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Early View

Research letter

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Home monitoring of lung mechanics by oscillometry before, during and after severe COVID-19 disease: a case study.

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Take-home message. A patient regularly self-performing home oscillometry developed severe COVID-19 pneumonia and continued testing during and after the disease. COVID-19 suddenly worsened oscillatory reactance, that took almost one year to recover to pre-COVID values.

Keywords: COVID-19, home-monitoring, lung mechanics, oscillometry, forced oscillation technique

To the Editor:

In November 2020, Europe faced the second Covid-19 pandemic wave. The need to manage patients while reducing potential exposure and healthcare system overload led to renewed interest in home-monitoring of respiratory variables. Together with variables related to COVID-19 infection (1), home-based lung imaging (2) and lung mechanics (3, 4) were used to monitor COVID-19 and chronic respiratory patients during limited access to traditional care. Home monitoring respiratory-specific variables may provide important information about patient health status and clinical course.

Lung mechanics monitoring may be particularly valuable in COVID-19 patients with respiratory comorbidities. Spirometry was successfully used at home during the pandemic (4); however, the test requires guidance, is difficult in naïve patients, prone to erroneous results (5), and may release contaminated aerosol. Oscillometry allows non-invasive monitoring of the respiratory resistance (mainly reflecting airway resistance) and reactance (primarily related to peripheral airway and lung volume recruitment/derecruitment) during spontaneous breathing (6). Moreover, oscillometry is suitable for home monitoring and provides accurate results and high patient adherence (7).

We report a unique dataset of weekly oscillometry measurements over one year for a patient before, during, and while recovering from severe COVID-19 disease.

The study was approved by the ethics committee of Politecnico di Milano University (n. 21/2022). Informed written consent for publication of his clinical details and images was obtained from the patient. The patient is a 59-year-old Caucasian man with a body mass index of 20.0 Kg/m^2. Past medical history included mild, controlled type two diabetes since 2010 treated with metformin 500 mg/day. He was a former cigarette smoker (20 pack-years till 2005). He did not

report respiratory symptoms since quitting smoking or drug allergies. He led a normal active life with moderate physical activities. As he is a clinical and commercial expert in the field of lung physiopathology, his diffusing capacity of the lungs for carbon monoxide (DLCO), spirometry (forced expired volume in 1 sec (FEV_1)= 102% predicted; forced vital capacity (FVC)= 108% predicted; FEV_1/FVC= 94% predicted), oscillometry (Figure 1), and lung volumes (vital capacity (VC) = 108% predicted; inspiratory capacity (IC) = 103% predicted) measurements were available months before the onset of the COVID-19 disease.

On October 28th 2020, he experienced shivers, moderate fatigue, and sudden shortness of breath a few days later. After 3 days of persistent symptoms, a nasopharyngeal swab test confirmed COVID-19 infection. Room air oxygen saturation (SpO_2) dropped to 82% on November 6th. Blood testing (November 11th) confirmed severe inflammation with an increase of D-Dimer index (2500 ng/mL; normal values < 500 ng/mL). Home thoracic chest ultrasounds on November 11th and 16th demonstrated diffuse bilateral B-lines compatible with COVID-19 interstitial pneumonia. The disease severity was “severe” per WHO classification. However, the patient was apprehensive about attending a busy hospital and opted for home-treatment, including oxygen by portable concentrator (up to 2-3 L/min for 24/24 hours), azithromycin, and low molecular weight heparin. Since the onset of symptoms, the patient performed weekly oscillometry measurements according to technical standards (6) in a seated position using a signal combining 5, 11, and 19 Hz (ResmonPro FULL, Restech Srl, Milan, Italy). After symptoms onset, oscillatory resistance at 5 Hz (R_5) increased and reactance (X_5) decreased (Figure 1), despite remaining within the range of normality (8). Intra-tidal changes in X_5 were always lower than 0.2 cmH_2O, indicating the absence of expiratory flow limitation during tidal breathing (9).

On December 10th, a chest computerized tomography (CT) scan demonstrated bilateral paraseptal emphysematous lesions (most likely pre-existing and due to prolonged exposition to

cigarette smoke) and bilateral diffuse ground glass. Systemic steroid (prednisone starting from 25 mg daily), initially avoided because of the subject's diabetes, was administered from December 14th. An initial fast partial improvement in lung mechanics was followed by a longer period of slower improvements in lung mechanics and clinical conditions. Resolution of hypoxemia took several weeks. Room air SpO_2 above 94% was achieved 30 days after peak acute worsening.

Two subsequent CT scans showed the disappearance of the ground glass opacities (Figure 1). Three months after symptom onset, complete cardiopulmonary exercise testing (CPET) showed a mild reduction of exercise capacity (maximum oxygen consumption, VO_2max, of 76% predicted with nadir SpO_2 of 87%), normal forced spirometry (Figure 1), moderate reduction of lung volumes (VC = 85% predicted; IC = 64% predicted), and severe reduction in DLCO, membrane conductivity (Dm), and volume of alveolar capillary blood (Vc) to 46, 54 and 35% of predicted values, respectively. Six months after symptoms' onset, lung volumes (VC = 99% predicted; IC = 71% predicted) and CPET improved (VO_2max = 76% predicted with 93% SpO_2), but DLCO was still abnormal (DLCO = 40% predicted; Dm = 41% predicted; Vc =34% predicted). One year after symptom onset, DLCO improved (68% predicted), approaching its baseline value, similar to X_5. R_5 remained lower than pre-COVID values. Lung volumes (VC = 103% predicted; IC = 85% predicted) and spirometry parameters (FEV_1=102% predicted; FVC= 103% predicted; FEV_1/FVC= 102% predicted) further improved but remained below pre-COVID values.

Our results show that home longitudinal monitoring of lung function by oscillometry allowed a unique evaluation of the mechanical properties of the lung before, during, and after COVID-19 interstitial pneumonia, including the long recovery phase. Despite not exceeding the lower limit of normality, X_5 decreased more than 400% from baseline values. The wide range of normality provided by existing oscillometry reference equations, together with fast improvement after commencement of steroid treatment, may explain the normal X_5 values found in several

severe COVID-19 patients (10). Spirometry results were also within the range of normality, despite worsened from pre-COVID values. This data underlines that alterations in lung mechanics are difficult to detect when only considering the lower limit of normality. Conversely, monitoring longitudinal changes may provide a more sensitive tool for evaluating the disease evolution and the impact of treatments. Oscillometry can facilitate longitudinal monitoring as it allows measurements in dyspneic patients and when spirometry is difficult or not indicated (as any forced or maximal maneuver during the acute pathology).

Follow-up data of COVID-19 patients showed pulmonary structural abnormalities and abnormal DLCO till several months post-infection (11). Our data seems to indicate that X_5 can also require a long time for full recovery, with values approaching baseline one year post-infection. R_5 remained lower than pre-COVID. Possible explanations may be tidal breathing occurring at higher lung volume (IC was still lower than pre-COVID), increased parenchymal elastic recoil, or reduced interstitial edema (12).

Measurements were performed in standardized conditions and with the same set-up. However, changes in patient's breathing patterns may have influenced oscillometry parameters. Also, the clinical care the patient agreed to did not follow standardized protocols as he refused hospitalization and received delayed steroids administration. Finally, because of the observational design of the study, causality could not be inferred. Despite these limitations, our study shows that longitudinal assessment of respiratory mechanics by oscillometry at home allowed tracking changes in lung function in a patient with severe interstitial COVID-19 pneumonia when limited monitoring data was available.

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Competing interests

RLD reports grants from Restech, personal fees from Philips Healthcare, outside the submitted work; In addition, Dr Dellaca' has a patent on the detection of EFL by FOT with royalties paid to Philips Respironics and Restech Srl, a patent on monitoring lung volume recruitment by FOT with royalties paid to Vyaire, and a patent on early detection of exacerbations by home monitoring of FOT with royalties paid to Restech and is co-founder and shareholder of Restech Srl, a spin-off company of the Politecnico di Milano University producing medical devices for lung function testing based on FOT. RP is the Vice President, Worldwide FOT and Asthma Management Business Development, MGC Diagnostics International. CV and FDM have nothing to disclose.

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Authors' contributions. CV: conceived and designed the study; analyzed the data; drafted the manuscript. RP: managed data acquisition and critically revised the manuscript. FDM: conceived and designed the study; interpreted data and drafted the manuscript. RD: conceived and designed the study; interpreted data and critically revised the manuscript. All the authors approved the final version of the manuscript.

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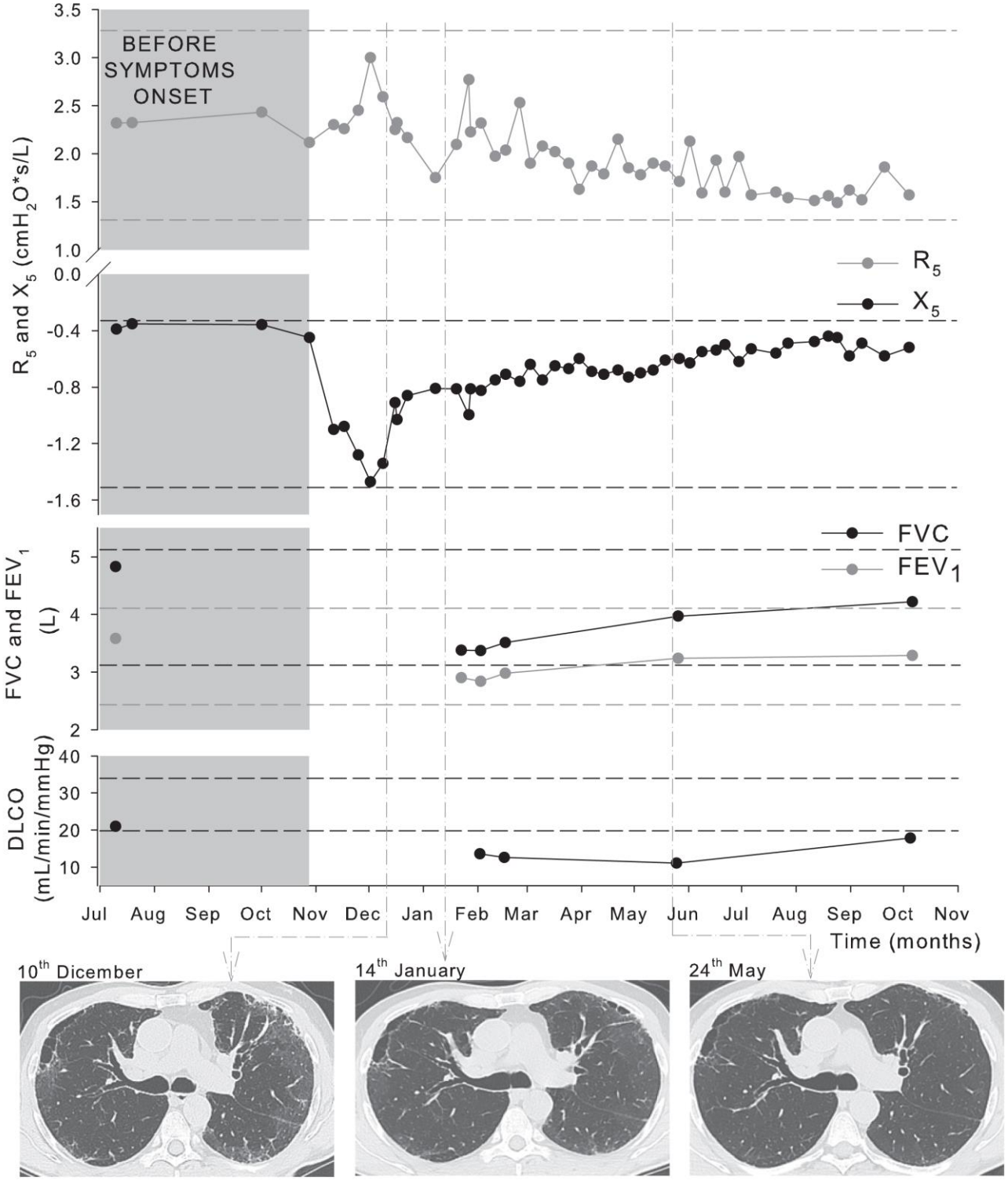
Figure Legend:

Figure 1. Respiratory resistance (R_5), respiratory reactance (X_5), forced vital capacity (FVC), forced expired volume in 1 sec (FEV_1) and diffusing capacity of the lungs for carbon monoxide (DLCO) data over 15 months. Spirometry and DLCO data were not recorded during the acute phase of the disease. Upper and lower limits of normality are reported (dashed lines). Images from CT scans at three different times are also shown.


BEFORE SYMPTOMS ONSET
R5 and X5 (cmH2O*s/L)
R5
X5
FVC and FEV1 (L)
FVC
FEV1
DLCO (mL/min/mmHg)
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Time (months)
10th Dicember
14th January
24th May