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Original Article

Cardiac Troponin T and Intravenous Immunoglobulin in the Diagnosis and Follow-up of Childhood Myocarditis

Çocukluk Çağı Miyokarditinin Tanı ve İzleminde Kardiyak Troponin T ve İntravenöz İmmünoglobulin

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ABSTRACT

Objective: Our aim was to investigate the therapeutic efficacy of intravenous immunoglobulin (IVIG) in pediatric patients with elevated cardiac troponin T (cTnT) levels and diagnosed with myocarditis confirmed by cardiac magnetic resonance imaging or clinically assessed as probable myocarditis (PM).

Method: We retrospectively reviewed 105 children (mean age 13.4±3.1 years; 81% male) hospitalized with PM between January 2013 and April 2025. Patients were classified as those whose diagnosis of myocarditis was confirmed using cardiovascular magnetic resonance (CMR-confirmed) or PM based on Lake Louise diagnostic criteria. Data concerning demographic features, electrocardiography (ECG), echocardiography, CMR, baseline and follow-up cTnT (Roche high-sensitivity assay; 99th-percentile 0.014 ng/dL), time to normalization of cTnT levels, and IVIG therapy (400 mg/kg/day up to 5 days) were analyzed.

Results: CMR abnormalities were found in 44 (41.9%) patients. Median baseline cTnT level was 0.135 ng/dL (range 0.016-9.057) and median normalization of cTnT levels was achieved within median period of 5 days (range: 2-42 days). IVIG was administered to 38 (36.2%) patients and more often patients with confirmed myocarditis (CM) received IVIG therapy rather than cases with PM (50% vs. 24.5%). Pathologic ECG findings were detected in 32% of all study participants and more frequently in IVIG-treated patients. Troponin normalization rate was slower in IVIG-treated patients (median: 10 vs 6 days), especially in patients with CM. Echocardiographic outcomes and recovery of left-ventricular systolic function had not shown any significant differences between IVIG-treated and untreated groups.

Conclusion: Serum cTnT is a useful adjunct for diagnosis and follow-up of patients with pediatric myocarditis. IVIG was more often used in clinically severe cases but showed no significant effect on recovery of ventricular function or on fluctuations in troponin levels. Larger multicenter studies should be conducted to clarify therapeutic benefit of IVIG.

Keywords: Intravenous immunoglobulin, myocarditis, pediatrics, troponin T

ÖZ

Amaç: Troponin T düzeyi yüksek, kardiyak manyetik rezonans (kMR) ile doğrulanmış veya klinik olarak olası miyokardit (PM) tanısı alan pediatrik hastalarda intravenöz immünoglobulinin (IVIG) tedavi etkinliğini değerlendirme amaçlanmıştır.

Yöntem: 2013-2025 yılları arasında PM nedeniyle yatırılan 105 çocuk (ortalama yaş 13,4±3,1 yıl; %81 erkek) geriye dönük incelendi. Hastalar Lake Louise kriterlerine göre kMR-doğrulanmış miyokardit (CM) veya PM olarak sınıflandırıldı. Demografik veriler, EKG, ekokardiyografi, kMR, seri troponin T düzeyleri ve IVIG tedavisi (400 mg/kg/gün, en fazla 5 gün) analiz edildi.

Bulgular: kMR bulguları 44 hastada (%41,9) pozitiftir. Ortanca başlangıç troponin düzeyi 0,135 ng/dL olup normale dönüş süresi 5 gündü. IVIG 38 hastaya (%36,2) uygulanmış ve CM grubunda daha sık kullanılmıştır. Patolojik EKG bulguları IVIG alanlarda daha yaygındı. Troponin normalizasyonu IVIG alanlarda daha yavaştı, özellikle CM grubunda. Sol ventrikül fonksiyonlarının düzelmesi açısından IVIG alan ve almayan gruplar arasında fark yoktu.

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Sonuç: Troponin T, pediatrik miyokarditin izleminde yararlı bir belirteçtir. IVIG daha ağır olgularda tercih edilmesine rağmen klinik gidiş veya troponin düşme süresi üzerinde anlamlı bir etkisi gösterilememiştir. IVIG'in etkinliğini belirlemek için daha geniş çalışmalara ihtiyaç vardır.

Anahtar kelimeler: İntravenöz immünoglobulin, miyokardit, pediatrik, troponin T

INTRODUCTION

Pediatric myocarditis is an inflammatory disease of the myocardium with a broad clinical spectrum ranging from mild chest pain to severe heart failure and life-threatening arrhythmias. In pediatric patients, viral infections represent the most common etiological factors, with parvovirus B19 and human herpesvirus type 6 among the most frequently reported pathogens[1].

Although endomyocardial biopsy is considered the gold standard for the definitive diagnosis of myocarditis, its routine use in children is limited due to procedural risks and the patchy distribution of myocardial inflammation, which may lead to sampling error and false-negative results. Therefore, in clinical practice the diagnosis of suspected myocarditis is generally based on the combined evaluation of clinical findings, biochemical markers, electrocardiographic (ECG) abnormalities, and results of non-invasive imaging techniques such as echocardiography and cardiac magnetic resonance imaging (CMRI)[2].

CMRI has become an important tool in the non-invasive evaluation of myocarditis. The updated Lake Louise diagnostic criteria support the diagnosis of myocardial inflammation by integrating T1-based markers of myocardial injury [such as late gadolinium enhancement (LGE) and increased native T1 values] and T2-based markers of myocardial edema[3,4,5].

Cardiac troponins are widely used biomarkers for the assessment of myocardial injury. Cardiac troponin T (cTnT) and cardiac troponin I are specific to myocardial tissue, and their elevation in serum reflects cardiomyocyte damage. Elevated troponin levels are frequently observed in pediatric myocarditis and are considered supportive evidence of myocardial injury; however, inconsistent literature data has been reported on the causal relationship between troponin levels and disease severity or prognosis[6,7,8].

Although no universally accepted specific therapy exists for myocarditis, intravenous immunoglobulin (IVIG) is commonly used in pediatric clinical practice. IVIG is thought to reduce myocardial inflammation through viral neutralization and modulation of cytokine activity. However, evidence regarding its clinical efficacy in pediatric myocarditis remains inconsistent[9,10,11].

In this study, we aimed to evaluate the clinical utility of cTnT as a supportive biomarker in the diagnosis and follow-up of pediatric patients hospitalized with suspected myocarditis. In addition, we investigated the relationship between IVIG treatment and clinical course in two groups of patients classified separately as having confirmed myocarditis (CM) and clinically suspected (probable) myocarditis.

MATERIALS and METHODS

This retrospective single-center study was conducted at a tertiary pediatric referral center. Ethical approval for the study was obtained from the institutional ethics committee of University of Health Sciences Türkiye İzmir Faculty of Medicine Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital (decision no.: 2025/14-12, date: 11.09.2025).

The medical records of pediatric patients hospitalized with a preliminary diagnosis of myocarditis between January 2013 and April 2025 were retrospectively reviewed. Data concerning demographic characteristics of the patients, physical examination, ECG, transthoracic echocardiographic, CMRI findings, baseline and follow-up cTnT levels, time to troponin normalization, and the administration of IVIG therapy were recorded.

Since CMRI was not available at our center before 2013, as cTnT assay Roche high-sensitivity troponin T test, with the 99th percentile upper reference limit defined as 0.014 ng/dL was used in this study, and patients admitted prior to that date were excluded from the study.

Patients with other clinical conditions that could cause troponin elevation including cardiomyopathies, muscular dystrophy, sepsis-related secondary cardiac dysfunction, significant valvular heart disease, congenital heart disease with ventricular dysfunction, and cardiac involvement secondary to systemic rheumatologic diseases were excluded.

Left ventricular systolic function was assessed via two-dimensional transthoracic echocardiography using the Simpson biplane method. An ejection fraction below 55% was considered indicative of systolic dysfunction. Although diastolic function was evaluated using transmitral Doppler and tissue Doppler parameters, these data were not included in the statistical analysis due to incomplete

documentation. Strain echocardiography was performed in some patients. However since a standardized protocol was not consistently applied during the study period, these relevant data were not systematically analyzed.

CMRI examinations were performed within the first week of hospitalization. CMRI was conducted using a 1.5-Tesla magnetic resonance imaging (MRI) scanner. The imaging protocol included cine, T1-and, T2-weighted sequences, and LGE imaging following administration of gadolinium as contrast agent. Gadolinium contrast agent was intravenously administered to all patients, and LGE imaging was evaluated in all cases. ECG synchronization was used for the monitoring of cardiac rhythm during imaging process. In patients with heart rates high enough to potentially compromise image quality, beta-blocker therapy was administered prior to CMR acquisition.

The diagnosis of myocarditis was based on the updated 2018 Lake Louise criteria. Findings indicating myocardial injury on T1-weighted imaging included LGE and increased native T1 values. Myocardial edema detected on T2-weighted imaging was considered indicative of myocardial inflammation. Patients with clinically suspected myocarditis who fulfilled these CMR criteria were classified as having CM. Patients with elevated troponin levels but no CMR abnormalities were classified as having probable myocarditis (PM).

Endomyocardial biopsy is not routinely performed at our center. According to national healthcare regulations, this procedure is performed only in transplant centers; therefore, endomyocardial biopsy could not be performed in this study.

The decision to administer IVIG therapy was made by the attending pediatric cardiologist based on clinical evaluation. IVIG therapy was preferentially administered to patients with markedly elevated troponin levels, persistent chest pain, significant ECG abnormalities, or left ventricular systolic dysfunction. IVIG was administered at a dose of 400 mg/kg/day for up to five days, with a maximum cumulative daily dose of 2 g/kg.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables were expressed as mean ± standard deviation, while non-normally distributed variables were reported as median (minimum-maximum) values. Categorical variables were presented as numbers and percentages.

Comparisons between groups were performed using the independent samples t-test for normally distributed continuous variables and the Mann-Whitney U test for non-normally distributed variables. Categorical variables were compared using the chi-square test. Time to normalization of troponin levels in patients receiving and not receiving IVIG was compared using the Mann-Whitney U test. A p-value <0.05 was considered statistically significant.

RESULTS

Study population (n=105) hospitalized with suspected myocarditis consisted of 85 (81%) male and 20 (19%) female pediatric patients. The mean age of the study population was 13.4±3.1 years (range: 6-17 years). According to CMRI findings, patients were divided into two separate groups as having CM, and PM. CMRI findings consistent with myocarditis were detected in 44 (41.9%) patients. There were no significant differences between the CM and PM groups in terms of age or sex distribution.

Electrocardiography was normal in 72 (68.6%), and pathological in 33 (31.4%) patients. Among patients with abnormal ECG findings, ST-segment elevation in the anterior leads was detected in 16 (15.2%), ST-segment elevation in the inferior leads in 7 (6.7%). ST-segment depression in the inferior leads in 2 (1.9%) and in the anterior leads in 1 (1%) patient. Pathological T-wave changes were detected in 5 (4.8%), QRS fragmentation in 1 (1%), and supraventricular tachycardia in 1 (1%) patient. A significant association was observed between baseline cTnT levels and the presence of ST-segment elevation. Median cTnT values were markedly higher in patients with ST elevation compared with those without (0.692 vs 0.084 ng/dL, $p<0.00001$). Pathological ECG findings were more frequently observed in patients receiving IVIG therapy. Nineteen patients in the IVIG group had abnormal ECG findings compared with fifteen patients in the non-IVIG group ($p=0.007$).

Two-dimensional transthoracic echocardiography was normal in 90 (85.7%). Patients mild mitral regurgitation was detected in 9 (8.6%), pericardial effusion in 2 (1.9%), mild aortic regurgitation in 1 (1%), mitral valve prolapse in 1 (1%), asymptomatic bicuspid aortic valve in 1 (1%), and left ventricular hypertrophy in 1 (1%) patient. No significant differences were observed between the CM and PM groups in terms of echocardiographic findings. Echocardiographic abnormalities were detected in patients receiving (n=9), and not receiving (n=7) IVIG therapy. Besides, statistically significant correlation was not observed between IVIG therapy and echocardiographic findings ($p=0.126$). One patient with pericardial effusion

also had left ventricular systolic dysfunction. Despite IVIG therapy, systolic function progressively deteriorated, and the patient required veno-arterial extracorporeal membrane oxygenation support.

CMRI demonstrated findings consistent with myocarditis in 44 (41.9%) patients. Among these patients, increased T1-weighted MRI signals observed in the lateral wall of the left ventricle in 28 (26.7%) patients. T2-weighted MRI detected myocardial edema in 10 (9.5%), early gadolinium uptake in the interventricular septum in 4 (3.8%), and both early gadolinium uptake and pericardial effusion in 6 (5.7%) and right ventricular dyskinesia in 1 (1%) patient. Based on these findings, patients fulfilling the diagnostic criteria were classified as having CM, whereas patients with elevated troponin levels but without CMR abnormalities were classified as suffering from PM.

The median baseline cTnT level in the entire cohort was 0.135 ng/dL (range: 0.016-9.057 ng/dL). The median time to normalization of troponin levels was 5 days (range: 2-42 days). The median baseline cTnT level was 0.647 ng/dL in 38 (36.2%) patients receiving IVIG therapy (range: 0.026-4.199 ng/dL), and it was 0.488 ng/dL (range: 0.016-9.057 ng/dL) in 67 (63.8%) patients not receiving IVIG therapy

IVIG therapy was administered to 24 patients (50%) in the CM and to 14 patients (24.5%) in the PM group, whereas IVIG was administered at a significantly higher rate in the CM group (p=0.012). The time to normalization of troponin levels was longer in patients receiving IVIG therapy. Troponin levels were normalized after a median of 10 days (range: 3-42 days) in the IVIG group and after a median of 6 days (range: 2-27 days) in the non-IVIG group. Clinical variables according to troponin normalization time are summarized in Table 1. In the subgroup analysis of the CM group, the time to normalization of troponin levels was significantly longer in patients receiving IVIG (p=0.006) therapy, whereas no significant difference was observed in terms of this parameter between those receiving and not receiving IVIG therapy in the PM group (p=0.204). Clinical variables according to troponin T levels and IVIG therapy are summarized in Table 2.

During long-term follow-up period exceeding one year, alternative or evolving diagnoses emerged in some patients. One patient receiving IVIG therapy was diagnosed with restrictive cardiomyopathy during follow-up. Another patient presented six months after discharge with recurrent troponin elevation; repeat CMRs did not reveal findings consistent with active myocarditis, and the persistent troponin elevation was ultimately attributed to macrotroponin positivity. In another patient with recurrent troponin elevations and a family history of cardiomyopathy, genetic testing revealed a desmoplakin (DSP) gene mutation. Serial Holter monitorings demonstrated non-sustained ventricular tachycardia, and follow-up CMR findings were consistent with arrhythmogenic right ventricular dysplasia.

DISCUSSION

In this retrospective study, we evaluated the role of cTnT in the diagnosis and follow-up of pediatric patients hospitalized with suspected myocarditis and

Table 1. Normalization of troponin levels according to IVIG treatment

Baseline cTnT levels (ng/dL)	IVIG (n=38)	No IVIG (n=67)	p-value
Time to normalization of troponin levels (days)	0.647 (0.026-4.199)	0.488 (0.016-9.057)	0.214
Pathological ECG findings, n	10 (3-42)	6 (2-27)	0.006
Echocardiographic abnormalities, n	19	15	0.007
Baseline cTnT levels (ng/dL)	9	7	0.126

IVIG: Intravenous immunoglobulin, ECG: Electrocardiography, cTnT: Cardiac troponin T

Table 2. Clinical characteristics according to troponin T levels and IVIG treatment

Variables	Confirmed myocarditis (n=48)	Probable myocarditis (n=57)	p-value
Baseline cardiac troponin T levels (ng/dL)	0.692 (0.018-9.057)	0.084 (0.016-2.940)	<0.00001
ECG findings (normal/pathological), n	27/21	44/13	0.007
Echocardiographic findings (normal/pathological), n	39/9	44/13	0.126
IVIG treatment (yes/no), n	24/24	14/43	0.012

Continuous variables are presented as median (min-max), and categorical variables as numerical values (n). Continuous variables were compared using the Mann-Whitney U test, and categorical variables using the chi-square test
IVIG: Intravenous immunoglobulin, ECG: Electrocardiography

examined the relationship between IVIG treatment and clinical course. The main findings of our study were that elevated troponin T levels were frequently observed in children with suspected myocarditis, pathological ECG findings—particularly ST-segment elevation—were associated with higher troponin levels, and IVIG therapy was more frequently administered in patients with CMR-CM. However, IVIG treatment was not associated with improvement in left ventricular systolic function or shortened time to troponin normalization.

Cardiac troponins are well-known biomarkers of myocardial injury and are widely used in the diagnosis of myocarditis. In pediatric patients, troponin elevation generally reflects myocardial inflammation or injury; however, based on literature data, the relationship between troponin levels and the clinical course or prognosis of the disease has not always been consistent[8]. In our study, elevated troponin levels were detected in all patients at presentation and were considered an important biomarker supporting the diagnosis of suspected myocarditis. Similarly, previous pediatric studies have reported frequent troponin elevations in children diagnosed with myocarditis or myopericarditis[12-14].

Generally non-specific ECG abnormalities are commonly observed in myocarditis. In our study, pathological ECG findings were detected in approximately one-third of the patients. The most frequent abnormality was ST-segment elevation, which was associated with higher troponin levels. This finding suggests that ST-segment variations may reflect more pronounced myocardial injury in pediatric myocarditis. Previous studies have also reported that ST-segment and T-wave abnormalities are common in pediatric myocarditis; however, the diagnostic specificity of these findings remains limited[15]. Although sinus tachycardia has been reported as the most common arrhythmia in myocarditis[16], only one patient in our cohort developed supraventricular tachycardia requiring intervention, and ventricular tachycardia was not observed in this patient.

IVIG therapy is frequently used in pediatric myocarditis despite the lack of definitive evidence regarding its efficacy. Proposed mechanisms of action include neutralization of viral pathogens, modulation of the immune response, and suppression of pro-inflammatory cytokines. However, studies evaluating the effectiveness of IVIG therapy in pediatric myocarditis have reported conflicting results. In a Cochrane review by Robinson et al.[10], IVIG therapy was not associated with a significant impact on mortality or survival in children[17]. Similarly, Mounts et al.[18] reported that mortality in pediatric fulminant myocarditis is observed at a higher rate than in adults and emphasized that the evidence supporting the benefit of IVIG therapy remains limited.

In our study, IVIG therapy was not associated with a significant improvement in left ventricular systolic function. In addition, the time to troponin normalization was relatively prolonged in patients receiving IVIG therapy. However, this finding may reflect the fact that IVIG is typically administered to patients with more severe clinical presentations rather than a direct effect of the therapy itself. In other words, this observation may represent a type of selection bias. Indeed, in our cohort IVIG therapy was preferentially administered to patients with more severe clinical features, including higher troponin levels, significant ECG abnormalities, or left ventricular systolic dysfunction.

Previous studies have reported varying results regarding the effectiveness of IVIG therapy. Hyun Jung Kim et al.[19] reported that IVIG therapy had no significant effect on ventricular function or survival in pediatric myocarditis. In contrast, Huang et al.[20] and Drucker et al.[21] reported that IVIG therapy might be associated with improvement in ventricular function and increased survival. These inconsistent findings indicate that there is still no clear consensus regarding the role of IVIG therapy in pediatric myocarditis.

One notable observation in our study was the emergence of different cardiomyopathies during long-term follow-up in some patients. In one patient with recurrent troponin elevations and a family history of cardiomyopathy, genetic analysis revealed a mutation in the *DSP* gene, and follow-up findings were consistent with arrhythmogenic right ventricular dysplasia. *DSP* gene mutations have previously been reported to present initially with myocarditis-like clinical episodes[22]. Similarly, one of our patients was diagnosed with restrictive cardiomyopathy during follow-up. In addition, recurrent troponin elevations in one patient were found to be associated with macrotroponin positivity. Although macrotroponin is most commonly reported in association with troponin I, it may rarely accompany troponin T as well[23].

Study Limitations

This study has several limitations. First, it was a retrospective single-center study. Furthermore, the diagnosis of myocarditis was not histopathologically confirmed; instead, its diagnosis was based on clinical

findings, elevated cardiac troponin levels, and CMRI findings. Since endomyocardial biopsy was not routinely performed, diagnostic misclassification may be performed in some patients.

Only patients who underwent cardiac MRI were included in the study, which may have introduced selection bias and may limit the generalizability of the results. Although troponin levels were evaluated serially, a systematic analysis of their relationship with some clinical indicators of disease severity—such as intensive care unit admission, inotropic support, severe arrhythmias, or mortality—could not be performed.

Additionally, echocardiographic assessment was largely based on conventional parameters, and strain echocardiography as well as detailed diastolic function analyses were not performed in all patients. Finally, the number of patients in certain subgroups, particularly those with PM receiving IVIG therapy, was limited, which prevented conduction of multivariable analyses.

CONCLUSION

In conclusion, cTnT levels represent an important biomarker supporting the diagnosis of suspected pediatric myocarditis and may provide useful information during follow-up. However, in this study IVIG therapy was not associated with a clear-cut improvement in clinical course or left ventricular systolic function. Since IVIG treatment was preferentially administered to patients with more severe clinical presentations, the longer time to normalization of troponin levels observed in the IVIG group most likely reflects baseline disease severity rather than a treatment effect. Larger -scale prospective multicenter studies are required to more clearly determine the true impact of IVIG therapy in pediatric myocarditis.

Ethics

Ethics Committee Approval: The ethical approval was obtained from the University of Health Sciences Türkiye Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital Ethics Committee (decision no: 2025/14-12, date: 02.09.2025).

Informed Consent: This is a retrospective study.

Footnotes

Author Contributions

Surgical and Medical Practices: M.M.B., Concept: M.M.Y., Design: O.H., Data Collection or Processing: C.D., Y.İ.D., Analysis or Interpretation: M.M.B., S.G., Literature Search: G.V., O.H., Writing: M.M.B.

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