Original Article

Echocardiograms and bed placement in patients with multisystem inflammatory syndrome in children

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Background: Understanding of multisystem inflammatory syndrome in children (MIS-C) continues to evolve with extensive evaluations, including echocardiograms, obtained in emergency departments (EDs) to assist with clinical decision making and bed allocation. We assessed the utility of obtaining echocardiograms in the ED to assist in determining bed placement for this patient population.

Methods: This 2-year retrospective single-center study of patients 0–21 years old without underlying cardiac disease hospitalized for MIS-C focused on individuals whose initial evaluation occurred in the institution's ED and whose echocardiogram was obtained either in the ED or within 24 hours of admission. Patients were placed in two cohorts—those remaining in their unit of admission without transfer (cohort WoT) and those transferred (cohort T) from their initial unit to one with a differing level of care within 24 hours. Pearson chi-square test assessed the relationship between echocardiogram status and appropriate bed placement, defined as no transfer within 24 hours.

Results: Of the 60 patients who met study criteria, no significant difference was detected in rates of transfer between patients whose echocardiograms were obtained in the ED versus those obtained within 24 hours of admission (odds ratio =2.08; 95% confidence interval: 0.58, 7.95; P=0.28).

Conclusions: Cardiac involvement is a known complication of MIS-C; however, our study yields no evidence in favor of obtaining echocardiograms in the ED to ensure appropriate bed placement. While this modality remains integral in evaluation and management, it does not appear to be requisite as part of an emergent workup prior to admission.

Keywords: Echocardiogram; pediatric cardiology; pediatric emergency medicine; pediatric hospital medicine

Submitted May 16, 2024. Accepted for publication Aug 09, 2024. Published online Aug 28, 2024.
doi: 10.21037/tp-24-161
View this article at: https://dx.doi.org/10.21037/tp-24-161

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Introduction

Background

Multisystem inflammatory syndrome in children (MIS-C) is a post-infectious inflammatory process secondary to severe acute respiratory syndrome coronavirus 2 infection. Its heterogeneous presentation is characterized by multi-organ involvement with up to 80% of patients experiencing cardiovascular injury including coronary artery aneurysm, ventricular dysfunction, and decreased cardiac output leading to shock, arrhythmias, or heart failure (1-4). While the incidence of MIS-C peaked early in the coronavirus disease 2019 (COVID-19) pandemic (October 2020–April 2021), it remains clinically relevant and continues to cause critical illness in children. In the United States, in 2023, 50% of patients with MIS-C required pediatric intensive care unit (ICU) level care (5).

Rationale and knowledge gap

Given its relative nascency, much of what is known has been derived from our understanding of Kawasaki disease, including diagnostic evaluation and treatment regimens though there are currently no known criteria regarding bed placement (3,6,7). Factors surrounding admission decisions from the emergency department (ED) to either the general pediatric unit or pediatric ICU vary not only by institution but also by providers who must utilize both clinical and non-clinical factors such as cognitive load, provider expertise and comfort level with disease process, and bed availability (8-10). While pediatric studies have shown increased risk of mortality in patients transferred to the pediatric ICU within 24 hours of admission when compared to those initially admitted to the pediatric ICU without transfer, there is limited data regarding the impact of transfer between units with differing levels of care in patients with MIS-C (11-13).

Objective

Given the uncertainty surrounding ED MIS-C workup in conjunction with the prevalence of cardiac involvement, our study sought to ascertain the utility of performing echocardiography in the ED versus deferring until admission by comparing rates of transfer within 24 hours of hospitalization between the two groups. We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-24-161/rc).

Highlight box

Key findings

- For those patients with multisystem inflammatory syndrome in children (MIS-C), there is no evidence in favor of obtaining echocardiography in the emergency department (ED) to ensure appropriate bed placement upon admission.

What is known and what is new?

- Cardiac involvement is a known complication of MIS-C as is the need for both evaluation and monitoring. Both in the initial criteria as well as that revised in 2022, it remains an integral aspect of diagnosis.
- In our study, no significant difference was detected in rates of transfer following admission between patients with echocardiography obtained in the ED versus those obtained within 24 hours of admission with an odds ratio of 2.08 (95% confidence interval: 0.58, 7.95; P=0.28).

What is the implication and what should change now?

- In patients with MIS-C, we recommend prioritizing clinical evaluation and deferring echocardiography in the ED as it pertains to ensuring appropriate bed placement. Tangible implications of this include decreased length of ED stay as well as optimization of emergent evaluative modalities and resources.

Methods

We conducted a single center retrospective observational study in a 455-bed tertiary freestanding children's hospital with 49,000 annual ED visit and over 6,000 annual ED admissions per year. The study population consisted of patients zero to 21 years old diagnosed with the 2020 Centers for Disease Control and Prevention (CDC) case definition of MIS-C following evaluation in and hospitalization from St. Louis Children's Hospital's ED between July 1st 2020 and July 1st 2022 (14). Patients were included if initial evaluation occurred in our ED and had an echocardiogram performed either by a certified cardiac sonographer or pediatric cardiology fellow either in the ED or within 24 hours of admission with ensuing read by a pediatric cardiologist. Bed placement was determined independently by ED providers prior to this retrospective study. Individuals with a history of cardiac disease were excluded from the study given concern for provider bias impacting the decision to obtain echocardiography in this patient population as well as provider comfort regarding bed placement upon admission regardless of cardiac workup

or clinical status.

Those with a diagnosis of MIS-C, confirmed via positive COVID-19 polymerase chain reaction prior to hospitalization or outpatient notes confirming diagnosis following discharge, were identified through the electronic health records as were demographics, laboratory workup, cardiac testing, and bed placement with chart review utilized to obtain patient history and hospital course. Patients diagnosed with MIS-C were subsequently allocated to two cohorts—those remaining on their unit of admission without transfer (cohort WoT) versus those transferred to a unit with differing level of care within 24 hours of admission (cohort T). Given the progressive nature of MIS-C, variability in presentation and length of admission, as well as impact of interventions following hospitalization, appropriate bed placement was defined as remaining on the unit of admission without transfer for 24 hours following hospitalization. We assessed rates of transfer during this 24-hour time period as opposed to rates over the entirety of patients' hospitalization so as to minimize the impact of disease progression or hospital interventions and allow for focusing solely on emergent ED evaluation and workup (15). This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) with approval obtained by the Institutional Review Board (IRB) of Washington University in St. Louis (No. 202209041) prior to study initiation. Individual consent for this retrospective analysis was waived.

During the midst of our data collection, in October 2022, the CDC case definition of cardiac involvement in MIS-C was revised from including shock, or elevated troponin and/or brain natriuretic peptide (BNP), or any echocardiogram abnormality, or arrhythmia to a more stringent set of criteria including left ventricular (LV) ejection fraction <55% or coronary artery dilation, aneurysm, or ectasia, or elevated troponin. However, it was determined that, considering the CDC's utilization of the 2020 case definition of MIS-C for those with illness onset prior to January 2023, such as those in our study population, as well as receipt of IRB approval with use of the previous definition, our study's patient population would remain as such without recategorization using the updated 2022 designation.

Statistical analysis

Categorical data were reported as frequency with percentage and compared between two cohorts using Chi-square or Fisher's exact tests. Continuous data were reported as means with standard deviation or medians with interquartile ranges (IQRs) and compared using *t*-test or Wilcoxon rank sum test. Logistic regression was utilized to calculate the unadjusted odds ratio (OR) for transfer rates between patients with echocardiograms obtained in the ED versus those with echocardiograms obtained within 24 hours of admission and 95% confidence interval (CI). Multivariable exact logistic regression analyses with prespecified age and race in the model separately were performed to estimate the adjusted OR of being transferred among patient with and without LV dilation given impact on both the LV mass as well as systolic and diastolic function in the pediatric and young adult populations (16,17). P values <0.05 were considered statistically significant with all statistical analysis conducted via SAS® (SAS Institute Inc., Cary, NC, USA) 9.4 version.

Results

Of the 135 individuals initially evaluated for the purposes of this study, 23 final diagnoses were found to be inconsistent with MIS-C, 27 patients had been discharged following evaluation in the ED while 18 were directly admitted without ED evaluation, and seven echocardiograms were neither obtained in the ED nor within 24 hours of admission (*Figure 1*). Thus, a final cohort of 60 patients were included with a diagnosis of MIS-C and echocardiograms adherent to the study criteria. The population's mean age was 9.6±4.8 years, 31 (52%) White and 38 (63%) males with no significant difference detected in age, race, sex, ethnicity, or past medical history (PMH) between the two cohorts.

Patient echocardiograms were obtained either in the ED or within 24 hours of admission (*Figure 1*); 41 (68.3%) patients were placed in cohort WoT and 19 (31.7%) patients were placed in the cohort T. Six (14.6%) echocardiograms in cohort WoT and 5 (26.3%) in cohort T were obtained in the ED prior to admission with the remaining patients' echocardiograms obtained following admission (*Figure 1*). No significant difference was noted in rates of transfer between patients with echocardiograms obtained in the ED versus those with echocardiograms obtained within 24 hours of admission with an OR of 2.08 (95% CI: 0.58, 7.95; P=0.28).

In addition, no significant difference was detected in patients with abnormal electrocardiograms or echocardiograms between the two cohorts, barring the occurrence of left ventricular dilation exclusively in cohort WoT (*Table 1*). In fact, those with LV dilation were less likely to be transferred with an OR of 0.18 (95% CI: 0,

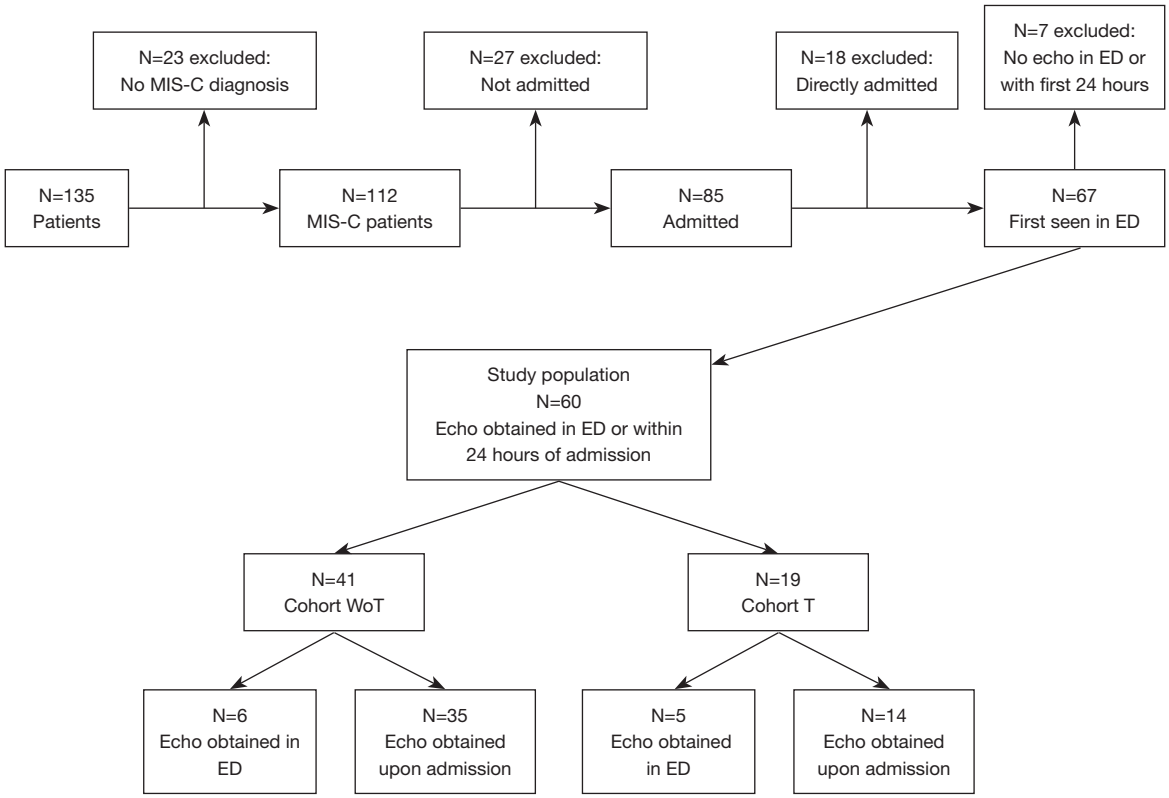

Figure 1 Exclusionary criteria and timing of echos obtained in cohorts WoT and T. MIS-C, multisystem inflammatory syndrome in children; ED, emergency department; echo, echocardiogram; WoT, without transfer within 24 hours; T, transfer within 24 hours.

0.96; P=0.045) after adjusting for age and 0.14 (95% CI: 0, 0.76; P=0.03) after adjusting for race. The decision to adjust for the aforementioned variables was secondary to known association with depressed function in younger, non-White patient populations (18,19). Further analysis of the two cohorts yielded no evidence of significant differences in the remaining cardiac evaluation (*Table 1*) or in the non-cardiac laboratory workup including CBC, lactate, fibrinogen, D-dimer, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) (*Table 2*).

Discussion

Key findings

As no difference was detected in rates of transfer for patients whose echocardiograms were obtained in the ED prior to admission versus those obtained following admission, our findings suggest obtaining echocardiograms as part of initial ED MIS-C workup to ensure appropriate bed placement following admission is not required. Cardiac involvement remains an integral aspect of the diagnostic criteria despite heterogeneity in both manifestation and resultant clinical presentation.

Explanation of findings

Physicians' perceived need for ICU care, limitations in assessing severity of the patients' illness, and ICU bed availability are factors known to impact bed placement (8,20-22). It may be postulated that clinical manifestations, such as hypotensive shock, palpitations and tachycardia, or chest pain during focused ED provider exam as well as cardiac markers on laboratory workup may have allowed for enough insight regarding cardiac function to determine bed placement following ED evaluation without requiring immediate, emergent echocardiography (23,24).

Our data also detected lower rates of transfer in those with LV dilation, even so when adjusted for age and race. It may be surmised that those with LV dilation presented with clinical manifestations of cardiac dysfunction such as cardiogenic or hypotensive shock as well as exertional

Table 1 Cardiac MIS-C ED workup

Reported variables	Total (n=60)	Cohort WoT (n=41)	Cohort T (n=19)	P value
BNP (pg/mL), median (IQR)	1,692 (569, 6,869.5)	1,783 (461, 7,176)	1,213 (597, 4,698)	0.97
Troponin (ng/mL)				
Normal, n [%]	22 [37]	15 [37]	7 [37]	0.98
Abnormal, n [%]	38 [63]	26 [63]	12 [63]	
Abnormal value (ng/mL)	0.2 (0.1, 0.6), n=38	0.3 (0.1, 0.7), n=26	0.1 (0, 0.4), n=12	0.09
Electrocardiogram, n [%]				0.75
Normal	14 [23]	9 [22]	5 [26]	
Abnormal	46 [77]	32 [78]	14 [74]	
Echocardiogram obtained in ED, n [%]				0.03
Yes	11 [18]	6 [15]	5 [26]	
No	49 [82]	35 [85]	14 [74]	
Echocardiogram results, n [%]				0.24
Normal	19 [32]	11 [27]	8 [42]	
Abnormal	41 [68]	30 [73]	11 [58]	
Right ventricular dilation, n [%]				NA
Yes	0 [0]	0 [0]	0 [0]	
No	60 [100]	41 [100]	19 [100]	
Right ventricular systolic function, n [%]				>0.99
Normal	57 [95]	39 [95]	18 [95]	
Abnormal	3 [5]	2 [5]	1 [5]	
Left ventricular dilation, n [%]				0.047
Yes	8 [13]	8 [20]	0 [0]	
No	52 [87]	33 [80]	19 [100]	
Coronary artery dilation, n [%]				0.25
Yes	9 [15]	8 [20]	1 [5]	
No	51 [85]	33 [80]	18 [95]	
Valvular regurgitation, n [%]				>0.99
Aortic and mitral	1 [3]	1 [5]	0 [0]	
Mitral	30 [97]	20 [95]	10 [100]	
Pericardial effusion, n [%]				0.56
Yes	16 [27]	10 [24]	6 [32]	
No	44 [73]	31 [76]	13 [68]	
Shortening fraction (%), median (IQR)	32 (25, 37.9)	34.7 (24.9, 38.8)	31.9 (27.9, 35.4)	0.45
Shortening fraction Z score, mean ± SD	−1.3±2.5, n=57	−1.3±2.6, n=38	−1.4±2.4	0.95

MIS-C, multisystem inflammatory syndrome in children; ED, emergency department; WoT, without transfer within 24 hours; T, transfer within 24 hours; BNP, brain natriuretic peptide; NA, not applicable; IQR, interquartile range; SD, standard deviation.

Table 2 Non-cardiac MIS-C emergency department workup

Variables	Total (n=60)	Cohort WoT (n=41)	Cohort T (n=19)	P value
WBC (k/cumm), median (IQR)	10.1 (7.3, 13)	10.2 (7.1, 12.7)	10 (7.9, 13.3)	0.55
Hemoglobin (g/dL), mean ± SD	11.9±1.7	11.9±1.5	11.8±2.2	0.82
Platelets (K/cumm), median (IQR)	162 (127, 241)	148 (121.5, 219.5)	201 (143, 271)	0.18
D-dimer (ng/mL), median (IQR)	1,936 (1,313, 4,035), n=55	1,907.5 (1,488, 4,035), n=38	2,127 (1,160, 2,641), n=17	0.44
Fibrinogen (mg/dL), mean ± SD	572.5±177, n=45	566±172.6, n=31	586.8±192.2, n=14	0.72
ESR (mm/hr), median (IQR)	44 (25, 58.5), n=56	41 (26, 56), n=37	49 (19, 76)	0.49
CRP (mg/L), mean ± SD	167.5±100.8, n=57	168.2±99.5, n=38	166.3±106.1	0.95

MIS-C, multisystem inflammatory syndrome in children; WoT, without transfer within 24 hours; T, transfer within 24 hours; WBC, white blood cells; IQR, interquartile range; SD, standard deviation; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.

dyspnea, fatigue, chest pain, and palpitations (25,26). These presentations may have resulted in more focused evaluations, thereby resulting in ensuing appropriate placement as this cardiac finding was detected exclusively in cohort WoT.

Implications

The findings of our study yield no evidence of obtaining echocardiography in the ED as part of initial MIS-C evaluation. It may be surmised that, by deferring cardiac imaging, this may subsequently decrease ED length of stay. Currently, time to completion of a typical echocardiogram is about 30 to 45 minutes with experienced sonographers (27,28). It may then also be postulated that in academic institution where trainees, such as cardiology fellows also assist in obtaining echocardiography, the study length may take longer to complete. Furthermore, upon obtaining imaging, subsequent interpretation and recommendations are also required prior to determination of bed placement with some variability in finalization of interpretation based on availability of an attending cardiologist (29-31). Thus, prioritizing ED clinical evaluation rather than echocardiographic evaluation, will allow for not only more rapid assessment of bed placement contingent on other biomarkers and clinical status, but also limit decisions based on preliminary echocardiogram interpretations.

Comparison with similar research

To our knowledge, this study is unique in evaluating a relationship between echocardiogram status and appropriate bed placement in patients with MIS-C. Previous studies have provided recommendations regarding ED evaluation and screening with algorithms formulated by institutions pertaining to this as well (2,4,32). However, there is currently no data pertaining to optimizing initial workup to subsequently ensure bed placement.

Strengths and limitations

This study was conducted in a single tertiary children's hospital whose MIS-C population displayed variability in clinical presentation when presenting to the ED, including those with severe cardiac involvement. As such, our aggregate data which suggests no value-added benefit of obtaining emergent echocardiograms in the ED upon initial evaluation, may be generalizable to other hospitals with similar catchment areas and patient population. In addition, the findings of this study yield the recommendation of prioritizing patient care by limiting unnecessary evaluative workup and focusing on clinical evaluation in the ED, thereby not only optimizing resource allocation, but also time in emergent situations and the ED. Furthermore, in resource limited centers, where cardiac dysfunction may not readily be assessed via use of limited echocardiography availability, clinical features such as tachycardia, hypotension, chest pain, and other physical exam findings may serve to optimize patient care and timely admission (33).

While this study assessed the initial laboratory and cardiac workup in the ED, we were not privy to the full decision-making process of our ED colleagues as it pertains to bed placement—including provider comfort, resource allocation, and workforce effects on admission (34). Thus, we elected to focus on laboratory and diagnostic workup rather than clinical presentation and hemodynamic values

in an effort to minimize variation in clinician interpretation and practice. However, as we have come to better understand the disease process, we feel this exclusion to have been a study limitation (35). While we recognize the benefit provided by echocardiograms in evaluating cardiac dysfunction, it must also be noted that while the setting in which our study was conducted yields to its strength, it may not be generalizable to other resource limited institutions where non-cardiologists have been trained to conduct echocardiograms, where aspects of MIS-C laboratory workup are not readily accessible, or, in non-pediatric centers wherein providers are unfamiliar with pediatric care echocardiography may be imaging modality required in order to conduct an appropriate cardiac evaluation (36-38). Furthermore, given known variability in MIS-C patient presentation, progression, and outcome-evaluation as it pertains to the timeline of the disease process may also impact the depth of ED workup (6,39). In addition, the declining prevalence of MIS-C, markedly so following the advent of vaccination in conjunction with study's small population yields to not only an increased risk of type two error, but also limits its generalizability to other institutions as patient characteristics, presentation, and disease severity may not be represented in our smaller study sample (40). As noted previously, ours is a tertiary care children's hospital and teaching center. Thus, those evaluated in our ED may present with worsened or refractory presentations requiring escalation of care that may not often be seen in other settings.

Conclusions

In summary, cardiac involvement is a known complication of MIS-C, however our study yields no significant evidence in support of obtaining echocardiograms in the ED to assist in guiding appropriate bed placement. While this modality remains crucial in evaluation and management, it does not appear to be requisite as part of an emergent workup prior to admission. Our study advocates for optimization of resource allocation during ED evaluation as it pertains to decision making regarding bed placement. Furthermore, it paves the way for future studies to discern the necessity of other evaluative modalities which are currently deemed both emergent and necessary for bed placement.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-24-161/rc

Data Sharing Statement: Available at https://tp.amegroups.com/article/view/10.21037/tp-24-161/dss

Peer Review File: Available at https://tp.amegroups.com/article/view/10.21037/tp-24-161/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-24-161/coif). W.B.O. received grant from the Missouri Chapter of the American College of Cardiology (ACC). The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) with approval obtained by the Institutional Review Board (IRB) of Washington University in St. Louis (No. 202209041) prior to study initiation. Individual consent for this retrospective analysis was waived.

References

1. Belhadjer Z, Méot M, Bajolle F, et al. Acute Heart Failure in Multisystem Inflammatory Syndrome in Children in the Context of Global SARS-CoV-2 Pandemic. Circulation 2020;142:429-36.
2. Mavrogeni SI, Kolovou G, Tsirimpis V, et al. The importance of heart and brain imaging in children and adolescents with Multisystem Inflammatory Syndrome in

Children (MIS-C). Rheumatol Int 2021;41:1037-44.
3. Wu EY, Campbell MJ. Cardiac Manifestations of Multisystem Inflammatory Syndrome in Children (MIS-C) Following COVID-19. Curr Cardiol Rep 2021;23:168.
4. Simpson JM, Newburger JW. Multisystem Inflammatory Syndrome in Children in Association With COVID-19. Circulation 2020;142:437-40.
5. Miller AD, Yousaf AR, Bornstein E, et al. Multisystem Inflammatory Syndrome in Children During Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Delta and Omicron Variant Circulation-United States, July 2021-January 2022. Clin Infect Dis 2022;75:S303-7.
6. Molloy EJ, Nakra N, Gale C, et al. Multisystem inflammatory syndrome in children (MIS-C) and neonates (MIS-N) associated with COVID-19: optimizing definition and management. Pediatr Res 2023;93:1499-508.
7. McAree D, Hauck A, Arzu J, et al. Clinical Predictors of Subacute Myocardial Dysfunction in Multisystem Inflammatory Syndrome in Children (MIS-C) Associated with COVID-19. Pediatr Cardiol 2024;45:876-87.
8. Ramos JGR, Ranzani OT, Dias RD, et al. Impact of nonclinical factors on intensive care unit admission decisions: a vignette-based randomized trial (V-TRIAGE). Rev Bras Ter Intensiva 2021;33:219-30.
9. Sperotto F, Gutiérrez-Sacristán A, Makwana S, et al. Clinical phenotypes and outcomes in children with multisystem inflammatory syndrome across SARS-CoV-2 variant eras: a multinational study from the 4CE consortium. EClinicalMedicine 2023;64:102212.
10. Haslak F, Yıldız M, Adrovic A, et al. A recently explored aspect of the iceberg named COVID-19: multisystem inflammatory syndrome in children (MIS-C). Turk Arch Pediatr 2021;56:3-9.
11. Snooks K, Scanlon MC, Remy KE, et al. Characteristics and Outcomes of Critically Ill Children With Multisystem Inflammatory Syndrome. Pediatr Crit Care Med 2022;23:e530-5.
12. Odetola FO, Rosenberg AL, Davis MM, et al. Do outcomes vary according to the source of admission to the pediatric intensive care unit? Pediatr Crit Care Med 2008;9:20-5.
13. Penk JS, Loke YH, Waloff KR, et al. Unplanned admissions to a pediatric cardiac critical care unit: a review of 2 years' experience. Pediatr Crit Care Med 2015;16:155-60.
14. DATA CT. CSTE/CDC Multisystem Inflammatory Syndrome in Children (MIS-C) Associated with SARS-CoV-2 Infection Surveillance Case Report Form Guidance, Effective. January 1, 2023. Available online: https://www.cdc.gov/mis/pdfs/mis-c_case-report-form-guidance-document.pdf
15. Slöcker Barrio M, Belda Hofheinz S, Guitart Pardellans C, et al. Characteristics and management of patients with SARS-CoV2 infection admitted to pediatric intensive care units: Data analysis of the Spanish national multicenter registry. Pediatr Pulmonol 2023;58:2916-29.
16. Pavlíček J, Strnadel J, Gruszka T, et al. Echocardiographic evaluation of cardiac structure and function in children with hypertension. Cor et Vasa 2016;58:e615-22.
17. Kishi S, Reis JP, Venkatesh BA, et al. Race-ethnic and sex differences in left ventricular structure and function: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. J Am Heart Assoc 2015;4:e001264.
18. Kapuku G, Howie M, Ghosh S, et al. Effects of Race, Cardiac Mass, and Cardiac Load on Myocardial Function Trajectories from Childhood to Young Adulthood: The Augusta Heart Study. J Am Heart Assoc 2021;10:e015612.
19. Brady TM, Fivush B, Flynn JT, et al. Ability of blood pressure to predict left ventricular hypertrophy in children with primary hypertension. J Pediatr 2008;152:73-8, 78.e1.
20. Mielke J, Martin DK, Singer PA. Priority setting in a hospital critical care unit: qualitative case study. Crit Care Med 2003;31:2764-8.
21. Giannini A, Consonni D. Physicians' perceptions and attitudes regarding inappropriate admissions and resource allocation in the intensive care setting. Br J Anaesth 2006;96:57-62.
22. Brisca G, Tardini G, Pirlo D, et al. Learning from the COVID-19 pandemic: IMCU as a more efficient model of pediatric critical care organization. Am J Emerg Med 2023;64:169-73.
23. Oragui CC. Cardiovascular Manifestations of Multisystem Inflammatory Syndrome in Children (MIS-C) Associated With COVID-19. Cureus 2023;15:e41950.
24. Karagözlü S, Ramoğlu MG, Bayram Ö, et al. Cardiovascular manifestations and cardiac magnetic resonance follow-up of multisystem inflammatory syndrome in children (MIS-C). Cardiol Young 2024;34:291-300.
25. Bouhemad B, Nicolas-Robin A, Arbelot C, et al. Acute left ventricular dilatation and shock-induced myocardial dysfunction. Crit Care Med 2009;37:441-7.
26. Zimmerman D, Shwayder M, Souza A, et al. Cardiovascular Follow-up of Patients Treated for MIS-C. Pediatrics 2023;152:e2023063002.
27. Mcllwain E. How Long? Journal of the American Society

of Echocardiography 2012;25:21A.
28. Kimura BJ, DeMaria AN. Time requirements of the standard echocardiogram: implications regarding limited studies. J Am Soc Echocardiogr 2003;16:1015-8.
29. Ruden EA, Way DP, Nagel RW, et al. Best practices in teaching echocardiography to cardiology fellows: a review of the evidence. Echocardiography 2016;33:1634-41.
30. Zhitny V, Iftekhar N, Alexander L, et al. Cardiology Fellow Diagnostic Accuracy and Data Interpretation Outcomes: A Review of the Current Literature. Vasc Health Risk Manag 2020;16:429-35.
31. Spahillari A, McCormick I, Yang JX, et al. On-call transthoracic echocardiographic interpretation by first year cardiology fellows: comparison with attending cardiologists. BMC Med Educ 2019;19:213.
32. Tritt A, Abda IN, Dahdah N. Review of MIS-C Clinical Protocols and Diagnostic Pathways: Towards a Consensus Algorithm. CJC Pediatr Congenit Heart Dis 2022;1:86-93.
33. Migowa A, Samia P, Del Rossi S, et al. Management of Multisystem Inflammatory Syndrome in Children (MIS-C) in resource limited settings: The Kenyan Experience. Pediatr Rheumatol Online J 2022;20:110.
34. Foster AA, Walls TA, Alade KH, et al. Review of pediatric emergency care and the COVID-19 pandemic. J Am Coll Emerg Physicians Open 2023;4:e13073.
35. Cole LD, Hammershaimb EA, Liang Y, et al. Awareness of Multisystem Inflammatory Syndrome in Children Among US Parents: A Cross-Sectional Survey. Open Forum Infect Dis 2023;10:ofad476.
36. Jain PN, Choi J, Katyal C. Pediatric Care in the Nonpediatric Emergency Department: Provider Perspectives. Hosp Pediatr 2019;9:216-9.
37. Rebmann T, Charney RL, Eschmann RL, et al. Non-Pediatric Nurses' Willingness to Provide Care to Pediatric Patients during a Disaster: An Assessment of Pediatric Surge Capacity in Four Midwestern Hospitals. Disaster Med Public Health Prep 2022;16:1053-8.
38. Acheampong B, Starnes JR, Awuku YA, et al. Feasibility of focused cardiac ultrasound training for non-cardiologists in a resource-limited setting using a handheld ultrasound machine. Cardiovasc J Afr 2023;34:268-72.
39. Elias MD, McCrindle BW, Larios G, et al. Management of Multisystem Inflammatory Syndrome in Children Associated With COVID-19: A Survey From the International Kawasaki Disease Registry. CJC Open 2020;2:632-40.
40. Hamad Saied M, van der Griend L, van Straalen JW, et al. The protective effect of COVID-19 vaccines on developing multisystem inflammatory syndrome in children (MIS-C): a systematic literature review and meta-analysis. Pediatr Rheumatol Online J 2023;21:80.

Cite this article as: Lodhi H, Singer E, McGlynn MC, Wang J, Hoefgen E, Srinivasan M, Orr WB. Echocardiograms and bed placement in patients with multisystem inflammatory syndrome in children. Transl Pediatr 2024;13(8):1406-1414. doi: 10.21037/tp-24-161