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The Effectiveness of Nurse-Led Interventions in Preventing Postoperative Atelectasis

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ABSTRACT: Postoperative atelectasis remains one of the most common pulmonary complications following surgery, particularly after thoracic and abdominal procedures, and contributes significantly to prolonged hospital stays, respiratory morbidity, and increased healthcare costs. Nurse-led interventions have emerged as a crucial component of prevention strategies, encompassing structured respiratory assessment, early ambulation protocols, incentive spirometry coaching, deep breathing and coughing exercises, patient positioning, and targeted preoperative education. By applying evidence-based assessment

tools and standardized protocols, nurses can identify at-risk patients early and initiate prophylactic measures before clinical deterioration occurs. The growing body of literature suggests that nurse-initiated respiratory care, when delivered consistently and systematically, can substantially reduce the incidence of atelectasis and improve overall pulmonary outcomes in the postoperative period.Evidence supporting the effectiveness of nurse-led interventions demonstrates consistent benefits across diverse surgical populations and clinical settings. Studies have shown that structured nursing protocols—including scheduled respiratory exercises, mobilization programs, and patient education—significantly lower atelectasis rates, improve oxygenation indices, and shorten recovery times compared with standard care. The success of these interventions is closely tied to factors such as nurse training, protocol adherence, patient compliance, and continuity of care across shifts. However, challenges persist, including variability in implementation, time constraints, and the need for stronger standardization and longitudinal follow-up. Overall, nurse-led interventions represent a cost-effective, scalable, and clinically meaningful approach to reducing postoperative atelectasis, though further high-quality randomized controlled trials are needed to establish optimal protocols and long-term effectiveness.

INTRODUCTION

Postoperative pulmonary complications remain among the most frequent and clinically significant adverse outcomes after major surgery, and atelectasis is central to this burden because it impairs gas exchange, reduces functional residual capacity, and predisposes patients to secretion retention, pneumonia, and respiratory failure. Reported incidence varies with surgical site, patient risk profile, and diagnostic criteria, but clinically important respiratory complications develop in a substantial proportion of patients undergoing abdominal and thoracic surgery, with atelectasis accounting for many of these events [1]. Because nurses maintain continuous bedside presence across the perioperative continuum, they are uniquely positioned to deliver structured respiratory assessment, education, breathing protocols, mobilization schedules, and coordinated care bundles. Nurse-led interventions—defined as assessments, educational programs, breathing exercises, airway clearance techniques, and care bundles initiated, coordinated, and evaluated by nursing staff—have therefore emerged as scalable, low-cost strategies for reducing postoperative pulmonary complications [2].

Pathophysiology of Postoperative Atelectasis

The development of atelectasis after surgery is multifactorial, but its final common pathway is a reduction in alveolar ventilation and a loss of surfactant-mediated alveolar stability. General anesthesia produces a cephalad shift of the diaphragm, a reduction in functional residual capacity, and alterations in chest wall mechanics that persist into the early postoperative period [3]. Abdominal and thoracic incisions further compromise respiratory mechanics by limiting diaphragmatic excursion and discouraging deep inspiration because of pain. Shallow breathing promotes closure of dependent airways and resorption of gas distal to obstruction, producing the characteristic pattern of dependent, segmental, or subsegmental atelectasis. Secretion retention amplifies this process: postoperative pain, opioid analgesia, and impaired cough reflexes compromise mucociliary clearance and effective expectoration, allowing mucus plugging to occlude smaller airways. Once obstruction occurs, alveolar gas is absorbed faster than it is replenished, and the affected lung segment collapses. This sequence explains why interventions that increase lung volumes—deep breathing, incentive spirometry, and positive expiratory pressure—and interventions that clear secretions—cough training, airway clearance techniques, and postural drainage—are both physiologically rational, albeit through different mechanisms [4]. It also explains why multimodal, nurse-delivered programs that address both volume loss and secretion retention are likely to outperform any single technique used in isolation [4].

Risk Factors and Nursing Assessment

Effective prevention begins with risk identification. Advanced age is associated with diminished pulmonary reserve, reduced respiratory muscle strength, impaired mucociliary clearance, and a higher burden of comorbidity, all of which increase susceptibility to atelectasis [5]. Obesity elevates the work of breathing and reduces chest wall compliance; smoking history and chronic obstructive pulmonary disease impair baseline airway function and secretion clearance; and the surgical site itself is a

powerful determinant, with upper abdominal and thoracic procedures carrying the highest risk. Prolonged anesthesia, emergency surgery, and inadequate postoperative analgesia further compound risk. Nurses are positioned to translate these epidemiological observations into actionable assessment. Preoperative nursing evaluation should document smoking status, body mass index, baseline oxygen saturation, respiratory rate, cough effectiveness, and the presence of obstructive or restrictive lung disease. Postoperative assessment should incorporate auscultation, observation of breathing pattern and depth, monitoring of oxygen saturation and arterial blood gases, assessment of pain during coughing and mobilization, and, where available, lung ultrasound. Structured risk assessment allows nurses to target intensive interventions toward the patients most likely to benefit and to escalate care when early signs of deterioration appear. Nursing assessment also guides the selection of breathing-cough exercises, percussion movements, postural drainage, and other preventive practices that are matched to the patient's secretion burden and respiratory mechanics [6].

PREOPERATIVE NURSE-LED EDUCATION AND BREATHING TRAINING

Preoperative education is the foundational component of most nurse-led respiratory programs. Its purpose is not merely to transmit information but to build procedural skill and self-efficacy before the patient is exposed to the discomfort and competing demands of the postoperative period. Randomized evidence supports this approach. In a randomized controlled trial of patients undergoing open-heart surgery, preoperative breathing exercises delivered by nurses were associated with reduced atelectasis development and improved postoperative respiratory parameters [7]. A separate randomized controlled trial examining nurse-led deep breathing and early mobilization in abdominal surgery patients reported favorable effects on postoperative recovery, pain reduction, and prevention of respiratory complications [8]. These findings are consistent with the broader literature indicating that preoperative training with breathing exercises and structured mobilization protocols reduces rates of atelectasis and pneumonia after surgery [9]. Preoperative education also establishes a relationship of coaching and reinforcement that continues into the postoperative period, when repeated encouragement and technique correction are essential to adherence. Such programs are often embedded within multidisciplinary perioperative bundles that coordinate respiratory care, analgesia, mobilization, and monitoring [10,11].

Deep Breathing Exercises and Cough Training

Deep breathing exercises are the most widely implemented nurse-delivered respiratory intervention. Diaphragmatic breathing, sustained maximal inspiration, and glossopharyngeal breathing aim to increase tidal volume, recruit collapsed alveoli, and improve ventilation-perfusion matching. When combined with effective cough training—including huff coughing and supported coughing—these exercises also promote secretion clearance from central and peripheral airways. In a randomized controlled trial of immediate post-extubation breathing exercises among patients undergoing elective upper abdominal open surgery at moderate-to-high risk of pulmonary complications, the breathing exercise group demonstrated significantly lower lung ultrasound scores at one hour after extubation and on three consecutive postoperative days, along with better oxygenation indices and a smaller postoperative decline in oxygenation [12]. These findings indicate that deep breathing, when initiated promptly and delivered under nursing supervision, can attenuate the early anatomical and functional changes that precede clinically overt atelectasis. Clinical studies of breathing techniques after surgical procedures further support the use of supervised deep breathing and coughing as core nursing interventions [13]. Cough training deserves particular emphasis because pain frequently undermines effective coughing. Nurses can teach patients to splint the incision with a pillow, to use a low-flow huff rather than a forceful explosive cough, and to time coughing sessions to coincide with the peak effect of multimodal analgesia [13].

Incentive Spirometry: Evidence, Controversy, and Appropriate Use

Incentive spirometry is among the most familiar nurse-supervised devices in postoperative care. By providing visual feedback and encouraging sustained maximal inspiration, it aims to reverse the low-volume breathing pattern that characterizes the early postoperative period. Numerous trials have reported improvements in vital capacity, oxygen saturation, and alveolar recruitment with regular incentive spirometry use, and some studies have observed fewer pulmonary complications and shorter hospital stays. Preoperative incentive spirometry training has likewise been associated with reduced atelectasis and pneumonia in surgical populations. However, the evidence for incentive spirometry as a standalone preventive strategy is less robust than its popularity might suggest. A randomized pilot trial comparing a novel oral positive expiratory pressure device with incentive spirometry on lung aeration in postoperative atelectasis reflects ongoing uncertainty about the relative efficacy of devices [14]. Moderate-

quality evidence has not consistently demonstrated a benefit for incentive spirometry in preventing postoperative pulmonary complications, and some reviews have concluded that routine use cannot be supported as a standalone therapy to prevent postoperative complications [15]. Airway clearance guidelines similarly emphasize that device-based therapy should be integrated with secretion clearance and mobilization rather than used in isolation [16]. The most defensible interpretation is that incentive spirometry is a useful adjunct within a comprehensive nurse-led program, not a substitute for supervised deep breathing, early mobilization, and secretion clearance; its value lies in structuring practice, providing feedback, and engaging patients, rather than in any unique physiological effect that cannot be achieved through coached deep breathing [17].

Positive Expiratory Pressure and Airway Clearance Techniques

Positive expiratory pressure therapy and active cycle of breathing techniques address the secretion-retention component of atelectasis more directly than inspiratory-only devices. By generating positive pressure during expiration, positive expiratory pressure devices help to maintain airway patency, mobilize secretions, and improve functional residual capacity. Airway clearance techniques such as the active cycle of breathing and positive expiratory pressure have been reported to be more effective in secretion removal than incentive spirometry alone, particularly in patients with increased mucus production or impaired cough function [16]. This distinction is clinically important because atelectasis arising from mucus plugging will not resolve with inspiratory training alone; the obstructing secretions must be cleared. Nurse-led airway clearance is typically multimodal. It may include postural drainage, chest percussion, vibration, and assisted coughing, delivered in sequences tailored to the auscultatory findings and the patient's hemodynamic stability [6]. The evidence base for these techniques is less extensive than that for deep breathing and mobilization, and some guidelines note the absence of high-level evidence for routine positive expiratory pressure use outside specific populations. Nevertheless, within a comprehensive program, airway clearance techniques fill an essential therapeutic niche and are appropriately delivered or coordinated by nurses. Comparative device evidence also suggests that positive expiratory pressure should be selected according to secretion burden and patient tolerance rather than adopted as a universal substitute for incentive spirometry [14].

Early Mobilization and Positioning

Early mobilization is perhaps the most physiologically compelling nurse-led intervention for preventing atelectasis. Upright positioning increases functional residual capacity, improves diaphragmatic excursion, and redistributes ventilation toward dependent lung regions that are most vulnerable to collapse. Mobilization also reduces the adverse effects of prolonged immobilization on muscle strength, venous return, and functional capacity. Nurse-led mobilization protocols typically begin on the first postoperative day, or immediately after extubation when hemodynamic parameters permit, and progress from sitting upright to transferring from bed to chair to assisted standing and walking [9]. The evidence supports mobilization both as an independent intervention and as a component of multicomponent bundles. Subgroup analyses and narrative reviews indicate that early ambulation is associated with a further significant decrease in the incidence of postoperative atelectasis and pneumonia, although the contribution of co-interventions requires careful interpretation [8]. Mobilization should be coordinated with breathing control and supported coughing, and nurses should assess tolerance continuously, recognizing that pain, dizziness, and hemodynamic instability may require modification rather than abandonment of the mobilization plan [8].

Pain Management as a Respiratory Intervention

Postoperative pain is not merely a comfort issue; it is a direct physiological threat to pulmonary function. Pain inhibits deep breathing and coughing, promotes shallow respiration, and contributes to secretion retention and alveolar collapse [3]. Nurse-led pain management is therefore an integral component of atelectasis prevention. Multimodal analgesia—combining regional techniques, non-opioid analgesics, and judicious opioid use—reduces the sedative and respiratory-depressant burden of pain control while enabling participation in breathing exercises and mobilization. Nurses are central to the timing and coordination of analgesia with respiratory therapy. Patients should be encouraged to perform deep breathing and coughing exercises within 20 to 30 minutes of receiving analgesics, when the analgesic effect is near its peak. Wound support with a small pillow during coughing further reduces pain and improves technique [4]. This integration of pain management with respiratory coaching exemplifies the distinctive value of nurse-led care: it addresses the barrier to participation rather than merely prescribing the intervention [4].

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NURSE-LED CARE BUNDLES AND STRUCTURED PROGRAMS

Single interventions produce modest and inconsistent effects; structured bundles produce more reliable benefits. Additional randomized evidence supports preoperative breathing exercises in open-heart surgery [18] and in coronary artery bypass grafting, where breathing exercises have been associated with reduced atelectasis [19]. Nursing preoperative training and standardized nursing measures for postoperative pulmonary care have also been described as essential components of respiratory prevention programs [20,21]. A systematic review and meta-analysis focused specifically on nurse-led respiratory care in elderly surgical patients concluded that nurse-led respiratory care significantly reduces the incidence of postoperative pulmonary complications, including pneumonia and atelectasis [22]. A systematic review and meta-analysis of preoperative and perioperative pulmonary rehabilitation nursing programs for thoracic surgery patients found that, compared with routine nursing, pulmonary rehabilitation nursing intervention was associated with a significant reduction in postoperative atelectasis rate (pooled odds ratio 0.50; 95% confidence interval 0.33 to 0.76; $p = 0.001$) and a statistically significant reduction in length of hospital stay (pooled standardized mean difference −0.64; 95% confidence interval −1.09 to −0.19; $p = 0.006$), although heterogeneity was high and pulmonary function tests did not differ significantly between groups [23]. Narrative review evidence similarly supports nurse-led deep breathing and early mobilization as coordinated strategies for reducing respiratory complications [24]. The ICOUGH bundle—incorporating incentive spirometry, coughing, oral care, understanding, getting out of bed, and head-of-bed elevation—has been evaluated in cardiac surgery patients and was associated with a significantly lower incidence of postoperative pulmonary complications, including atelectasis, hypoxia, and pneumonia, compared with standard care [10]. Quasi-experimental evidence has reinforced the potential of the ICOUGH bundle to reduce postoperative pulmonary complications in cardiac surgical populations [25]. This convergence of evidence across surgical populations and review methods supports the conclusion that nurse-led care is effective when delivered as a coordinated program rather than as a collection of isolated tasks [11].

Table 1. Summary of Evidence on Nurse-Led Interventions for Prevention of Postoperative Atelectasis

Intervention	Mechanism	Representative evidence	Reported effect on atelectasis or pulmonary complications
Preoperative breathing education and training	Rehearsal of breathing and coughing techniques; improved self-efficacy and adherence	Randomized controlled trials in cardiac surgery [7,18,19]	Reduced atelectasis development; improved postoperative respiratory parameters
Deep breathing exercises	Alveolar recruitment; increased tidal volume and functional residual capacity	Randomized controlled trial of immediate post-extubation breathing exercises [12]	Lower lung ultrasound scores; improved oxygenation; reduced early atelectasis
Incentive spirometry	Sustained maximal inspiration; visual feedback and structured practice	Systematic reviews, device trials, and clinical evidence [14,15,17]	Improvements in vital capacity and oxygenation; inconsistent evidence for standalone use in preventing complications
Positive expiratory pressure and airway clearance	Maintenance of airway patency; secretion mobilization	Comparative and guideline evidence [6,16]	More effective secretion removal than incentive spirometry alone in patients with mucus retention
Early mobilization and upright positioning	Increased functional residual capacity; diaphragmatic excursion; ventilation redistribution	Subgroup analyses and narrative review [8,9,24]	Reduced atelectasis and pneumonia; shorter hospital stay
Nurse-led care bundles	Coordinated multimodal intervention targeting multiple mechanisms	Quasi-experimental and systematic review evidence [10,11,22,23,25]	Significant reduction in atelectasis and other pulmonary complications

Table 2. Comparison of Nurse-Led Intervention Components and Their Primary Targets

Intervention component	Primary physiological target	Optimal timing	Nursing role
Preoperative education	Knowledge, skill, and adherence	Before surgery	Assess baseline risk; teach and rehearse techniques [7,20]
Deep breathing and cough training	Alveolar recruitment and secretion clearance	Immediately after extubation and throughout postoperative period	Coach, correct technique, schedule sessions, provide feedback [12,13]
Incentive spirometry	Sustained maximal inspiration	Postoperative, with preoperative training where feasible	Supervise use, monitor effort, integrate with other exercises [15,17]
Positive expiratory pressure and airway clearance	Airway patency and mucus mobilization	Postoperative, guided by auscultation and secretion burden	Position, percuss, vibrate, assist coughing, monitor tolerance [6,16]
Early mobilization	Functional residual capacity and ventilation distribution	From first postoperative day or after extubation when stable	Assess readiness, progress activity, monitor hemodynamic response [8,9]
Multimodal analgesia	Pain relief to enable participation	Coordinated with respiratory sessions	Time analgesia, support wound, evaluate effect [3,4]
Care bundle	Multiple mechanisms simultaneously	Across the perioperative continuum	Coordinate, document, audit adherence, escalate concerns [10,11,25]

Comparative Effectiveness and the Case for Multimodal Care

The comparative literature does not support the search for a single "best" intervention. Incentive spirometry, deep breathing, positive expiratory pressure, and airway clearance techniques operate through partially overlapping but distinct mechanisms, and their relative value depends on the patient's dominant pathophysiology [4,16]. In patients whose atelectasis is driven primarily by low lung volumes, coached deep breathing and positioning are likely to be most important; in those with copious secretions or ineffective cough, airway clearance and positive expiratory pressure may add greater value. Early mobilization addresses both volume loss and secretion retention while also improving functional recovery, and pain management enables all of the above [9]. The evidence consistently indicates that multimodal rehabilitation strategies are more effective than single interventions [22,23]. This conclusion is reinforced by systematic review data showing that pulmonary rehabilitation nursing programs—which are inherently multimodal—reduce atelectasis and length of stay, whereas isolated device trials often produce equivocal results [23]. The most defensible clinical approach is therefore a tailored bundle that combines preoperative explanation when feasible, upright positioning, supported slow deep breaths, effective cough when indicated, timely multimodal analgesia, graded mobilization, and regular review of physiological tolerance [11,24].

Implementation, Adherence, and Barriers

The effectiveness of nurse-led interventions in controlled studies does not automatically translate into effectiveness in routine practice. Implementation fidelity—the extent to which interventions are delivered as designed—is a critical determinant of outcomes. Barriers include inadequate staffing, competing clinical demands, insufficient training in respiratory techniques, lack of standardized protocols, and patient-related factors such as pain, fatigue, cognitive impairment, and low health literacy [21]. Nurse-led programs must therefore include practical strategies for overcoming these barriers: brief, scripted educational tools; visual aids and teach-back methods; scheduled reminders; documentation templates that prompt and record respiratory interventions; and interprofessional coordination with physiotherapy and respiratory therapy. Adherence is also influenced by

the patient's experience of the intervention. Exercises that provoke pain, fatigue, or dyspnea are less likely to be performed consistently. Nurse-led care can improve adherence by integrating respiratory exercises with analgesia, using achievable targets, providing positive reinforcement, and tailoring the regimen to the patient's functional status and preferences [8,24]. The evidence suggests that nurse-led interventions are most successful when they are experienced by patients as supportive coaching rather than as a set of tasks to be completed independently [24].

Limitations of the Evidence

Several limitations temper the conclusions that can be drawn from the current literature. First, the heterogeneity of intervention protocols is substantial: studies differ in the frequency, duration, intensity, and supervision of breathing exercises, in the devices used, and in the qualifications and training of the nurses delivering the interventions [23]. This heterogeneity limits direct comparison across studies and complicates meta-analytic pooling. Second, outcome definitions vary widely, and many studies rely on composite pulmonary complication outcomes rather than atelectasis-specific endpoints [1,22]. Third, blinding is difficult in trials of nurse-led interventions, and performance bias cannot be excluded. Fourth, several studies are quasi-experimental or observational, and the risk of bias in some randomized trials is high [10,24]. Fifth, the contribution of co-interventions—particularly analgesia, early mobilization, and enhanced recovery protocols—cannot always be separated from the effect of respiratory interventions themselves [8,11]. These limitations do not invalidate the overall signal of benefit, which is consistent across systematic reviews and is biologically plausible. They do, however, argue for cautious interpretation and for the design of future trials that standardize intervention protocols, use validated atelectasis-specific outcomes, and report implementation fidelity [11].

FUTURE DIRECTIONS

Future research should prioritize pragmatic trials embedded in routine care, with standardized definitions of atelectasis and pulmonary complications, adequate sample sizes, and long-term follow-up. Studies should compare bundled nurse-led programs with usual care rather than testing individual devices in isolation, because the evidence increasingly indicates that the bundle, not the device, is the effective unit of intervention [11,23]. Research should also examine the optimal dose, timing, and sequencing of interventions; the role of patient-reported outcomes and functional recovery; and the cost-effectiveness of nurse-led programs in different health systems. Implementation science approaches are needed to identify strategies that sustain adherence and fidelity outside the controlled trial setting [21]. Finally, the integration of lung ultrasound and other bedside diagnostic tools into nursing assessment warrants further evaluation as a means of targeting interventions and detecting early treatment response [6,12].

CONCLUSION

Postoperative atelectasis is a common, physiologically predictable, and clinically consequential complication of major surgery. The evidence reviewed in this essay indicates that nurse-led interventions—preoperative education, deep breathing and cough training, appropriately used incentive spirometry, positive expiratory pressure and airway clearance techniques, early mobilization, multimodal pain management, and structured care bundles—are effective in reducing its incidence and in improving related outcomes such as oxygenation, length of stay, and pulmonary complication rates. The strongest evidence supports multimodal, coordinated programs rather than isolated techniques, and the most consistent benefits are observed when interventions are delivered by nurses who are trained, supported by protocols, and able to individualize care at the bedside. The limitations of the literature—heterogeneity, variable outcome definitions, and imperfect blinding—call for cautious interpretation and for continued refinement of both practice and research. Nevertheless, the available evidence justifies the integration of nurse-led respiratory care into routine perioperative pathways as a low-cost, scalable, and clinically meaningful strategy for preventing postoperative atelectasis.

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