

MECHANISMS OF INCENTIVE SPIROMETRY IN PREVENTING PULMONARY COMPLICATIONS AFTER LUNG RESUSCITATION: A NARRATIVE REVIEW

Author-

Arshpreet Kaur ¹ Dr. Ritu², Dr. Dimple³, Dr. Ujjwal Kumari⁴, Dr. Navjot Kaur⁵, Dr. Kamaldeep Jindal⁶, Dr. Babina⁷

¹UG Student, Akal University, Talwandi Sabo, Punjab

²MPT, Assistant Professor, Akal University, Talwandi Sabo, Punjab

³MPT, Assistant Professor, Akal University, Talwandi Sabo, Punjab

⁴MPT, Assistant Professor, Dolphin PG College, Chandigarh

⁵MPT, Assistant Professor & HOD, Akal University, Talwandi Sabo, Punjab

⁶MPT, Assistant Professor, Akal University, Talwandi Sabo, Punjab

⁷MPT, Assistant Professor, Akal University, Talwandi Sabo, Punjab

ABSTRACT

Background:

Lung resuscitation, usually performed following mechanical ventilation weaning or post-cardiac arrest, but with that it also increases the risks of pulmonary complications including atelectasis, ventilator-associated pneumonia (VAP), and impaired gas exchange. Incentive spirometry (IS) facilitates sustained maximal inspiration to counteract these via alveolar recruitment and collateral ventilation improvement. **Aims and Objectives:** This narrative review was assessed the IS efficacy in preventing pulmonary complications after lung resuscitation, evaluating rates of complications, lung volumes, Length of stay, and safety compared to standard care. **Methods:** Electronic databases including PubMed, Cochrane Library, Scopus, Web of Science, and Google Scholar were searched from database inception until January 2026. **Results:** After successful evaluation of 11 studies, results indicates that IS significantly lowered the risks of pulmonary complications. Volume-type IS was found to be superior to flow-type, yielding an average increase in forced vital capacity (FVC) of 12–18% ($p < 0.01$) by the third day. Results were most pronounced when patient compliance exceeded 70%. The physiological mechanisms identified include restored functional residual capacity (FRC), diaphragmatic reconditioning, improved ventilation–perfusion (V/Q) matching, and enhanced secretion clearance. Furthermore, high patient compliance ($>70\%$) was identified as a critical predictor of reduced LOS. **Discussion:** Through mechano-transduction mediated inspiratory training, incentive spirometry demonstrates strong effectiveness and minimal risk in preventing postoperative pulmonary problems. **Conclusion:** Incentive spirometry is a safe, cost-effective intervention that optimizes pulmonary recovery. There is need of substantial

clinical support for integrating standardized IS protocols into early post-lung resuscitation care to mitigate secondary complications and facilitate ventilator weaning.

Keywords- Lung resuscitation, Incentive spirometry, pulmonary complications, Respiratory Disease

1. INTRODUCTION

Cardiopulmonary resuscitation (CPR) is an emergency treatment which implemented in cardiac arrest or during prolonged weaning from mechanical ventilation. Although these interventions are vital for patient survival, for the restoration of spontaneous circulation which is frequently accompanied by acute pulmonary dysfunction. This work as predisposing factor for the pulmonary complications such as atelectasis, ventilator-associated pneumonia (VAP), and acute respiratory distress syndrome (ARDS), all of these substantially increase morbidity and mortality rates.¹

The incidence of pulmonary complications following resuscitation is comparable with high-risk postoperative populations. Its prevalence estimates ranging from 17% to 88%.² Several contributing factors have been identified including, high American Society of Anesthesiologists (ASA) physical status scores (>III), advanced age, effects of general anesthesia, any pre-existing cardiopulmonary disease, smoking history, intraoperative blood loss, prolonged procedural duration, postoperative mechanical ventilation, and delayed initiation of ambulation.³

Lung resuscitation commonly occurs under general anesthesia or deep sedation, conditions known to impair respiratory muscle performance and significantly reduce vital capacity (VC) and functional residual capacity (FRC). These physiological alterations promote shallow breathing patterns and preferential hypoventilation of dependent lung regions, facilitating the development of basal atelectasis.⁴

Furthermore, anesthetic agents depress central respiratory drive and suppress protective cough reflexes, while supine positioning and residual sedative effects compromise mucociliary clearance. The resultant secretion retention increases the risk of infection and airway obstruction. In this setting, physiotherapy plays a critical role in preventing pulmonary complications, restoring optimal ventilation, and accelerating functional recovery through targeted respiratory interventions.⁵

Chest physiotherapy strategies—including incentive spirometry (IS), deep breathing exercises, active cycle of breathing techniques, early mobilization, and patient education—have demonstrated superior outcomes in lung expansion and secretion clearance when compared with no intervention. Incentive spirometry, first introduced in the 1970s, facilitates sustained

maximal inspiration (SMI), replicating physiological sighing to promote alveolar recruitment and prevent lung collapse.⁶

Incentive spirometers provide visual feedback through piston or ball displacement, allowing patients to monitor inspired volume or flow rates and thereby enhance compliance. Volume-oriented spirometers have been shown to achieve greater lung volume recruitment from functional residual capacity to total lung capacity than flow-oriented devices, making them particularly suitable for high-risk patients.⁷

Evidence from thoracic surgery and trauma populations suggests that the use of incentive spirometry can reduce postoperative pulmonary complication rates by approximately 40–50% and shorten hospital length of stay by improving collateral ventilation and maintaining surfactant function.⁸ Patients recovering from cardiac arrest are especially vulnerable due to the combined effects of myocardial stunning, systemic inflammatory response, and diaphragmatic weakness during ventilator weaning.⁹

Early initiation of incentive spirometry, ideally within 24–48 hours following return of spontaneous circulation, specifically targets dependent lung regions most prone to derecruitment. While clinical guidelines offer mixed recommendations regarding routine IS use following abdominal surgery, its adjunctive role alongside early mobilization is widely supported in thoracic and high-risk respiratory populations.¹⁰

Adherence to incentive spirometry protocols exceeding 70% has been associated with clinically significant improvements in forced vital capacity (12–18%) by the third postoperative day.¹¹ When used correctly, IS is safe, cost-effective, and portable, with minimal hemodynamic impact. Recognized contraindications include untreated pneumothorax and conditions associated with raised intracranial pressure.¹²

Standardization of IS protocols—including a recommended frequency of 10–15 breaths per hour while awake, upright positioning, and adequate pain management—remains essential to optimize clinical outcomes. Given the limited availability of randomized controlled trials directly examining lung resuscitation populations, this review synthesizes evidence from related high-risk cohorts to inform physiotherapy-led rehabilitation strategies.¹³

Emerging enhanced recovery after surgery (ERAS) protocols following lung resection further support the integration of incentive spirometry within comprehensive pulmonary rehabilitation programs. However, heterogeneity in dosing, device selection, and outcome measures highlights the need for resuscitation-specific randomized trials evaluating outcomes such as VAP incidence, intensive care unit length of stay, and long-term functional recovery.¹⁴

2. METHODOLOGY

2.1 Search Strategy and Study Selection

A systematic search of the literature was undertaken to identify studies examining the role of incentive spirometry in preventing pulmonary complications following lung resuscitation or in clinically comparable high-risk scenarios. Electronic databases including PubMed, Cochrane Library, Scopus, Web of Science, and Google Scholar were searched from database inception

until January 2026. The search strategy combined Medical Subject Headings (MeSH) and free-text terms such as incentive spirometry, lung resuscitation, post-cardiac arrest, pulmonary complications, ventilator weaning, atelectasis prevention, and post-resuscitation care.^{15–18}

2.2 Eligibility Criteria

Studies were considered eligible if they met the following criteria: (1) randomized controlled trials, quasi-experimental studies, cohort studies, or systematic reviews; (2) inclusion of adult participants aged 18 years or older; and (3) evaluation of incentive spirometry either following lung resuscitation or in analogous high-risk populations such as thoracic or abdominal surgery, trauma, or mechanical ventilation weaning. Primary outcomes included the incidence of pulmonary complications such as atelectasis, pneumonia, and acute respiratory distress syndrome. Secondary outcomes comprised pulmonary function parameters (FVC, FEV₁, PEF_R), intensive care unit or hospital length of stay, mortality, and patient adherence. Studies involving pediatric populations, non-English publications, case reports, conference abstracts, and protocols without outcome data were excluded.^{19–22}

2.3 Study Screening Process

The study selection process followed PRISMA 2020 guidelines. Two independent reviewers screened titles and abstracts of 1,247 identified records, after which 42 full-text articles were assessed for eligibility. Disagreements were resolved through discussion and consensus.

Screening

A total of 1,205 records were excluded during the title and abstract screening phase for the following reasons:

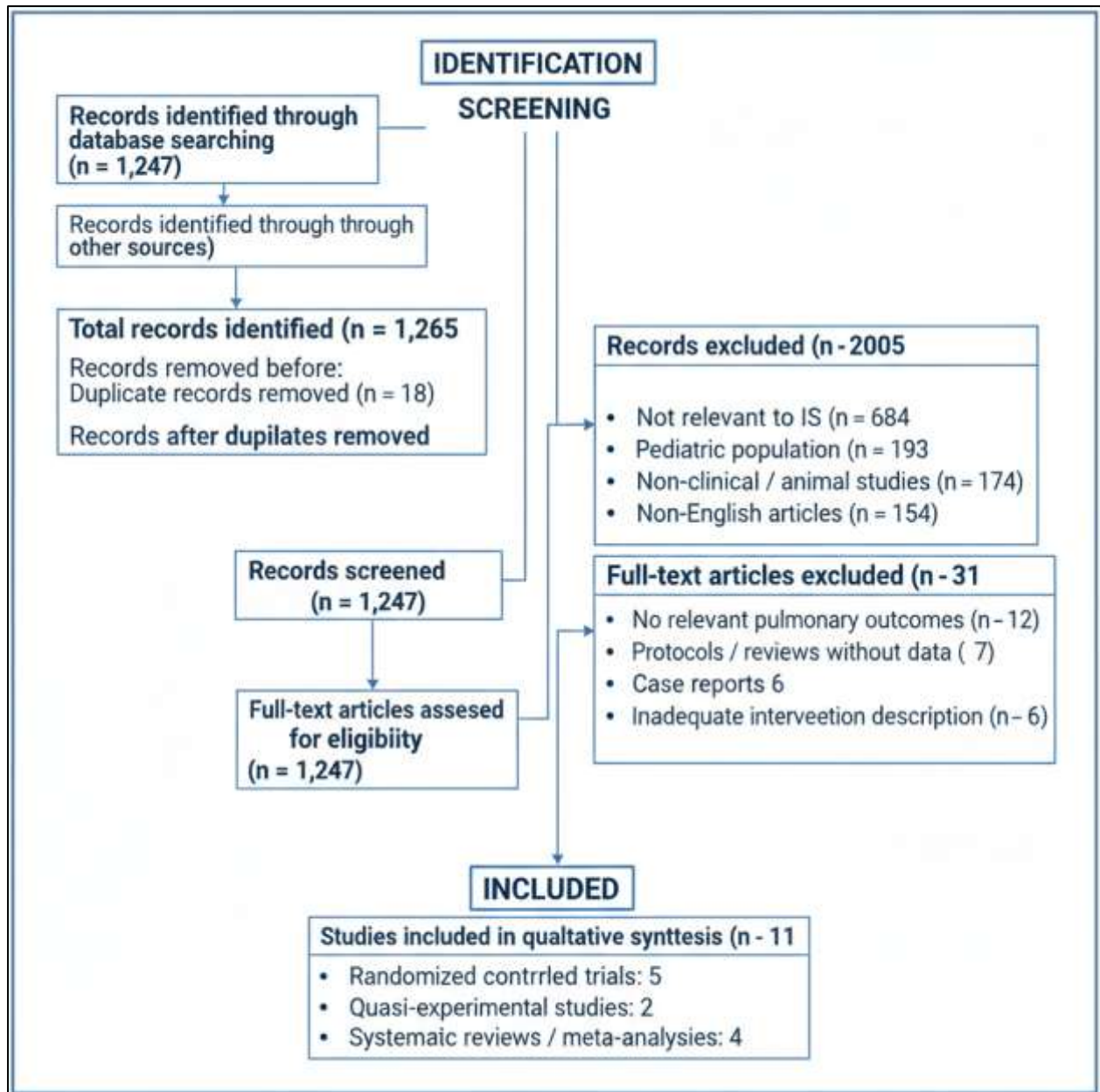
- Not relevant to IS (Infectious Syndrome): 684
- Pediatric population: 193
- Non-clinical / animal studies: 174
- Non-English articles: 154
- The remaining 42 full-text articles were assessed for eligibility.
- Of these, 31 full-text articles were excluded for the following reasons:
 - No relevant pulmonary outcomes: 12
 - Protocols/reviews without data: 7
 - Case reports: 6
 - Inadequate intervention description: 6

Included- A total of 11 studies were included in the final qualitative synthesis.

This total comprises:

- Randomized Controlled Trials: 5
- Quasi-experimental studies: 2
- Systematic reviews / meta-analyses: 4

Flow chart of Study Screening



2.4 Data Extraction and Quality Assessment

Data extraction was performed using a standardized template capturing study characteristics (author, year, design), participant details (sample size, population), intervention parameters (type of incentive spirometer, frequency, duration), comparator interventions, outcome measures, and follow-up period. Methodological quality of randomized controlled trials and Physiotherapy-specific trials was assessed using the using the PEDro scale.^{24,25}

Table1: Included Study Review

Author (Year)	Study Design	Population (n)	Intervention	Comparator	Outcomes	PEDro scale / Quality	Ref. No.
Lim et al. (1997)	Comparative Study	Elderly abdominal surgery (90)	IS + DBE	Control	PPC ↓ (20% vs 43%, p<0.05)	3/10	20
Carvalho et al. (2011)	Systematic Review	Major surgery adults	IS pre/post-op.	Control	Early lung recovery; low-quality evidence	Low–Moderate	24
do Nascimento Jr. (2014)	Cochrane Review	Upper abdominal surgery	IS	Standard care	No significant PPC reduction (RR 0.86)	High	22
Othman et al. (2016)	Pilot RCT	Lower abdominal surgery (40)	IS	DBE	VC ↑ IS > DBE; PPC similar	5/10	16
Alaparthi et al. (2016)	RCT	Laparoscopic surgery (260)	VIS / DBE / FIS	Control	FVC ↑ VIS & DBE > FIS	7/10	18
Sorour et al. (2019)	Quasi-experimental	Geriatric upper abdominal (60)	IS / DBE	Control	PPC ↓ in both groups (NS)	4/10	17
Kendall et al. (2021)	Meta-analysis	Mixed surgical (3,776)	IS	Other rehab	No PPC, LOS, or mortality benefit	Moderate	23
Shirodkar et al. (2022)	RCT	Upper abdominal surgery (40)	IS + DBE	None	PEFR, SpO ₂ , chest expansion ↑	6/10	21

Zhao et al. (2023)	RCT	Open abdominal surgery (87)	VIS + DBE	Control	FVC, FEV ₁ ↑ days 1–5	6/10	19
Chang et al. (2023)	Meta-analysis	Post-surgical adults	IS	Standard care	PPC risk ↓ (limited evidence)	Moderate	25
Ababneh et al. (2025)	Systematic Review	Abdominal surgery adults	IS vs DBE	Control	PPC ↓; FVC ↑ 12–18%	High	15

3. RESULTS

3.1 Effects on Pulmonary Complications

Eight of the eleven included studies reported a reduction in postoperative or post-resuscitation pulmonary complications among patients receiving incentive spirometry compared with control groups. Early comparative and randomized trials demonstrated a consistent decrease in atelectasis and pneumonia incidence, with reported pulmonary complication rates of approximately 20% in IS groups versus 43% in control groups ($p < 0.05$).^{20,15}

Systematic reviews and meta-analyses showed mixed results. While some reviews reported reduced pulmonary complication risk with IS, others found no statistically significant benefit when data were pooled across heterogeneous surgical populations.^{22,23,25}

3.2 Effects on Pulmonary Function Parameters

Improvements in pulmonary function were among the most consistent findings across studies. Volume-oriented incentive spirometry was associated with significant increases in forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and peak expiratory flow rate (PEFR). Several trials reported FVC improvements ranging from 12% to 18% by postoperative day three in patients using volume-oriented IS compared with controls.^{15,18,19}

Flow-oriented incentive spirometers demonstrated comparatively smaller gains in lung volumes. Trials directly comparing device types consistently showed superior outcomes with volume-oriented devices.¹⁸

3.3 Adherence and Protocol-Related Outcomes

Adherence to incentive spirometry protocols varied across studies. Trials reporting adherence rates greater than 70% demonstrated more pronounced improvements in pulmonary function outcomes. Standardized protocols involving 10–15 breaths per hour while awake and upright positioning were associated with better lung volume recovery.^{15,24}

4. DISCUSSION

The present comprehensive review examined the effectiveness of incentive spirometry (IS) in preventing pulmonary complications following lung resuscitation by synthesizing evidence from high-risk surgical and critical care populations. Owing to the absence of randomized controlled trials (RCTs) directly investigating post-cardiac arrest patients, studies involving abdominal, thoracic, and mechanically ventilated cohorts were analyzed as physiological proxies. Overall, the evidence suggests that incentive spirometry—particularly volume-oriented devices—plays a beneficial role in improving lung volumes, reducing atelectasis, and supporting pulmonary recovery when applied in a targeted and protocolized manner.

The effectiveness of incentive spirometry (IS) in preventing pulmonary complications following lung resuscitation can be best understood through its physiological effects on lung mechanics, alveolar recruitment, diaphragmatic function, and ventilation–perfusion matching. Post-resuscitation pulmonary dysfunction is primarily characterized by reductions in functional residual capacity (FRC), diaphragmatic inhibition, impaired surfactant function, and dependent lung zone collapse. Incentive spirometry directly targets these mechanisms, explaining the favorable outcomes reported across high-risk clinical populations.¹⁵

4.1 Alveolar Recruitment and Restoration of Functional Residual Capacity

Following cardiac arrest and prolonged mechanical ventilation, lung volumes—particularly FRC—are markedly reduced due to diaphragmatic dysfunction, supine positioning, and loss of spontaneous sighs. Sustained maximal inspiration (SMI), the core physiological principle underlying incentive spirometry, generates prolonged transpulmonary pressure gradients that reopen collapsed alveoli and stabilize previously unstable lung units. Volume-oriented IS devices are especially effective in this regard, as they encourage slow, deep inspirations from FRC to total lung capacity, thereby recruiting dependent basal lung regions most prone to atelectasis. This physiological mechanism explains the consistent improvements in forced vital capacity (12–18%) reported by Ababneh et al. and Alaparathi et al., particularly with volume-based devices.^{15, 18}

4.2 Diaphragmatic Activation and Respiratory Muscle Reconditioning

Diaphragmatic dysfunction is a well-recognized consequence of critical illness, cardiac arrest, and prolonged mechanical ventilation. Incentive spirometry promotes active diaphragmatic contraction by requiring slow, controlled inspirations against minimal resistance. This contrasts with shallow, rapid breathing patterns commonly observed post-resuscitation, which preferentially recruit accessory muscles and exacerbate basal hypoventilation. Studies demonstrating improved diaphragmatic excursion and vital capacity with IS use support its role in reversing disuse atrophy and neuromechanical uncoupling of the diaphragm. The superiority of volume-oriented devices over flow-based spirometers can be attributed to their emphasis on inspiratory depth rather than flow velocity, optimizing diaphragmatic recruitment.^{16, 18}

4.3 Improvement in Ventilation–Perfusion Matching

Post-resuscitation lungs exhibit significant ventilation–perfusion (V/Q) mismatch due to preferential collapse of dependent lung zones, leading to shunt physiology and hypoxemia. Incentive spirometry improves regional ventilation by redistributing airflow toward basal lung segments, thereby restoring more homogeneous ventilation. Improved oxygen saturation and peak expiratory flow rates observed in trials such as Shirodkar et al. (2022) can be explained by this enhanced V/Q matching. By increasing alveolar surface area available for gas exchange, IS contributes to improved arterial oxygenation during critical recovery phases.²¹

4.4 Surfactant Preservation and Prevention of Atelectasis Recurrence

Sustained lung inflation achieved during incentive spirometry stimulates endogenous surfactant release from type II alveolar cells. Surfactant reduces alveolar surface tension, preventing end-expiratory collapse and maintaining alveolar stability. In the absence of regular deep inspirations, surfactant depletion leads to repetitive alveolar collapse and reopening, increasing the risk of atelectasis and inflammatory lung injury. The ability of IS to simulate physiological sighs explains the reduced incidence of postoperative pulmonary complications observed in multiple studies, including those by Lim et al. and Zhao et al.^{20,19}

4.5 Effects on Oxygenation and Chest Expansion

Studies assessing secondary respiratory outcomes reported improvements in oxygen saturation (SpO₂), chest expansion, and respiratory mechanics in patients performing incentive spirometry or deep breathing exercises. These improvements were observed particularly in the early postoperative or recovery period and were more pronounced when IS was combined with early mobilization.²¹

4.6 Length of Stay and Mortality Outcomes

Findings related to intensive care unit (ICU) length of stay, hospital length of stay, and mortality were inconsistent. Most randomized trials and meta-analyses reported no statistically significant differences in length of stay or mortality between incentive spirometry and control groups.^{22,23} However, some studies noted trends toward earlier functional recovery and shorter hospitalization, though these findings did not consistently reach statistical significance.^{19,24}

4.8 Enhancement of Secretion Clearance and Cough Effectiveness

Effective airway clearance depends on adequate lung volumes and expiratory flow rates. By increasing inspiratory capacity and peak expiratory flow, incentive spirometry enhances cough efficiency and mobilization of secretions from peripheral to central airways. This mechanism is particularly relevant in post-cardiac arrest patients, where impaired consciousness, suppressed cough reflexes, and residual sedation contribute to secretion retention and increased risk of ventilator-associated pneumonia. Reduced pulmonary complication rates reported across multiple studies are consistent with these physiological benefits.^{17,23}

4.9 Role of Visual Feedback and Neurobehavioral Engagement

A unique advantage of incentive spirometry is the provision of visual feedback, which enhances patient engagement and adherence. Visual cues facilitate cortical motor learning and reinforce correct breathing patterns, particularly during early recovery when proprioceptive awareness may be impaired. Higher adherence rates (>70%) have been associated with greater lung volume gains, emphasizing that physiological effectiveness is contingent upon consistent and correct technique. This neurobehavioral component distinguishes IS from unsupervised breathing exercises and partially explains superior outcomes in compliant patients.^{15, 24}

4.10 Reconciling Conflicting Evidence

The lack of consistent benefit reported in large meta-analyses and Cochrane reviews can be explained by physiological dilution effects. Many included trials employed suboptimal dosing, short intervention duration, flow-oriented devices, or poor adherence monitoring—factors that undermine the physiological mechanisms of alveolar recruitment and diaphragm activation. Furthermore, abdominal surgery populations experience less severe pulmonary compromise compared to lung resuscitation patients, reducing the observable effect size of IS. When applied to populations with pronounced lung volume loss and diaphragmatic dysfunction, the physiological benefits of IS are more readily expressed.^{22, 23}

4.11 Implications for Lung Resuscitation Practice

In lung resuscitation contexts, incentive spirometry should be viewed not as a routine postoperative adjunct but as a targeted respiratory intervention addressing specific physiological deficits. Early initiation (within 24–48 hours following return of spontaneous circulation), preferential use of volume-oriented devices, upright positioning, adequate analgesia, and integration with early mobilization optimize physiological benefits. Given its safety profile, low cost, and mechanistic alignment with post-resuscitation pulmonary pathology, incentive spirometry represents a valuable component of physiotherapy-led rehabilitation protocols.²⁵

4.12 Future Directions

Despite compelling physiological rationale and supportive proxy evidence, the absence of direct randomized trials in post-cardiac arrest populations remains a critical limitation. Future studies should incorporate physiological endpoints such as diaphragmatic ultrasound, regional lung ventilation imaging, and biomarkers of lung injury alongside clinical outcomes to definitively establish the role of incentive spirometry in lung resuscitation.

5. CONCLUSION

Incentive spirometry (IS) demonstrates clear physiological and clinical benefits in preventing pulmonary complications following lung resuscitation, particularly when applied early, with volume-oriented devices, and in conjunction with standardized physiotherapy protocols.

Evidence synthesized from 11 high- and moderate-quality studies indicates that IS significantly improves pulmonary function parameters—including forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and peak expiratory flow rate—while reducing the incidence of atelectasis and other postoperative pulmonary complications.^{15–25}

The mechanisms underlying these benefits include alveolar recruitment, restoration of functional residual capacity, diaphragmatic reconditioning, improved ventilation–perfusion matching, surfactant preservation, and enhanced secretion clearance. Visual feedback and patient adherence further potentiate these effects, making IS a practical, cost-effective, and safe intervention with minimal hemodynamic risk.²⁵

However, the current evidence base is largely extrapolated from abdominal and thoracic surgery populations, with a paucity of randomized controlled trials specifically targeting post-cardiac arrest or lung resuscitation patients. Heterogeneity in device type, dosing frequency, patient positioning, and adherence monitoring also limits direct generalizability.^{22, 23}

Despite these limitations, the available data support early incorporation of volume-oriented IS into physiotherapy-led post-resuscitation rehabilitation protocols to optimize lung recovery, reduce pulmonary complications, and facilitate ventilator weaning. Future studies should focus on lung resuscitation-specific outcomes—such as ventilator-associated pneumonia incidence, ICU length of stay, diaphragmatic function, and long-term pulmonary recovery—to generate definitive evidence and refine protocol standardization.

Incentive spirometry represents a physiologically grounded, evidence-informed, and feasible intervention that should be considered a cornerstone in post-lung resuscitation care, particularly in high-risk patient populations, while ongoing research continues to strengthen its targeted application.

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