Archivos de Bronconeumología 62 (2026) 665–669

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Sociedad Española de Neumología y Cirugía Torácica

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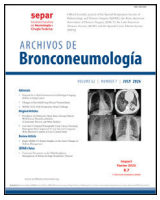

Scientific Letter

Structured Approach to Mechanical Ventilation and Training Standardization: Multinational Modified Delphi Survey

To the Director,

Mechanical ventilation (MV) is a cornerstone of critical care practice, yet substantial variability persists in bedside ventilator management across institutions, disciplines, and resource variable environments [1]. Such heterogeneity may contribute to inconsistent physiologic optimization, delayed recognition of mechanical ventilation (MV)-related complications, and may adversely affect patient outcomes [2]. Structured algorithmic frameworks offer an opportunity to standardize essential ventilator management principles while preserving clinician judgment and physiologic adaptability. The STOP (Standardized, evidence-based management of critically ill patients) framework was developed to provide a physiology-informed, workflow-integrated approach to bedside MV management, emphasizing safety and usability [3]. In this study, we used a single-round modified Delphi process to evaluate multinational expert consensus regarding the clarity, feasibility, and clinical applicability of this structured decision-support algorithm across resource-variable settings.

An international needs assessment survey conducted through the Checklist for Early Recognition and Treatment of Acute Illness (CERTAIN) network, previously demonstrated substantial heterogeneity in mechanical ventilation practices among 150 clinicians across multiple regions and disciplines [4,5]. Based on these findings, we recruited a multidisciplinary panel of 50 clinicians (physicians, nurse practitioners, and respiratory therapists) using purposive sampling. Eligibility criteria included active critical/acute care practice, direct responsibility for MV management, and academic or educational engagement. Panel diversity was intentionally sought to reflect variation in geography, professional roles, and resource environments (Fig. 1A, B, D). Participants were contacted by email and provided additional study information through a dedicated project webpage (https://www.icertain.org/certainvmv).

The MV algorithm was developed using an iterative framework adapted from the STOP methodology, emphasizing physiologic coherence, bedside usability, feasibility, and workflow integration [3]. This process incorporated a comprehensive review of current guidelines and expert recommendations, followed by development of a multidisciplinary prototype using a rapid prototyping approach. The algorithm underwent structured iterative refinement through multiple review cycles with frontline clinicians with progressive simplification and standardization of decision thresholds. Seven structured statements corresponding to eight algorithm steps were constructed to evaluate the framework's clarity and clinical applicability. The algorithm steps addressed management of abnormal vital signs and ventilator alarms (step 1); assessment of ventilation adequacy, including tidal volume discrepancies and elevated peak pressure (steps 2 and 3); elevated plateau pressure (step 4); prevention of ventilator-induced lung injury (step 5); prevention of oxygen toxicity (step 6); identification and management of patient-ventilator asynchrony (step 7); and assessment for readiness for ventilator liberation (step 8). Survey items were internally reviewed for construct validity and pilot-tested with five independent experts prior to dissemination. The algorithm was intentionally designed as a high-level cognitive decision-support tool to standardize foundational ventilator management principles while preserving clinician judgment.

Between May and September 2024, we conducted a structured single-round modified Delphi process, in which expert consensus was obtained without iterative re-rating or additional survey using REDCap platform. Agreement was defined as responses of "agree" or "strongly agree" on a 5-point Likert scale. Consensus was predefined as ≥70% agreement and strong consensus as ≥80%, consistent with published Delphi methodology standards [6]. All survey items achieved strong consensus in the single-round, accompanied by qualitative feedback. Free-text feedback was subsequently reviewed during a structured virtual meeting to clarify interpretation and inform minor wording refinements; no re-rating was performed. The study design and reporting followed established CREDES/ACCORD guidance for Delphi studies [7]; a detailed checklist is provided in the supplement.

Of 54 responses received, 50 complete surveys were included in the final analysis. Panel demographics, professional roles, and geographic representation are summarized in Fig. 1. Participants represented multiple disciplines and practice environments across four continents.

The survey evaluated consensus across eight algorithm domains addressing: abnormal vital signs and ventilator alarms (step 1); abnormal ventilation parameters, tidal volume discrepancies, and elevated peak airway pressure (steps 2 and 3); elevated plateau pressure (step 4); mitigation of ventilator-induced lung injury (step 5); oxygen titration (step 6); patient–ventilator asynchrony (step 7); and ventilator liberation (step 8) (Fig. 2).

Strong consensus (≥80%) was achieved across all domains in the single Delphi round without iterative re-rating. The highest level of agreement was observed for ventilator liberation (96%), followed by plateau pressure management (94%) and ventilator-induced lung injury prevention (90%). Recognition of patient–ventilator asynchrony achieved 82% agreement (Fig. 1C). Minor wording refinements were incorporated based on qualitative feedback; no additional quantitative re-rating was performed. Collectively, these

https://doi.org/10.1016/j.arbres.2026.03.009
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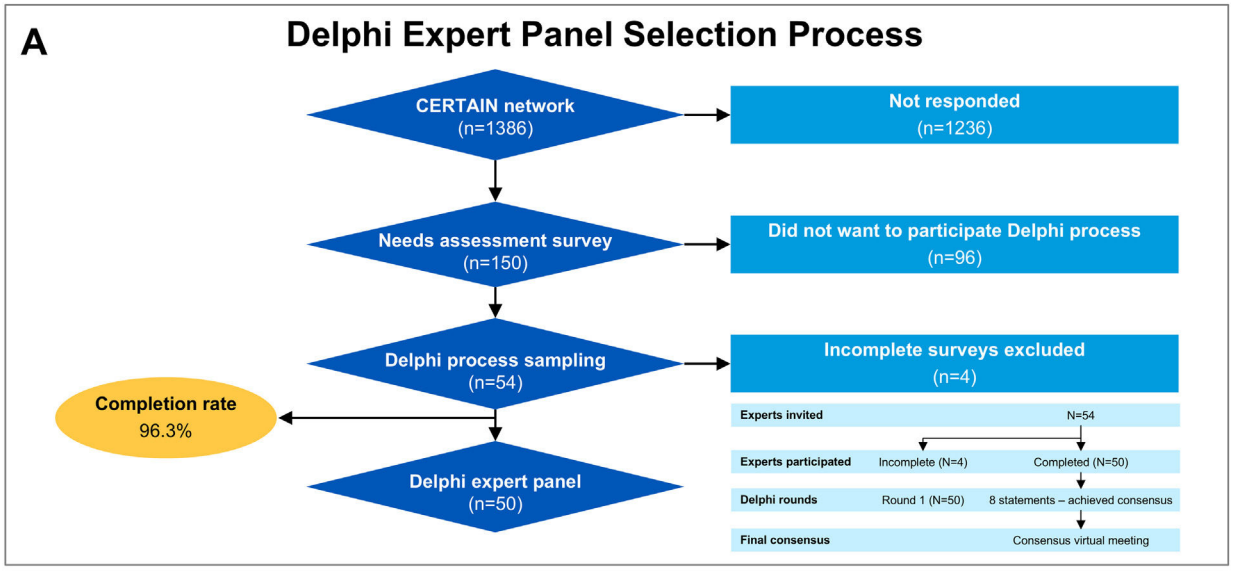
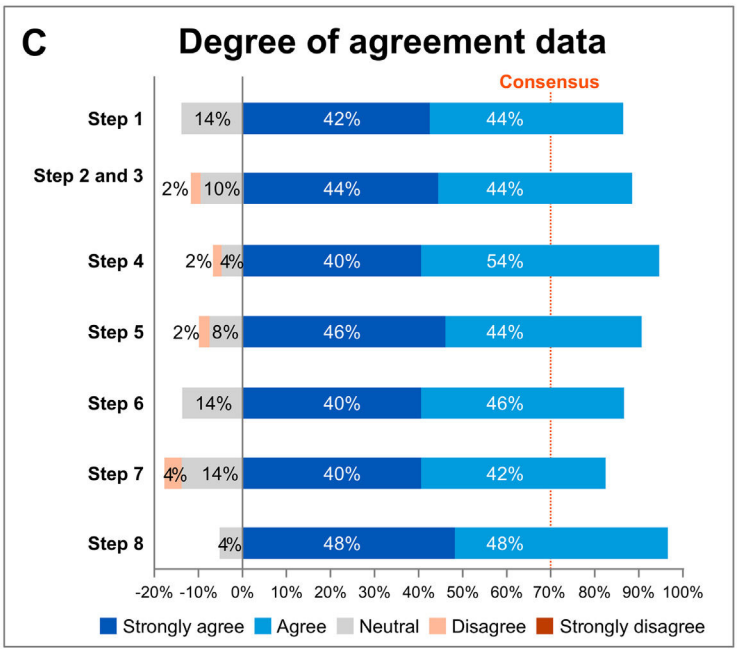


B Demographic data

Characteristic (N=50)	No. (%)
Gender	
Female	18 (36%)
Male	32 (64%)
Profession	
Physician	43 (86%)
Nurse Practitioner	2 (4%)
Respiratory Therapist	5 (10%)
Specialty (n=7)	
Internal Medicine	19 (38%)
Anesthesiology	12 (24%)
Pulmonology	3 (6%)
Surgery	3 (6%)
Cardiology	2 (4%)
Pediatric	2 (4%)
Other	9 (18%)
Years of experience	
<1	2 (4%)
1-5	17 (34%)
6-10	10 (20%)
11-15	9 (18%)
Over 15	12 (24%)



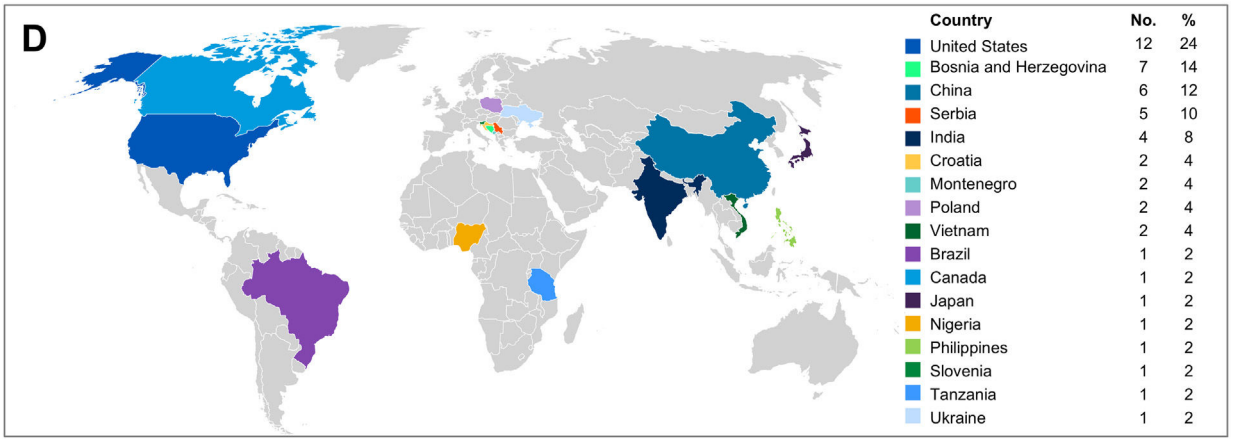


Fig. 1. Modified Delphi workflow and panel characteristics. Panel A. Recruitment and inclusion flow diagram. Panel B. Professional composition and demographics of the Delphi panel. Panel C. Degree of agreement and consensus thresholds for each of the steps. Panel D. Geographic representation of participants.

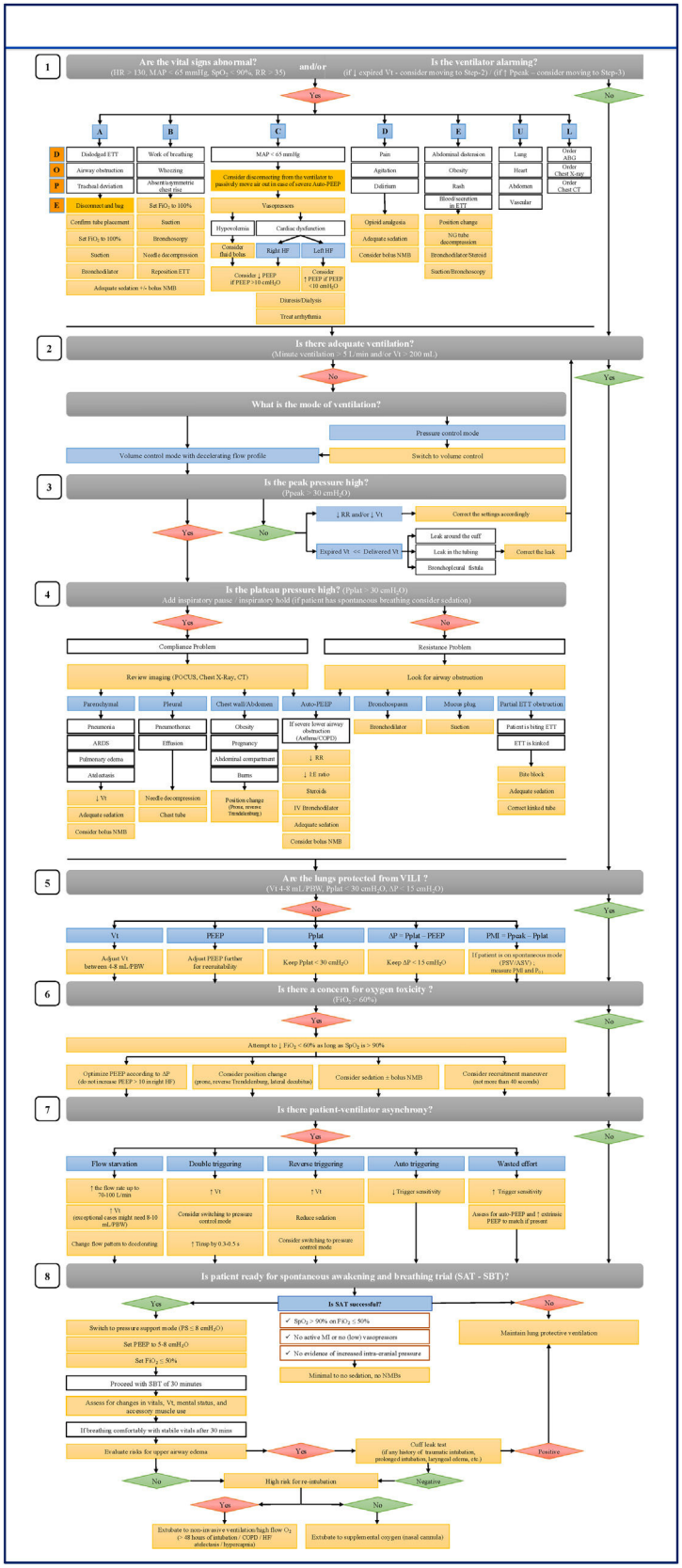


Fig. 2. The finalized STOP algorithm for management of bedside mechanical ventilation (MV).

findings support the algorithm's content validity and its alignment with evidence-based principles of bedside ventilator management.

The present study provides multinational expert consensus of a structured, physiology-informed framework for bedside mechanical ventilation management. Rather than introducing new ventilator targets or replacing established guidelines, the STOP algorithm operationalizes foundational ventilator principles into a coherent, stepwise cognitive scaffold designed to support bedside reasoning. Strong consensus across all eight domains suggests that diverse clinicians practicing in varied resource environments recognize the framework's clarity, feasibility, and conceptual alignment with evidence-based practice. Similar to expert-defined rule sets used in digital twin ICU models, this framework translates multidisciplinary reasoning into structured bedside logic [8,9]. The algorithm integrates perspectives grounded in published evidence into a structured stepwise non-linear approach intended to support bedside decision-making and education, particularly in settings where respiratory therapist availability may be inconsistent.

Importantly, consensus was achieved across core physiologic domains that underpin safe mechanical ventilation, including lung-protective ventilation, systematic evaluation of ventilator mechanics, oxygen titration, recognition of patient–ventilator asynchrony, and structured ventilator liberation. A recent network meta-analysis and few other studies suggest that LPV and targeted treatment of underlying etiology remain central to preventing VILI in ARDS [10,11]. High support for tidal volumes of 4–8 mL/kg predicted body weight and plateau pressure $\leq$ 30 cm H_2O is consistent with the ARDSNet trial and is the cornerstone of ARDS management on MV [12–14]. Subsequent studies have demonstrated mortality benefits and mitigation of VILI when stress and strain are carefully limited [15]. Driving pressure is increasingly recognized as a surrogate of dynamic lung stress further supports systematic assessment of plateau pressure and PEEP (positive end expiratory pressure) to reduced VILI [16]. Beyond VILI, emerging evidence highlights the risk of patient self-inflicted lung injury (P-SILI), wherein excessive spontaneous effort and high transpulmonary pressures worsen lung damage, underscoring the importance of synchrony assessment and titration of support to balance protection and diaphragm preservation [16]. The merit of this work is not the reiteration of these principles, but their integration into a structured bedside framework that promotes consistent application in real-world clinical settings.

Similarly, strong consensus regarding structured ventilator liberation aligns with guideline recommendations advocating daily spontaneous breathing trials (SBT) and protocolized weaning for patients ventilated > 24 h [17]. A meta-analysis of randomized studies (RCTs) comprising 1917 patients demonstrated that protocolized weaning reduces duration of MV and ICU length of stay without increasing reintubation or mortality [18]. Additional consensus supported oxygen titration to normoxemia (SpO_2 92–96%) to prevent oxygen-mediated injury [19]. Beyond physiologic alignment, the structured format emphasizes the need to implement best practices in MV management. Variability in staffing models, particularly in environments where dedicated respiratory therapists are not consistently available, may contribute to inconsistent application of best practices. A standardized cognitive scaffold may therefore function as a practical safety net—supporting trainees, multidisciplinary teams, and resource-variable ICUs in maintaining adherence to core ventilator management principles while preserving clinician agency.

Several limitations should be acknowledged. The current work evaluated expert consensus regarding a broad conceptual decision-support framework rather than prospective clinical outcome validation. Although consensus supports content validity, patient-level clinical effectiveness and implementation impact require further evaluation. Second, the modified Delphi design prioritized high-level structural consensus rather than granular micro-interventions, and complex domains such as advanced waveform interpretation and detailed asynchrony phenotyping were not exhaustively explored. Third, consensus was achieved in a single round, and while predefined thresholds were consistent with published standards, alternative expert compositions or iterative rounds may have yielded incremental refinements [6,9]. Fourth, geographic representation, though multinational and spanning over 4 continents, was not globally exhaustive. Finally, real-world workflow integration, usability burden, and implementation feasibility were not formally assessed and remain important priorities for future study. Despite these limitations, this work provides foundational expert agreement of a structured cognitive decision-support framework for MV management.

Future research should focus on prospective validation of the algorithm's impact on decision consistency, adherence to lung-protective ventilation, workflow integration, clinician confidence, and patient-centered outcomes. Simulation-based testing and pragmatic multicenter implementation studies will be essential to determine scalability, equity, and real-world integration across diverse health systems. The transparent, evidence-based, nonlinear structure of the STOP framework may also serve as a foundation for hybrid decision-support models. Integration of real-time physiological data (ventilator, patient parameters, waveforms) with interpretable clinical logic will bridge structured bedside reasoning with future adaptive systems.

In summary, this single-round modified Delphi study demonstrates strong multinational, multidisciplinary consensus supporting a physiology-informed mechanical ventilation decision-support framework. These findings provide foundational expert consensus and support its potential role as a standardized bedside cognitive tool intended to promote consistency, safety, and physiological coherence in ventilator management.

Authors' contributions

conceptualization: NM, OK, OG, AL.

Data accrual and analysis: NM, OK, KDC, YD, DK, BW, MN.

Result interpretation: NM, OK, KDC, YD, DK, BW, MN, OG, AN, RAO, AL.

Main manuscript draft: NM, OK, KDC, YD, DK, BW, MN, OG, AN, RAO, AL.

Critical review and final approval: NM, OK, KDC, YD, DK, BW, MN, OG, AN, RAO, AL.

Disclosures

None.

Ethics approval and consent to participate

Approved by Mayo Clinic IRB# 24-001384.

Consent for publication

NA.

Artificial intelligence involvement

None.

Funding

Mayo Clinic Clinical and Translational Science (CCaTS) Small Grants Program (SGP).

Conflict of interests

None.

Availability of data and material

Data will be available for review upon request.

Acknowledgements

This study was approved by Mayo Clinic institutional review board (IRB #24-001384) and conducted in compliance with ethical standards. Informed consent was obtained from all Delphi survey participants to ensure their voluntary participation and agreement to share their perspectives. The authors sincerely thank all survey participants for their time, thoughtful responses and valuable contributions to the study. Preliminary results of the study findings were presented at the SCCM annual meeting 2025.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.arbres.2026.03.009.

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