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Short communication

Respiratory function assessment at the time of a new respiratory virus pandemic

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ABSTRACT

We must be aware that new respiratory virus pandemic can happen frequently. Standard lung function tests should keep their crucial role to assist the clinicians in the decision-making process, but they are at risk for the spread of infection because of the generated droplets. We used opto-electronic plethysmography to investigate the post-COVID-19 syndrome on 12 patients after ICU. We found normal ventilatory pattern at rest, a restrictive pattern located in the ribcage during vital capacity and surgical mask to significantly increase minute ventilation. The attention on unconventional respiratory function tests should be sponsored for the important information they can provide.

To the editor.

In February 2020, COVID-19 invaded Lombardy, that soon became the epicentre of the COVID-19 outbreak in Italy while representing also the beginning of epidemic in Europe and then worldwide. The clinicians had to face new unexpected stressful challenges, while dealing with the infected subjects who experienced the most severe and critical aspects of this new particularly severe disease. In the worst scenario, it evolves in severe interstitial pneumonia, acute respiratory distress syndrome and multi-organ dysfunction, requiring the admission in intensive care unit (ICU) [1–3]. At the end of the first pandemic wave, Lombardy was left with one of the highest crude mortality rate (167.6/100 k) [4] and with patients experiencing unexpected post-COVID-19 syndrome [5], now known as long COVID-19 [6], with a variety of symptoms and organ-related injuries to be investigated. Assessing pulmonary functions in post-COVID-19 syndrome was therefore a crucial part of the healing process of the patients and for the clinicians to manage the disease. However, standard lung function tests (spirometry, static lung volumes assessment and diffusion capacity of the lungs for carbon monoxide tests) generate aerosols in the form of droplets, due to coughing and/or the generation of high flow rates, and they all require tube circuits attached to a mouthpiece. These features posed the tests at considerable risk for the spread of infection to operators and patients, even the asymptomatic ones. For this reason, at the beginning of the pandemic, a document of the European Respiratory Society recommended no patients with COVID-19 or flu-like symptoms to be tested under any circumstances for a minimum of 30 days after the infection [7]. Pandemic had therefore enormously impacted and limited the wide-spread application of spirometry, while prompting much attention on hygienic procedures and on noncontact spirometers [8]. In June 2020, therefore at the end of the first dramatic wave in Lombardy, we implemented dedicated security procedures for opto-electronic plethysmography (OEP), a non-invasive, motion analysis system capable to quantify respiratory volume variations without the use of mouthpiece [9,10]. We investigated the effects of post-COVID-19 syndrome on 12 patients who were admitted to ICU for a median time of 14 days (interquartile range 12–18.7 days), as a consequence of the progressive deterioration of respiratory functionalities. This group of patients was composed by 9 males (median age: 59 years old) and 3 females (46 years old). A control group of COVID-19-naïve healthy subjects with the same sex and age distribution was also evaluated with the same protocol.

We firstly tested both groups during 6 min of quiet breathing in seated and supine position, finding no differences in the ventilatory pattern (Fig. 1).

OEP does not require mouth instrumentation and therefore the impact of surgical mask on the ventilatory pattern at rest could be tested. In seated position, the surgical mask made patients increase their minute ventilation (11.8 *vs* 10.8 $Lmin^{-1}$) because of shorter total breath duration due to reduced expiratory time (Fig. 1).

Because no standard lung function tests could be performed at that time [7], chest wall and thoraco-abdominal volumes were measured also

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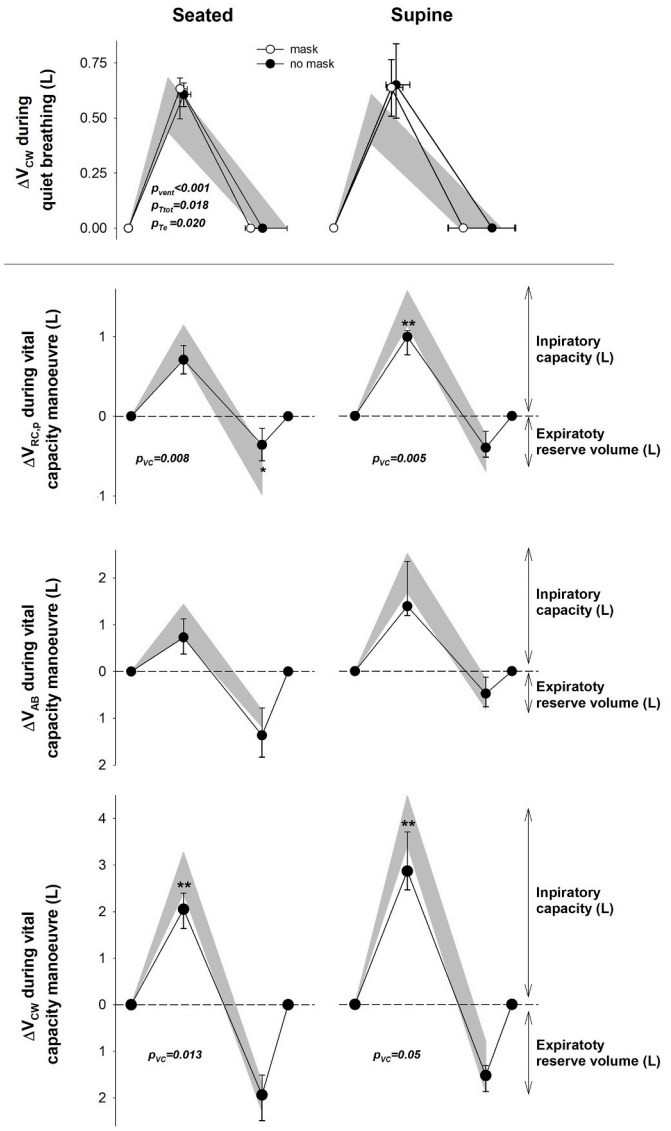

Fig. 1. Top panels: median (symbols) and interquartile range (whiskers) of start inspiratory, end-inspiratory and end-expiratory chest wall volumes in post-COVID syndrome patients during quiet breathing at rest in seated (left) and supine position (right) without (black) and with (white) surgical mask. The grey area represents the corresponding interquartile range of the control group of Covid-naïve healthy subjects without the surgical mask. p_{vent}: *p-value* of minute ventilation; p_{Ttot}: *p-value* of total breath duration; p_{Te}: *p-value* of expiratory time. Lower panels: Median (symbols) and interquartile range (whiskers) of start inspiratory, inspiratory capacity, residual volume and end-expiratory pulmonary ribcage (RC,p), abdominal (AB) and chest wall (CW) volumes in post-COVID syndrome patients during vital capacity manoeuvre in seated (left) and supine position (right) without surgical mask. The grey area represents the corresponding interquartile range of the control group of Covid-naïve healthy subjects without the surgical mask.
**: $p < 0.01$. p_{VC}: *p-value* of the vital capacity.

during vital capacity (VC) manoeuvre. In both postures, VC was significantly lower in patients because of reduced inspiratory capacity, with such restrictive pattern being entirely located in the pulmonary ribcage (Fig. 1).

Considering the period of the time they were acquired, these data are unique and carry out important considerations.

Firstly, the results showed the importance of developing mouthpiece-free systems to assess pulmonary function [11] [–] [13]. Nowadays even after more than one year of pandemic, it is still crucially important to understand and quantify the post-COVID-19 residual effects. In June 2020, therefore, clinicians found themselves in the paradoxical situation where they needed to understand the evolution of an unknown disease without having access to the standard functional tests.

Secondly, the results showed that patients were characterised by restricted lung pattern, with the restriction being located in the inspiratory capacity and in the pulmonary ribcage compartment. We can speculate that the lung of these patients was stiffer because of the presence of fibrotic tissue and that the stiffness impacted the overall VC while limiting only the maximal inspiratory phase. These conclusions were somewhat theoretically expected, considering the severe pneumonia, but they resulted from a radiation-free technique and without the use of mouthpiece, underlining also the importance to investigate thoraco-abdominal volumes.

Thirdly, the results showed that the most severe form of the disease, once resolved, does not impact on the ventilatory pattern at rest. This result seems in line with the clinical unpublished consideration that the CT-scans of the lung of these patients were better than expected (considering the acute episodes of pneumonia), suggesting different cellular fibrotic mechanisms of COVID-19 (to be investigated).

Lastly, the results underlined that surgical mask impacts on the ventilatory pattern of patients in seated position. Considering that at the end of the protocol they reported a dyspnoea BORG scale of 0 (interquartile range 0–0.5), we wonder if the mask-induced altered pattern was mostly like to be consequence of some psychological aspects [14,15] rather than to specific ventilatory drive alterations.

The limits of the results are intrinsically linked to the protocol itself and they were unavoidable: 1) the lack of standard lung function assessment, banned at that period [7]; 2) the lack of evaluation during some exercise task, due to patients suffering from important unexpected locomotor impairments [16–18], that were the primary question of the clinicians; 3) the low number of patients, due to the delicate period to gather people in a research laboratory, that was re-opened for that purpose at the end of a rigid national lockdown [19].

To conclude, although we are experiencing an extraordinary event, we must be aware that new respiratory virus pandemic can happen more frequently than expected [20]. Respiratory function assessment should keep its crucial role in the diagnosis, treatment and follow-up, particularly during the most severe pandemic wave, to assist the clinicians in their delicate decision-making process to heal patients. The attention on unconventional respiratory function tests should be therefore increased and sponsored for the important information they can provide as shown by the present dataset.

Statements.

Contributorship

All authors designed the study, discussed the results, contributed to and agreed on the final manuscript.; ALM and FG: acquired the data; ALM analysed the data and draft the manuscript.

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Nothing to declare.

Competing interests

Nothing to declare.

Exclusive license

Nothing to declare.

Ethics statement

The study was registered by the local ethical committee of Ospedale

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References

[1] G. Grasselli, A. Pesenti, M. Cecconi, Critical care utilization for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response, JAMA, J. Am. Med. Assoc. 323 (2020) 1545–1546, https://doi.org/10.1001/jama.2020.4031.

[2] M. Cieri, C. De Carlo, M. Valeri, et al., How are we facing it? Dispatches from pathology residents in a COVID-19 Lombardy hospital, Front Public Heal 8 (2020), https://doi.org/10.3389/fpubh.2020.00259.

[3] A. Sahu, R. Mathew, P. Aggarwal, et al., Clinical determinants of severe COVID-19 disease - a systematic review and meta-analysis, J. Global Infect. Dis. 13 (2021) 13–19, https://doi.org/10.4103/jgid.jgid_136_20.

[4] L. Villani, M. McKee, F. Cascini, et al., Comparison of deaths rates for COVID-19 across Europe during the first wave of the COVID-19 pandemic, Front Public Heal 8 (2020), https://doi.org/10.3389/fpubh.2020.620416.

[5] A. Dennis, M. Wamil, J. Alberts, et al., Multiorgan impairment in low-risk individuals with post-COVID-19 syndrome: a prospective, community-based study, BMJ Open 11 (2021), https://doi.org/10.1136/bmjopen-2020-048391.

[6] A.W. Vaes, Y.M.J. Goërtz, M. Van Herck, et al., Recovery from COVID-19: a sprint or marathon? 6-month follow-up data from online long COVID-19 support group members, ERJ Open Res 7 (2021) 141–2021, https://doi.org/10.1183/23120541.00141-2021.

[7] ERS Group 9.1, ERS Group 4.1. Recommendation from ERS Group 9.1 (Respiratory function technologists/Scientists)Lung function testing during COVID-19 pandemic and beyond. https://ers.app.box.com/s/zs1uu88wy51monr0ewd990itoz4tsn2h.

[8] S. Ranzieri, M. Corradi, Conducting spirometry in occupational health at COVID-19 times: international standards, Med. Lav. 112 (2021) 95–106, https://doi.org/10.23749/mdl.v112i2.11420.

[9] S.J. Cala, C.M. Kenyon, G. Ferrigno, et al., Chest wall and lung volume estimation by optical reflectance motion analysis, J. Appl. Physiol. 81 (1996) 2680–2689, accessed, http://www.ncbi.nlm.nih.gov/pubmed/9018522. (Accessed 15 June 2015).

[10] M. Romei, Mauro A. Lo, M.G. D'Angelo, et al., Effects of gender and posture on thoraco-abdominal kinematics during quiet breathing in healthy adults, Respir. Physiol. Neurobiol. 172 (2010) 184–191, https://doi.org/10.1016/j.resp.2010.05.018.

[11] A. Aliverti, Wearable technology: role in respiratory health and disease, Breathe 13 (2017) e27–36, https://doi.org/10.1183/20734735.008417.

[12] C. Liu, Y. Yang, F. Tsow, et al., Noncontact spirometry with a webcam, J. Biomed. Opt. 22 (2017), 057002, https://doi.org/10.1117/1.jbo.22.5.057002.

[13] H. Rehouma, R. Noumeir, S. Essouri, et al., Advancements in methods and camera-based sensors for the quantification of respiration, Sensors 20 (2020) 1–55, https://doi.org/10.3390/s20247252.

[14] A.P. Bouças, J. Rheinheimer, J. Lagopoulos, Why Severe COVID-19 Patients Are at Greater Risk of Developing Depression: A Molecular Perspective, *Neuroscientist* Published Online First, 2020, https://doi.org/10.1177/1073858420967892.

[15] L.M. Drummond, Does coronavirus pose a challenge to the diagnoses of anxiety and depression? A view from psychiatry, BJPsych Bull. (2020) 1–3, https://doi.org/10.1192/bjb.2020.102.

[16] W. Camargo-Martínez, I. Lozada-Martínez, A. Escobar-Collazos, et al., Post-COVID 19 neurological syndrome: implications for sequelae's treatment, J. Clin. Neurosci. 88 (2021) 219–225, https://doi.org/10.1016/j.jocn.2021.04.001.

[17] D. Nuzzo, G. Cambula, I. Bacile, et al., Long-term brain disorders in post covid-19 neurological syndrome (Pcns) patient, Brain Sci. 11 (2021), https://doi.org/10.3390/brainsci11040454.

[18] S. Belli, B. Balbi, I. Prince, et al., Low physical functioning and impaired performance of activities of daily life in COVID-19 patients who survived hospitalisation, Eur. Respir. J. 56 (2020), https://doi.org/10.1183/13993003.02096-2020.

[19] Casella G, Castagneto-Gissey L, Lattina I, et al. Repercussions of covid-19-related national lockdown on emergency surgery department: a longitudinal cohort monocentric study. Minerva Surg Published Online First: 28 May 2021. doi: 10.23736/S2724-5691.21.08851-1.

[20] G.C. Gray, E.R. Robie, C.J. Studstill, et al., Mitigating future respiratory virus pandemics: new threats and approaches to consider, Viruses 13 (2021), https://doi.org/10.3390/v13040637.