PEDIATRIC IMAGING

I J Radiol. 2024 January; 21(1):e143026. https://doi.org/10.5812/ijradiol-143026.

Published online 2024 June 29. **Research Article**

Ultrasonic Cardiac Output Monitor (USCOM) Parameters in Pediatric COVID-19 Patients: A Case Series

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Received 2023 November 29; **Revised** 2024 May 17; **Accepted** 2024 May 20.

Abstract

Background: The increase in the spread of the novel coronavirus (SARS-CoV-2) has put many children at risk around the world. Some of these patients are in critical condition and present with shock symptoms and cardiac system problems. The ultrasonic cardiac output monitor (USCOM) is a non-invasive device that determines a person's cardiac output using continuous wave Doppler ultrasound.

Objectives: The current study aims to present the clinical and laboratory manifestations of children with coronavirus disease (COVID-19) and to use a USCOM device for hemodynamic assessment to record and review their clinical information.

Patients and Methods: We introduce 22 cases of children infected with coronavirus admitted to a public hospital in Iran. We examined the hemodynamics of these patients using USCOM and reported our experience with pediatric patients presenting with shock. This was a retrospective study, and data were collected using medical records.

Results: In this study, 22 pediatric cases (10 girls and 12 boys) infected with coronavirus were reported. The youngest was 3 months old and the oldest was 14 years old. The most commonly observed symptoms were low back pain (N = 15), fever (N = 12), and seizures (N = 10). We found that the hemodynamics of the patients, including systemic vascular resistance (SVR), were abnormal and were associated with hypotension and unstable hemodynamics. The children responded well to the administration of an intravenous norepinephrine drip.

Conclusion: This study presents detailed clinical and laboratory results of 22 children with COVID-19. Additionally, their hemodynamic status was measured and presented using the USCOM device. This information can provide physicians with a comprehensive understanding of the clinical history of patients referred with COVID-19, thereby improving their knowledge and care delivery.

Keywords: USCOM, COVID-19, Hemodynamic, Cardiac Output, Pediatrics

1. Background

The coronavirus disease (COVID-19) has spread widely around the world. Studies indicate that children are less affected than adults, exhibiting milder symptoms and lower mortality rates (1, 2). However, the clinical and epidemiological characteristics and the definitive treatment protocol in children are not yet clear. Li et al. highlighted this significant knowledge gap and attempted to introduce and categorize these symptoms in their systematic review of 96 case studies on children (3). Lai et al.'s study notes that few studies have addressed the characteristics and clinical manifestations of children with COVID-19 (4). In children, shock has also been reported as a complication of COVID-19, treated under the multisystem inflammatory syndrome in children (MIS-C) (5). Shock occurs in up to 67% of patients in intensive care and has been associated with high mortality (6). Close monitoring of cardiac output (CO), intravascular volume (IVV), and hemodynamic parameters is essential for these severe cases, which typically require mechanical ventilation (7). In recent years, there has been a gradual reduction in the use of pulmonary artery catheters

and thermodilution measurement of CO (8), and less invasive methods (9) have replaced them. However, these alternatives have not been satisfactory due to a lack of accuracy. Therefore, there is an urgent need for reliable and cost-effective non-invasive devices for CO monitoring (10). The ultrasonic cardiac output monitor (USCOM) is a non-invasive device that determines a person's cardiac output using continuous wave Doppler ultrasound (11). Introduced in 2001, USCOM is now used in a wide range of clinical settings and plays a significant role in monitoring intensive care (12). Although preload, contractility, systemic vascular resistance (SVR), stroke volume (SV), and CO can also be measured by echocardiography, this method requires a skilled and specialized physician (13). The accuracy and reliability of USCOM have been confirmed in various studies (12, 13). In this study, we present the results obtained from the USCOM device and other clinical findings of COVID-19 patients.

2. Objectives

The current study aims to present the clinical and laboratory manifestations of children with COVID-19 and to use a USCOM device for hemodynamic assessment to record and review their clinical information. The research questions are: (1) what are the clinical and laboratory results of children with COVID-19? (2) what is the hemodynamic status of children with COVID-19 using a USCOM device? (3) what treatments have been considered for children with COVID-19, and what have been the results?

3. Patients and Methods

This retrospective study was conducted in a public hospital in Iran. Children infected with COVID-19 who visited this facility between September and October 2022 were included in the study. Confirmation of the COVID-19 diagnosis in these patients was done by one of the following methods: Lung CT scan, real time-PCR test, or serology. Twenty-two patients who agreed to participate in the study and completed the informed consent form were selected as samples. All patients were well-informed about the procedures and the potential side effects. The Ethics Committee of Iran University of Medical Sciences approved this study. In addition to completing the informed consent form, patients were assured that their data would be published without revealing their identities.

Inclusion criteria included all children under 18 years of age and older than one month who were hospitalized in the PICU, treated with the diagnosis of COVID-19, and had hemodynamic instability in the evaluations. They were diagnosed with COVID-19 according to the final diagnosis in the medical record. Exclusion criteria included age under one month, hemodynamic stability, and children with other concurrent diseases or underlying heart disease. Data related to tests, clinical evaluations, and imaging findings of these patients were extracted from their medical records. The data was collected using a form whose validity was confirmed by experts. This form included the patient's demographic, clinical, and laboratory information, as well as the treatment and medication administered.

A USCOM device was used to check the hemodynamic data of the patients, and this evaluation was done by a specialist doctor. The evaluation of each patient took a few minutes, measuring the following items: Corrected flow time (FTC) (preload), peak velocity (VPK) (contractility), and SVR. The operators who performed the USCOM assessments were pediatricians and PICU fellows who had been well trained to work with the device and had several months of experience. Data analysis was presented using descriptive statistics and in the form of tables and graphs. All data were analyzed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

4. Results

In this study, we reported 22 pediatric cases infected with coronavirus who were admitted to a public hospital in Iran. Ten of them were girls and twelve were boys. The youngest was 3 months old and the oldest was 14 years old. Most of the children were between 1 - 5 years old and 5 - 10 years old. Table 1 shows the demographic information of these patients.

Table 2 shows the signs and symptoms observed in children. Various symptoms developed in the children, with the most commonly observed being low back pain (N = 15), fever (N = 12), seizures (N = 10), respiratory distress (N = 10), and low consciousness (N = 9). All percentages presented in the table are based on the total number of patients.

Table 3 provides information related to examination and laboratory findings as well as USCOM results.

Most patients had lymphopenia and elevated erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP). Six patients were intubated. Antiviral treatment, antibiotics, and supportive care were provided for the patients. Except for two cases, all other patients were discharged after clinical recovery. All of these

Table 1. Characteristics of the Sample Population

Population Characteristics	No. (%)
Sex	
Boy	12 (54.5)
Girl	10 (45.5)
Total	22 (100)
Age	
Under 1 year	4 (18.1)
1 - 5	7 (31.8)
5 - 10	7 (31.8)
Above 10 years	4 (18.1)
Total	22 (100)

Table 2. Signs and Symptoms of Patients

Sign and Symptoms	No. (%)
Abdominal pain	4 (18.18)
Fever	12 (54.55)
Cough	4 (18.18)
Vomiting	6 (27.27)
Headache	1 (4.55)
Rhinorrhea	1 (4.55)
Seizure	10 (45.45)
Loss of consciousness	9 (40.91)
Low BP	15 (68.18)
Edema	4 (18.18)
Respiratory distress	10 (45.45)
GI Bleeding	1 (4.55)
Gastroenteritis	3 (13.64)
Diarrhea	2 (9.09)
Skin maculopapular rash	1 (4.55)
Upward gaze for 15-minute	1 (4.55)
Pleural effusion	1 (4.55)

Table 3. Examination, Laboratory, and Ultrasonic Cardiac Output Monitor Finding

Feature and Title	Mean ± SD
Examination & laboratory finding	
WBC (mm^3)	11518.2 ± 5761.8
Lymph %	19.2 ± 11.4
Segs %	74.8 ± 14.3
Hb (g/d)	10.9 ± 1.9
Plt (mm^3)	250909.1 ± 180022.5
ESR (mm)	22.2 ± 18.8
CRP (mm)	37.3 ± 26.0
D-dimer (ng/m)	3415.4 ± 5249.3
PT (se)	14.9 ± 3.0
PTT (se)	45.5 ± 26.8
INR (index)	1.3 ± 0.5
Troponin (ng/L)	352.1 ± 769.4
Blood pressure-systole (mmHg)	75.4 ± 12.5
Blood pressure-diastole (mmHg)	50.8 ± 13.0
USOM results	
SVRI (ds cm^{-5} m^2)	743.1 ± 86.3
VPK (m/s)	1.3 ± 0.3
Heart rate (bpm)	112.0 ± 12.2
FTC (ms)	367.1 ± 20.4
Duration of drug use	
Duration of norepinephrine	6.6 ± 4.9
Duration of epinephrine	7.5 ± 4.0
Duration of hospitalization (days)	16.5 ± 12.3

Abbreviations: WBC, white blood cell; Hb, hemoglobin; Plt, platelets; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; PT, prothrombin time; PTT, partial thromboplastin time; INR, international normalized ratio; SVRI, systemic vascular resistance index; VPK, peak velocity; FTC, corrected flow time.

patients had low systemic vascular resistance index (SVRI), and six of them had normal blood pressure and were not treated with inotropic drugs. The average length of hospitalization was about 16.5 days. The information related to all patients is presented separately in Table 4.

As seen, this study encompasses 22 pediatric patients with varied clinical presentations. Patients presented with symptoms such as seizures, abdominal pain, respiratory distress, fever, and shock, necessitating treatments including antibiotics, antivirals, immunoglobulins, and vasopressors. Mechanical ventilation was required for several patients due to respiratory compromise, and arrhythmias were observed in some cases. Despite the severity of the illness, the majority of patients were discharged in stable condition after receiving appropriate medical intervention. Unfortunately, one patient succumbed to the illness.

5. Discussion

In the current study, all 22 patients presented with a low systemic vascular resistance index. Six patients had low SVRI despite normal blood pressure. Systemic vascular resistance plays an important role in creating and regulating blood pressure (14). Clinical examination is a crucial tool for evaluating and treating critically ill patients with hemodynamic disorders. However, in complex cases, this assessment may be done incorrectly.

Echocardiography is an excellent tool for checking hemodynamic status and heart function, but it requires a cardiologist and is time-consuming. The USCOM device is very useful for accurate and quick assessment of hemodynamic status. It is also valuable for treatment follow-up and serial evaluation of patients (15). The USCOM device helped us assess the hemodynamics and response to the treatments performed in COVID-19 patients. With this device, we serially checked the hemodynamic parameters of the patients and adjusted the fluid therapy and inotropic drugs based on the results.

We found that the hypotension and decreased urine output of patients were secondary to the reduction of systemic vascular resistance. With the administration of norepinephrine, the patients' conditions stabilized well. The USCOM monitor plays an important role in intensive care monitoring. It is non-invasive, fast, accurate, affordable, safe, tolerable, and easy to learn to use. However, during the learning phase, USCOM measurements are somewhat operator-dependent. This device is suitable for use in cases of shock, dehydration, hypotension, and low cardiac output states.

In conclusion, this study presents detailed clinical and laboratory results of 22 children with COVID-19. Additionally, information related to their hemodynamic status was measured and presented using the USCOM device. While multiple studies have assessed COVID-19 characteristics, viral genetics, signs, symptoms, and complications, the use of USCOM in the evaluation and treatment of COVID-19 patients has not been reported until now. We recommend the use of the USCOM device for patient evaluation. It is hoped that this study will increase awareness of the specific subtype of shock associated with COVID-19 and its treatment. This information can provide physicians with a comprehensive understanding of the clinical history of patients presenting with COVID-19, thereby improving their knowledge and care delivery. However, this information is not sufficient to draw a final conclusion, and more studies are needed. We are currently using USCOM to evaluate other patients with hemodynamic disorders and will publish the results in the future.

Acknowledgments

The authors thank all patients and their families for letting us share their experience.

Footnotes

Authors' Contribution: M.V., R.Z.M., and A.G., conceived of the presented idea. A.M.A., M.S., and G.G. managed the clinical and therapeutic part of the research. M.R., M.K., and M.V., collected data and prepared the draft manuscript. R.Z.M., and A.G. verified the analytical methods and supervised the findings of this work. All authors reviewed the results and approved the final version of the manuscript.

Conflict of Interests Statement: The authors declares that there is no financial, personal, or other conflict of interest regarding the publication of this paper.

Data Availability: The data used to support the findings of this study are included within the article.

Ethical Approval: This study was approved by the Research Ethics Committees of Iran University of Medical Sciences (REC number: IR.IUMS.FMD.REC.1401.332).

Funding/Support: The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent: Written informed consent was obtained from the patient's legal guardian for publication of this study and any accompanying images.

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Table 4. Summary of Clinical Presentation of Patients

Title	Age	Gender	Symptoms and signs	Chest CT Scan	WBC (mm^3)	Lymph %	Segs %	Hb (g/d)	Plt (mm^3)	ESR (mm/h)	CRP (mg/L)	D-dimer (ng/m)	PT (s)	PTT (s)	INR (index)	B/C	Troponin (ng/L)	COVID-19 PCR	COVID-19 serology (index)	SVRI (ds cm^{-5} m^2)	VPK (m/s)	Heart rate (bpm)	FTC (ms)	Blood pressure (mmHg)	Duration of norepinephrine (day)	Duration of epinephrine (day)	Duration of hospitalization (day)
Patient #1	9	Boy	Abdominal pain, vomiting, cough, generalized tonic colonic seizure, loss of consciousness, GI bleeding, acral edema, low blood pressure	Peripheral ground glass opacities due to COVID-19	3700	37	59	13.8	107000	25	26	12715	18	69	1.7	Neg	1998	Neg	IgM = 0.1, IgG = 0.2, (neg)	632	0.9	107	369	75/31	4	4	15
Patient #2	10	Girl	Abdominal pain, headache, fever, vomiting and diarrhea, acral edema, low blood pressure	Mild pleural effusion and ground glass opacities	7500	5.6	92	10.5	87000	58	62	2413	16	47	1.4	Neg	331.4	Pos	IgM = 1.3, IgG=1.2, (pos)	802	1.3	104	372	71/46	6	4	18
Patient #3	7.5	Girl	Fever, vomiting, skin maculopapular rash, epigastric abdominal pain, acral edema, low blood pressure	Peripheral ground glass opacities dominant in left lower lobe due to COVID-19	5800	20	71	10	102000	50	59	4291	13	32	1	Neg	86.6	Neg	IgM = 0.8 → 1.3, IgG = 0.9 → 1.2, (pos)	620	1.9	148	403	67/53	5	-	10
Patient #4	7	Boy	Fever, rhinorrhea, diarrhea, generalized tonic colonic seizure, low blood pressure	No significant data	2600	35	54	11.8	177000	17	72	1538	13	27	1	Neg	121.9	Neg	IgM = 0.3 → 1, IgG = 0.3 → 1.1	720	1.3	110	380	70/60	2	-	5
Patient #5	13	Girl	Fever and cough, movements suspected of seizures, loss of consciousness, periorbital and acral edema, low blood pressure	Peripheral ground glass patchy opacities due to COVID-19 and Evidence of aspiration pneumonia	8300	17	77	14.2	280000	58	27	3317	15	37	1.3	Neg	17	Neg	IgM = 0.1 → 0.9, IgG = 0.3 → 0.8	880	0.85	108	344	68/56	14	2	14
Patient #6	5	Girl	Abdominal pain, vomiting, status tonic colonic seizure	Mild peripheral ground glass patchy opacities	13000	45	50	11.7	419000	10	24	23000	14	28	1.2	Neg	29	Neg	IgM = 0.6; IgG = 1.5, (pos)	747	1.4	94	346	65/45	4	-	14

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Table 4. Summary of Clinical Presentation of Patients (Continued)

Patient #7	7	Girl	Cough, atonic seizure, respiratory distress, loss of consciousness, low blood pressure	Peripheral ground glass opacities due to COVID-19	28000	17	75	11.3	123000	1	21	757	13	37	1	Neg	21	Neg	IgM = 0.1, IgG = 0.2, (neg)	765	1.2	103	322	84/40	5	-	10
Patient #8	4	Boy	Fever, upward gaze for 15-minute, loss of consciousness, low blood pressure	Ground glass opacities and upper left lung collapse	10000	21	75	11.2	167000	10	30	890	13	29	1	Neg	1.5	Neg	IgM = 0.3, IgG = 1.2, (pos)	713	1.3	105	370	77/44	7	-	15
Patient #9	0.25	Girl	Fever, gastroenteritis, loss of consciousness, low blood pressure	Peripheral ground glass opacities due to COVID-19	11600	29	59	9.2	110000	7	1	2524	17	49	1.7	Neg	151	Neg	-	630	1.4	134	370	65/52	7	-	16
Patient #10	14	Girl	Fever, gastroenteritis, low blood pressure	White lung, pleural effusion	6300	17	80	11.3	183000	56	60	6100	15	34	1.3	Neg	1325	Neg	-	614	0.8	110	380	60/30	20	18	60
Patient #11	14	Boy	Tonic colonic seizure, loss of consciousness, low blood pressure	Peripheral ground glass patchy opacities due to COVID-19	16000	6	90	13	391000	3	1	3115	13	31	1	Neg	2984	Pos	-	794	1.2	106	344	68/46	7	-	23
Patient #12	1.5	Boy	Fever, respiratory distress, low blood pressure	Opacities highly suggestive for COVID-19	10400	14	83	11.2	140000	37	45	1818	16	66	1.4	Candi	29	Pos	IgM = 0.7, IgG = 0.1, (neg)	792	1.1	121	345	55/35	8	-	32
Patient #13	1.5	Boy	Fever, respiratory distress, pleural effusion, low blood pressure	Peripheral ground glass opacities due to COVID-19	13200	12	84	8.9	349000	10	40	614	14	28	1.1	Neg	0.1	Neg	IgM = 0.2, IgG = 0.3, (neg)	580	1.9	110	328	86/47	4	-	26
Patient #14	7	Boy	Fever, respiratory distress, loss of consciousness, low blood pressure	Ground glass opacities due to COVID-19	13900	2	92	12.6	257000	17	32	998	22	120	2.4	Neg	37	Neg	-	713	1.3	105	370	77/44	7	-	25
Patient #15	1	Boy	Vomiting, status epilepticus, loss of consciousness, low blood pressure	Opacities due to COVID-19 and aspiration pneumonia	6700	23	43	8.6	293000	17	2	837	13	30	1	Neg	11.9	Neg	-	830	1.4	123	376	65/50	4	-	24
Patient #16	3	Boy	Vomiting, tonic colonic seizure, gastroenteritis, low blood pressure	Opacities due to COVID-19	11700	36	86	11.8	303000	9	13	398	13	30	1	Neg	589	Neg	IgM = 0.1, IgG = 0.1, (neg)	714	1.6	115	385	68/40	2	-	7

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Table 4. Summary of Clinical Presentation of Patients (Continued)

Patient #17	13	Girl	Respiratory distress, loss of consciousness	Peripheral ground glass patchy opacities due to COVID-19	17400	17	80	5.8	117000	40	88	6677	24	120	2.9	Neg	1.4	Pos	-	750	1.4	111	380	95/68	-	-	7
Patient #18	8	Boy	Fever, respiratory distress and focal seizure	Opacities suggestive for COVID-19	5600	7	90	13	115000		66	397	14	44	1.1	Neg	11	Neg	-	892	1.4	113	368	100/71	-	-	10
Patient #19	0.5	Girl	Fever, respiratory distress and cough	Bilateral peripheral ground glass opacities due to COVID-19	17000	23	61	10.4	465000	13	1	674	13	31	1	Neg	0.1	Neg	-	780	1.7	100	380	99/70	-	-	6
Patient #20	4	Girl	Febrile convulsion and respiratory distress	Opacities due to COVID-19 and aspiration pneumonia	13000	12	84	10.6	20900	5	26	1036	13	39	1	Neg	0.03	Neg	-	763	1.4	97	376	89/68	-	-	10
Patient #21	2	Boy	Respiratory distress	Opacities due to COVID-19	15000	7	83	9.7	882000	25	58	634	13	46	1	Neg	0.1	Neg	-	840	1.4	120	380	85/67	-	-	11
Patient #22	0.92	Boy	Respiratory distress and seizure	Opacities due to COVID-19	16700	19	78	10	244000	9	67	396	13	27	1	Neg	0.2	Neg	-	778	1.5	119	389	70/49	-	-	5

Abbreviations: WBC, white blood cell; Hb, hemoglobin; Plt, platelets; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; PT, prothrombin time; PTT, partial thromboplastin time; INR, international normalized ratio; B/C, blood culture; SVRI, systemic vascular resistance index; VPK, peak velocity; FTC, corrected flow time; Neg, negative; Pos, positive; IgM, immunoglobulin M; IgG, immunoglobulin G.