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Computed Tomography of the Chest in Proved COVID-19 Infected Patients in Paediatric Age Group. What to Expect?

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Abstract

Background: Worldwide, in children, pneumonia is the single leading cause of death. After COVID-19 crisis, many cases were reported as Polymerase chain reaction (PCR) positive COVID-19 in pediatric age group. In contrast to adults, most infected children appear to have milder disease course and have better outcomes. Early diagnosis can reduce spread of infection, help in gaining satisfactory outcomes and reduces disease morbidity and mortality rates. The main objective of our study is to be aware of CT imaging features of COVID-19 pneumonia in pediatric population.

Aim of Study: The main goals of this study are to demonstrate different findings found in CT chest performed in pediatric age group admitted & proved to be infected with SARS-COV-2 by positive real-time reverse transcription-polymerase chain reaction (PCR) & to monitor other associated additional radiological findings.

Patients and Methods: This cross-sectional prospective study included fifty patients (33 males & 17 females) referred to us from pediatric outpatient clinic, their ages ranged from 3 months to 16 years with mean age being (5.66 years), all patients confirmed with COVID-19 infection by a positive reverse transcriptase polymerase chain reaction (RT-PCR) or a positive rapid antigen test and were referred for MSCT assessment of the chest.

Results: This prospective study was carried out on fifty patients (33 males & 17 females), their ages ranged from 3 months to 16 years with mean age being (5.66 years). CT chest examination was done for all patients. CT findings were bilateral in 37 patients (23 males and 14 females) and unilateral in 13 patients (10 males and 3 females). In 37 patients with bilateral CT findings, the findings included consolidation in 23 patients (62.2%), ground glass patches in 37 patients (100%), pleural effusion in 6 patients (16.2%), and mediastinal lymphadenopathy in 8 patients (21.6%), atelectatic bands in 16 patients (43.2%). In patients with unilateral lesions, CT findings included consolidation in 5 patients (38.5%), ground glass patches in 13 patients (100%), pleural effusion in 3 patients (23.1%). The distribution of these findings were described within the study.

Conclusion: There is an increasing need to early detect COVID-19 pneumonia infection in pediatric age group and to be familiar with characteristic CT chest findings, as most of them act as carrier/transmitter and can increase infection rate among families. This research describes CT features of COVID-19 in pediatric age group thus providing early and satisfactory medical treatment & reduces viral transmission among families.

Key Words: *CT chest findings – COVID-19 pneumonia – Pediatric.*

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Introduction

WORLDWIDE, pneumonia is the single leading cause of death in children. Every Year, about 120 million cases of pneumonia occur in pediatric age group leading to Approximately 1.3 million deaths **[1]**. In the developing countries, children below 2 years old represents about 80% of pediatric deaths due to pneumonia. In the developed countries, prognosis of pneumonia is much better with lower number of deaths **[2]**.

Invasion of lower respiratory tract, below larynx by pathogens reaching it either through inhalation, respiratory epithelium invasion, aspiration, or blood spread leads to development of pneumonia. Viruses are the most common pathogens **[3]**. Several anatomical & cellular barriers prevent the occurrence

List of Abbreviation:

2019-nCOV	: 2019 novel coronavirus.
ARDS	: Acute respiratory distress syndrome.
COVID-19	: Corona Virus Disease.
CT	: Computed Tomography.
GGOs	: Ground Glass Opacities.
GE	: General Electric.
HU	: Housefield unit.
MDCT	: Multi-Detector Computed Tomography.
MSCT	: Multi-Slice Computed Tomography
PCR	: Polymerase chain reaction.
RT-PCR	: Reverse transcriptase polymerase chain reaction
SARS-Cov-2	: Severe acute respiratory syndrome coronavirus 2.

of respiratory infection. Any factor disrupts these barriers can lead to infection, either by droplet inhalation (mostly virus infection) or nasopharyngeal colonization (mostly bacterial infection), with subsequent inflammation and injury or death of surrounding respiratory epithelium and alveoli, degrading the oxygenation process later on. Hospitalizations may be required in about third or half of infected cases [4].

Many patients with pneumonia present with non-specific clinical manifestation, including fever, cough, dyspnea and tachypnea [5]. Abdominal pain may be one of the manifestations in young children. Several items should be checked during history taking as duration of symptoms, contact with infected persons, chronic illness, symptoms recurrence, choking, vaccination history, medical status of the mother, or occurrence of complications during birth in neonates [6].

Since the beginning of COVID-19 pandemic, many cases with PCR positive test were reported in pediatric age group. The most common routs of transmission of SARS-CoV-2 (a single-stranded RNA virus) are respiratory droplets of infected individual during coughing and sneezing, aerosols especially in crowded and/or poorly ventilated rooms. Contact with contaminated surfaces is a less common rout of transmission [7].

Till September 15, 2020, more than 216 million people were infected with the virus, with more than 933,000 deaths worldwide. In April in the United States, the pediatric age group (<18 years) represented 2572 (1.7%) of 149,082 diagnosed patients with the infants (<1 year) constituted 15% of pediatric COVID-19 cases [8].

The clinical manifestations accompanying SARS-CoV-2 infection, range from mild common cold to severe respiratory illness that may lead to acute respiratory distress syndrome (ARDS) and eventually death. The infection in children usually mild, with a wider range of clinical manifestation, less need of hospital admission as well as lower number of deaths. The asymptomatic form of infection occurs more frequently in children, as they have lower frequency of exposure to SARS-CoV-2 virus and less matured angiotensin-converting enzyme-2 receptors [9,10].

In pediatric population, assessment by radiological investigation is less commonly needed, as they showed lower incidences of infection, and lower number of symptomatic, and severe cases as compared to adults. The effect of the developing immune system in children with COVID-19 on disease progression and imaging features is still puzzling unclear [9].

Infected children have less incidence of positive radiological findings, as reported in first results. As a result of this as well as of the side effects of exposure to ionizing radiation in children, the use of chest imaging should not be a routine in COVID-19 pediatric patients and its indications should be restricted [11,12].

The European Society of Pediatric Radiology recommends that in pediatric COVID-19, imaging should done only when it is supposed to affect the management strategy and its use should depend on to the clinical status of the patients [13]. The use of Ultra-sonographic examination of the lung (U/S) in pediatric age group is limited in contrast to adult group in which, (US) reported to be helpful in early detection of lung pathology [14]. In spite of, the widespread use of chest CT in adults with COVID-19 pneumonia, its indications in children are restricted due to its high dose of radiation and the need of sedation in most of pediatric patients [15].

The spread of viral infection from children to their contacts would be a serious problem for older family members leading to increase number of patients with severe illness. Moreover, the number of asymptomatic affected children who are especially in the initial phases of the COVID-19 increases in the setting of family clusters [16].

Infection with COVID-19 in infants can lead to diffuse inflammatory process that may affect different organs & tissues during different phases. In the early pandemic wave, this inflammatory activation was in the form of mucocutaneous inflammatory syndrome resembling Kawasaki disease [17,18]. This syndrome was called later on multi-system inflammatory syndrome in children (MIS-C) associated with COVID-19 [19,20].

MIS-C has diagnostic criteria including fever, abdominal pain, hypotension, evidence of cardiac or other end-organ injury with at least two of the following: Conjunctivitis, maculopapular rash, non-purulent muco-cutaneous inflammation and gastrointestinal (GIT) manifestations [21].

CT scans of chest are 3 time more likely to be normal in children as compared to adult, according to some reports, in spite of the higher sensitivity of (CT) than chest X-ray in detection of pulmonary changes in COVID-19 infected patients. However, pooling together literature data, percentage of negative CT is very variable, ranging between 10% and 30% [22,23].

CT chest findings reported were ground-glass opacities (GGOs) with description of opacities distribution (central or peripheral; unilateral or bilateral), number of the opacities and consolidations as well as associated abnormalities such as pleural effusion, mediastinal and/or hilar lymphadenopathy [16].

Aim of work, What to expect?:

The main goals of this study are to demonstrate different findings found in CT chest performed in pediatric age group admitted & proved to be infected with SARS-COV-2 by positive real-time reverse transcription-polymerase chain reaction & to monitor other associated additional radiological findings.

Patients and Methods

Ethical consideration:

A written informed consent was taken from parents of all patients enrolled in this study. The results of this research were used only in scientific purposes and not in any other aims. And the confidentiality was completely protected.

This study was approved by the research committee of Faculty of Medicine, Kasr Al-Ainy Hospital, Cairo University.

Study design:

This cross-sectional prospective study included fifty patients (33 males & 17 females) referred to us from pediatric outpatient clinic, their ages ranged from 3 months to 16 years with mean age being (5.66 years), all patients confirmed with COVID-19 infection by a positive reverse transcriptase polymerase chain reaction (RT-PCR) or a positive rapid antigen test and were referred for MSCT assessment of the chest. All patients were subjected to full clinical data taking including age, sex, exposure history and clinical complaint. The study was conducted during the period from April 10, 2020, to February 20, 2021 in Abo El-Reesh Teaching Hospital, Cairo, Egypt. (Table 1).

Table (1): Demographic data.

Total	50	100%
Male	33	66%
Female	17	34%

Inclusion criteria:

Children with MSCT chest findings and confirmed to be infected with COVID-19 by positive reverse transcriptase polymerase chain reaction (RT-PCR) or a positive rapid antigen test.

Exclusion criteria:

Children with CT chest findings with negative reverse transcriptase polymerase chain reaction (RT-PCR).

Children with severe respiratory motion artifacts on CT images.

Methods:

All patients involved in this study were subjected to through history taking from the relatives, laboratory evaluation & examined by Computed tomography (CT) of the chest. The CT scanner used was 64 channels MSCT GE machine. The detailed parameters for CT acquisition were as follows: Tube voltage, 80-100kVp. Tube current, standard (reference mAs, 25-60) Slice thickness 1.0mm. Reconstruction interval 1.0-3.0mm. Using a sharp reconstruction algorithm. CT images were obtained with the patient in the supine position with suspended full inspiration and without contrast medium. All images were viewed on both lung window (width, 1500 HU; level, –700 HU) and mediastinal window (width, 350 HU; level, 40 HU) settings. For the non-compliant patients we administrated a short and light-acting sedative of chloral hydrate at a dose of 50mg/kg.

The images acquired were sent to a separate workstation and different reconstructions were obtained. The chest CT scan was evaluated by two expert radiologist separately and assessed for faint ground glass opacities, distribution (unilateral or bilateral, central or peripheral), zonal distribution (upper, middle or lower lobes) and focality (single, multifocal or diffuse). Associated findings such as pleural effusion, mediastinal and hilar lymphadenopathy & atelectatic bands were reported.

Statistical analysis:

Findings are presented as medians and interquartile ranges due to small sample size categeoral variables are described as whole numbers, with percentages in brackets.

Results

This prospective study was carried out on fifty patients (33 males and 17 females) referred to us from pediatric outpatient clinic, their ages ranged from 3 months to 16 years with mean age being (5.66 years).

CT examination was done for all patients. CT findings were bilateral in 37 patients (23 males and 14 females) and unilateral in 13 patients (10 males and 3 females). In 37 patients with bilateral CT findings, the findings included ground glass patches in 37 patients 100% (Figs. 1,3,5,8), atelectatic bands in 16 patients 43.2% (Figs. 2,3,4) consolidation in 23 patients 62.2% (Figs. 6,7), pleural effusion in 6 patients 16.2%,mediastinal lymphadenopathy in 8 patients 21.6%. The distribution of these findings were in right lung upper lobe in 30 and lower lobe in 31 patients, left lung upper lobe 26 and lower lobe 35 patients (Table 2 and Fig. 9).

Table (2): CT findings in bilateral cases.

	Number of the patients	Percentage
Lesion distribution:		
Right lung:		
Upper	30	81
Lower	31	83.7
Left lung:		
Upper	26	70.3
Lower	35	94.5
Consolidation	23	62.2
Ground glass patches	37	100
Pleural effusion	6	16.2
Mediastinal lymphadenopathy	8	21.6
Atelectatic bands	16	43.2

In patients with unilateral lesions, CT findings included consolidation in 5 patients 38.5%, ground glass in 13 patients 100%, pleural effusion in 3 patients 23.1 % (Fig. 6), mediastinal lymphadenopathy and atelectasis 0 patients 0%. The distribution of these lesions was right lung in 10 patients, upper lobe involvement in 6 and lower lobe affection in 7 patients, left lung upper lobe 0 and lower lobe 3 patients (Table 3 and Fig. 9).

Table (3): CT findings in unilateral cases.

	Number of the patients	Percentage
Lesion distribution:		
Right lung (10 patients, 76.9%):		
Upper	6	46.2
Lower	7	53.8
Left lung (3 patients, 23.1 %):		
Upper	0	0
Lower	3	23.1
Consolidation	5	38.5
Ground glass patches	13	100
Pleural effusion	3	23.1
Mediastinal lymphadenopathy	0	0
Atelectatic bands	0	0

- For lesion distribution in unilateral cases, 3 patients had lesions at the right upper and lower lobes.

Other CT findings that were found include tree on bud in 4 patients, lung abscess in 1 patients, sliding hiatus hernia in 4 patients, fatty liver infiltration in 2 patients, crazy paving in 1 patient, atrophic kidney in 1 patient and infantile gynecomastia in 1 patient (Table 4).

Table (4): Other CT findings.

CT findings	No. of the patients
Tree in bud	4
Lung abscess	1
Sliding hiatus hernia	4
Fatty infiltration of the liver	2
Crazy paving	1
Atrophic kidney	1
Infantile gynecomastia	1

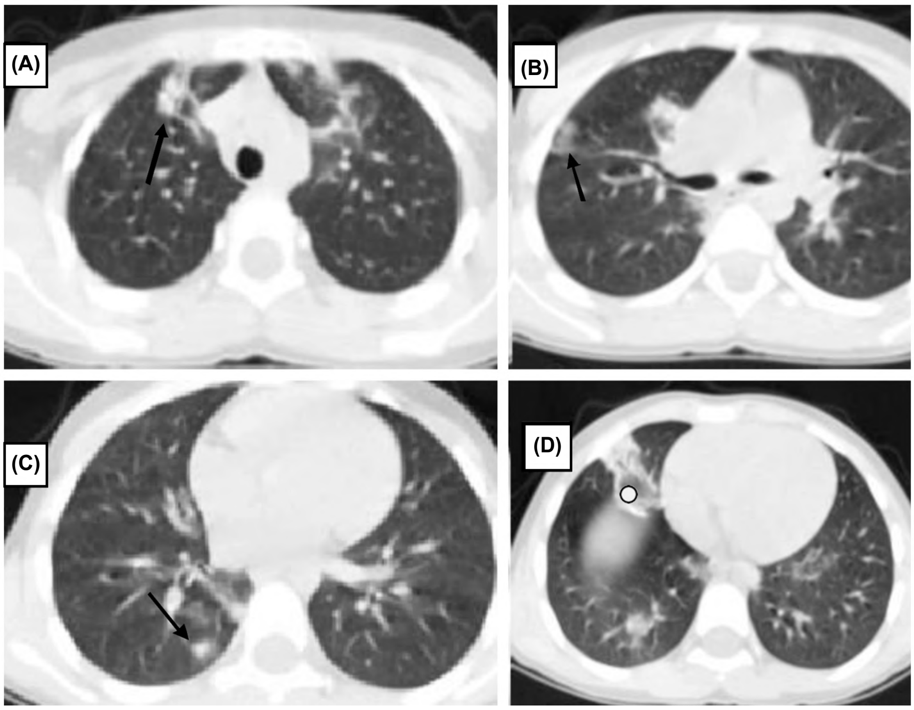

Fig. (1): 7 year old male child, presenting with dyspnea and fever. His parents have been recently diagnosed with COVID-19. Nasopharyngeal swab was done and RT-PCR was positive. Full laboratory investigations were done and revealed lymphopenia with mild monocytosis. CT was done and revealed bilateral peripherally located patchy areas of ground glass attenuation (arrows in a,b, and c). Right lower lobar anterior basal segmental peripherally located consolidative patch is also noted (yellow dot at, d). He was confirmed to have COVID-19 and admitted to hospital under medical treatment.

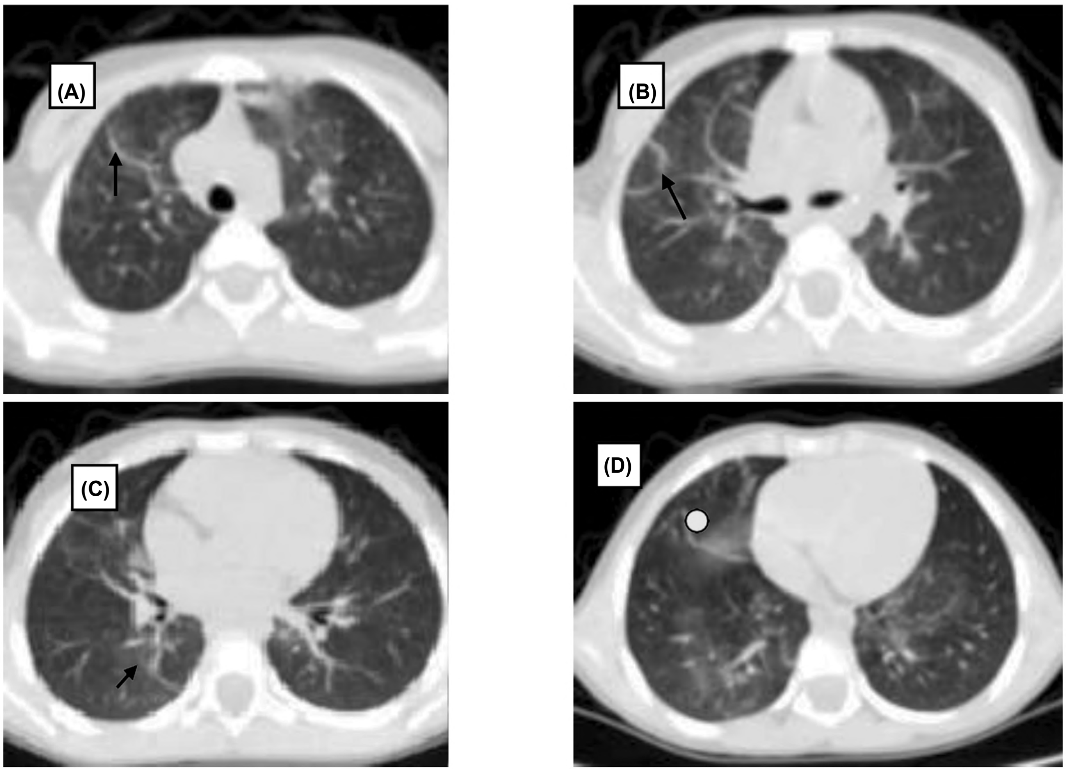

Fig. (2): Follow-up done for the previous 7 year old male child, after 11 days of medical treatment. Almost complete resolution of the previously noted peripherally located, patchy areas of ground glass attenuation with newly developed atelectatic bands (arrows in a, b and c). Almost complete resolution of the consolidative patch at the right lower lobar anterior basal segment with residual thin atelectatic band (yellow dot at ,d).

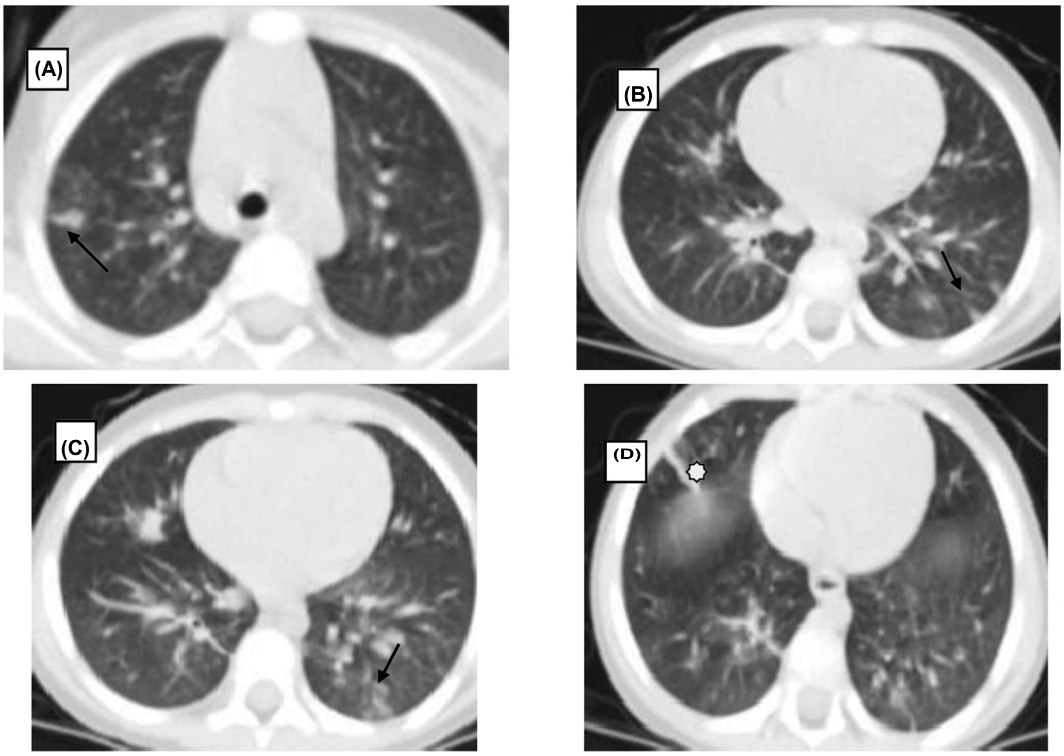

Fig. (3): 23 month old male infant presenting with fever and increased respiratory rate. His mother was recently admitted to respiratory isolation hospital with COVID-19. Nasopharyngeal swab was not possible. Laboratory investigations revealed absolute lymphopenia with normal hemoglobin level and normal platelet count. CT chest was done and revealed multiple bilateral small peripherally located patchy areas of ground glass attenuation (arrows in a,b and c) with right lower lobar thick atelectatic bands (yellow mark at, d).He was admitted to hospital on medical treatment.

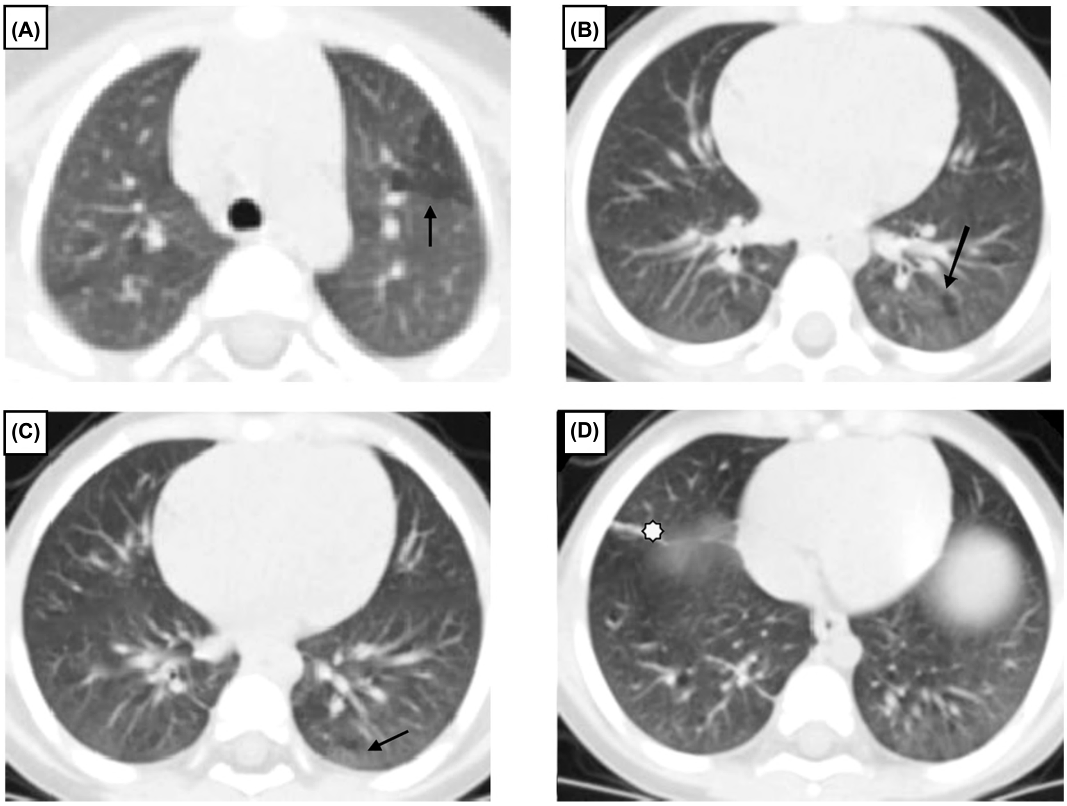

Fig. (4): Follow-up of the previous 23 month old male infant, after 8 days of medical treatment. It revealed almost complete resolution of the previously noted multiple bilateral small peripherally located patchy areas of ground glass attenuation. Residual areas of air-trapping are noted (arrows in a and b). Reduction in attenuation of the left lower lobar posterior basal small patchy area of ground glass attenuation (arrow in c).Regressive course as regards the thickness of the right lower lobar atelectatic band (yellow mark at d).

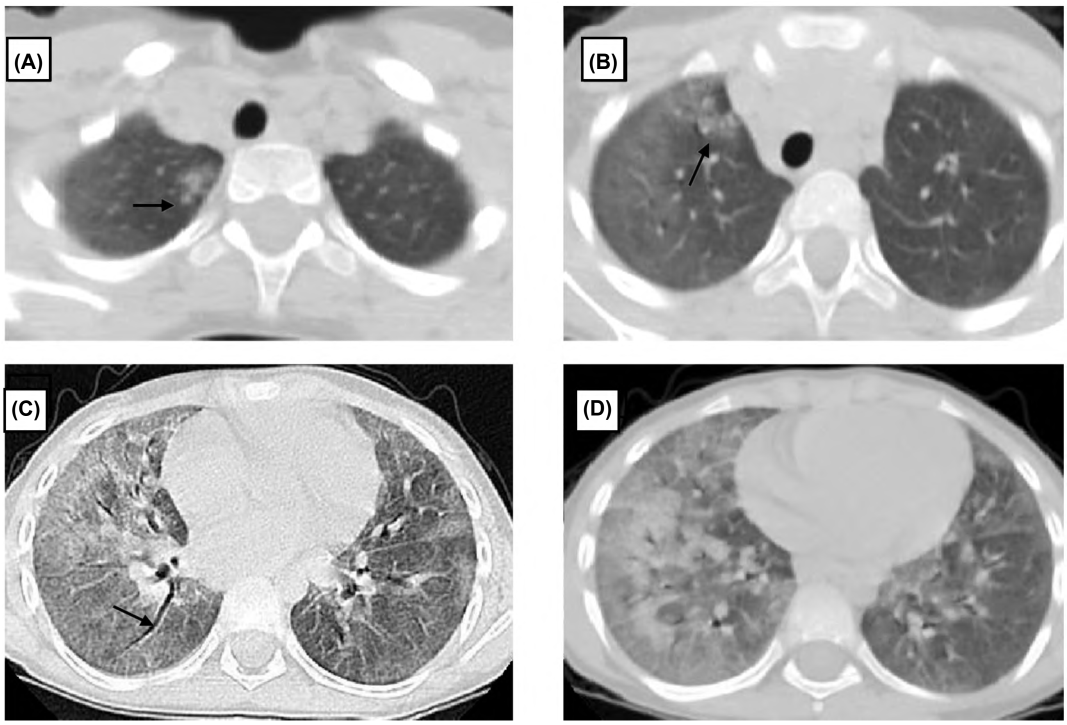

Fig. (5): 9 year old female child presenting with severe dyspnea, oxygen saturation 65% as measured by pulse oximeter ,dry cough and fever. Nasopharyngeal swab was done and RT-PCR was done and found to be positive for COVID-19. Full laboratory investigations were done and revealed lymphopenia. Non contrast CT chest was done and revealed multiple bilateral discrete (arrows in a and b) and confluent patchy areas of ground glass attenuation, septal thickening and air bronchogram (arrow in c). She was confirmed to have COVID -19 viral pneumonia and admitted to pediatric ICU on oxygen and intensive medical treatment.

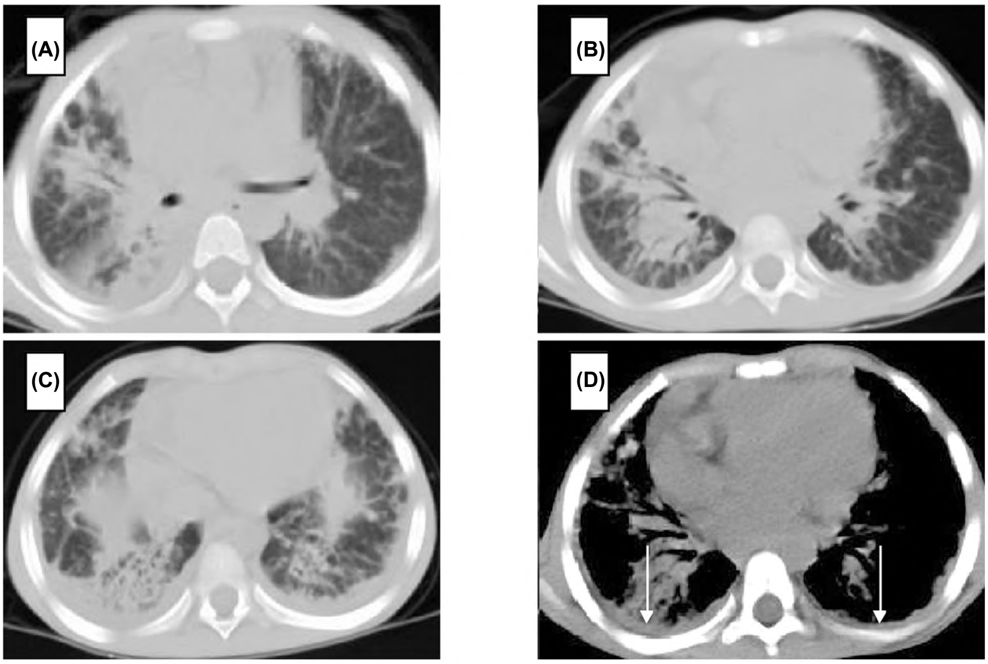

Fig. (6): 7 year old female child presenting with severe dyspnea, oxygen saturation 50% as measured by pulse oximeter and fever. Nasopharyngeal swab was done and RT-PCR was done and found to be positive. Full laboratory investigations were done and revealed absolute lymphopenia. Normal HB concentration and normal platelet count. Non contrast CT chest was done and revealed diffuse thickening of the pulmonary interstitium with multiple bilateral discrete and confluent patchy areas of ground glass attenuation, air space consolidation and air bronchogram. Bilateral basal pleural thickening is also noted (arrows in, d). She was confirmed to have COVID -19 viral pneumonia and admitted to pediatric ICU on invasive oxygen therapy and intensive medical treatment.

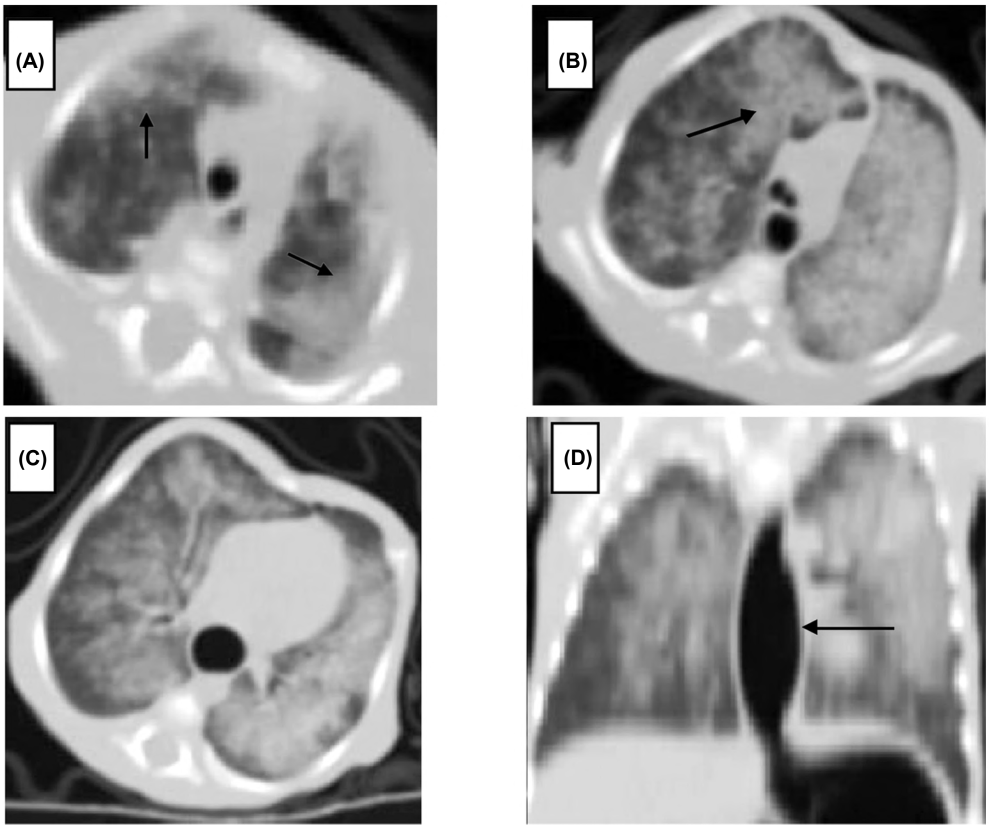

Fig. (7): 5 months old male infant presenting with fever and increased respiratory rate. His family was recently admitted to respiratory isolation hospital with COVID-19.Nasopharyngeal swab was not possible .Laboratory investigations revealed absolute lymphopenia with normal hemoglobin level and normal platelet count. CT chest was done and revealed multiple bilateral upper lobar peripherally located patchy areas of ground glass attenuation (arrows in a) with right middle lobar and bilateral lower lobar confluent consolidative patches (arrow in b) with septal and vascular thickening. He was admitted to pediatric ICU on invasive oxygen therapy and intensive medical treatment. Accidental finding of large sliding hiatus hernia is noted (arrow in d).

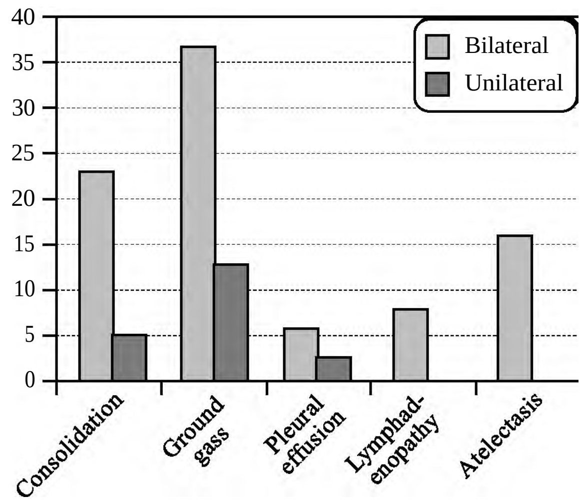

Fig. (8): CT findings in bilateral and unilateral cases.

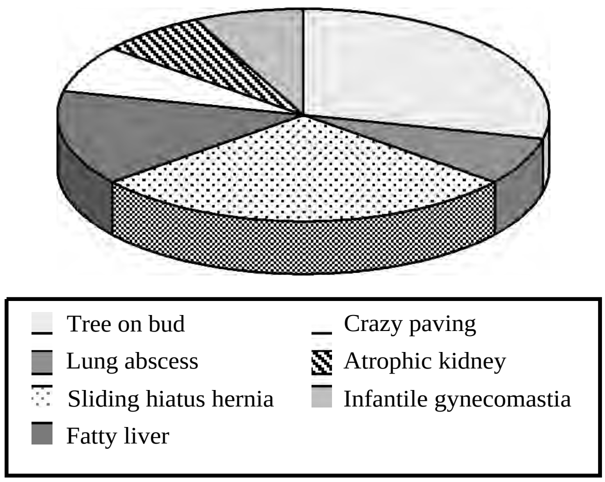

Fig. (9): Other CT findings.

Discussion

In early publications, no reported cases of children infected with COVID-19 under the age of fifteen years and it was thought that children were not susceptible to this viral infection [24]. With the increase in the number of infected adult contacts that occurred with progression of the world pandemic, the number of pediatric infections increased, and later publications showed that COVID-19 pneumonia could appear in all age groups [25,26]. Furthermore, children with COVID-19 infection usually have a mild form of the disease and show better prognosis [27].

In spite of, mild clinical symptoms seen in most of pediatric patients, several cases of infected children have been recorded with severe form of the infection or even death; moreover, children with COVID-19 can transmit infection to others. Because of this, careful assessment of children with suspected infection should be done, for early detection of positively infected cases, to manage them properly and to protect their contacts [28].

While managing children with suspected COVID-19 infection, a balance should be made between the risk of radiation and the need for CT scan. Moreover, it is much safer to use low-dose CT in pediatric population in order to reduce radiation exposure. Actually, a combination of RT-PCR test and chest CT imaging should be done during the assessment of symptomatic children [28].

In our study, we included only symptomatic patients with positive PCR test and with positive CT findings to raise the accuracy of our results and to be aware of different changes that occur in CT examination of those patients. As regarding this, we differed from previous studies done in children including study done by Huijing M, et al., [29], who examined patients with positive and negative PCR test and patients with negative and positive CT findings and classified them into three groups from A to C. Group A: Children with COVID-19 exposure history, positive CT, and positive PCR. Group B: Children with COVID-19 exposure history, negative CT, and positive PCR. Group C: Children with COVID-19 exposure history, positive CT, and persistently negative PCR results. Sharon S, et al., [30] studied 30 patients with positive PCR test and they found normal CT appearance (negative CT findings) in 23 of 30 patients (77%).

We found that most common pattern of CT affection were ground glass opacification followed by consolidation. This goes with the findings reported in previous studies done by Sanaz K, et al., [28], which documented that ground-glass opacities and consolidations were found as the main characteristics of SARS-CoV-2 infection in pediatric patients, and matches with another studies done by Sharon S, et al., Susan C, et al., [30,31].

In most of our patients the lung affection were bilateral and lower lobar. This could be explained by the anatomy of the lower lung bronchus, which is short in length and thick, making the lower bronchus easy to be catched by the virus. This matched with the study done by Sharon S, et al., and Susan C, et al., [30,31], who found that in the pediatric population the affection was predominantly appeared as ground-glass opacities in a bilateral, peripheral, and lower-lobe distribution, but disagrees with study done by Sanaz K, et al., [28]. Which found that most of the patients showed unilateral lung affection.

The other findings we noticed were pleural effusion (which were found more frequently in cases of bilateral lung affection), mediastinal lympadenoathy and atelecatasis, (which did not present in patients with unilateral lung lesions). Tree in bud, lung abscess and crazy paving pattern are found in little number of cases. This did not match with study done by Sharon S, et al., **[30]** who reported that pleural effusions and lymph adenopathy were absent in their all patients.

Overall findings in our study were matching with the results detected by study done by Pablo CD, et al., **[32]** who found that the most common CT findings in 24 cases of COVID-19 in children are ground glass opacities with a peripheral distribution in the lower lobes and airspace consolidation, but they did not go with our study in very infrequent detection of Lymphadenopathy and significant pleural effusions in their study.

In our study the number of males was more than females (66% as compared to 34%) this matched with study done by Sharon S, et al., **[30]** in which the study population showed equal number of males and females but with increased prevalence of positive CT findings among male patients (86%), similar to the what reported in the literature: (Predominance of infection among male patients noted on adult and pediatric populations) **[33]**.

The characteristic CT findings mentioned above are matching with the typical findings published in the Radiological Society of North America's expert consensus statement on reporting chest CT findings in adults with COVID-19, including peripheral and bilateral ground-glass opacities, a crazy paving pattern, and a reverse halo sign **[34]**. Recognition of these patterns can help to differentiate COVID-19 pneumonia from other diseases such as a lobar pneumonia, which is more commonly appears as consolidation more than ground-glass opacity and is mostly confined to one lobe. The other CT features including: Crazy paving pattern, halo sign, and reverse halo sign, are not specific to COVID-19 and can be found in association with other atypical viral pneumonias or drug reactions **[30]**.

The limitations of our study were: The small sample size which decreased the accuracy of the study. In addition to, absence of adult patients group to compare their chest CT features with the pediatric group, as well as, lack of follow-up due to the short time for data collection.

Conclusion:

There is an increasing need to early detect COVID-19 pneumonia infection in pediatric age group and to be familiar with characteristic CT chest findings, as most of them act as carrier/ transmitter and can increase infection rate among families. Early diagnosis can reduce spread of infection, help in gaining satisfactory outcomes and reduces disease morbidity and mortality rates. Our study aims to be familiar with CT imaging features of COVID-19 pneumonia in pediatric population.

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التصوير المقطعى للصدر فى مرضى مصابين بفيروس كوفيد ١٩ ثبت إصابتهم بالفئة العمرية للأطفال : ما يمكن توقعه

فى جميع أنحاء العالم، يعد الالتهاب الرئوى السبب الرئيسى الوحيد للوفاة عند الأطفال. بعد أزمة COVID-19، تم الإبلاغ عن العديد من الحالات على أنها تفاعل البو ليمير از المتسلسل (PCR) إيجابى COVID-19 فى الفئة العمرية للأطفال. على عكس البالغين، يبدو أن معظم الأطفال المصابين يعانون من مرض أكثر اعتدال أو يحققون نتائج أفضل. يمكن أن يقلل التشخيص المبكر من انتشار العدوى، ويساعد فى الحصول على نتائج مرضية ويقلل من معدلات الإصابة بالأمراض والوفيات.

الهدف الرئيسى من دراستنا هو أن نكون على دراية بسمات التصوير المقطعى المحوسب للالتهاب الرئوى COVID-19 لدى الأطفال.