Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

with the ability to live independently after surgery. *Br J Anaesth* 2021; **127**: e87–90
8. Wolter N, Jassat W, Walaza S, et al. Early assessment of the clinical severity of the SARS-CoV-2 omicron variant in South Africa: a data linkage study. *Lancet* 2022; **399**: 437–46
9. Dobbs TD, Gibson JAG, Fowler AJ, et al. Surgical activity in England and Wales during the COVID-19 pandemic: a nationwide observational cohort study. *Br J Anaesth* 2021; **127**: 196–204
10. CDC. *CDC updates and shortens recommended isolation and quarantine period for general population, CDC Online Newsroom*. Available from: https://www.cdc.gov/media/releases/2021/s1227-isolation-quarantine-guidance.html. [Accessed 30 January 2022]

doi: 10.1016/j.bja.2022.02.005
Advance Access Publication Date: 16 February 2022

Assessment of a splitter for protective dual-patient ventilation in patients with acute respiratory distress syndrome

Daniel H. Arellano[1,2], Eduardo A. Tobar[1], Marioli T. Lazo[1], Veronica A. Rojas[1], Abraham I. J. Gajardo[1], Nicolás Montecinos[3], Tomás Regueira[4] and Rodrigo A. Cornejo[1,5,*]

[1]Unidad de Pacientes Críticos, Departamento de Medicina, Hospital Clínico Universidad de Chile, Santiago, Chile, [2]Departamento de Kinesiología, Facultad de Medicina, Universidad de Chile, Santiago, Chile, [3]Centro de Pacientes Críticos, Clínica Las Condes, Santiago, Chile, [4]Facultad de Medicina, Universidad Finis Terrae, Santiago, Chile and [5]Center of Acute Respiratory Critical Illness (ARCI), Santiago, Chile

*Corresponding author. E-mail: racornej@gmail.com

Keywords: COVID-19; dual-patient ventilation; mechanical ventilation; protective ventilation; respiratory mechanics

Editor—In dual-patient ventilation, the tidal volume (V_T) delivered to patients depends on their respiratory mechanics, which can vary significantly between them.[1–4] Thus, dual-patient ventilation might provide non-protective high V_T to one patient, while supplying inadequate ventilation to the other because of low V_T.[5,6] To address this issue, splitters capable of regulating V_T individually through implementation of valves and flow limiters have been devised. Dual-patient ventilation has been used in patients with similar respiratory mechanics, both without and with a splitter.[4,7] The effect of changes in compliance (C_{rs}) or inspiratory resistance (R_{aw}) in one patient during dual-patient ventilation with a splitter has only been assessed on test lungs.[7–9]

Shortages of mechanical ventilators during the COVID-19 pandemic prompted the development of mechanical ventilators and splitter prototypes, including under the '*A breath for Chile*' initiative (sponsored by the Ministry of Sciences). In this study, we assessed the performance of the splitter after the electromedical safety inspection. Our objective was to evaluate dual-patient ventilation, without and with a splitter, when one subject develops sudden changes in respiratory mechanics, extreme air leaks, airway disconnection, or airway occlusion in experimental and clinical assessments.

First, dual-patient ventilation was used to ventilate two test lungs (SmartLung 2000; IMT Analytics®, Buchs, Switzerland), without and with a splitter, using a mechanical ventilator (PB 840, Medtronic®, Minneapolis, MN, USA). Pressure-controlled mode was programmed to deliver a V_T of 400 ml to each test lung at the study onset, with a ventilatory frequency (VF) of 15 bpm, fraction of inspired oxygen (FiO_2) 0.21, and PEEP 9 cm H_2O. The C_{rs} of lung A was modified (75, 60, and 25 ml [cm H_2O]$^{-1}$) every 15 min with inspiratory resistance (R_{aw}) of 5 and 20 cm H_2O s L^{-1}, while C_{rs} and R_{aw} of lung B remained constant (75 ml [cm H_2O]$^{-1}$ and 5 cm H_2O s L^{-1}, respectively). The R_{aw}/C_{rs} combinations in lung A were repeated while lung B remained with C_{rs} 60 and 25 ml (cm H_2O)$^{-1}$, with R_{aw} 5 and 20 cm H_2O s L^{-1}. Five measurements of R_{aw}/C_{rs} combination were obtained at the end of each 15-min period. Finally, occlusion (R_{aw} 200 cm H_2O s L^{-1}) and air leak manoeuvres were performed in test lung A. During these modifications, V_T, PEEP, and airway pressures in both lungs were recorded (pneumotachograph FluxMed GrE, MBMed®, Buenos Aires, Argentina).

Second, dual-patient ventilation with a splitter (NeyunSplit, DTS®, Santiago, Chile) was performed to ventilate both a test lung and a patient. Five patients older than 18 yr with COVID-19-associated acute respiratory distress syndrome (ARDS), haemodynamic stability, and deep sedation were included. The active humidification system was replaced by a heat and moisture exchanger filter (HMEF). The mechanical ventilator was set to pressure-controlled mode to deliver a V_T of 6 ml kg^{-1} to the patient and a similar V_T to the test lung. The VF, FiO_2, and PEEP programmed for the patients were maintained. The same R_{aw}/C_{rs} combinations and occlusion and air leak manoeuvres used in the experimental phase were performed in a test lung (further details of ventilation splitting are provided as Supplementary Fig. 1).

Third, dual-patient ventilation with a splitter was also used to ventilate two ARDS patients at the same time. Ventilatory, hemodynamic, and gas exchange parameters were recorded.

The study was conducted between May and September 2020 after approval by the Institutional Review Board (IRB, approval number 037/2020, Hospital Clínico Universidad de Chile). The IRB authorised telephonic informed consent obtained from patients' next of kin, because most were in quarantine and hospitals severely restricted visitor access before vaccination. Results are expressed as median (inter-quartile range) and compared with Friedman's test. A *P*-value <0.005 was considered strong statistical evidence to account up to 10 simultaneous comparisons (with Bonferroni correction).

Dual-patient ventilation without a splitter generated significant changes in V_T, PEEP, plateau pressure, and peak pressure of test lungs (*P*-value <0.001). However, dual-patient ventilation with a splitter did not generate changes in V_T, and only minimal changes were observed in PEEP, plateau pressure, and peak pressure (Fig. 1a).

Seven patients were assessed using dual-patient ventilation with a splitter: five with a test lung, and two together (age 65 [61.5–65.5] yr, Pa_{O_2}:FiO_2 22 [16–24] kPa, V_T 6.5 [6.1–6.5] ml kg^{-1} predicted body weight, and time on mechanical ventilation 8 [4.5–14] days). Patient V_T, PEEP, plateau pressure, and peak pressure remained similar despite R_{aw}/C_{rs} combinations set in the test lung (*P*>0.05, Fig. 1b). Pa_{O_2}:FiO_2, HR, and MAP remained unchanged during these assessments, and Pa_{CO_2} increased in three patients. Both patients synchronously ventilated through dual-patient ventilation with a splitter maintained stability in their ventilatory, haemodynamic, and gas exchange parameters after 3 h of assessment (Fig. 1c).

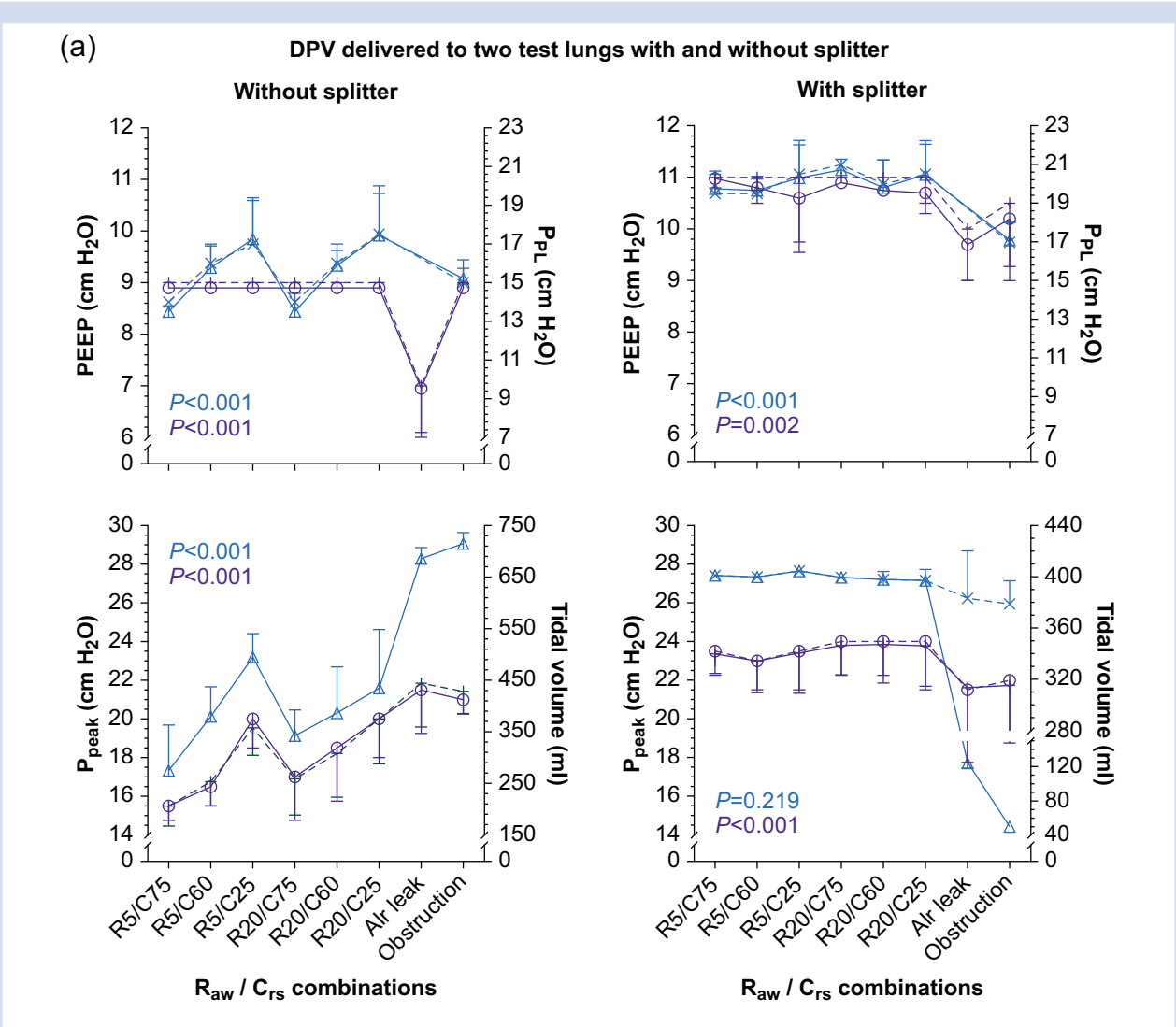

Fig 1. Tidal volume, plateau and peak pressures, and PEEP during dual-patient ventilation without or with a splitter. Median and inter-quartile range of PEEP, plateau pressure (P_{PL}), peak pressure (P_{peak}), and tidal volume showing changes during dual-patient ventilation (DPV) under different combinations of airway resistance (R_{aw}) and compliance (C_{rs}) (R5/C75, R5/C60, R5/C25, R20/C75, R20/C60, and R20/C25), and during air leak or airway obstruction. (a) DPV with or without a splitter was delivered to two test lungs (lung A (dashed line) and B (solid line). (b) DPV with a splitter was delivered to a patient (dashed line) and a test lung (solid line). (c) DPV with a splitter was delivered to two patients (dashed and solid lines) for 3 h. Friedman test *P*-values are displayed for the lung A or patient.

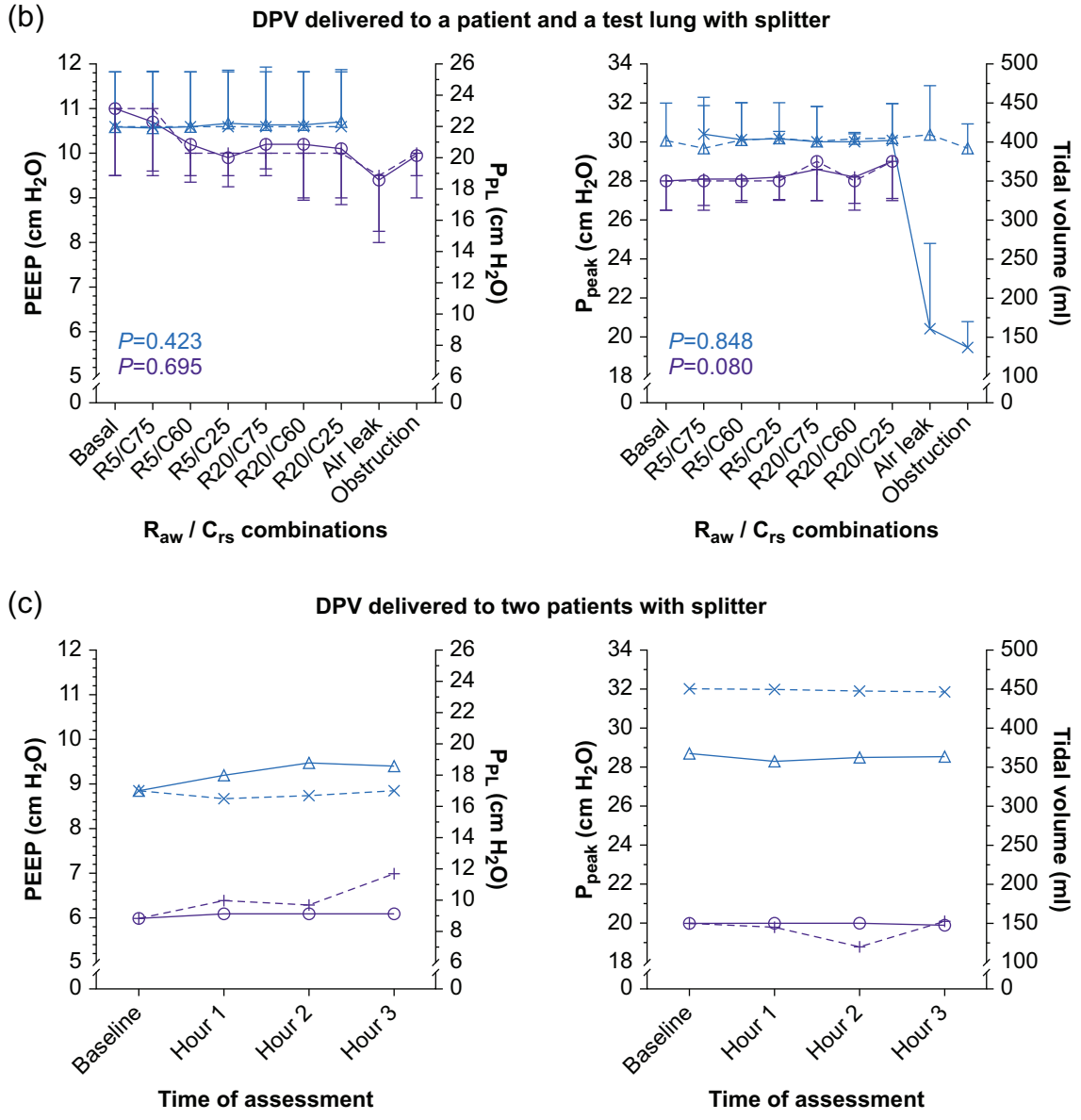

Fig 1. *Continued*

When dual-patient ventilation was used to ventilate a patient and a test lung, the splitter was able to maintain stable and differentiated V_T, PEEP, and airway pressures in the patient independent of the changes in C_{rs} and R_{aw} of the test lung, even with air leak and occlusion manoeuvres. On the contrary, the same changes in respiratory mechanics during dual-patient ventilation without a splitter generated significant (clinically relevant) changes in V_T, PEEP, and airway pressure in lung simulators; V_T was higher for the lung with better C_{rs} and lower resistance.

As in other reports,[7–10] a splitter was able to provide a defined and different V_T to two patients despite differences in respiratory mechanics. Of note, we tested for the first time in humans whether sudden changes in lung C_{rs}, airway resistance, or both in one simulated patient (test lung) affect the other patient (ARDS patient), including extreme conditions such as massive leak and airway occlusion. The NeyunSplit allows adjustments to a flow limiting valve to keep the V_T stable; notwithstanding the extreme changes in C_{rs} and resistance, only two patients needed adjustments, achieving the desired V_T in a few seconds.

The increase in Pa_{CO_2} was mainly attributable to the change from active humidification to HMEF by increasing dead space.[11] The V_T and VF were not modified during the study. Under real conditions, it is feasible to make changes to compensate for the increase in Pa_{CO_2}.

When initiating dual-patient ventilation, higher initial set V_T in the mechanical ventilator is required to ventilate two

patients. A greater V_T at high VF can induce entrapment and auto-PEEP by limiting expiratory time; this phenomenon can be compensated by adjusting the splitter flow limiter. Use of splitters requires meticulous assembly but can be potentially useful in pandemic scenarios.

Acknowledgements

We thank Diego Ugalde for his assistance in figure design.

Declarations of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2022.02.007.

References

1. Sommer DD, Fisher JA, Ramcharan V, Marshall S, Vidic DM. Improvised automatic lung ventilation for unanticipated emergencies. *Crit Care Med* 1994; **22**: 705–9
2. Neyman G, Irvin CB. A single ventilator for multiple simulated patients to meet disaster surge. *Acad Emerg Med* 2006; **13**: 1246–9
3. Chatburn RL, Branson RD, Hatipoğlu U. Multiplex ventilation: a simulation-based study of ventilating 2 patients with a single ventilator. *Respir Care* 2020; **65**: 920–31
4. Beitler JR, Mittel AM, Kallet R, et al. Ventilator sharing during an acute shortage caused by the COVID-19 pandemic. *Am J Respir Crit Care Med* 2020; **202**: 600–4
5. Laffey JG, Chikhani M, Bates DG, Hardman JG. Supporting more than one patient with a single mechanical ventilator: useful last resort or unjustifiable risk? *Br J Anaesth* 2020; **125**: 247–50
6. Tonetti T, Zanella A, Pizzilli G, et al. One ventilator for two patients: feasibility and considerations of a last resort solution in case of equipment shortage. *Thorax* 2020; **75**: 517–9
7. Milner A, Siner JM, Balcezak T, Fajardo E. Ventilator sharing using volume-controlled ventilation during the COVID-19 pandemic. *Am J Respir Crit Care Med* 2020; **202**: 1317–9
8. Solís-Lemus JA, Costar E, Doorly D, et al. A simulated single ventilator/dual patient ventilation strategy for acute respiratory distress syndrome during the COVID-19 pandemic. *R Soc Open Sci* 2020; **7**: 200585
9. Srinivasan SS, Ramadi KB, Vicario F, et al. A rapidly deployable individualized system for augmenting ventilator capacity. *Sci Transl Med* 2020; **12**, eabb9401
10. Chen GH, Hellman S, Irie T, Downey RJ, Fischer GW. Regulating inspiratory pressure to individualise tidal volumes in a simulated two-patient, one-ventilator system. *Br J Anaesth* 2020; **125**: e366–8
11. Prin S, Chergui K, Augarde R, Page B, Jardin F, Vieillard-Baron A. Ability and safety of a heated humidifier to control hypercapnic acidosis in severe ARDS. *Intensive Care Med* 2002; **28**: 1756–60

doi: 10.1016/j.bja.2022.02.007
Advance Access Publication Date: 21 February 2022

Personal protective equipment provision amongst Chinese anaesthesia departments before and after the outbreak of COVID-19

Ying-Jie Du[1], Jian-Qiang Song[2], Li-Li Wu[1], Hao Cheng[3], Jun Li[4], Lei Wang[5] and Gu-Yan Wang[1,*]

[1]Department of Anaesthesiology, Beijing Tongren Hospital, Capital Medical University, Beijing, China, [2]Department of Anaesthesiology, Zhengzhou Central Hospital Affiliated with Zhengzhou University, Zhengzhou, China, [3]Department of Anaesthesiology, Beijing Ditan Hospital, Capital Medical University, Beijing, China, [4]Department of Anaesthesiology, The Sixth Medical Center of General Hospital PLA, Beijing, China and [5]Department of Anaesthesiology, Beijing Haidian Maternal & Child Health Hospital, Beijing, China

*Corresponding author. E-mail: guyanwang2006@163.com

Keywords: anaesthesiologist; China; COVID-19; infection control; personal protective equipment

Editor—Adequate provision of personal protective equipment (PPE) is important in the fight against COVID-19, which is transmitted through droplets, direct contact, and aerosols.[1,2] Anaesthesiologists may need to intubate the trachea of patients with COVID-19, which is a high-risk procedure because of access to the oropharynx and exposure to respiratory secretions that can carry a high viral load. In addition, anaesthesiologists inevitably encounter undiagnosed patients, namely those with false-negative reverse transcription–polymerase chain reaction (RT–PCR)