Brief Report

Clinical spectrum of previously undiagnosed pediatric cardiac disease

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ABSTRACT

Previously undiagnosed pediatric cardiac disease represents a clinical challenge for the emergency physician. The clinical presentation of these disorders can mimic other conditions of the respiratory, gastrointestinal and neurologic systems at a time when the need for early identification and treatment is at a premium. A high index of suspicion and superb clinical acumen is required to make a timely diagnosis and initiate optimal care.

Methods: A retrospective chart review using explicit criteria and a structured data collection process was performed on all children presenting with previously undiagnosed cardiac disease over a five and half year period.

Results: Thirty-six patients were identified over a five and a half year period representing one patient per 4838 pediatric ED presentations. A diverse set of chief complaints, triage categories, clinical presentations and diagnoses were identified. Undiagnosed congenital lesions, acquired cardiac disease, dysrhythmias and infectious diseases of the heart were represented. The need for surgical intervention (22%) and mortality (6%) was substantial.

Conclusion: In the aggregate, these conditions occur at an important rate and represent a high risk subset of pediatric patients presenting to the emergency department. Individually, the conditions occur infrequently and 'pattern recognition' may not aid the clinician. Early diagnosis and prompt intervention is important in this population.

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1. Introduction

Emergency physicians assess pediatric patients for potential cardiac disease on a daily basis in children presenting with chest pain, syncope, shortness of breath, palpitations and other complaints that could be related to the cardiac system [1-3]. Recent data suggest that children are presenting with these symptoms with increasing frequency [4]. Though the prevalence of cardiac disease in these children is low, the morbidity and mortality of those with disease is substantial, and the need for prompt diagnosis and therapeutic intervention is imperative. Recent data from a large medical malpractice database demonstrates that missed cardiac disease is one of the highest risk diagnostic categories in pediatric emergency medicine [5].

Advances in neonatal screening for congenital heart disease over the last 30 years have reduced the number of critical congenital cardiac conditions that remain undiagnosed beyond the newborn period [6]. This would be expected to lower the total number of undiagnosed cardiac diseases presenting to the pediatric ED, and change the clinical spectrum of cases such that acquired cardiac disease would make up a greater proportion of cases. Given the high frequency of complaints related to the chest in children, and the low prevalence of previously undiagnosed cardiac disease, an elevated index of suspicion and superb

clinical acumen is required to make a timely diagnosis and initiate appropriate care. Understanding the clinical spectrum of pediatric cardiac disease is central to this diagnostic process. In order to better define and clinically characterize this population, a retrospective study of all patients with previously undiagnosed cardiac disease presenting to our department was performed.

2. Methods

All cases of previously undiagnosed cardiac disease presenting between February 2013 and November 2018 were identified through the review of several databases: medical records database search utilizing pertinent ICD9 codes; departmental performance improvement database; and admission, discharge and transfer logs. These cases were reviewed by trained reviewers (JF, RB) using a standardized form and explicit data extraction criteria. Charts were reviewed for demographic information and details of clinical presentation such as chief complaint, vital signs, triage category, physical exam findings, laboratory and diagnostic testing, therapeutic interventions, disposition and outcome. Waiver of informed consent was obtained from our hospital's IRB. Agreement between reviewers on the details of the chart review was monitored. Patients in whom a prior cardiac diagnosis requiring surgery or ongoing medical therapy, those at high risk of cardiac disease due to known underlying disease (such as Marfan syndrome or rheumatic fever), and patients who died in the Emergency Department, were excluded. Patients were included in the study if the cardiac condition

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identified in the pediatric emergency department had not been diagnosed in the past and the patient required one of the following: admission to the pediatric intensive care unit, emergency cardiac medication administration (anti-arrhythmic agents, vasopressors, vasodilators, diuretics, contractility agents), vagal maneuvers for the conversion of supraventricular tachycardia, cardioversion or defibrillation, pericardiocentis, cardiac catheterization, or cardiac surgery. Since Kawaski disease is frequently mentioned as a common acquired etiology of cardiac disease in children, a search for this diagnosis was also performed using the methods and database described above. The patient's final diagnosis was confirmed at follow up with our pediatric cardiology group within six months of discharge from the hospital. The diagnosis of those children who died in the hospital was determined through review of the final pediatric cardiologist consultation prior to death.

3. Results

Thirty-six cases were identified representing one case for every 4838 pediatric emergency visits over the study period. Age at presentation ranged from 16 days to 17 years. The chief complaints were varied – chest pain (33%), cardiac or respiratory arrest (14%), palpitations (11%), cough/dyspnea (8%), seizure (8%), and syncope (8%). A sizable subset of cases (47%) were not triaged as Emergency Severity Index class 1 or 2 (resuscitation or emergent). On initial physician evaluation, 64% had no evidence of cardiac or respiratory distress. Arrhythmia was the primary pathophysiology in 42% of cases (Table 1), 7 of which were supraventricular tachycardia, 2 forms of heart block, and 6 ventricular rhythm disorders. A 10 year old presenting with ventricular tachycardia was successfully cardioverted with electrical cardioversion in the ED. On echocardiogram he was found to have an aberrant right coronary artery and arrhythmogenic foci that ultimately required ablation. A 5 year old with complete heart block due to Coxsackie myocarditis, suffered an episode of asystole/cardiac arrest in the ED which responded to chest compressions and epinephrine infusion, followed by transcutaneous pacing. No cases of supraventricular tachycardia required electrical cardioversion as all were converted with adenosine. There were no patients managed with vagal maneuvers alone.

Structural or congenital heart disease not diagnosed in the perinatal period represented five of the 36 cases (Table 2). All of these patients required surgical repair. Acquired or infectious etiologies represented 44% of patients, predominantly patients with myocarditis or pericarditis (Table 3). One patient with overt myocarditis, a 6 year old female with chest pain, fever, tachycardia and reduced ejection fraction, also had a stable, wide complex rhythm that was managed with IV fluid boluses in the ED. She ultimately required propranolol in the ICU setting to control rate and made a complete recovery. The two fatalities were a 14 year old female with myocarditis and markedly depressed left ventricular output that progressed to cardiac arrest within 24 h, and a 5 year old male with asthma and previously undiagnosed pulmonary hypertension who suffered right ventricular failure, ventricular fibrillation and cardiac arrest within 72 h of admission. One patient in the acquired category suffered a traumatic cardiac injury. Initially presenting as a patient with head injury after a fall involving a television, the patient was discovered on bedside ultrasound to have hemorrhagic tamponade due to blunt chest injury resulting in a tear to his superior vena cava/ right atrial juncture. Bedside, percutaneous, ultrasound guided aspiration of the tamponade was performed. Overall mortality in the series was 6% (2/36).

A total of eight patients in the cohort required surgical intervention representing 22% of the cohort. Three other patients required placement of an implantable cardioverter defibrillator. Idiopathic cardiomyopathy, Brugada syndrome, long QT syndrome, aortic dissection, aortic valve insufficiency, partial anomalous pulmonary venous return, infradiaphragmatic totally anomalous pulmonary venous return (TAPVR) and traumatic cardiac tamponade were also represented in

Table 1
Arrythmia patients. n = 15.

Age	CC	EKG findings	Triage category	HR	RR	BP	Mental status	Circ/resp distress	ED Intervention	Hospital course/outcome
1 m	Poor feeding	WPW	2	282	60	79/40	Responds to pain	Yes	Adenosine	Full recovery
23 m	Seizure	SVT	2	275	30	88/58	Alert	No	Adenosine	Full recovery
3 y	Pallor, vomiting	SVT	3	224	32	87/60	Alert	No	Adenosine	Full recovery
4 y[a]	Seizure	Complete heart block	3	54	20	84/45	Alert	Yes	Epinephrine infusion, transcutaneous pacing	Coxsackie myocarditis- Full recovery
7 y	Chest pain	First degree heart block-junctional escape	3	56	18	117/78	Alert	No	None – admit to PICU for telemetry	Full recovery
10 y[b]	Palpitations	Ventricular tachycardia	2	222	18	110/60	Alert	No	Electrical cardioversion	Aberrant coronary right artery on echo; received ablation- full recovery
10 y	Palpitation	Atrial fibrillation/tachycardia	2	149	15	122/81	Alert	No	Adenosine	Full recovery
11 y	Palpitations	Long QT syndrome	3	109	20	121/85	Alert	No	None – admit to PICU for telemetry	SCN 5A deletion - full recovery
13 y	Arrest (prehospital)	Ventricular fibrillation	2	106	Mech	151/107	GCS = 3	Yes	Defibrillation (pre-hospital)	RYR2 gene mutations - defibrillator implanted- full recovery
13 y	Chest pain	SVT	1	232	22	96/68	Alert	No	Adenosine	Full recovery
13 y	Syncope	WPW	2	108	25	117/58	Alert	Yes	Defibrillation (pre-hospital)	Full recovery
15 y	Seizure	Brugada/sinus tachycardia	2	133	20	121/71	Alert	No	None – Admit to PICU for telemetry	Defibrillator implanted - full recovery
16 y	Palpitations	SVT	2	222	20	127/79	Alert	No	Adenosine	Full recovery
16 y	Chest pain	Bigeminy	2	76	14	128/45	Alert	No	None – admit PICU for telemetry	Full recovery
17 y	Arrest (pre-hospital)	Ventricular torsade (prehospital)	2	88	Mech	139/91	GCS = 4	Yes	Defibrillation (pre-hospital)	Defibrillator implanted- full recovery

WPW – Wolff-Parkinson-White syndrome, SVT – supraventricular tachycardia, Mech – receiving mechanical ventilation.
a Suffered witnessed, asystolic cardiac arrest in the ED, responded to CPR.
b Patient found to have aberrant coronary right artery on echo; ultimately treated with ablation.

Table 2
Congenital/structural. n = 5.

Age	Presentation	ESI	CVR distress	HR	RR	Sat	BP	Dx	ED intervention	Hospital course
16 d	Resp failure	1	Yes	119	bvm	70	75/55	Cardiomyopathy/PDA	PGE – PICU admit	Surgical repair- metabolic workup-recovery
1 m	Resp failure	1	Yes	97	bvm	UO	UO	TAPVR (subdiaphragmatic)	PGE – PICU admit	Surgical repair- recovery
12 y	Syncope	3	No	110	22	99	110/80	Partial APVR	None – PICU admit	Surgical repair -recovery
14 y[a]	Poor feeding, vomiting	3	No	105	16	99	131/68	Severe MR, AI	None – PICU admit	Surgical repair- recovery
16 y	Back pain, chest pain	3	No	58	24	99	148/68	B-type aortic dissection	Nicardipine drip	Surgical repair- progression to A type-recovery

ESI – Emergency Severity Index (triage category). CVR – cardio-respiratory.
AI – aortic valve insufficiency, MR – mitral regurgitation, Partial APVR – partial anomolous venous return,
TAPVR- totally anomolous pulmonary venous return, PGE – prostaglandin E1, UO – unable to obtain.
  [a] Child had severe autism, non-verbal.

the cohort. During the study period, nineteen children were admitted for the diagnosis of Kawaski disease. None of these patients had evidence of clinical or echocardiographic signs of cardiac disease in the ED. One patient had evidence of coronary arteritis on echocardiogram during their hospital stay.

4. Discussion

Previously undiagnosed pediatric cardiac disease presents to the emergency department at a relatively low rate. We report a case series of 36 children presenting to the ED with cardiac disease that had previously been undiagnosed. This represents approximately one new case per 5000 Pediatric ED visits. The cases represent a wide spectrum of infectious, congenital, electrophysiologic and structural disorders. The clinical manifestations at presentation are highly varied, as evidenced by triage categories ranging from non-urgent to cardiac arrest and chief complaints involving the neurologic, cardiovascular, respiratory and gastrointestinal systems. Our data demonstrate what makes the emergency physician's search for previously undiagnosed pediatric cardiac disease in children challenging. In the aggregate, the frequency of undiagnosed cardiac disease in our data set suggests most emergency departments will see such a case every one to two years. The specific

diagnoses, however, are rare and the individual ED physician is unlikely to have clinical exposure to each disorder with much frequency. These factors make clinical 'pattern recognition' less likely to be helpful with these presentations. As a result, the risk of diagnostic delay or misdiagnosis is elevated. Our data suggest that a large subset of these patients will present in a subacute manner given that the majority of the cases were initially assessed as triage category 3. Careful review of each case is therefore essential to maximize the learning opportunity on each unique patient encounter.

Most prior studies on pediatric cardiac disease in the ED have focused on a single chief complaint or clinical presentation such as patients presenting with chest pain, syncope, arrythmia or cardiac arrest. Hurst et al. reported on 26 cases of cardiac disease presenting with syncope. Only three patients in their sample were previously undiagnosed cardiac cases, one case of myocarditis and two cases of SVT [2]. Drossner et al. reported on 24 cases of pediatric cardiac disease presenting to the ED with a chief complaint of chest pain [3]. The patients in that study differed from ours in that only 50% of these patients required admission and there were no deaths. Myocarditis, pericarditis, long QT syndrome and myocardial infarction were represented in the sample. Clausen et al. describe 444 children presenting with cardiac arrhythmia to their large children's hospital in Australia [7]. Nearly 70% of these

Table 3
Acquired/infectious etiology. N = 16.

Age	Presentation	ESI	CVR distress	HR	RR	BP	Mental status	Dx	ED intervention	Hospital course
2 y	Cardiac arrest (pre-hospital)[c]	1	Yes	123	5	76/38	GCS -3	Myocarditis	Epinephrine- PICU admit	Full recovery
5 y[a]	Fall, head injury	2	Yes	162	35	92/60	GCS -8	Hemorrhagic tamponade	Bedside, US guided pericardiocentesis	Thoracotomy – repair of laceration at SVC/RA junction – full recovery
6 y	Resp distress	2	Yes	127	44	UO	Alert	Pulmonary HTN, asthma	Solumedrol, Albuterol- PICU admit	Fatality
6 y	Chest pain[c]	2	Yes	141	34	76/48	GCS -14	Myocarditis[d]	IVF, Ceftriaxone – PICU admit	Full recovery
6 y	Back pain	3	No	149	20	95/68	Alert	Pericardial effusion	None – PICU admit	Full recovery
12 y	Chest pain[c]	3	No	110	22	119/81	Alert	Influenza A myocarditis	IVF bolus– PICU admit	Full recovery
13 y[b]	Cough	2	Yes	145	20	101/80	Alert	CHF- MD, OSA	Lasix - PICU admit	Tracheostomy - full recovery
14 y	Dyspnea	2	Yes	140	45	124/74	Alert	Pericardial effusion/CML	Lasix – PICU admit	Pericardial window in OR
14 y	Syncope	3	No	103	20	94/70	GCS-14	Myocarditis	IVF bolus – PICU admit	Fatality
15 y	Chest pain	3	No	71	20	118/66	Alert	Pericarditis	None – PICU admit	Full recovery
15 y	Chest pain	3	No	55	16	113/59	Alert	Myocarditis	IVF bolus – PICU admit	Full recovery
15 y	Chest pain[c]	3	No	105	15	116/68	Alert	Myocarditis	IV Solumedrol – PICU admit	Full recovery
15 y	Fever[c]	3	Yes	110	20	88/54	Alert	Bacterial endocarditis	IVF, Vancomycin, Ceftriaxone	Full recovery
16 y	Chest pain	3	No	96	16	142/89	Alert	Pericarditis	None – PICU admit	Full recovery
16 y	Chest pain[c]	3	Yes	112	18	87/58	Alert	Myocarditis	IVF – PICU Admit	Full recovery
17 y	Chest pain	3	No	119	20	115/71	Alert	Pericardial effusion	Aspirin – PICU	Pericardial window in OR

ESI – Emergency Severity Index (triage category); CVR distress – cardiac/respiratory distress. AMS – altered mental status; CHF – congestive heart failure; CML – chronic myelogenous leukemia; HTN – hypertension; IVF- intravenous fluids; OSA – obstructive sleep apnea; MD- muscular dystrophy; UO – unable to obtain.
  [a] Child brought by EMS for head injury after an unwitnessed fall, altered mental status, initial mechanism of injury uncertain.
  [b] Child with global development delay and spasticity with cough and irritability.
  [c] Patients with elevated Troponin levels.
  [d] Child had an ejection fraction of 40% on echo with wide complex tachycardia that remained clinically stable with IV fluid administration.

children had prior cardiac diagnoses. One patient in that series required cardioversion, and three others required anti-arrhythmic therapy other than adenosine.

Research on the frequency of congenital heart disease presenting undiagnosed to the ED is limited. Savitsky et al. published their experience with congenital heart disease in the ED over a six year period in Los Angeles. Only 8 previously undiagnosed patients were identified. Conditions causing left sided obstruction and left ventricular failure, left to right shunts resulting in volume overload, and a patient with coronary artery aberrancy resulting in myocardial ischemia, were represented [8]. A larger study from the ED at the Seoul National University Hospital in Korea recently reported on 82 cases of previously undiagnosed congenital heart disease. The distribution of cases was similar to the Los Angeles data though more children with cyanotic presentations were reported. The large majority of their series were referred in from other facilities [9].

Infectious and acquired diseases of the heart represent a sizable percentage of our cohort (44%) and accounted for both of our two fatalities. Two other cases in our series that were ultimately diagnosed with myocarditis suffered cardiac arrests (one pre-hospital) from which they made a full recovery. Fulminant myocarditis is the most feared acquired cardiac disease in children. There are several small case series which elucidate the significant pediatric morbidity and mortality associated with this condition [10,11]. Freedman et al. recently reported in a detailed fashion on 31 cases of acute myocarditis presenting to their ED and described the frequency of diagnostic abnormalities [12]. Similar to our data, they reported a prevalence of 1 in 5000 ED patients and a mortality of 10%. They also reported a delay in diagnosis until after admission in 26% of their cohort, demonstrating the subtlety of initial presentation in many of these cases.

Our study is limited by it's retrospective design. Cases may have been missed by our search methods and this would impact the prevalence and mortality data. Children presenting to the ED in arrest who subsequently died in the ED may have had undiagnosed cardiac disease that was not identified, thus reducing our reported disease prevalence. It is not routine for patients dying in our ED to have post-mortem exams unless there is concern for child abuse or neglect, or if the family requests the exam. Cases such as this are quite rare. Our retrospective design also impacts the accuracy of reported clinical findings. Documentation of clinical findings may have been performed after the ED diagnosis was made, falsely elevating the sensitivity of initial clinical assessment.

5. Conclusion

Previously undiagnosed pediatric cardiac disease presents to the Emergency Department at a low but important rate. Cases present with a variety of chief complaints and are often triaged as Urgent (ESI Level 3) as opposed to a Resuscitation or Emergent (ESI Level 1 or 2) triage categories. In the aggregate, previously undiagnosed cardiac disease is seen at low but significant rate. Individually, many of the cardiac conditions that make up this diagnostic category will be seen infrequently and with variable presentations. These cases will require a high degree of clinical suspicion to make a timely diagnosis, with careful attention to clinical detail. Early diagnosis and treatment is important given the substantial morbidity and mortality in this population.

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