



Electrical impedance tomography clues to detect pulmonary thrombosis in a teenager with COVID-19

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Abstract

We report a case of pulmonary thrombosis in a teenager during a hypercoagulable state associated with COVID-19 (coronavirus disease 2019) caused by SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2). A condition rare in children and adolescents, pulmonary thrombosis underdiagnosis likely increases morbidity and mortality. A pulmonary thrombosis diagnosis requires a high level of suspicion and relies on the combination of clinical presentation, D-dimer elevation, and computed tomography (CT) pulmonary angiography or ventilation/perfusion scans, imaging techniques that are difficult to perform. Electrical impedance tomography (EIT) has gained attention, as it provides real-time ventilation distribution analysis. In addition, lung pulsatility images can be obtained through this technique using electrocardiogram gating to filter out ventilation. In this case report, the reduced EIT pulsatility corresponded to the perfusion defect found on the CT scan, information that was obtained at the bedside without radiation or contrast exposure.

Keywords Children · Coronavirus disease 2019 · Electrical impedance tomography · Lung · Pulmonary thrombosis

Introduction

Pulmonary thrombosis is relatively rare in the pediatric population when compared to adults, but it is highly recommended to consider this complication since undiagnosed cases potentially increase morbidity and mortality [1]. Very recent data relate SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) infection to a hypercoagulable state, and local thrombi formation may follow the activation of the inflammatory processes

during the cytokine storms, causing endothelial damage or dysfunction. In addition, SARS-CoV-2 activates the coagulation pathway by binding to the angiotensin-converting enzyme 2 (ACE-2) receptor [2]. Children with this coronavirus disease 2019 (COVID-19)-associated hypercoagulation state are at increased risk for thrombosis [3].

Case report

We present the case of a previously healthy 15-year-old girl, weighing 64 kg with a body mass index of 26.3 kg/m², who developed fever, odynophagia and coryza. The initial viral panel investigation was negative, but SARS-CoV-2 was detected subsequently in the nasal swab by a polymerase chain reaction (PCR) test. After 4 days, she presented with sudden dyspnea, low oxygen saturation (92% with the use of a non-rebreather mask) and asymmetrical lung sounds on auscultation. Blood tests revealed leukocytosis, normal platelet count and an elevated D-dimer level (17079 ng/ml). Based on her

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clinical and laboratory presentation, pulmonary thrombosis was considered. Chest computed tomography (CT) pulmonary angiography, showing a filling defect in the left pulmonary artery, confirmed the diagnosis (Fig. 1). The patient was also monitored with electrical impedance tomography (EIT) (Enlight 1800; Timpel, São Paulo, Brazil) and altered electrocardiogram (ECG)-gated pulsatility in the left lung was detected, in agreement with CT pulmonary angiography (Fig. 2). Additional work-up included a normal transthoracic Echocardiogram (with a left ventricle ejection fraction of 66% and no coronary abnormalities), an ultrasound of the lower limbs that ruled out deep vein thrombosis and a negative thrombophilia screening. The patient was discharged from the pediatric intensive care unit to the ward 4 days after therapeutic low-molecular-weight heparin was started, without any respiratory support.

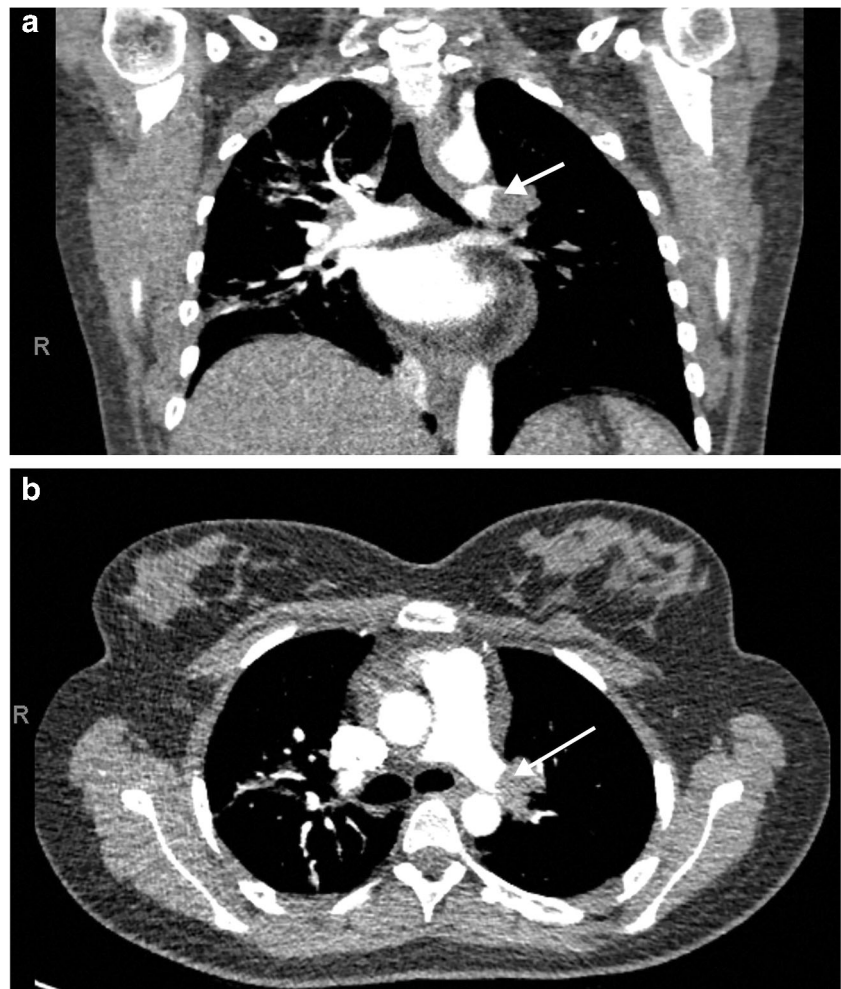
Discussion

Pulmonary thrombosis can be diagnosed based on the combination of a patient's clinical history, D-dimer levels,

and ventilation/perfusion (V/Q) scans or CT pulmonary angiography. Both imaging techniques expose patients to radiation and are costly and time consuming, and CT pulmonary angiography also includes risks related to contrast injection. These exams are therefore difficult to perform in critically unstable children [4].

EIT is a noninvasive, radiation-free method of measuring the relative change in impedances within regions of a cross-section of the thorax and has recently gained attention in patients with respiratory failure as it provides real-time ventilation images [5, 6]. EIT also produces pulmonary perfusion images, which have not yet been validated in children because they require intravenous injection of hypertonic saline, which acts as a contrast agent [7]. Conversely, ECG gating can filter out ventilation and provide EIT lung pulsatility images without exposure to hypertonic saline. The thoracic electrical impedance is influenced by changes in gas, tissue and blood. The isolation of the EIT signal within the cardiac frequency domain allows determination of pulsatility [8]. Thus, EIT has the advantage of providing continuous monitoring of ventilation and pulsatility at the same time. In some clinical

Fig. 1 Computed tomography (CT) pulmonary angiography in a 15-year-old girl. **a, b** Coronal (**a**) and axial (**b**) images show a central filling defect in the left pulmonary artery, consistent with an occlusive thrombus (CT dose index: 7.46 mGy). The arrows indicate the thrombus



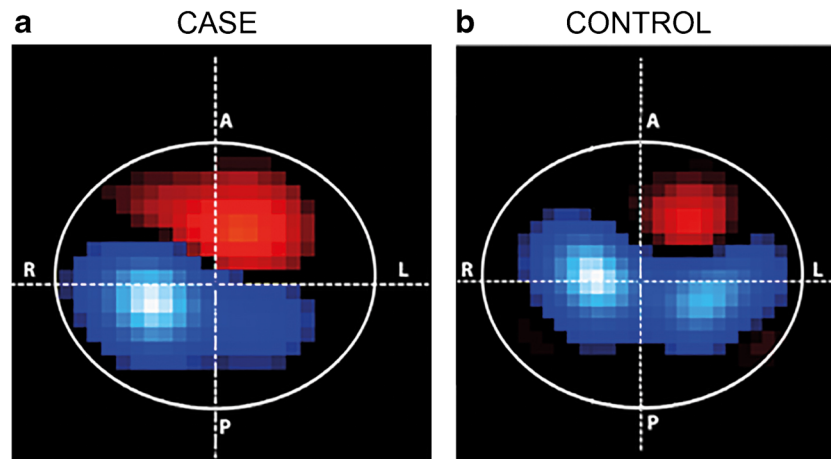


Fig. 2 Axial electrical impedance tomography (EIT) pulsatility maps. The pulsatility images are electrocardiogram gated and filter out the ventilation component in the thoracic impedance variation, thus representing impedance variations related to the cardiac cycle. **a, b** The off-line image shows the heart in *red* and the pulsatility in the lungs in *blue*. Of note, the higher detected pulsatility in this EIT algorithm is displayed in *white* and *light blue* colors. An image from the 15-year-old

girl (**a**) shows reduced pulsatility in the left lung, secondary to the pulmonary thrombosis. The *dashed lines* intersect at the center of the thorax. For comparison, we present an image obtained from another 15-year-old girl without ventilation or perfusion abnormalities (**b**). Note that the pulsatility in the right image is more evenly distributed between the right and left lungs. A anterior, L left, P posterior, R right

scenarios, mismatch between EIT pulsatility and ventilation maps can suggest pulmonary thrombosis. In our case, patient position affected ventilation distribution, but the pulsatility defect remained unaltered. This finding led to increased suspicion of pulmonary thrombosis. Due to the low EIT spatial resolution, however, a CT angiogram was performed to rule out pulmonary thrombosis [8]. A filling defect was later shown to be responsible for the changes in pulmonary pulsatility (Fig. 3).

Conclusion

We presented an abnormal pulsatility EIT image secondary to pulmonary thrombosis detected in a teenager with COVID-19 in accordance with CT pulmonary angiography findings. No other risk factors were found, which highlights that a high level of suspicion is warranted in children infected with SARS-CoV-2, since pulmonary thrombosis often remains under-recognized. New diagnostic technologies, such as EIT,

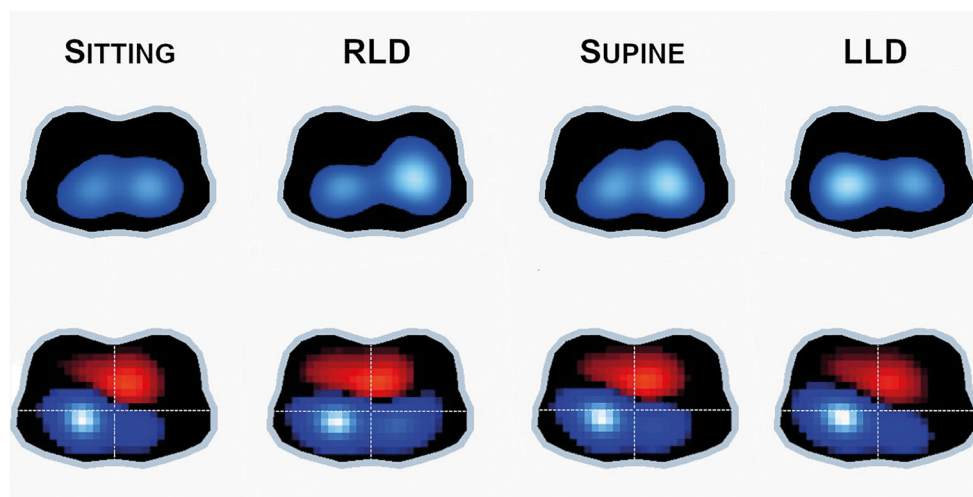


Fig. 3 Axial electrical impedance tomography (EIT) imaging performed in four different positions: sitting, right lateral decubitus (*RLD*), supine and left lateral decubitus (*LLD*). The upper figures display EIT lung ventilation maps in scales of blue (the higher the tidal volume detected, the lighter the colors). Noticeably, ventilation distribution varies as the

patient changes position. In the lower images, EIT electrocardiogram-gated pulsatility maps were not impacted by the four different studied positions. The pulsatility, also presented on a scale of blue to white, is always diminished in the left lung area. The heart position is in *red*

might help in the diagnosis and treatment monitoring of respiratory symptoms in critically ill children.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00247-021-05199-1>.

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Declarations

Conflicts of interest None

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