Rapidly scalable mechanical ventilator for the COVID-19 pandemic

Intensive Care Med (2020) 46:1642–1644
https://doi.org/10.1007/s00134-020-06113-3

LETTER

Rapidly scalable mechanical ventilator for the COVID-19 pandemic

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The SARS-CoV-2 pandemic is straining healthcare systems worldwide, and a global ventilator shortage is fueling the dire situation. As a response, the MIT E-Vent Team (S1) manufactured a scalable ventilator prototype for mass production and demonstrated basic clinical feasibility.

MIT E-Vent engineering information and capabilities, but also missing safety features are provided on the MIT E-Vent website (https://e-vent.mit.edu/) and in the attachments (Fig. 1a, S2). Pressure-based alarms were implemented including in the `Spiro Wave' device that is based on the MIT E-vent and was just authorized for emergency use by the US FDA. In brief, the MIT E-Vent houses a manual resuscitator, an external compression mechanism, and a control system for adjusting tidal volumes, inspiration-to-expiration ratio, and respiratory rate (Fig. 1a, S3, S4). The MIT E-Vent is equipped with a pressure relief and a positive end-expiratory pressure (PEEP) valve. It delivers unassisted (Fig. 1b) and assisted (not shown) volume control ventilation (VCV). As a proof of concept, a pig was ventilated with the MIT E-Vent or a standard mechanical ventilator (SMV) at distinct settings and arterial blood gases, ventilator waveforms, and flow-volume loops were obtained.

The MIT E-Vent performed similar to a SMV at identical respiratory settings. After 36 h of usage including at high demand settings (TV 600 cc, RR 30, PEEP 20), no signs of device failure were noted (S5).

Tidal volume delivery

MIT E-Vent waveforms showed a smooth tidal volume delivery (Fig. 1b). It revealed similar flow-volume loops when compared to manual ventilation using a manual resuscitator (Fig. 1c).

Gas exchange

MIT E-Vent settings were changed to achieve 'low' and 'high' minute ventilation, and 'low' and 'high' FiO2 states as reflected in the ABGs (Fig. 1d, e).

The MIT E-Vent provides (un-)assisted VCV, variable MV, and PEEP with airway pressure profiles comparable to a SMV. The MIT E-Vent is not equipped to provide pressure control ventilation (PCV), which may make it unsuitable for awake and the most complex ARDS patients. However, this device is meant as a bridging tool when a conventional ventilator is not available, to serve as 'destination ventilator device' in the absence of any alternatives, or to help free up SMV in certain cases.

The MIT E-Vent Team was determined to equip the MIT E-Vent with comprehensive safety features including oxygen and flow sensors, but due to widespread hardware supply shortages, this became impossible. Omitting these safety features was deemed necessary to provide a rapidly scalable prototype. Consequently, increased clinical monitoring is required to provide adequate safety during the use of the MIT E-Vent (S2). Despite these limitations, the MIT-E Vent offers basic mechanical ventilation for selected patients during this ventilator shortage.

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The MIT E-Vent Team group details are listed in the acknowledgement section.

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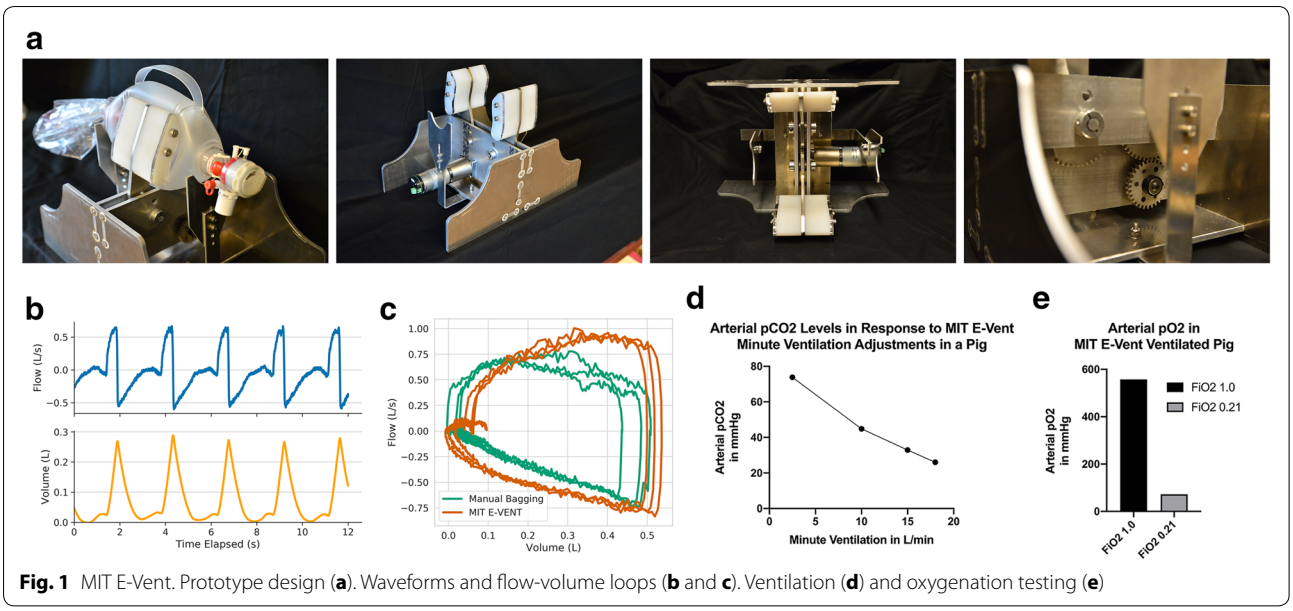

Fig. 1 MIT E-Vent. Prototype design (**a**). Waveforms and flow-volume loops (**b** and **c**). Ventilation (**d**) and oxygenation testing (**e**)

The MIT E-Vent Team invites the global community to improve and distribute a version of this scalable, low-cost ventilator during this COVID-19 pandemic.

Oxygenation and ventilation capabilities of a scalable, low-cost ventilator were demonstrated. MIT E-Vent engineering documentation was made public to rapidly implement the MIT E-Vent into the clinical care of patients requiring invasive mechanical ventilation.

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s00134-020-06113-3) contains supplementary material, which is available to authorized users.

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Compliance with ethical standards

Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Publisher's Note

Accepted: 11 May 2020
Published online: 25 June 2020