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Bilateral phrenic nerve block as an effective means of controlling inspiratory efforts in a COVID-19 patient

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ABSTRACT

Bilateral continuous phrenic nerve block effectively regulates refractory persistent, strong inspiratory effort in a patient with coronavirus disease (COVID-19). A 73-year-old man with acute respiratory distress syndrome (ARDS) due to COVID-19 was admitted to the intensive care unit (ICU). Use of neuromuscular blocking agents (NMBAs) was stopped due to uncontrollable strong inspiratory efforts and worsened lung injury. We performed bilateral continuous phrenic nerve block, which suppressed inspiratory efforts, resulting in lung injury improvement. A bilateral continuous phrenic nerve block is a viable alternative to control refractory strong inspiratory effort leading to lung injury in cases with prolonged NMBA use.

1. Introduction

Patients with acute respiratory distress syndrome (ARDS) due to coronavirus disease (COVID-19) require mechanical ventilation [1]. Spontaneous breathing with mechanical ventilation has been reported to contribute to lung injury, especially in severe ARDS [2]. Lung damage caused by strong respiratory efforts is called "patient self-inflicted lung injury" (*P*-SILI) [3], which may exacerbate ARDS due to COVID-19 [4]. Oesophageal pressure (P_{es}) measurement, which reflects pleural pressure [5], detects excessive inspiratory efforts [6]. Tonelli et al. showed that spontaneous breathing with a tidal change in oesophageal pressure (ΔP_{es}) of $\geq$10 cm H_2O was excessive [7]. Short-term use of neuromuscular blocking agents (NMBAs) is recommended for strong spontaneous breathing that cannot be controlled by ventilator setting adjustment and sedation [8]. However, the prolonged use of NMBAs leads to intensive care unit-acquired weakness (ICU-AW). Methods to control intractable excessive spontaneous breathing have not yet been established. In this study, bilateral continuous phrenic nerve block effectively regulated refractory persistent strong inspiratory effort in a patient with COVID-19-related ARDS.

2. Case presentation

Nine days prior to ICU admission, a 73-year-old man developed fever and cough and showed a positive polymerase chain reaction result for severe acute respiratory syndrome coronavirus 2. He had a history of hypertension, diabetes, chronic obstructive pulmonary disease, obesity (body mass index: 32.7 kg/m^2), and smoking (20 pack-years). He was referred to our ICU for the treatment of hypoxemia.

On ICU admission, he was alert, and his blood pressure was 97/52 mmHg with a regular heart rate (75 bpm). He was febrile with a body temperature of 37.8 °C, and his respiratory rate was 24 breaths/min with an SpO_2 level of 91% (oxygen mask: 5 L/min). Physical examination revealed vigorous spontaneous breathing, such as shoulder breathing, and mechanical ventilation was initiated. The P/F ratio was 149 with a 16 cm H_2O positive end-expiratory pressure (PEEP). Chest computed tomography (CT) showed atelectasis of the dorsal lower lobe and multiple bilateral ground-glass shadows (Fig. 1-A).

Abbreviations: ΔP_{es}, change in oesophageal pressure; ARDS, acute respiratory distress syndrome; COVID-19, coronavirus disease; CT, computed tomography; Edi, electrical activity of the diaphragm; ICU, intensive care unit; ICU-AW, intensive care unit-acquired weakness; NMBAs, neuromuscular blocking agents; P_{es}, oesophageal pressure; *P*-SILI, patient self-inflicted lung injury; PEEP, positive end-expiratory pressure.

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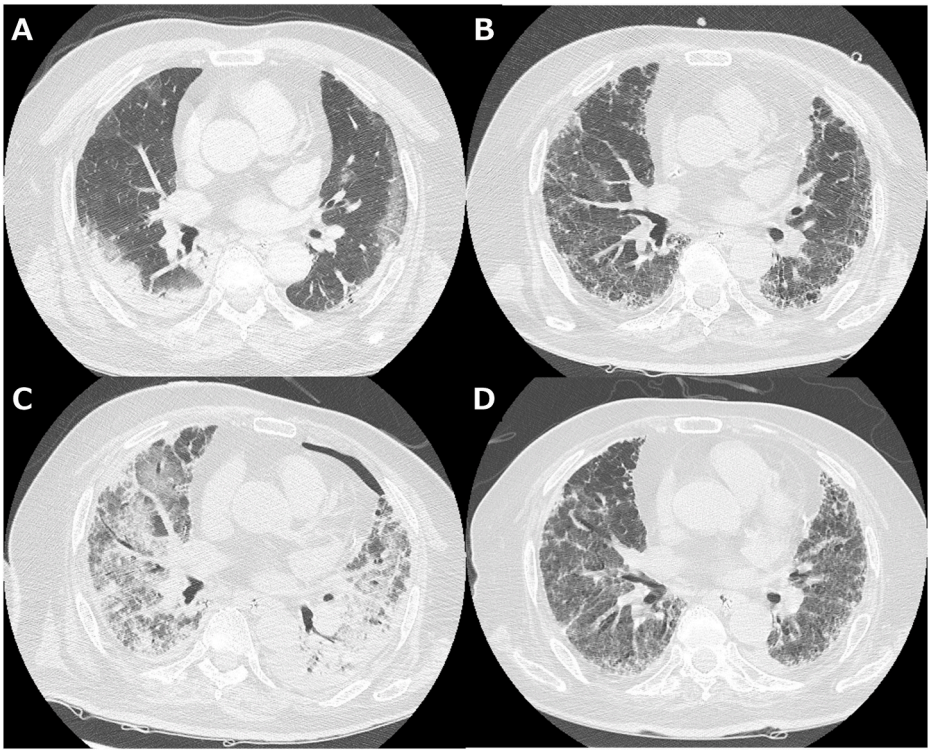

Fig. 1. Time-series results for computed tomography (CT). Time-series results for chest CT in a 73-year-old man with coronavirus disease-related acute respiratory distress syndrome. (A) CT on day 1 showing atelectasis of the dorsal lower lobe and multiple bilateral ground-glass shadows. (B) CT on day 41 showing an improvement in infiltrative shadows. (C) CT on day 56 showing exacerbation of infiltrative shadows in both lungs. (D) CT on day 121 showing an improvement in infiltrative shadows.

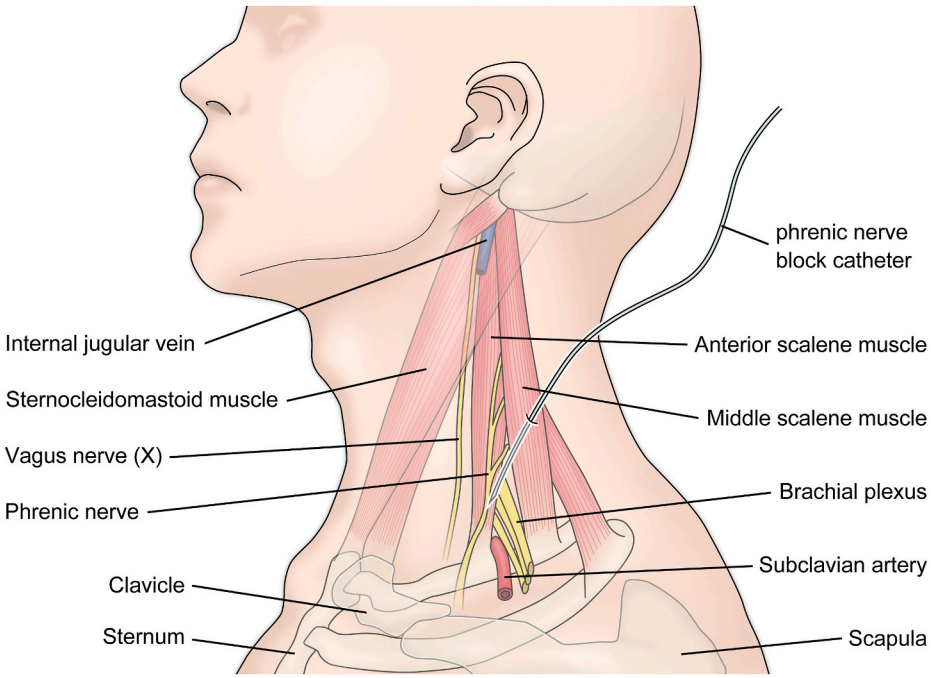

Fig. 2. Schematic of phrenic nerve block. This diagram shows a continuous phrenic nerve block.

Lung-protective ventilation and prone ventilation were performed. However, termination of the NMBAs resulted in spontaneous breathing with a ΔP_{es} exceeding 10 cm H_2O and exacerbation of oxygenation. Administration of NMBAs was continued because his strong respiratory efforts could not be controlled by adjusting the ventilator setting, sedation, or a high PEEP.

On the 19th day after ICU admission, the inflammatory response remained high; thus, we started administering prednisolone (0.5 mg/kg) to control hyperinflammation of the lung injury after ruling out other infections. NMBAs were terminated on day 41 after confirming a decrease in the inflammatory response and an improvement in infiltrative shadows on CT (Fig. 1-B). However, the patient still exhibited strong inspiratory effort. Lung compliance and the P/F ratio decreased, while the inflammatory response increased. When NMBAs were restarted on day 58, his oxygenation improved. To introduce rehabilitation while preventing ICU-AW, we performed an interscalene ultrasound-guided bilateral phrenic nerve block. Consequently, spontaneous breathing was restrained, and oxygenation did not worsen. From days 94–124,

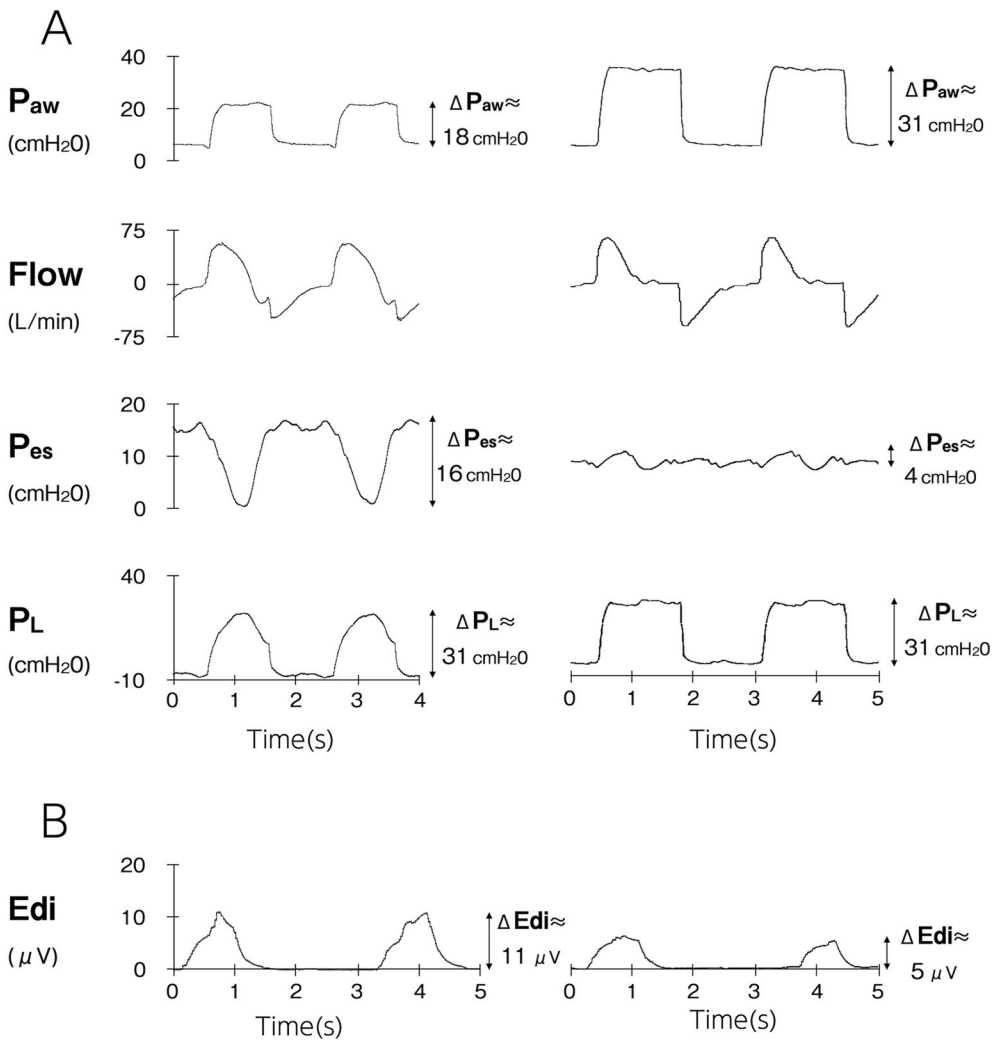

Fig. 3. Ventilator waveforms. The left side of the waveform was seen before the application of the nerve block, and the right side was seen after the application of the nerve block. This waveform shows a reduction in (A) tidal change in oesophageal pressure (ΔP_{es}) and (B) the electrical activity of the diaphragm (Edi).

bilateral continuous phrenic nerve block (Fig. 2) with 1.5% lidocaine (total: 2–4 cc/h continuous infusion) suppressed the ΔP_{es} and electrical activity of the diaphragm (Edi) (Fig. 3). During this period, the patient remained awake, and his rehabilitation proceeded. CT performed on day 121 showed improvement in pulmonary damage to a certain level (Fig. 1-D). The patient was transferred for rehabilitation on day 146 after completing the phrenic nerve block without the exacerbation of oxygenation. There were no obvious complications during this procedure.

3. Discussion

We describe a COVID-19 case wherein intractable persistent strong inspiratory effort resulting in *P*-SILI was suppressed by bilateral continuous phrenic nerve block. To the best of our knowledge, this is the first case to present a means of directly suppressing respiratory effort aside from using NMBAs and sedation.

The diaphragm, which governs most of the normal inhalation process, is controlled by the phrenic nerve [9]. Phrenic nerve block, which is a frequent complication in interscalene brachial plexus block [10], can decrease the forced expiratory volume in 1 s, forced vital capacity [11,12], and estimated percentage of lung ventilation on electrical impedance tomography [13]. In the present case, continuous phrenic nerve block decreased the ΔP_{es} and Edi, indicating a reduction in respiratory effort.

Tonelli et al. clinically demonstrated that suppressing strong inspiratory effort alleviated lung injury [7]. High negative pleural pressures due to strong spontaneous breathing in patients with ARDS cause pendelluft, which increases local lung stress, lung strain, and lung oedema [14]. Regulating the respiratory effort prevents the progression of lung injury and leads to clinical improvement. Although the phrenic nerve block was effective, we do not recommend it as a standard treatment for ARDS. Bilateral continuous phrenic nerve block may be an alternative for patients who require continuous NMBA administration due to lung injury caused by refractory persistent strong inspiratory efforts.

4. Conclusion

A bilateral continuous phrenic nerve block is a viable alternative treatment option for controlling refractory, strong inspiratory effort leading to lung injury, or *P*-SILI, in cases involving a risk of ICU-AW due to prolonged use of NMBAs.

Ethics approval and consent to participate

The patient family's written consent was obtained for this procedure. The application of this intervention was deemed appropriate by a joint conference involving the entire hospital, and the need for ethics approval was waived owing to the emergent situation.

Consent for publication

Appropriate written informed consent was obtained from the patient for the publication of this case report and accompanying images.

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Authors' contributions

RN wrote this manuscript. NB, AS, KT, and RN designed this work. YI, RN, and YG prepared the artwork. NB and NY helped in writing this manuscript. NB, RK, SU, and EN perform the analysis and substantially revised the manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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