Introduction

Acute myocarditis is rare in children. It has an estimated annual incidence of 1 to 2 per 100,000 children. It is most commonly seen following a viral infection, and is rarely caused by bacteria in immunocompetent children. Affected children initially present with respiratory or gastrointestinal symptoms, cardiovascular manifestations or shock. Approximately 50% of children with myocarditis have gastrointestinal symptoms such as vomiting or poor feeding. Non-typhoidal Salmonella (NTS) are an important cause of gastroenteritis (usually self-limiting) but are rarely associated with myocarditis. Here, we report a case of myocarditis associated with NTS gastroenteritis in a previously healthy 15-year-old boy. The case report was exempted from the requirement of informed consent by the Institutional Review Board (IRB No. KUMC 2019-07-052).

Case

A 15-year-old boy visited the emergency...
department with fever (up to 38.5°C). He presented with 1-day history of profuse watery, non-bloody diarrhea, peri-umbilical abdominal pain, and chest discomfort around the mid-sternum. He reported no significant past medical history or family history.

The initial vital signs were as follows: blood pressure, 112/64 mmHg; heart rate, 64 beats per minute; respiratory rates, 20 breaths per minute; temperature, 37.7°C; and oxygen saturation, 100% on room air. Cardiac examination was unremarkable, and lung sounds were clear. Abdominal examination showed mild epigastric tenderness without rebound one.

Initial laboratory evaluation showed a white blood cell count of 10,850/μL with 79% segmented neutrophil without anemia or thrombocytopenia and a C-reactive protein concentration of 2.3 mg/dL. The serum electrolytes, glucose, creatinine, liver function tests and urinalysis were all within normal limits. We measured concentration of troponin I to assess myocardial injury related to his chest discomfort. The concentration was 107.8 ng/L (reference value, <20.7 ng/L). Concentrations of the other myocardial enzymes were within normal limits: creatinine kinase (CK), 110 U/L (reference value, 58–348 U/L); CK-MB, 1.4 ng/mL (reference value: <6.6 ng/mL); and B-type natriuretic peptide, 10 pg/mL (reference value: <100 ng/mL).

Fig. 1. Initial electrocardiogram showing normal sinus rhythm with nonspecific ST segment changes (A). Follow-up electrocardiogram showing sinus rhythm with ST segment elevation in leads II, III, aVF, and V3-V6, suggestive of inferolateral myocardial injury (B).
The venous blood gas analysis was normal: pH, 7.38; PCO\(_2\), 41.7 mmHg; and HCO\(_3\), 24.9 mEq/L. There were no remarkable findings on the initial electrocardiogram (ECG) (Fig. 1A) and chest radiograph. After his blood, urine, and stool cultures were collected, intravenous ceftriaxone was administered empirically based on the suspicion of bacterial gastroenteritis associated with unknown myocardial injury.

As his chest discomfort worsened with dizziness, follow-up laboratory evaluation and ECG were performed. The concentrations of troponin I and CK-MB increased to 4,370.0 ng/L and 15.2 ng/mL, respectively. Unlike the initial ECG, follow-up ECG performed after 12 hours showed an ST-segment elevation up to 1.8 mm in leads II, III, aVF, and V3–V6 suggestive of inferolateral myocardial injury (Fig. 1B). Findings suggesting pericardial effusion or tamponade, such as electrical alternans and low-voltage QRS complex, were not observed. Initial bedside echocardiogram did not show structural or regional wall motion abnormalities. However, there was mildly reduced left ventricular (LV) systolic function with an ejection fraction of approximately 50%. Based on clinical and laboratory findings, the presumed diagnosis was myocarditis associated with bacterial gastroenteritis.

The boy was transferred to the intensive care unit. Intravenous immunoglobulin was administered once (400 mg/kg). Dopamine and milrinone were infused intravenously to improve the LV systolic dysfunction and reduce the afterload. On day 4, we noted resolution of the chest discomfort and normal LV function on a follow-up echocardiogram. At this point, intravenous dopamine and milrinone were discontinued. The abnormal ECG findings were normalized and troponin I was decreased to 992.8 ng/L. On day 6, cardiac magnetic resonance imaging (MRI) findings showed sub-epicardial lesions suggestive of myocarditis (Fig. 2). Salmonella serogroup B was identified in the stool culture; blood and urine cultures yielded negative results. No viruses were found in polymerase chain reaction. In addition, no other possible causes (drugs, autoimmune or metabolic diseases) could be recognized. The final diagnosis was myocarditis associated with Salmonella serogroup B gastroenteritis based on the clinical, microbiologic, and imaging findings. He was discharged in a stable condition on day 9. After 1 month, he was in a good condition and had no abnormalities in cardiac enzymes, ECG, and echocardiogram.

![Fig. 2. Cardiac magnetic resonance images in long axis (A) and mid-short axis (B) planes showing late gadolinium enhancement in the sub-epicardium at the anterolateral and inferolateral left ventricle walls, suggestive of myocardial fibrosis-associated with myocarditis (arrows).](image-url)
Discussion

The adolescent who presented with chest discomfort, fever, diarrhea, and abdominal pain was diagnosed with acute myocarditis associated with Salmonella serogroup B gastroenteritis. No complications developed due to early diagnosis and prompt management. The early diagnosis was possible thanks to the focus on aggravating chest discomfort and laboratory evidence of myocardial injury, and subsequent repetition of cardiac enzymes and ECG. Park et al. first reported a case of a previously healthy 5-year-old Korean boy who had myocarditis associated with Salmonella gastroenteritis, complicated by complete atrioventricular block requiring permanent pacemaker insertion. This patient had a 3-day history of fever, abdominal pain, and vomiting. The most important therapeutic issue of myocarditis is prompt and appropriate diagnosis prior to clinical deterioration. Fortunately, our patient came to the emergency department early and was diagnosed promptly, allowing appropriate treatment to be carried out. Our experience suggests that myocarditis should be included in differential diagnosis when gastroenteritis patients present with cardiac manifestations.

Among diverse causes of myocarditis, viral infection is most common in children, whereas bacterial infections are comparatively rare. Physical examination may show respiratory findings ranging from tachypnea, retraction, and rales to direct evidence of cardiac dysfunction, abnormal heart sounds, and murmurs. ECG findings are usually abnormal but nonspecific; for example, sinus tachycardia with nonspecific ST segment changes and T wave abnormalities. Cardiac enzymes, particularly troponins I and T, are commonly used to screen myocarditis. Although elevated concentrations of the enzymes reflect myocardial damage, troponins have a 34% sensitivity and 89% specificity for the diagnosis of myocarditis. Thus, the abnormalities should be interpreted cautiously along with other clinical and echocardiographic findings. Cardiac MRI can be a noninvasive and valuable diagnostic tool to identify the location and extent of myocarditis, allowing the safe and efficient performance of endomyocardial biopsies. However, because of frequent delays in arranging the test, it is difficult to perform cardiac MRI in emergency settings, and it may not accurately reflect the initial severity. Salmonella species are gram-negative bacilli responsible for significant morbidity and mortality. Both typhoidal Salmonellae and NTS can cause extra-intestinal manifestations. However, among the manifestations, myocarditis is uncommon. Though antibiotic therapy is not recommended for NTS gastroenteritis, it is warranted in certain patients at high risk for infection. Recent systematic review on cases of NTS myocarditis shows predominant occurrence in young adults and association with poor outcome. Although Salmonella or other bacteria are rare causes, the possibility of myocarditis should be considered in any gastroenteritis patients presenting with cardiac manifestations. This is especially important considering known complications of myocarditis, such as dilated cardiomyopathy and sudden death.

It is worth mentioning 2 caveats in the diagnosis of the present case. First, endomyocardial biopsy is considered the gold standard for diagnosis, but the biopsy has limitations because of its invasiveness and low sensitivity due to patchiness of lesions. When the biopsy is not possible, cardiac MRI is increasingly used to diagnose the entity. In our patient, a sufficient diagnosis could be made based on the combination of clinical, laboratory, echocardiogram, and cardiac MRI findings. Second, according to somatic (O) and flagella (H) antigens, more than 2,500 Salmonella serotypes were identified. Although Salmonella serotyping is essential for specific diagnosis, treatment, and epidemiologic surveillance, it is time-consuming and expensive to perform. In our center, serotyping with only O antigen–specific and Vi–specific antibodies are performed. Thus, it was unable to serotype Salmonella species.

To summarize, children with myocarditis can
present with gastrointestinal manifestations. Particularly for children presenting with diarrhea, NTS may be considered as a microbiological diagnosis.

**Conflicts of interest**

No potential conflicts of interest relevant to this article were reported.

**References**

1. Nugent AW, Daubeney PE, Chondros P, Carlin JB, Cheung M, Wilkinson LC, et al. The epidemiology of childhood cardiomyopathy in Australia. N Engl J Med 2003;348:1639-46.
2. Lipshultz SE, Sleeper LA, Towbin JA, Lowe AM, Orav EJ, Cox GF, et al. The incidence of pediatric cardiomyopathy in two regions of the United States. N Engl J Med 2003;348:1647-55.
3. Arola A, Pikkarainen E, Sipila JO, Pykari J, Rautava P, Kyto V. Occurrence and features of childhood myocarditis: a nationwide study in Finland. J Am Heart Assoc 2017;6:e005306.
4. Wu MH, Wu ET, Wang CC, Lu F, Chen HC, Kao FY, et al. Contemporary postnatal incidence of acquiring acute myocarditis by age 15 years and the outcomes from a nationwide birth cohort. Pediatr Crit Care Med 2017;18:1153-8.
5. Fisher RG, Boyce TG, Correa AG. Moffet’s pediatric infectious diseases: a problem-oriented approach. 5th ed. Philadelphia (PA): Wolters Kluwer; 2017.
6. Park YA, Kim YH, Park IS. Acute myocarditis complicated by permanent complete AV block associated with salmonella group B gastroenteritis. Korean Circ J 1995;25:698-703. Korean.
7. Canter CE, Simpson KE. Diagnosis and treatment of myocarditis in children in the current era. Circulation 2014;129:115-28.
8. Childs L, Gupta S. Salmonella enteritidis induced myocarditis in a 16-year-old girl. BMJ Case Rep 2012;2012:bcr2012007628.
9. Schultz JC, Hilliard AA, Cooper LT Jr, Rihal CS. Diagnosis and treatment of viral myocarditis. Mayo Clin Proc 2009;84:1001-9.
10. Levine MC, Klugman D, Teach SJ. Update on myocarditis in children. Curr Opin Pediatr 2010;22:278-83.
11. Sanchez-Vargas FM, Abu-El-Haija MA, Gomez-Duarte OG. Salmonella infections: an update on epidemiology, management, and prevention. Travel Med Infect Dis 2011;9:263-77.
12. Hohmann EL. Nontyphoidal salmonellosis. Clin Infect Dis 2001;32:263-9.
13. Villablanca P, Mohananey D, Meier G, Yap JE, Chouksey S, Abegunde AT. Salmonella Berta myocarditis: case report and systematic review of non-typhoid Salmonella myocarditis. World J Cardiol 2015;7:931-7.
14. Brighenti M, Danti A, Giulia Gagliardi M, Maschietto N, Marini D, Lombardi M, et al. Endomyocardial biopsy safety and clinical yield in pediatric myocarditis: an Italian perspective. Catheter Cardiovasc Interv 2016;87:762-7.
15. Ghelani SJ, Spaeder MC, Pastor W, Spurney CF, Klugman D. Demographics, trends, and outcomes in pediatric acute myocarditis in the United States, 2006 to 2011. Circ Cardiovasc Qual Outcomes 2012;5:622-7.
16. Kim S. Salmonella serovars from foodborne and waterborne diseases in Korea, 1998-2007: total isolates decreasing versus rare serovars emerging. J Korean Med Sci 2010;25:1693-9.