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RESEARCH

Kawasaki disease in the pre- and post-COVID-19 era: shifts in patterns and outcomes from a multi-center study

Maryam Alfalasi[1] · Rania Snobar[2] · Ikram Shaalan[3] · Aisha Alkhaaldi[2] · Khulood Khawaja[4] · Huda Aldhanhani[1] · Ghassan Ghatasheh[5] · Kamran Mahmood[3] · Najla Aljaberi[5,6]

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Abstract

Purpose Kawasaki disease (KD) is an acute vasculitis of childhood, with potential complications such as coronary artery aneurysms (CAAs). The COVID-19 pandemic introduced challenges in KD diagnosis and management due to its overlap with multisystem inflammatory syndrome in children (MIS-C). This study aims to compare the clinical presentation, laboratory findings, treatment approaches, and outcomes of KD before and after the COVID-19 pandemic across four centers in the United Arab Emirates (UAE).

Methods This retrospective study analyzed pediatric KD cases (classified per the American Heart Association "AHA" criteria) from four tertiary hospitals in the UAE. Patients were categorized into group 1 (pre-COVID-19: January 2017–January 2020) and group 2 (post-COVID-19: February 2020–January 2023). Patients not meeting the AHA criteria and those with MIS-C were excluded. Data collection included demographics, clinical and laboratory features, and echocardiograms, with coronary artery abnormalities assessed per AHA guidelines.

Results Among 138 included patients (67 in group 1, 71 in group 2), incomplete KD was significantly more common post-COVID-19 (45% vs. 25%, $p=0.020$). Lower occurrence of cervical lymphadenopathy (72% vs. 50%, $p=0.009$) and strawberry tongue (90% vs. 70%, $p=0.006$) were noted. Compared to group 1, group 2 had higher use of steroids (40.8% vs. 12.5%, $p=<0.001$) and biologics (8% vs. 1.5%, $p=0.502$). Although not statistically significant, CAAs were more frequent in group 2 (21% vs. 10%, $p=0.139$), with trends toward increased giant CAAs.

Conclusions: Our study highlights shifts in the patterns of KD in the post-COVID-19 era. We observed a higher prevalence of incomplete KD cases over the 3 years following the pandemic.

What is Known:
- *Post-COVID-19 pandemic era demonstrated the emergence of multi-system inflammatory syndrome in children (MIS-C) which overlaps with Kawasaki disease (KD).*
- *While most studies of KD and COVID-19 compare KD with MIS-C, very few describe changes in KD well after the peak of the pandemic.*

What is New:
- *This study combines data from four healthcare centers of KD patients classified per the American Heart Association (AHA) criteria with the exclusion of MIS-C patients to provide direct comparison of KD before and after COVID-19.*
- *Compared to the pre-COVID-19 era, KD cases post-COVID-19 tend to present in an incomplete form with less occurrence of cervical lymphadenopathy and strawberry tongue.*

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Maryam Alfalasi and Rania Snobar contributed equally to this work.

✉ Najla Aljaberi
najla.aljaberi@uaeu.ac.ae

[1] Department of Pediatrics, Sheikh Khalifa Medical City, Abu Dhabi, UAE

[2] Department of Pediatrics, Al Qassimi Women's & Children's Hospital, Sharjah, UAE

[3] Pediatric Rheumatology Division, Department of Pediatrics, Sheikh Shakhbout Medical City, Abu Dhabi, UAE

[4] University Hospitals of Leicester NHS Trust, Leicester, UK

[5] Department of Pediatrics, Tawam Hospital, Al Ain, UAE

[6] Department of Pediatrics, College of Medicine & Health Sciences, UAE University, Al Ain, UAE

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Keywords Kawasaki disease · Vasculitis · COVID-19

Abbreviations

AHA	American Heart Association
CAAs	Coronary artery aneurysms
CDC	Centers for Disease Control and Prevention
CRP	C-reactive protein
CMV	Cytomegalovirus
EBV	Epstein-Barr virus
ESR	Erythrocyte sedimentation rate
ICD-10	International Classification of Diseases-10
IRB	Institutional review board
IVIG	Intravenous immunoglobulin
KD	Kawasaki disease
KDSS	Kawasaki disease shock syndrome
MIS-C	Multi-system inflammatory syndrome in children
MRA	Magnetic resonance angiography
PA	Peripheral angiography
SARS-CoV-2	Severe acute respiratory syndrome coronavirus
UAE	United Arab Emirates

Introduction

Kawasaki disease (KD), an acute vasculitis primarily affecting children, continues to pose a significant public health concern due to its potential for causing coronary artery aneurysms (CAAs). While advancements in diagnosis and management have improved outcomes, understanding the disease's evolvement, particularly in the context of global health disruptions, is crucial. It has been hypothesized that the COVID-19 pandemic has affected KD in terms of presentation, laboratory workup, management, and outcomes[1]. Evidence shows that viruses like Epstein-Barr virus (EBV) and cytomegalovirus (CMV) increase the risk of autoimmunity, and severe acute respiratory syndrome coronavirus (SARS-CoV-2) may have a similar effect[2]. Viral infections are believed to induce autoinflammatory reactions involving molecular mimicry and bystander activation, raising the risk of autoimmunity[3–5]. Studies indicate an increased incidence of certain autoimmune disorders, including type 1 diabetes mellitus, ulcerative colitis, psoriasis, and autoimmune thyroiditis[6–8].

With the emergence of autoimmunity, a new inflammatory disorder emerged related to COVID-19 multisystem inflammatory syndrome in children (MIS-C)[9]. The diagnostic criteria as per the Centers for Disease Control and Prevention (CDC) involve clinical and laboratory workup in addition to exposure to a COVID-19 to define MIS-C[10]. The overlap between KD and MIS-C causes difficulties in the diagnosis and management[11]. The majority of MIS-C cases occur in children over the age of 5 years, while KD typically presents in younger age[1]. With regard to clinical features, it has been shown that KD patients are more likely to have rash, conjunctival injection, and CAAs, while patients with MIS-C are more likely to have gastrointestinal symptoms and thrombocytopenia[1, 12, 13]. Additionally, the cardiac involvement in MIS-C is more likely ventricular dysfunction and/or pericardial effusion [12–14].

Several reports outline that KD has changed in pattern after COVID-19[15–18]. While the abovementioned overlapping features between KD and MIS-C influence this conclusion, there may be discernible shifts in how classic KD has changed after the pandemic. This study aims to address this knowledge gap by comparing the patterns and outcomes of complete and incomplete KD before and well after the peak of the COVID-19 pandemic, across four tertiary hospitals in the United Arab Emirates (UAE).

Methods

Ethical approvals

The data was collected from various tertiary hospitals across the UAE using the International Classification of Diseases-10 (ICD-10) coding. The institutional review board (IRB) approval was obtained from the respective hospitals under the Department of Health for multi-center projects (reference number: DOH/CVDC/2023/1092). The hospitals that were included were Sheikh Khalifa Medical City (SKMC) in Abu Dhabi, Sheikh Shakhbout Medical City (SSMC) in Abu Dhabi, Tawam Hospital in Al Ain, and Al-Qassimi Women's & Children's Hospital (AQWCH) in Sharjah. Informed consent was waived as per the standard for retrospective studies.

Study design, patients, and data collection

This research was conducted as a retrospective descriptive study. It included all pediatric patients in four tertiary hospitals across the UAE, who were less than 16 years old and have been diagnosed with KD based on the American Heart Association (AHA) criteria[19]. Patients were classified as typical or complete KD upon having a fever of at least 5 days with the presence of at least four of the following five clinical signs: rash (maculopapular, or erythema-multiforme), cervical lymphadenopathy (at least 1.5 cm in diameter), usually unilateral, bilateral bulbar conjunctival injection without exudate, erythema and crackling of the lips, strawberry tongue, and/or oral and pharyngeal mucosal

erythema, erythema and edema of the hands and feet in the acute phase and/or periungual desquamation in the subacute phase. Patients were classified as incomplete KD if they had a fever for more than 5 days in addition to 2–3 of the above five mentioned clinical signs along with at least 3 of the 6 supportive laboratory criteria (albumin ≤ 3.0 g/dL, anemia for age, elevated ALT, platelets ≥ 450,000/mm^3, WBC ≥ 15,000/mm^3, urine WBC ≥ 10/high-power field), or a positive echocardiogram as per AHA guidelines.

As per the AHA criteria, the presence of a coronary artery aneurysm with a Z-score of 2.5 or above despite the absence of other criteria features confirmed the diagnosis of KD[19]. The updated MIS-C definition published in 2022[20] included patients under 21 years of age, presenting with fever (without a duration specified), CRP more than 30 mg/L, and new onset of at least 2 of the following: cardiac involvement, mucocutaneous involvement, shock, gastrointestinal involvement, and hematological involvement, with laboratory or epidemiological findings confirming SARS-CoV2. Patients who had overlapping symptoms of KD and MIS-C were also subject to the application of the AHA criteria for complete and incomplete KD. Those who met the AHA guidelines and had negative epidemiological evidence of SARS-CoV2 infection were considered to have KD (complete or incomplete). Finally, any patients not fulfilling the above-mentioned criteria or considered likely to have MIS-C were excluded.

Collected data included demographics, clinical features, laboratory values, and imaging results at onset and at follow-up. Laboratory values were taken at the peak or nadir of the specified test during the acute phase to be representative. If fewer than 10 patients had a specific laboratory value, these values were removed from the analysis; this includes interleukin-6 (IL-6), pro-BNP, and troponin levels, which were seldom done pre-COVID-19. Echocardiogram data were collected at predefined time points: 1 month, 6 months, and 1 year after the initial echocardiogram. The definitions of CAAs, including giant CAA, were used as per the AHA guidelines[19]. For those patients who exhibited giant CAAs, we collected echocardiogram data up to 2 years after discharge.

Finally, patients were categorized per their time of KD presentation into pre-COVID-19 group or "Group 1" (January 2017–January 2020) or post-COVID-19 group or "Group 2" (February 2020–January 2023).

Statistical analysis

Descriptive analysis was completed for all collected data. Comparisons were made between group 1 and group 2 with regard to clinical manifestations, laboratory markers, treatment patterns, and echocardiographic outcomes using the chi-square test (Fisher's exact test when appropriate) and independent *t*-test. IBM SPSS Statistics software, version 29.0.0.0 (241), was used to perform the statistical analyses.

Results

Figure 1 demonstrates a flowchart of patient inclusion and categorization into groups. A total of 430 patients with ICD-10 codes consistent with KD were identified. After applying the inclusion and exclusion criteria, 138 patients were included in the final analysis. Of those, 67 cases belonged to group 1 (pre-COVID-19) and 71 cases belonged to group 2 (post-COVID-19). The two groups had near equal proportions of males (60% vs. 66%, $p = 0.539$). Between the two groups, the mean age at diagnosis was 35 months in group 1, and 31 months in group 2, which was not statistically different ($p = 0.341$).

The direct comparison between group 1 and group 2 is outlined in Table 1. The clinical presentation between the two groups was mostly similar, with the exception of cervical lymphadenopathy (72% in group 1 vs. 50% in group 2, $p = 0.009$) and strawberry tongue (90% in group 1 vs. 70% in group 2, $p = 0.006$). The majority of the primary clinical features of KD, however, remained similar with the application of the inclusion and exclusion criteria. This minor shift in clinical features is also reflected strongly in the proportion of incomplete KD in the two groups. Of the 67 cases in group 1, 17 cases (25%) presented as incomplete KD. Of the 71 cases in group 2, 32 cases (45%) presented as incomplete KD. This shows a significantly higher number of incomplete KD post-COVID-19 ($p = 0.02$) even after applying the known KD diagnostic criteria and after removing MIS-C cases. The distribution of KD cases, including the proportion of incomplete KD each year, is demonstrated in Fig. 2.

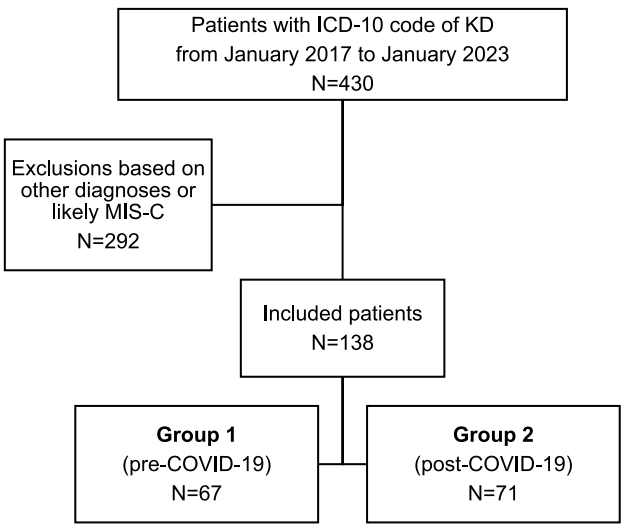

Fig. 1 Flowchart of included patients and the main categories of comparison

There were certain differences in laboratory parameters between the groups. Notably, group 1 patients exhibited higher levels of inflammatory markers, including C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), ferritin, and procalcitonin. Blood cell counts were equivalent between the two groups aside from a significant reduction of hemoglobin in group 2 ($p = 0.028$). There were no differences in liver enzymes, albumin, or coagulation markers (data not shown).

The management of KD cases showed significant changes between the two periods (Table 1). Intravenous

Table 1 Detailed description of the clinical, laboratory, treatment, and outcome differences between patients with KD before and after COVID-19 (group 1 vs. group 2)

Parameter	Group 1 ($N = 67$)	Group 2 ($N = 71$)	p-value
Clinical presentation			
Fever for 5 days	67 (100%)	68 (96%)	0.654
Cervical lymphadenopathy	48 (72%)	35 (50%)	**0.009**
Bilateral conjunctival injection	54 (81%)	59 (83%)	0.826
Rash	59 (88%)	58 (82)	0.348
Peripheral extremity changes	47 (69%)	43 (61%)	0.375
Strawberry tongue and/or cracked lips	60 (90%)	50 (70%)	**0.006**
Neurologic involvement	5 (8%)	7 (10%)	0.844
Incomplete KD	17 (25%)	32 (45%)	**0.020**
Laboratory values			
Hemoglobin (g/dL)	74.5 (40)	58.7 (43)	**0.028**
Lymphocytes ($\times 10^9$/L)	3.6 (3)	3.9 (3.7)	0.703
Neutrophils ($\times 10^9$/L)	10.7 (5.9)	9.57 (6.9)	0.323
Platelets ($\times 10^9$/L)	542 (285)	619 (337)	0.151
Creatinine (mg/dL)	38 (33)	31 (13)	0.095
ESR (mm/h)	74 (45)	60 (31)	**0.034**
CRP (mg/L)	162 (108)	126 (80)	**0.027**
Procalcitonin (ng/mL)	23.5 (38)	4.7 (10)	**< 0.001**
Management			
IVIG given	65 (97.0%)	71 (100.0%)	0.451
More than one IVIG Dose	18 (28%)	12 (17%)	0.151
IVIG adverse reactions*	0 (0%)	3 (4.4%)	0.264
Aspirin	61 (91%)	70 (99%)	0.103
Steroids	8 (12.5%)	29 (40.8%)	**< 0.001**
Steroid dose			0.705
Pulse (≥ 10 mg/kg)	4 (50%)	10 (35%)	
High dose (> 2 mg/kg)	1 (13%)	6 (21%)	
Low dose (0.5–1 mg/kg)	3 (38%)	13 (45%)	
Any biologics	1 (1.5%)	6 (8%)	0.502
Complications			
Shock	3 (5%)	4 (6%)	1.000
Coronary artery aneurysm	7 (10%)	15 (21%)	0.139
Giant artery aneurysm	1 (14%)	3 (20%)	0.987
Decreased LVF	0 (0%)	2 (2.8%)	0.502
Prognosis			
Abnormal Z-score at 1 month of discharge	5 (9%) $N = 54$	7 (14%) $N = 51$	0.549
Abnormal Z-score at 6 months of discharge	2 (7%) $N = 29$	5 (15%) $N = 33$	0.433
Abnormal Z-score at 1 year of discharge	2 (13%) $N = 16$	3 (21%) $N = 14$	0.191

Values are described as mean (SD) for numeric variables and frequency (%) for categorical variables. Bolded values indicate statistically significant differences ($p < 0.05$).

*Adverse reactions from IVIG: allergic reaction or anaphylaxis.

immunoglobulin (IVIG) was administered to almost all patients in both groups (two patients in group 1 declined IVIG treatment and had normal coronary arteries). While analyzing IVIG dosing patterns, some cases were not given the classic 2 g/kg dose at once; therefore, we compared the frequency of having more than one IVIG between the two groups, indicating possible repeat dosing and refractoriness of the typical 2 g/kg dose. The portion of patients who received multiple doses of IVIG (> 2 g/kg total) was not significantly different between the groups (28% in group 1 vs. 17% in group 2, $p = 0.151$). Steroid use was notably higher in group 2, with 40% of patients given steroids as compared to 12% of patients in group 1. Pulse steroid and high-dose steroids were also more prevalent in group 2. The use of biologics remained infrequent in both groups, but with trends towards using more biologics in group 2.

The two groups were compared with regard to complications and outcomes of their KD presentation. When hypotension and poor perfusion present with KD, it is termed as Kawasaki disease Shock syndrome (KDSS)[21]. In our included patients, 4.5% had KDSS in group 1 and 5.6% in group 2 without statistical significance. Despite having small numbers in this cohort, CAAs were more prevalent in group 2, with a higher proportion of giant CAAs. On the other hand, the incidence of ventricular dysfunction was also higher in group 2. Those cases were not frequent enough to show statistical significance. Regarding long-term outcomes, as measured by *Z*-scores through echocardiography, there was a trend towards more abnormal *Z*-scores in group 2, particularly at the 1-year follow-up. However, this difference did not reach statistical significance.

Upon closer look at the four cases of giant CAAs in our cohort, we found that all presented in infancy (< 12 months of age). Out of those, two patients were incidentally found to have systemic arterial aneurysms (SAAs). The affected vessels included internal and external carotid arteries, brachial, axillary, vertebral, abdominal aorta, renal, splenic, inferior mesenteric, and internal iliac arteries. The first patient presented at 8 weeks of age with fever, loose stools, and unilateral lymph node enlargement. Labs were significant for transaminitis, coagulopathy, and hyperbilirubinemia. He was treated initially as a case of MIS-C, but due to persistent fever, an echocardiogram was obtained which revealed giant aneurysms. Given his age and CAA presentation, he was labeled as KD. After anti-inflammatory treatment with high-dose steroids, IVIG, high-dose aspirin, anakinra, and infliximab, he was maintained on an anticoagulation regimen with warfarin, low-dose aspirin, and clopidogrel. At 2 years of follow-up, he continues on anticoagulation therapy and cardiac monitoring with improvement in some coronaries but remaining giant CAA. The second patient presented at 8 months of age with fever, diarrhea, rash, and peripheral limb edema. He also had a protracted fever with echocardiogram showing giant CAAs leading to the diagnosis of KD. He also had SAA in addition and was treated aggressively with a similar regiment of anti-inflammatory treatment. Interestingly, he also developed erythema nodosum, which is a feature of small to medium-vessel vasculitis and is part of systemic vasculitides[22]. He underwent whole-exome sequencing given his atypical presentation, and it was negative for variants of interest including *ADA2* gene mutations. After the initial KD treatment, his acute symptoms resolved including the erythema nodosum. Follow-up showed resolution of his CAAs and SAAs. The other two patients were not investigated for SAA. The third patient was a previously healthy 7-month-old boy who presented with complete KD. He developed giant left coronary and right coronary aneurysm with left coronary artery thrombus. The thrombus was large enough to occlude the left coronary artery, leading to cardiac arrest needing resuscitation and initiation of extra-corporeal membrane oxygenation. He required pulse steroids, thrombolytic therapy for cardiac thrombus, plasmapheresis, heparin, inotropes, aspirin, clopidogrel, infliximab, and anakinra. Unfortunately, with all the therapies, and after 4 months in the PICU, he was discharged to a long-term facility with complications of hypoxic ischemic encephalopathy and acquired cardiomyopathy. The fourth

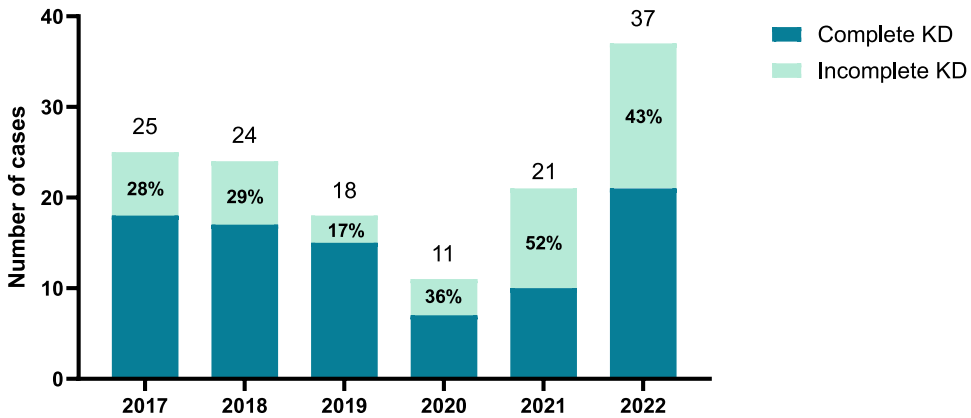

Fig. 2 Number of KD cases per year (total number is above each bar) including the percentage of incomplete KD cases each year (lighter top part of the graph). Data collection extended to January 2023 ($N = 2$ cases), but this is not included in the graph as the data does not represent a whole year

patient had the most favorable outcome; he was a 4-month-old boy who presented at day 14 of fever and met the criteria for complete KD. The largest aneurysm was at the left anterior descending artery with a *Z*-score of 14. He received one dose of IVIG, aspirin, and clopidogrel. He was discharged after 6 days in the regular ward. His clopidogrel was discontinued after 14 months. Echocardiogram at age 6 years revealed the largest aneurysm in the proximal right coronary artery with a *Z*-score of 4.5. He is growing well and continuing to follow up with cardiology while being maintained on aspirin.

Discussion

This study investigated the impact of the COVID-19 pandemic on KD presentation and outcomes by comparing cases diagnosed before and after the COVID-19 pandemic across four tertiary pediatric hospitals in the UAE. While most clinical features remained consistent given the selective nature of this study, there was a significantly higher proportion of incomplete KD in the era post-COVID-19. Some of the first studies describing MIS-C in early 2020 as "Kawasaki-like disease" reported a high proportion of incomplete KD[9]. Many of those cases were later given the designation MIS-C after further charachterization[1, 12, 23]. In our study, we aimed to narrow the spectrum by eliminating cases that did not meet the AHA criteria for KD. The evolution of KD clinical patterns poses a diagnostic challenge and requires more focused efforts to raise the awareness of such atypical presentations. Regional and international collaboratives serve as major platforms to enhance the diagnostic process and inform the practicing physicians about the impact of early treatment[24–26].

We note a slightly younger age of presentation in our cohort after COVID-19, which has been demonstrated in other studies[18]. We do not report on the incidence of KD before and after COVID-19 in our study given the limited retrospective design. However, we do note the decline in reported cases in 2020 in line with other reports where it has been attributed to lower use of healthcare facilities and lower prevalence of common viral pathogens that would typically trigger KD[2, 27, 28].

In our population, KD has characteristically presented in an incomplete form more often after COVID-19. This is reflected by similar results in many centers internationally, where incomplete KD had a higher incidence rate in the post-pandemic as compared to the pre-pandemic[18, 26]. Similarly, a significant reduction in strawberry tongue and cervical lymphadenopathy was observed in our study and internationally[15, 29].

A notable finding was the elevated levels in inflammatory markers (ESR and CRP) in the pre-COVID group, suggesting a more severe inflammatory response in these patients. We hypothesize that, due to the more rapid response during COVID-19, identification and prompt management of KD cases led to lower peaks of inflammation. However, this cannot be ascertained in this study, as we do not have data on the onset of treatment.

Patients in our study have received IVIG at the standard dose of 2 g/kg once or more in cases of refractory KD. This was less frequent in the post-COVID-19 group, which was associated with higher and more frequent doses of steroids as well as more frequent use of biologics. Receiving less IVIG post-COVID-19 in our cohort could be either due to successful response to the first dose or refractoriness and escalation of treatment with steroids and biologics. Refractoriness to first-dose IVIG was also noted in other reports during the pandemic period[30]. Given the parallel presence of MIS-C cases during the post-COVID-19 period, we believe that many physicians in our cohort simulated treatment patterns of MIS-C and applied them to KD. This pattern of treatment was encouraged in severe cases of MIS-C, where it has been recommended to use cytokine blockade after failure of a single dose of IVIG[23]. The same theory applies to the more frequent use of steroids and biologics in our post-COVID-19 cohort, where a more aggressive treatment approach was used due to perceived disease severity[30] or changes in treatment guidelines in response to the pandemic and the surge of MIS-C cases[23]. Analyzing the influence of those treatment patterns on overall outcomes and on CAAs is of incredible value but is limited, given the small sample size.

Several reports noted the higher number of CAAs and giant CAAs after COVID-19[31–33]. We note the same trend, although without statistical significance. We also identified incidental SAAs, which are infrequently reported in the literature. In one of the largest studies from China, high-risk patients were screened with full-body magnetic resonance angiography (MRA) or peripheral angiography (PA). They found that patients with SAA had a younger median age at onset (5 months) and a longer duration of fever. Notably, there was no difference with regard to the day at which IVIG was administered[34]. Most importantly, the regression rate of those SAAs is high, which is reassuring.

While our study provides valuable insights, it is limited by its retrospective design. The relatively short post-pandemic period may not fully capture the long-term impact of the pandemic on KD, but it is one of the few studies demonstrating data 3 years during and post-pandemic. The influence of concurrent pandemic-related factors, such as changes in healthcare-seeking behaviors, cannot be entirely discounted. Our study emphasized the application of the known AHA criteria to include cases of

complete and incomplete KD, while cases of MIS-C were excluded to a high degree to provide as clear a distinction as possible and to understand the post-pandemic impact on KD while using the traditional criteria. Nonetheless, we recognize that some degree of diagnostic uncertainty is inherent, given the clinical overlap between KD and MIS-C, particularly in atypical presentations. This represents a potential limitation in interpreting our findings, despite our efforts to apply standardized definitions rigorously.

The findings of this study highlight the need for continued surveillance and research to understand the long-term implications of the COVID-19 pandemic on KD. Longer follow-up periods with adjudicated KD cases meeting the traditional criteria would be of high value that could influence practice in the long run.

Conclusion

In conclusion, our study provides insights into the evolving landscape of KD following the COVID-19 pandemic. We found that KD patients presented more often with an incomplete presentation within the 3 years post-COVID-19. Features like cervical lymphadenopathy and strawberry tongue were lower in occurrence.

Author contributions Study conceptualization was performed by Najla Aljaberi, Maryam Alfalasi, Kamran Mahmood, Aisha Alkhaaldi, Ghassan Ghatasheh, Huda Aldhanhani and Khulood Khawaja. Data collection and analysis were performed by Maryam Alfalasi, Rania Snobar, Ikram Shaalan and Najla Aljaberi. The first draft of the manuscript was written by Maryam Alfalasi, Rania Snobar and Najla Aljaberi. All authors read, edited and approved the final manuscript.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate The study was performed in accordance with the Declaration of Helsinki and was approved by the Department of Health (DOH) for multi-center projects (reference number: DOH/CVDC/2023/1092). Informed consent was waived as per the regulation for retrospective studies.

Competing interests The authors declare no competing interests.

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