Systematic review

Med Crit. 2026;40(5):405-412

doi: 10.35366/124683

Population-specific cut-offs for cough peak flow in predicting extubation outcomes: a systematic review and meta-analysis

Valores de corte específicos para cada población en el flujo pico de tos para predecir los resultados de la extubación: una revisión sistemática y un metaanálisis

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ABSTRACT

Introduction: Cough Peak Flow (CPF) is a validated predictor of extubation success; however, its clinical implementation is hindered by a marked heterogeneity in reported cutoff points, varying from 35 L/min to over 160 L/min. This disparity limits its standardization in the intensive care unit. **Objectives:** to determine the global diagnostic accuracy of CPF for predicting extubation failure, evaluate the impact of measurement techniques (voluntary vs. reflex) and neurological status, and propose an evidence-based clinical decision algorithm. **Material and methods:** we conducted a systematic review and diagnostic meta-analysis (PROSPERO CRD420261350532) across PubMed, Scopus, SciELO, and LILACS databases. Study quality was assessed using QUADAS-2. A bivariate generalized linear mixed model was utilized to calculate pooled sensitivity, specificity, and the area under the summary receiver operating characteristic curve (AUC-SROC) specifically for endotracheal extubation. **Results:** fifteen studies were included in the quantitative synthesis. The global diagnostic accuracy of CPF demonstrated a pooled sensitivity of 73% (95%CI: 66-78%), specificity of 78% (95%CI: 70-84%), and an AUC of 0.79. Subgroup analysis revealed that voluntary CPF in cooperative patients provided a balanced profile (sensitivity 74%, specificity 73%). Conversely, reflex CPF in neurocritical patients exhibited a lower sensitivity (62%) but an outstanding specificity of 89%, demanding a stricter safety threshold. **Conclusion:** a universal CPF threshold is physiologically flawed. CPF interpretation must be context-dependent. We propose a structured algorithm that dichotomizes patients by cooperation level, enforcing a strict > 60 L/min threshold for neurocritical patients while introducing a «Gray Zone» (40-59 L/min) managed by the CPF x Tidal Volume index for cooperative patients, optimizing weaning safety.

Keywords: cough peak flow (CPF), extubation, ventilatory weaning, predictive value, extubation failure.

RESUMEN

Introducción: *el flujo pico de tos (PFT) es un predictor validado del éxito de la extubación; sin embargo, su aplicación clínica se ve obstaculizada por una marcada heterogeneidad en los valores de corte reportados, que varían desde los 35 L/min hasta más de 160 L/min. Esta disparidad limita su estandarización en la unidad de cuidados intensivos.* ***Objetivo:*** *determinar la precisión diagnóstica global del PFT para predecir el fracaso de la extubación, evaluar el impacto de las técnicas de medición (voluntaria vs refleja) y del estado neurológico, y proponer un algoritmo de decisión clínica basado en la evidencia.* ***Material y métodos:*** *llevamos a cabo una revisión sistemática y un metaanálisis diagnóstico (PROSPERO CRD420261350532) en las bases de datos PubMed, Scopus, SciELO y LILACS. La calidad de los estudios se evaluó mediante el método QUADAS-2. Se utilizó un modelo lineal mixto generalizado bivariado para calcular la sensibilidad y la especificidad combinadas, así como el área bajo la curva característica operativa del receptor resumida (AUC-SROC), específicamente para la extubación endotraqueal.* ***Resultados:*** *se incluyeron quince estudios en la síntesis cuantitativa. La precisión diagnóstica global de la PFT mostró una sensibilidad combinada de 73% (IC de 95%: 66-78%), una especificidad de 78% (IC de 95%: 70-84%) y un área bajo la curva (AUC) de 0.79. El análisis de subgrupos reveló que la PFT voluntaria en pacientes cooperativos proporcionó un perfil equilibrado (sensibilidad de 74%, especificidad de 73%). Por el contrario, la PFT refleja en pacientes neurocríticos mostró una sensibilidad menor (62%), pero una especificidad sobresaliente de 89%, lo que exige un umbral de seguridad más estricto.* ***Conclusión:*** *un umbral universal para el CPF es fisiológicamente erróneo. La interpretación del PFT debe depender del contexto. Proponemos un algoritmo estructurado que clasifica a los pacientes en dos grupos según su nivel de cooperación, aplicando un umbral estricto de > 60 L/min para pacientes neurocríticos, al tiempo que introduce una «zona gris» (40-59 L/min) gestionada mediante el índice PFT x volumen corriente para pacientes cooperativos, lo que optimiza la seguridad del destete.*

Palabras clave: *flujo pico de tos (PFT), extubación, desvinculación ventilatoria, valor predictivo, fallo en la extubación.*

Abbreviations:

ACT = Assisted Cough Techniques
CPF = Cough Peak Flow
ICU = Intensive Care Unit
NIV = Non-Invasive Ventilation
SBT = Spontaneous Breathing Trial

INTRODUCTION

Extubation failure, generally defined as the need for reintubation within 48 to 72 hours following the removal of an artificial airway, occurs in approximately 10 to 20% of mechanically ventilated patients.[1] This event is associated with devastating clinical consequences, including increased rates of ventilator-associated pneumonia, prolonged Intensive Care Unit (ICU) length of stay, and significantly higher mortality rates.[1] While the Spontaneous Breathing Trial (SBT) remains the cornerstone of the weaning process, successfully passing an SBT only evaluates respiratory mechanics and gas exchange, often failing to assess the patient's ability to protect the airway and clear secretions once the endotracheal tube is removed.[2]

Consequently, airway competence (specifically cough strength) has emerged as a critical determinant of extubation success.[3] Cough Peak Flow (CPF), measured objectively via spirometry or a ventilator's built-in pneumotachograph, has been widely validated as a reliable surrogate for cough strength and airway protection.[4] However, the clinical implementation of CPF in routine ICU protocols is currently hindered by a marked heterogeneity in the literature. Reported optimal cutoff points for predicting extubation success vary drastically, ranging from as low as 40 L/min to over 160 L/min.[5]

This threshold disparity is largely driven by the physiological and methodological differences among

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Received: 11-28-2025. Accepted: 06-30-2026.

How to cite: Treviño-Rocha L, Zaragoza JJ, Ávila-Oscos AP. Population-specific cut-offs for cough peak flow in predicting extubation outcomes: a systematic review and meta-analysis. Med Crit. 2026;40(5):405-412. https://dx.doi.org/10.35366/124683

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studied populations.[6] A «one-size-fits-all» cutoff fails to account for critical variables, such as the patient's level of consciousness (which dictates whether the cough is voluntary or a provoked reflex) and the specific neurological status of the patient.[7] Previous systematic reviews have often aggregated these distinct populations, diluting the clinical applicability of their findings.

Therefore, a tailored approach is urgently needed. The primary objective of this systematic review and diagnostic meta-analysis is to determine the global predictive value of CPF for extubation failure in adult ICU patients. Furthermore, as a secondary objective, we aimed to analyze the impact of the cough trigger (voluntary vs involuntary) and patient subgroups (e.g., neurocritical patients) on the diagnostic accuracy of CPF. Ultimately, by establishing population-specific, evidence-based cutoffs, this study aims to propose a standardized clinical decision algorithm to optimize the extubation workflow.

RESULTS

Study selection and characteristics

The initial systematic search identified a total of 208 records across all databases. Following the removal of 16 duplicates, 196 records underwent title and abstract screening. Of these, 23 full-text articles were assessed for eligibility. Eight articles were excluded for various reasons, including lack of raw contingency data, inaccurate test index, or evaluation of different clinical outcomes (e.g., tracheostomy decannulation). Ultimately, 15 studies were included in the quantitative diagnostic meta-analysis focusing strictly on endotracheal extubation.[8-27] The complete selection process is detailed in the PRISMA flow diagram *(Figure 1)*. The baseline clinical characteristics, cutoff thresholds, and individual diagnostic performance metrics of the included studies are summarized in *Table 1*.

Quality assessment

The methodological quality and risk of bias for the included studies were evaluated using the QUADAS-2 tool *(Figure 2)*.[28] The overall quality was exceptionally high. Most studies demonstrated a low risk of bias across all four domains. A minor proportion of studies presented an unclear or high risk of bias in the «Index Test» domain, primarily due to the lack of a pre-specified CPF cutoff threshold prior to data analysis.

Global diagnostic accuracy of CPF

The bivariate random-effects model for the global cohort (endotracheal tube interface) revealed that CPF is a strong predictor of extubation outcomes. The pooled sensitivity was 73% (95%CI: 66-78%) and the pooled specificity was 78% (95%CI: 70-84%), as illustrated in the coupled forest plot *(Figure 3)*. The global Area Under the SROC Curve (AUC) was 0.79 (95%CI: 0.75-0.82), indicating good overall diagnostic accuracy *(Figure 4)*. The Deeks' funnel plot asymmetry test yielded a p-value of 0.748, confirming the absence of significant publication bias across the included literature *(Figure 5)*.[29]

Subgroup analysis: impact of cough trigger and neurological status

Significant between-study heterogeneity was observed (I-squared = 87.9% for specificity), justifying the predefined subgroup analysis to evaluate the clinical application of CPF under different physiological conditions.

When stratified by the mechanism of cough stimulation, voluntary cough (cooperative patients) demonstrated a balanced predictive profile, with a pooled sensitivity of 74% (95%CI: 66-80%) and a specificity of 73% (95%CI: 64-80%). Conversely, involuntary or reflex cough measurements yielded a slightly lower sensitivity of 72% (95%CI: 54-85%) but a markedly higher pooled specificity of 86% (95%CI: 77-92%).

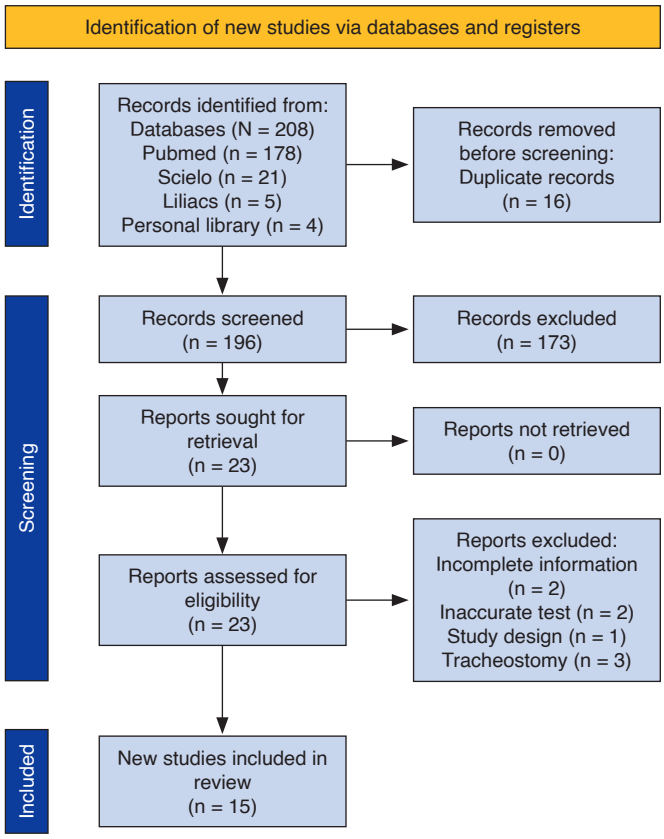


Figure 1: PRISMA Flow Diagram. Diagram depicting the literature search and study selection process.

Table 1: Threshold Disparity Analysis (TDA).

No	Year	Study ID	Country	Design	N	Subgroup	Age mean	Severity	Days of MV	Trigger	Interface	CPF cutoff	TP	FP	FN	TN	Failures	Sensitivity	Specificity	PPV	NPV	AUC
24	2003	Smina, 2003	USA	Prospective cohort	111	Cardiac	63.9 ± 1.7	23.2 ± 0.8	3	Voluntary	Tube	60	9	25	4	73	13	69	74			0.7
19	2004	Salam, 2004	USA	Prospective cohort	88	General ICU	62.3 ± 1.8	23.8 ± 0.8	4	Voluntary	Tube	60	7	27	2	47	14	71.4	81.1			
13	2009	Beuret, 2009	France	Prospective cohort	130	General ICU	62	45-48	8 [4-17]	Voluntary	Tube	35	11	34	3	82	14	79	71			
14	2010	Chan, 2010	China	Prospective cohort	32	ICU neurological patients	64.5 (15.8)		4.4 (4.9)	Involuntary	Tracheostomy	29	6	3	5	18	11	85.7	54.5			0.814
22	2010	Wen-Lin, 2010	Taiwan	Prospective cohort	150	General ICU	67.0 (20.0, 95.0)	16.0 (2.0, 32.0)		Involuntary	Tube	58.5	23	38	9	80	32	78.8	78.1	93	50	0.802
18	2013	Smailes, 2013	UK	Prospective cohort	125	Burn ICU patients	38.8	TBSA: 30.4	7.9	Voluntary	Tube	52.1	10	7	7	101	17	95	88.2	84	86	0.96
12	2014	Jun Duan, 2014	China	Prospective cohort	115	General ICU	68.42 ± 15.12	24.2 ± 6.7	5.80 ± 5.55	Voluntary	Tube	62.4	17	34	3	61	20	85	64.2			0.74
21	2015	Jun Duan, 2015	China	Prospective cohort	186	General ICU	68.3 (16.0)	25.3 (5.6)	7.4 (10.5)	Voluntary	Tube	62.4	23	71	5	87	28	82.1	55.1			0.678
8	2017	Enrichi, 2017	Italy	Cross-sectional	74	ICU neurological patients	51.5 ± 16.8			Voluntary	Tracheostomy	160	17	37	3	17	20	85	31.5	31.5	85	
11	2017	Gobert, 2017	France	Prospective cohort	92	General ICU	69 [60-76]	SAPS II: 48 [37-62]	7 [4-12]	Voluntary	Tube	60	7	24	4	57	11	70.4	63.6	94.4	35	0.61
27	2017	Linfu Bai, 2017	China	Prospective cohort	126	General ICU	77 ± 13		9.3 ± 4.4	Voluntary	Tube	56	11	17	4	94		73	85	39.3	95.9	0.83
16	2018	Terzi, 2018	France	Multicenter prospective cohort	125	General ICU	59.8 ± 16.4	SOFA: 7.7 ± 5	12.7 ± 8.8	Voluntary	Tube	85	33	31	11	50	44	74	62			0.71
20	2018	Xiao, 2018	China	Prospective cohort	139	General ICU	77 ± 11	14 ± 3		Voluntary	Tube	60	15	36	7	81	22	68.2	69.2			
10	2020	Almeida, 2020	Brazil	RCT	81	General ICU	46.0 ± 20.0	8.0 ± 0.3	3.6 ± 2.6	Involuntary	Tube	60	29	4	4	44	33	91.7	87.9			0.93
25	2022	Bishnoi, 2022	India	Prospective cohort	50	ICU neurological patients	18-85		5.78 ± 3.99	Voluntary	Tracheostomy	160	1	11	6	32	7	14.3	74.4			
9	2023	Fossat, 2023	France	Cross-sectional	61	General ICU	65.5 ± 13.9		7 [4-14]	Voluntary	Tube	35					9					0.64
15	2024	Murata, 2024	Japan	Retrospective cohort	76	General ICU	56 [18-87]	16.0 ± 7.4	4.4 ± 4.6	Involuntary	Tube	60	5	11	0	60	5	78.5	90.9	41.7	98.1	0.897
26	2025	Min Gao, 2025	China	Retrospective cohort	240	ICU neurological patients	55.78 ± 13.88		3 [1-7]	Involuntary	Tube	68.5	13	16	18	193	31	41.9	92.3			0.82
17	2025	Zhou, 2025	China	Prospective cohort	785	ICU neurological patients	49 [36-57]	15 [12-18]	4 [2-11]	Involuntary	Tube	63.2	96	81	48	560	144	87.4	66.7	92.1	54.2	0.81

Summary of included studies stratifying CPF cutoffs by measurement technique (Voluntary vs. Stimulated) and patient population.
AUC = Area Under the Curve. CPF = Cough Peak Flow. FN = False Negative. FP = False Positive. ICU = Intensive Care Unit. MV = Mechanical Ventilation. NPV = Negative Predictive Value. PPV = Positive Predictive Value. RCT = Randomized Controlled Trial. SAPS = Simplified Acute Physiologic Score. SOFA = Sequential Organ Failure Assessment. TBSA = Total Body Surface Area. TN = True Negative. TP = True Positive.

This disparity was even more pronounced when isolating the neurocritical patient subgroup. In ICU neurological patients, the pooled sensitivity decreased to 62% (95%CI: 55-69%), whereas the pooled specificity peaked at 89% (95%CI: 86-91%). These findings demonstrate that while a failed voluntary CPF test leaves a «gray zone» of uncertainty, failing to achieve CPF thresholds during an involuntary reflex cough in neurocritical patients is highly specific for extubation failure.

DISCUSSION

From a universal threshold to contextual interpretation

The central finding of this systematic review and meta-analysis is that the search for a single, universal Cough Peak Flow (CPF) cutoff point for extubation is methodologically flawed. The literature reports a wide variance in predictive thresholds, ranging from as low as 35 L/min[4] to over 160 L/min.[14] Our analysis demonstrates that this heterogeneity is not random noise, but rather a direct function of the patient's neurological status and the specific measurement technique employed (voluntary vs. stimulated).

This shift toward contextual interpretation is further supported by recent high-impact data suggesting that, in patients with acquired brain injury, the specific method of the SBT (e.g., T-piece vs pressure support) is less relevant for predicting extubation failure than objective airway competence.[30] This finding reinforces the paradigm shift proposed in recent literature: moving from traditional respiratory load assessments toward a prioritized evaluation of airway protection capacity, where CPF serves as the primary metric.[31] Distinguishing between voluntary CPF and stimulated/reflex CPF is not merely a technical nuance, but a functional classification that dictates predictive capacity. Therefore, clinical protocols must migrate from a binary pass/fail approach based on a static number to a dynamic, context-sensitive interpretation.

Proposal for an effort-based stratification framework

To address this disparity, we propose classifying CPF results into «effort levels» based on patient cooperation. For cooperative patients capable of generating a maximal voluntary cough, our pooled data (sensitivity 74%, specificity 73%) confirms that the traditional threshold of > 60 L/min remains the robust standard for safety and successful extubation.[23,24]

Conversely, for non-cooperative patients (neurocritical or unarousable), the physiological context shifts dramatically. Previously, it was hypothesized that in this «low effort» context, a threshold of > 40 L/min might establish a minimum physiological floor required to prevent immediate reintubation.[20] However, our updated pooled analysis challenges this assumption. Neurocritical patients lack cortical control and crucial bulbar compensatory mechanisms. Relying on reflex cough maneuvers in this subgroup yields an outstanding pooled specificity of 89%, meaning that failing to reach

A)

	Risk of bias domains				
Study	D1	D2	D3	D4	Overall
Smina, 2003	+	×	+	+	×
Salam, 2004	+	+	+	+	+
Beuret, 2009	+	×	+	+	×
Wen-Lin,2010	+	+	+	+	+
Smailes, 2013	+	+	+	+	+
Jun Duan, 2014	×	×	+	+	×
Jun Duan, 2015	+	×	+	+	×
Gobert, 2017	×	+	+	×	×
Linfu Bai, 2017	+	×	+	+	×
Terzi, 2018	+	+	+	×	×
Xiao, 2018	+	×	+	+	×
Almeida, 2020	×	+	+	+	×
Murata, 2024	+	+	+	+	+
Min Gao, 2025	+	+	+	+	+
Zhou, 2025	+	+	+	+	+

B)

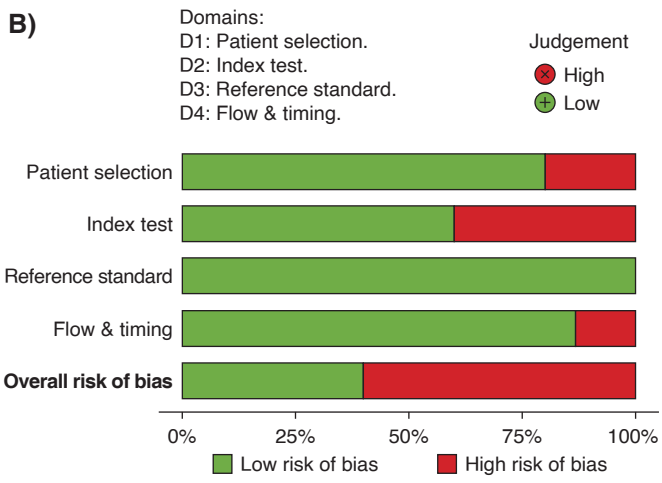


Figure 2: QUADAS-2 Risk of Bias Assessment. Risk of bias and applicability concerns summary. **A)** Traffic light plot detailing the reviewer judgments for each included study across all four domains. **B)** Weighted bar plot summarizing the overall percentages of low, high, and unclear risk across the evaluated studies, demonstrating a predominantly low risk of bias.

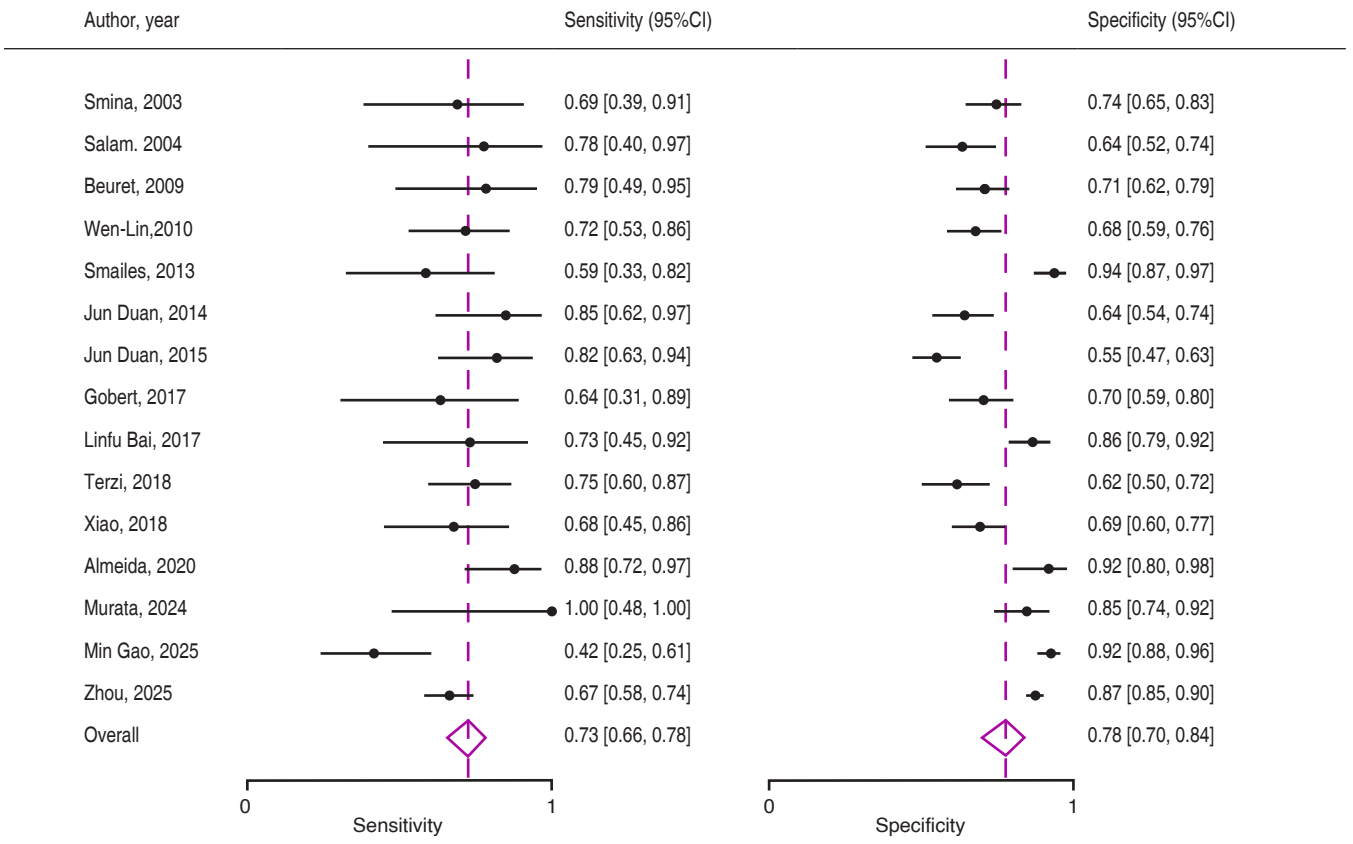


Figure 3: Coupled forest plot of sensitivity and specificity. Pooled diagnostic accuracy of Cough Peak Flow (CPF) for predicting extubation outcomes in patients with an endotracheal tube interface. Blue squares represent individual study estimates with their 95% confidence intervals (horizontal lines). The red diamonds represent the overall pooled sensitivity (0.73) and specificity (0.78) generated via a bivariate generalized linear mixed model.

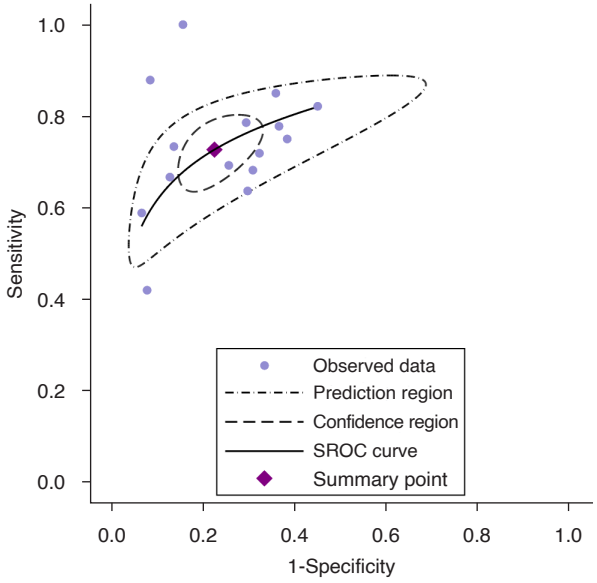


Figure 4: Summary Receiver Operating Characteristic (SROC) curve. Global predictive performance of Cough Peak Flow for extubation outcomes. The solid red line represents the SROC curve, the inner dotted region delineates the 95% confidence contour, and the outer dashed line represents the 95% prediction contour. The global Area Under the Curve (AUC) is 0.79.

a robust threshold is highly indicative of impending failure. Consequently, contemporary data mandate a strict safety threshold of > 60 L/min for reflex CPF in this population.[8,19] In these non-cooperative patients, falling below this value dictates extubation deferral, early tracheostomy consideration, or specialized airway clearance protocols.

The «gray zone» as a therapeutic window

A critical contribution of this framework is the redefinition of the 40–59 L/min range specifically for cooperative patients. Historically, values in this range might have led to delayed extubation. We argue that this «gray zone» should be interpreted as a therapeutic window of opportunity rather than an absolute contraindication. In this range, the risk of failure is moderate but potentially modifiable. Recent evidence supports this by demonstrating that inspiratory effort during the SBT is intrinsically linked to subsequent expiratory capacity, suggesting that a borderline CPF often reflects an underlying imbalance in respiratory mechanics.[32]

Instead of deferring extubation automatically, clinicians should integrate secondary respiratory

variables to improve predictive accuracy. Specifically, evaluating a borderline CPF in conjunction with a pre-cough Tidal Volume (V_T) > 0.55 L identifies patients who generate sufficient volume to clear secretions effectively, yielding a positive predictive value of 94.4% for extubation success. This combined assessment acts as a reliable tie-breaker, allowing clinicians to cautiously proceed with extubation, ideally supported by immediate optimization strategies such as prophylactic non-invasive ventilation (NIV) or Assisted Cough Techniques (ACT).

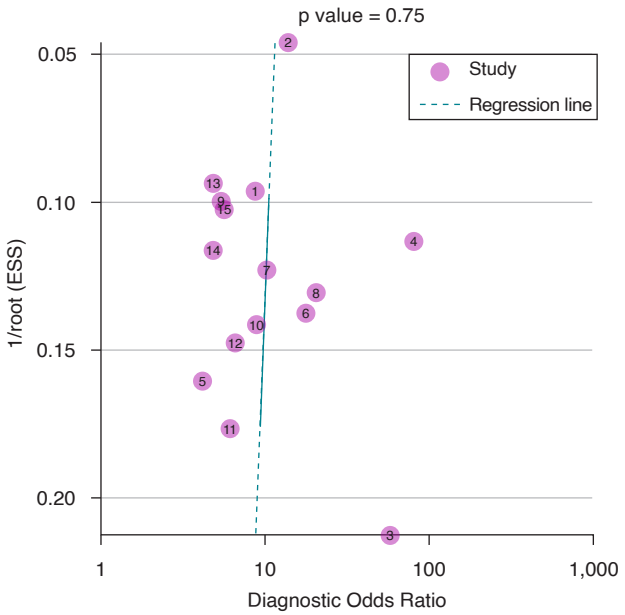
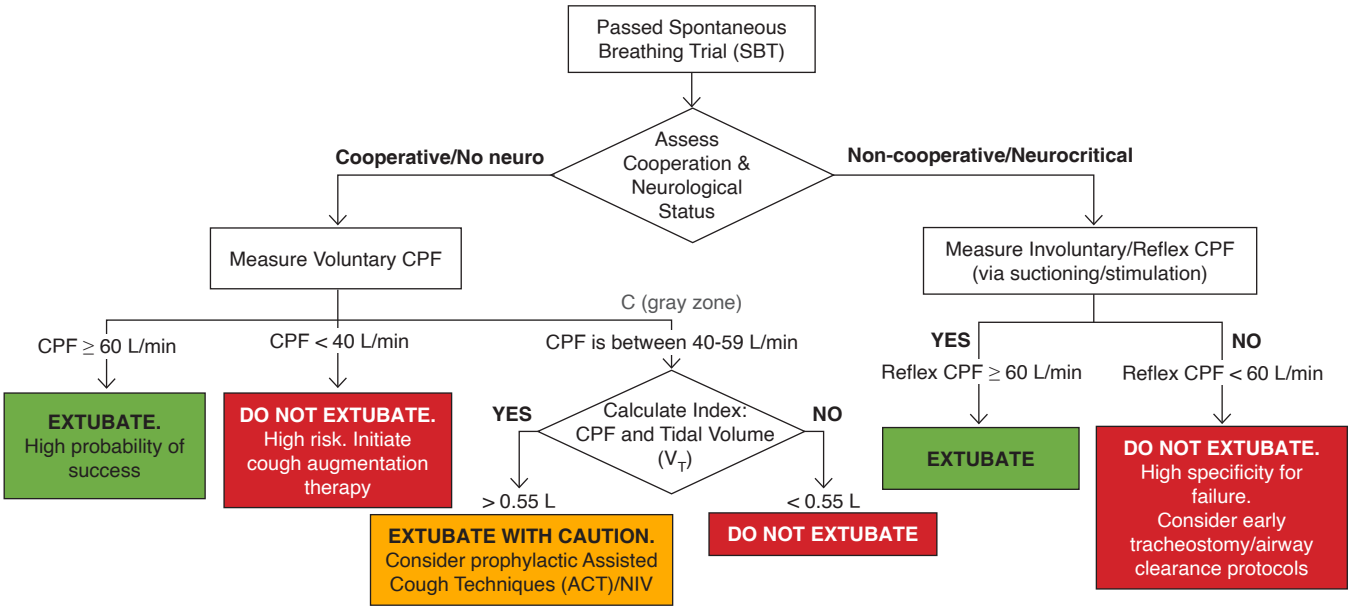


Figure 5: Deeks' funnel plot asymmetry test.

Strengths and limitations

The primary strength of this study lies in its rigorous methodology. By adhering to PRISMA-DTA guidelines[33] and employing a bivariate generalized linear mixed model, we respected the intrinsic correlation between sensitivity and specificity across varying thresholds. Furthermore, the exclusion of tracheostomy decannulation studies from the primary pool ensured strict clinical homogeneity, and the Deeks' funnel plot asymmetry test confirmed the absence of publication bias (p = 0.748), reinforcing the reliability of our pooled estimates. Finally, translating these statistical findings into an actionable, bedside decision-making algorithm bridges the gap between raw meta-analytical data and daily critical care practice.

Nevertheless, this review has limitations inherent to the design of primary studies. The majority are observational cohorts with inherent variability in their inclusion criteria. There is also technical heterogeneity regarding the measurement devices used (handheld spirometers vs. built-in ventilator pneumotachographs). Although ventilator-derived measurements have shown good correlation with spirometry,[9] minor



Color legend: **Green**: proceed to standard extubation. **Yellow**: extubate with planned assistance (Gray Zone). **Red**: defer extubation due to high risk of airway failure.
ACT = Assisted Cough Techniques. CPF = Cough Peak Flow. NIV = Non-Invasive Ventilation. SBT = Spontaneous Breathing Trial. V_T = Tidal Volume.

Figure 6: Standardized decision algorithm for extubation based on Cough Peak Flow (CPF).

discrepancies in airflow resistance may exist. Lastly, while the «gray zone» concept and the CPF and V_T index is physiologically sound and supported by current evidence, large-scale, prospective randomized controlled trials are required to definitively validate the efficacy of specific prophylactic interventions (e.g., ACT or NIV) within this precise range.

CONCLUSIONS

Cough Peak Flow is a reliable predictor of extubation outcomes, but its clinical utility is compromised when applied as a universal threshold. The predictive capacity of CPF is strictly context dependent. The standardized decision algorithm proposed in this study *(Figure 6)* stratifies patients into cooperative and non-cooperative pathways, providing an evidence-based strict cutoff (> 60 L/min) for neurocritical patients and integrating the CPF and V_T index to safely navigate borderline cooperative cases. Shifting from a binary, static number to a dynamic, effort-based interpretation will allow clinicians to optimize weaning protocols and safely reduce the incidence of extubation failure.

ACKNOWLEDGMENTS

We express our sincere gratitude to Rocío Baños-Lara, PhD, for her critical review of this manuscript and her valuable methodological contributions. We also thank the Universidad Popular Autónoma del Estado de Puebla (UPAEP) for providing the academic support and research framework necessary for this study. Finally, we extend our appreciation to the staff and leadership of Hospital H+ Querétaro; their commitment to excellence in patient care provides the essential foundation that makes high-quality clinical research possible.

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