VT20 method for Chartis assessment of collateral ventilation with flexible bronchoscopy under procedural sedation

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To the Editor:

Increasing morbidity and mortality from COPD worldwide make it necessary to optimise diagnostic and therapeutic options for patients with advanced lung emphysema [1]. Lung emphysema is a severe, debilitating form of COPD, characterised by severe dyspnoea due to hyperinflation. Endoscopic lung volume reduction (ELVR) therapy with one-way valves is an important treatment that improves breathing mechanics [2–5]. Treatment success highly depends on careful assessment of collateral ventilation (CV) of the target lobe prior to ELVR [4], as the absence of collateral ventilation in the target lobe is a prerequisite. The Chartis Pulmonary Assessment System (Pulmonx Corporation, Redwood City, CA, USA) is integral to determine presence or absence of CV. During Chartis assessment, the expiratory airflow and inspiratory pressure are measured *via* a catheter with a balloon at the distal tip. The balloon is used to temporarily occlude the lobar bronchus [6]. Results are visually characterised into four Chartis phenotypes: CV-negative (CV^-), CV-positive (CV^+), low flow and low plateau [7]. Conclusive Chartis phenotypes characterise CV as absent (CV^-) or present (CV^+). Low flow, which has also been referred to as "airway collapse phenotype", and low plateau phenotypes are inconclusive Chartis assessments with no definitive conclusion with regards to CV, although low flow occurs almost exclusively in CV^- cases. Chartis is routinely performed in experienced emphysema centres. Chartis assessment is a complex and time-intensive procedure and if performed under procedural sedation requires an optimal interplay between sedation and breathing [8, 9]. Koster *et al*. [10] published the "volume trend (VT) 20 method" for Chartis assessments, validating the distinction between CV^+ and CV^- phenotypes, as well as shortening the duration of the procedure. The volume trend over 20 s (VT20) measurement involves the algorithm of continuous calculation and display of the total expired volume over the preceding 20 s. Findings from Koster *et al*. [10] demonstrated that a CV^- phenotype can be reliably predicted when the VT20 measurement of exhaled air from the target lobe reaches or falls below a threshold of 6 mL, thereby eliminating the need to wait for complete cessation of airflow. However, their VT20 validation was limited to Chartis procedures performed under general anaesthesia with mechanical ventilation [10]. The current study aims to extend this validation to include Chartis procedures performed under procedural sedation and spontaneous ventilation or high-frequency jet ventilation, specifically evaluating the efficacy of the VT20 threshold of $\leqslant$6 mL as an indicator of CV^- phenotypes and $\geqslant$7 mL as indicative of CV^+ phenotypes.

In a retrospective, single-centre analysis at Charité Universitätsmedizin Berlin, 140 Chartis assessments of patients with advanced lung emphysema evaluated for ELVR were analysed. All patients provided informed consent and were included in an open-label clinical trial approved by the local ethics committee (A2/149/17 and EA1/136/13). Chartis assessments were performed during flexible bronchoscopy with mild-to-moderate procedural sedation with intravenous administration of midazolam and propofol. The airway was secured with a 7.5-mm endotracheal tube (Bronchoflex; Rüsch, Rems-Murr, Germany) to ensure proper ventilation during bronchoscopy. The ventilation mode was chosen by the bronchoscopist according to the patient's cardiorespiratory needs. Notably, a recent study showed that changes in ventilation mode did not affect Chartis outcome [11]. The study protocol described by Koster *et al*. [10] was applied, and for analysis, only conclusive Chartis assessments (CV^+ and CV^-) were included in this study. Chartis assessments were recorded using the latest console and software version 6.1.1, which included the VT20 feature. For statistical analysis, SPSS (version 24.0.0.0; IBM, Armonk, NY, USA) was

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VT20 is applicable for Chartis assessments with conscious sedation and spontaneous ventilation or high-frequency jet ventilation, and the cut-off of $\leqslant$6 mL remains the same to distinguish between CV^- and CV^+ phenotypes https://bit.ly/3HG9iMQ

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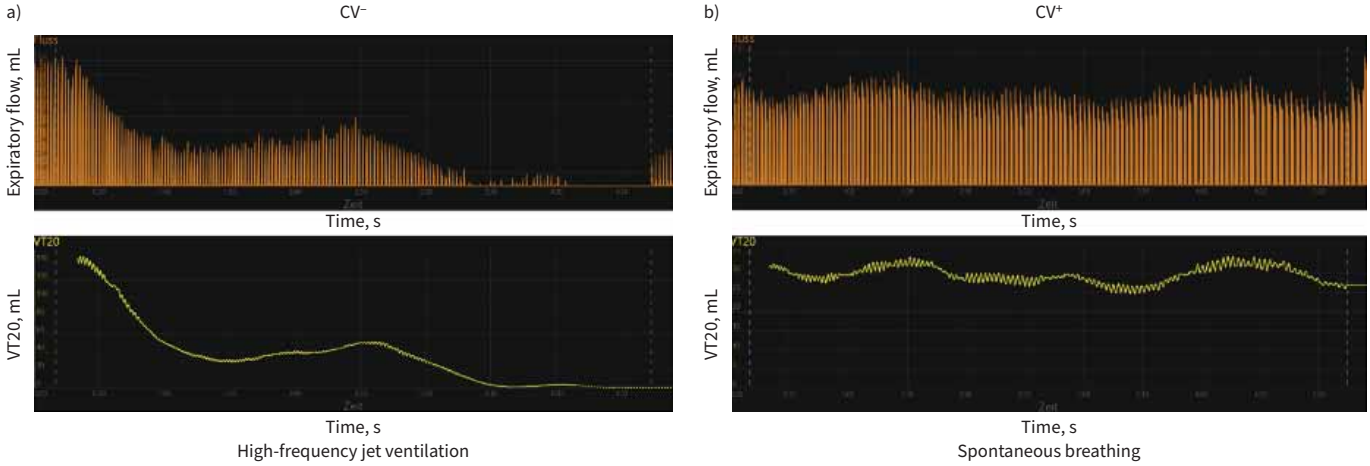
used. Categorical variables are shown as n (%), and continuous variables as median (range). Wilcoxon test was used for statistical comparisons. p-values <0.05 were considered statistically significant.

A total of 140 Chartis assessments were included (n=65 CV^-, n=75 CV^+). 96 Chartis assessments in spontaneous breathing (SB) and 44 in high-frequency jet ventilation (JV) were recorded. All patients underwent the Chartis procedure and assessments were terminated based on standard of care, without applying the VT20 threshold. However, time to reach or exceed VT20 thresholds were documented during the procedure for retrospective analysis. All CV^- assessments reached a VT20 of ⩽6 mL, and all CV^+ measurements had a VT20 of ⩾7 mL. Furthermore, all median VT20 values ($VT20_{SB}$, VT_{JV}, VT_{total}) were lower compared to total time of Chartis assessments in all ventilation modes. Minimal VT20 (total) reached 3 (0–6) mL for CV^- measurements compared to 38 (7–148) mL for CV^+ ($p<0.05$). Minimal VT20 for spontaneous breathing and high-frequency ventilation are shown in detail in figure 1c. In CV^- cases, the median (range) duration to reach a $VT20_{total}$ of 6 mL was 143 (28–406) s, which was shorter than the total Chartis assessment duration without applying VT20 160 (58–415) s.

Our study is the first study analysing VT20 with flexible bronchoscopy under mild-to-moderate procedural sedation. It confirms the efficacy of a VT20 cut-off of ⩽6 mL to differentiate between CV^+ and CV^- cases. Additionally, the analysis identified a significant reduction in procedure time, with an average median (range) time saving of 11 (0–268) s using VT20. Comparatively, the median times recorded in this study for Chartis assessments using VT20 during moderate procedural sedation were shorter than those reported by Koster *et al.* [10] for their cases under general anaesthesia. Specifically, the average median (range) time was 160 s for CV^- cases and 196 s for CV^+ cases, in contrast to the 226 s (CV^-) and 304 s (CV^+) reported by Koster *et al.* [10]. The reduced median times in this study could be attributed to prior knowledge of the benefits of the VT20 method, potentially leading to earlier termination of Chartis assessments. In a similar context, a publication by Welling and co-workers [12, 13] from the same



c)

	CV⁻			CV⁺			p-value		
	Spontaneous breathing	High-frequency jet ventilation	Total	Spontaneous breathing	High-frequency jet ventilation	Total	Spontaneous breathing CV^- *versus* CV^+	High-frequency jet ventilation CV^- *versus* CV^+	Total CV^- *versus* CV^+
Subjects, n	38	27	65	58	17	75			
Min VT20 value, mL	2.5 (0–6)	4.0 (0–6)	3.0 (0–6)	39.5 (7–148)	31.0 (9–101)	38.0 (7–148)	**<0.05**	**<0.05**	**<0.05**
Total time Chartis assessment, s	173 (59–415)	124 (58–345)	160 (58–415)	189 (82–353)	233 (95–416)	196 (82–416)	0.69	0.07	0.10
Time at which VT20=6 mL, s	158.5 (28–406)	119 (59–353)	143 (28–406)						
Time saved, s	14 (0–268)	9 (0–97)	11 (0–268)						

FIGURE 1 Chartis phenotypes in high-frequency jet ventilation and spontaneous breathing. a) Collateral ventilation negative (CV^-) phenotype: continuous decrease in expiratory flow with concomitant decrease in volume trend over 20 s (VT20); b) collateral ventilation positive (CV^+) phenotype: no decrease in expiratory flow and no decrease in VT20. c) Chartis phenotype values. Data are presented as n or median (range), unless otherwise stated. Bold type represents statistical significance.

research group observed shorter durations for Chartis assessments under general anaesthesia compared to procedural sedation, attributable to fewer disruptions such as coughing, mucus presence, bronchus spasms or sedation complications, among other factors. Nevertheless, the VT20 method shortens Chartis procedure in general anaesthesia and procedural sedation. A limitation of this study is its retrospective nature.

In conclusion, VT20 is also applicable for Chartis assessments with procedural sedation and spontaneous breathing or high-frequency jet ventilation, and the cut-off of ⩽6 mL remains the same to distinguish between CV^- and CV^+ phenotypes. When using VT20, CV^- Chartis measurements were shorter. Shortening overall intervention time in patients with advanced emphysema may ultimately reduce complications.

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Ethics statement: The research presented in this article was conducted according to the standards of the World Medical Association Declaration of Helsinki and the appropriate guidelines for human studies. All data were derived from prospective open-label clinical studies in our institution which were approved by the Ethics Committee of the Charité Universitätsmedizin Berlin, Germany (EA2/149/17 and EA1/136/13). All patients consented to participation. Inability to sign the consent form was an exclusion criterion.

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