly or abnormal cardiac examination results frequently are absent, when the diagnosis of pneumonia or asthma is uncertain clinicians should have a low threshold for the performance of ancillary investigations, such as chest radiographs and ECGs.

It is commonly stated that myocarditis can be confused easily with gastroenteritis[4,5]; however, the evidence to date has been in the form of case reports.[3] The literature does contain several reports of adult myocarditis associated with *Campylobacter*,[6] *Shigella*,[6,21] and rotavirus[22] infection. In such cases, however, the patients complain of chest pain in addition to their gastrointestinal symptoms. Myocarditis presenting with abdominal pain and vomiting in the absence of proven acute gastrointestinal infection is probably underreported, be-

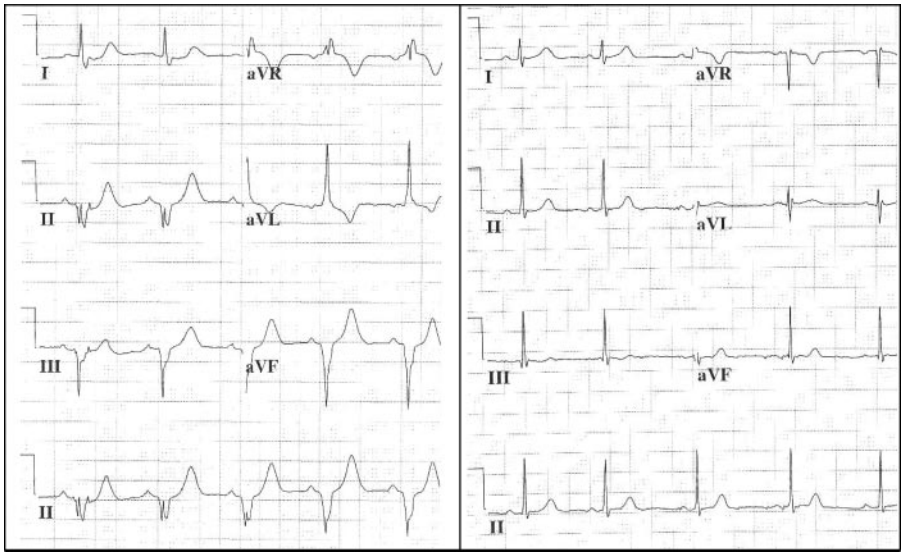

FIGURE 2
Sample ECGs from a 15-year-old female patient with myocarditis. The initial ECG (left) demonstrates normal sinus rhythm with left-axis deviation, right bundle-branch block (bifascicular block), and an infarction pattern with Q waves with the inferior leads. An ECG obtained 50 days later (right) demonstrates resolution of all abnormalities.

cause our current series included 2 such cases, in addition to 4 autopsy cases. Only 1 of those children had diarrhea. The symptom complex may be attributable to reduced gastrointestinal tract perfusion secondary to myocardial dysfunction. Shortly after the development of hypotension, activation of the sympathetic system results in local vasoconstriction and gut ischemia.[4,23] In cases of known gastrointestinal tract infection, myocarditis can occur through direct invasion, toxin production, or an immune-mediated mechanism.[6,24] Our autopsy data highlight the need for continued clinical vigilance, particularly when vomiting occurs in the absence of diarrhea.

Similar to previous reports, we found that pediatric myocarditis remains uncommon even in tertiary centers.[9] However, the true incidence remains unknown, because myocarditis may be asymptomatic.[2] Children <3 years of age and those in mid-adolescence most commonly are diagnosed as having myocarditis, and we found that presenting symptoms were age related, with patients >10 years of age presenting predominantly with chest pain, similar to reports in the adult literature.[20] A potential explanation for this finding is that infants and young children may not be able to verbalize that they have chest pain. Although some reviews of pediatric chest pain do not recommend routinely obtaining a chest radiograph or ECG[25] and state that teenagers are more likely to have psychogenic pain[26,27] and that cardiac causes can always be identified with history and physical examination,[26] our study identified several children for whom chest pain was an isolated finding. Given the low cost and high yield, at least an ECG should be performed for adolescents with new-onset chest pain.

Although they are recommended routinely for the evaluation of myocarditis,[2–5,10] few data exist on the sensitivity of chest radiographs.[11] In our series, only 50% of myocarditis cases had abnormal chest radiograph findings. Therefore, chest radiographs are not sensitive enough to be used alone. We did find that excellent sensitivity could be achieved when they were combined with ECGs. It was stated previously that the 2 most important ECG features are low-voltage QRS complexes and flat or inverted T waves in the standard and/or precordial leads.[28] We found that decreased ventricular voltages were present in only 7% of the ECGs; however, ST/T wave abnormalities were common in our case series.

Although a previous report of axis deviation associated with myocarditis exists,[29] ours is the first case series to report such a finding. Axis deviations in our sample included right (n = 7), left (n = 4), and northwest (n = 1). Its occurrence in myocarditis is confirmed by its resolution in the majority of cases (see example in Fig 1), and its importance may lie in the finding that it was present in all 3 children in our case series who died. A similar association of axis deviation and death was reported for children with primary myocardial disease.[30] Therefore, we suggest that a reasonable screen for myocarditis would include both a chest radiograph and an ECG. If neither test demonstrates any features consistent with myocarditis, then echocardiography is likely un-

TABLE 5 **Abnormalities Detected in Initial Echocardiograms (n = 30)**

	Definite Cases (n = 15)	Probable Cases (n = 15)	Total (n = 30)	P
Decreased function, n (%)	13 (87)	9 (60)	22 (73)	.22
Ejection fraction, mean ± SD, %	33.8 ± 22.3	50.6 ± 11.0		.02
Shortening fraction, mean ± SD, %	28.1 ± 18.4	28.9 ± 6.0		.89
Valvular regurgitation, n (%)	14 (93)	6 (40)	20 (67)	.005
Left ventricular dilation, n (%)	8 (53)	3 (20)	11 (37)	.13
Pericardial effusion, n (%)	6 (40)	4 (27)	10 (33)	.70
Wall motion abnormality, n (%)	1 (7)	0 (0)	1 (3)	1.00

TABLE 6 **Initial Laboratory Results for Myocarditis Cases ($n = 31$), Dichotomized Into Normal/Abnormal on the Basis of Age-Appropriate Normal Reference Values[17]**

	Definite				Probable			
	No. of Samples	Parameter		Proportion Abnormal, %	No. of Samples	Parameter		Proportion Abnormal, %
		Median	Range[a]			Median	Range[a]	
AST level, U/L	14	66	44–180	79	12	116	63–168	92
ESR, mm/h	10	7	3–28	50	11	16	6–103	64
White blood cell count, $\times 10^9$ cells per L	16	10.8	7.6–19.2	44	15	11.8	9.4–13.4	27
ALT level, U/L	15	28	19–108	40	12	48	29–105	58
Hemoglobin level, g/L	16	122	104–136	38	15	129	104–142	47
Lactate level, mmol/L	14	2.0	1.3–4.8	36	7	1.3	1.2–1.6	14
SUN level, mmol/L	16	5.2	3.8–8.1	25	14	4.9	3.2–6.7	21
Creatinine level, μmol/L	16	59	42–69	19	14	51	39–80	7

SUN indicates serum urea nitrogen; ALT, alanine aminotransferase; ESR, erythrocyte sedimentation rate.
[a] Ranges are reported as 25th to 75th percentiles.

necessary unless clinical suspicion for myocarditis is very high. The interpretation of chest radiographs and ECGs should be performed by individuals with expertise in these areas; otherwise, subtle abnormalities may be overlooked.

Although measurements of cardiac enzyme levels are generally thought not to be helpful for patients suspected of having myocarditis, because of their low sensitivity,[4,31] a recent report found that a troponin T cutoff point of 0.052 ng/mL had a sensitivity of 71% and specificity of 86% for diagnosing pediatric myocarditis.[32] We did not present troponin results because troponin T and I levels were measured for only 23% and 29% of our subjects, respectively. We did find, however, that patients with myocarditis frequently had elevated AST levels. Although modest elevations of liver enzyme levels may be seen in patients suffering from passive hepatic congestion,[33] we found that 12 children (39%) had values of >100 U/L. A previous report indicated that an alanine aminotransferase/AST ratio of >1.0 was seen more frequently with enteroviral perimyocarditis than with myocardial infarction or idiopathic dilated cardiomyopathy.[34] Our results directly contradict those findings, because only 2 (6%) of 31subjects had alanine aminotransferase/AST ratios of >1. This may be related to differences in either patient ages, because the former study was performed with adult subjects, or etiologic agents, because there has been a movement from enterovirus to parvovirus and human herpesvirus-6 as predominant etiologic agents.[20] It should be noted that AST elevations are not specific to myocarditis and do occur in other conditions, such as Kawasaki syndrome, following hypoperfusion, and in conjunction with many viral illnesses.

This study was a retrospective chart review. Therefore, the data are dependent on historical records, whose accuracy and completeness cannot be guaranteed. During the classification of patients into presentation categories, it was noted that many patients had symptoms of >1 category. We assigned the classification on the basis of the predominant concern that brought the child to the ED. We used multiple reviewers, in an attempt to minimize bias and to account for different interpretations. In addition, because the majority of patients were transferred to our institution, some data might not have been available in the transfer records. Finally, the lack of unequivocal diagnostic criteria allows one to question the diagnosis of myocarditis in some children. This problem is not unique to this study. A recent publication from the North American Pediatric Cardiomyopathy Registry database indicated that 42% of the cases of myocarditis were classified as "probable."[35]

CONCLUSIONS

This report demonstrates that pediatric myocarditis presents primarily with respiratory and cardiac complaints. Although gastrointestinal complaints were uncommon overall, isolated vomiting was reported frequently in our autopsy cases. Many of the children in our series were not diagnosed as having myocarditis at the initial physician encounter, which highlights the need for clinicians to maintain a high index of suspicion for myocarditis even in the absence of clinical findings of congestive heart failure. When adequate clinical suspicion exists, screening tests should include chest radiographs and ECGs. Evidence of elevated liver enzyme levels should raise additional concern regarding myocarditis in the appropriate clinical scenario.

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APPENDIX ***International Classification of Diseases, Ninth Revision, Clinical Modification* Codes Used to Identify Potential Myocarditis Patients**

Code	Diagnosis
032.82	Diphtheritic myocarditis
036.43	Meningococcal myocarditis
074.23	Coxsackie myocarditis
093.82	Syphilitic myocarditis
130.3	Myocarditis attributable to toxoplasmosis
391.2	Acute rheumatic myocarditis
398.0	Rheumatic myocarditis
422	Acute myocarditis
422.0	Acute myocarditis in diseases classified elsewhere
422.9	Other and unspecified acute myocarditis
422.90	Acute myocarditis, unspecified
422.91	Idiopathic myocarditis
422.92	Septic myocarditis
422.93	Toxic myocarditis
429.0	Myocarditis, unspecified

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