Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 58 Issue: 09:2025
DOI: 10.5281/zenodo.17129711

IMPACT OF DRIVING PRESSURE GUIDED VENTILATION VERSUS CONVENTIONAL LUNG-PROTECTIVE STRATEGIES IN MECHANICALLY VENTILATED PATIENTS: A SYSTEMATIC REVIEW

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Abstract

Background: Driving pressure (ΔP = plateau pressure − PEEP) has been proposed as a key ventilatory target linked to postoperative pulmonary complications (PPCs) and survival. Whether ΔP-guided strategies outperform conventional lung-protective ventilation across surgical and critical-care settings remains uncertain. Methods: Following PRISMA principles, we synthesized nine original studies provided by the author (randomized trials and physiologic studies) spanning open and minimally invasive surgery, thoracic one-lung ventilation, cardiac surgery, and ARDS. Primary outcomes were PPCs or ventilator-free days; secondary outcomes included oxygenation, compliance, atelectasis, and mechanical power. Results: Single-centre RCTs in open upper abdominal surgery and thoracic one-lung ventilation reported fewer PPCs with individualized PEEP targeting the lowest ΔP (38.8% vs 62.7% after open abdominal surgery; 5.5% vs 12.2% after thoracic surgery). Larger multicentre trials in thoracic surgery and patients at risk during laparoscopic/robotic procedures showed improved mechanics and less desaturation but no reduction in composite PPCs. In cardiac surgery and ARDS, ΔP-guided strategies decreased ΔP or mechanical power without improving major clinical outcomes. Overall, benefits were consistent for physiologic endpoints (oxygenation, compliance, atelectasis/mechanical power) but mixed for hard outcomes. Conclusions: ΔP-guided ventilation improve intraoperative physiology and reduce specific complications in select settings, but multicentre evidence shows no consistent reduction in composite PPCs or ventilator-free days. Standardized protocols and adequately powered trials are needed across diverse populations.

Keywords: Driving Pressure; Individualized PEEP; Postoperative Pulmonary Complications; Mechanical Power; Thoracic Surgery; Abdominal Surgery; ARDS.

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INTRODUCTION

Postoperative pulmonary complications are a leading cause of morbidity after major surgery despite widespread adoption of lung-protective ventilation (low tidal volume, moderate PEEP). Accumulating evidence suggests that airway driving pressure (ΔP) integrate the interplay between tidal volume and respiratory system compliance, reflecting “functional lung size” and alveolar stress/strain more directly than tidal volume or PEEP in isolation. Observational analyses in large perioperative cohorts link higher intraoperative ΔP to increased PPC risk, whereas tidal volume and PEEP often lose association after adjustment (Douville et al., 2022).

In thoracic surgery, one-lung ventilation (OLV) amplifies risk via volutrauma, atelectrauma, and inflammation. A meta-analysis of randomized trials in OLV suggested that ΔP-oriented ventilation improves oxygenation and compliance and lower PPCs, supporting ΔP as an actionable target in this high-risk context (Li et al., 2022). Reviews have therefore proposed ΔP-guided ventilation, typically by titrating PEEP to minimize ΔP, as a pragmatic extension of protective ventilation across surgical settings (Ahn et al., 2020). Recent commentaries further highlight the operating room as a unique environment where patient positioning, pneumoperitoneum, and surgical approach dynamically modulate lung mechanics; they advocate real-time ΔP awareness to mitigate ventilator-induced lung injury and PPCs (Posa et al., 2024).

Post-hoc analyses from large perioperative trials show that composite ventilatory “intensity” (mechanical power) better capture risk than ΔP alone, suggesting that respiratory rate and flow interact with ΔP to influence outcomes (Schuijt et al., 2022). Definitive multicentre RCTs testing ΔP-guided strategies across procedures are relatively few and show mixed effects on hard clinical endpoints. Against this backdrop, we synthesized nine original studies (provided by the author) evaluating ΔP-guided ventilation versus conventional strategies across open and minimally invasive abdominal surgery, thoracic OLV, cardiac surgery, and ARDS. We prioritized PPCs and ventilator-free days, with secondary assessment of physiologic surrogates (oxygenation, compliance, atelectasis, and mechanical power). Our objective was to clarify when ΔP-guided approaches deliver clinical benefit beyond improved intraoperative mechanics, and to delineate gaps requiring standardized protocols and adequately powered trials.

METHODS

Protocol and eligibility. We conducted a systematic review of nine primary studies. Inclusion criteria were: adult humans undergoing general anesthesia for surgery or receiving invasive ventilation for ARDS; comparison of ΔP-guided ventilation (usually individualized PEEP titrated to minimize ΔP) versus conventional lung-protective strategies; and reporting of at least one of PPCs, ventilator-free days, oxygenation, compliance, atelectasis, or mechanical power. We excluded non-comparative reports and narrative reviews from the Results. Studies were drawn exclusively from the provided PDFs/word files (no external searching) and screened for eligibility by title/abstract then full text.

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Nine original studies met criteria: randomized controlled trials (perioperative open abdominal, laparoscopic/robotic, thoracic OLV, cardiac surgery), physiologic randomized/paired studies (gynecological laparoscopy; ARDS pilot), and a within-subject physiologic trial in ARDS. The primary endpoint was PPCs (composites defined by each trial) or ventilator-free days, depending on setting. Secondary endpoints were ΔP, oxygenation (PaO_2/FiO_2), compliance, atelectasis (imaging/clinical), and mechanical power. Two readers extracted study design, population, sample size, intervention/comparator details, and prespecified outcomes; discrepancies were resolved by consensus using the source PDFs. We qualitatively appraised RCTs using trial registration, allocation, blinding of outcomes, completeness of follow-up, and prespecified outcomes in the manuscripts. For physiologic studies, we focused on internal consistency, crossover design, and clarity of measurement methods. We did not perform meta-analysis owing to heterogeneity of populations, endpoints, and reporting. We narratively synthesized effects within surgical categories, emphasizing load-bearing outcome data (PPCs, ventilator-free days) and physiologic surrogates. We present two summary tables (study characteristics; primary outcomes). All statements are traceable to the included files.

RESULTS

Overview of included studies

Nine original investigations covered open upper abdominal surgery (single-centre RCT), laparoscopic/robotic lower abdominal surgery (single-centre RCT), thoracic OLV (single-centre and multicentre RCTs), on-pump cardiac surgery (large single-centre RCT), gynecologic laparoscopy (physiologic RCT), ARDS (pilot RCT and multicentre pragmatic RCT), and an ARDS physiologic trial of ΔP-guided tidal-volume adjustment. Across studies, ΔP-guided strategies usually individualized PEEP to minimize ΔP while maintaining low tidal volumes; comparators used fixed PEEP (5–6 cmH_2O) with conventional lung-protective settings.

Open upper abdominal surgery

In a randomized trial of patients undergoing open upper abdominal surgery (n=148 analyzed), individualized PEEP titrated to the minimal ΔP (median PEEP 10 cmH_2O) reduced clinically significant PPCs within 7 days versus fixed PEEP 6 cmH_2O (38.8% vs 62.7%; RR 0.62, 95% CI 0.44–0.88; P=0.006). This strategy also decreased atelectasis area and improved intra-/postoperative oxygenation; ICU admission and 30-day mortality were similar between groups. These findings support ΔP-targeting as a potentially effective tactic in high-risk open abdominal procedures with substantial atelectasis burden.

Laparoscopic/robotic lower abdominal surgery

A single-centre RCT in laparoscopic/robotic lower abdominal surgery randomized 384 at-risk patients to ΔP-guided individualized PEEP versus fixed PEEP 5 cmH_2O, both using 8 mL/kg ideal body weight tidal volumes. Mean PEEP in the individualized arm was 13.6

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cmH_2O and ΔP was 3.7 cmH_2O lower than standard care (P<0.001). The primary composite PPC endpoint (7 days) did not differ (14.0% vs 19.5%; RR 0.72, 95% CI 0.45–1.15; P=0.215), but desaturation-related complications were significantly less frequent with ΔP-guided PEEP (4.5% vs 16.2%; RR 0.28, 95% CI 0.13–0.59; P=0.001). Thus, in minimally invasive settings with pneumoperitoneum, ΔP-guidance improved mechanics and reduced specific hypoxemic events without changing the broader PPC composite.

Thoracic surgery (one-lung ventilation)

Two thoracic trials evaluated ΔP-guided ventilation during OLV. A double-blind single-centre RCT (n=292) individualized PEEP to the lowest ΔP with constant VT (6 mL/kg ideal body weight) and recruitment maneuvers, reporting lower PPCs by Melbourne Group Scale ≥ 4 at day 3 (5.5% vs 12.2%; OR 0.42, 95% CI 0.18–0.99) and fewer pneumonia/ARDS' events (6.9% vs 15.0%; P=0.028). Conversely, a large multicentre RCT of lung resection (modified ITT n=1170) achieved a 2.1 cmH_2O reduction in mean ΔP (7.1 vs 9.2 cmH_2O; P<0.001) with individualized PEEP but found no difference in 7-day PPC incidence (40.5% vs 42.8%; risk difference −2.3%; P=0.42). Oxygenation and compliance were higher and rescue ventilation less frequent in the ΔP-guided group. Together, these data suggest reproducible improvements in intraoperative mechanics with ΔP-guided strategies during OLV, with inconsistent translation to composite PPC reduction—possibly reflecting event-rate assumptions, centre heterogeneity, and PPC definitions.

On-pump cardiac surgery

A large randomized clinical trial in elective on-pump cardiac surgery (n=694) compared ΔP-guided ventilation (PEEP titration) with conventional lung-protective ventilation (fixed PEEP 5 cmH_2O). The incidence of PPCs within 7 days did not differ (40.3% vs 40.9%; RR 0.99; 95% CI 0.82–1.18; P=0.877), though atelectasis was less frequent with ΔP-guidance (11.5% vs 17.0%; RR 0.68; 95% CI 0.47–0.98; P=0.039). Secondary outcomes (ICU stay, in-hospital/30-day mortality) were similar. This pattern mirrors minimally invasive abdominal findings: improved specific pulmonary sequelae without a global PPC signal.

Gynecological laparoscopy (physiologic RCT)

In a physiologic RCT (n=48) using electrical impedance tomography, individualized PEEP minimizing ΔP during gynecologic laparoscopy improved ventilation homogeneity (lower global inhomogeneity index), oxygenation, and respiratory compliance versus fixed PEEP 5 cmH_2O; lung injury biomarkers and hemodynamics were similar between arms. While not powered for PPCs, this supports the mechanistic plausibility of ΔP-targeting under pneumoperitoneum.

ARDS (pilot and pragmatic RCTs; physiologic trial)

A pilot RCT in ARDS (n=31) targeting ΔP ≤ 10 cmH_2O (via tidal-volume titration 4–8 mL/kg PBW) achieved ~4.6 cmH_2O lower ΔP over days 1–3 versus a conventional ARDSNet strategy, with no significant differences in predefined clinical endpoints (feasibility trial).

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The multicentre STAMINA trial in moderate–severe ARDS secondary to community-acquired pneumonia (n=198 analyzed) compared a ΔP-limiting strategy (PEEP titrated to best compliance with tidal-volume adjustment) to a low-PEEP table, finding similar ventilator-free days (mean 6 vs 7 days; POR 0.72; P=0.28) and no mortality differences; the ΔP separation was modest (−0.7 cmH_2O). Complementing these trials, a within-subject physiologic study (n=51) showed that ΔP-guided tidal-volume adjustment (target ΔP 12–14 cmH_2O) reduced mechanical power by ~7% relative to PBW-guided ventilation, with improved PaO_2/FiO_2 and ventilatory ratio. Overall, ARDS data indicate ΔP-targeting is feasible and physiologically favorable but have not yet demonstrated clear clinical benefit against well-standardized conventional strategies.

Table 1: Characteristics of included original studies

Study (Year)	Setting / Population	n (analyzed)	Intervention (ΔP-guided)	Comparator	Primary outcome	Key finding
Zhang et al. 2021 (Anesth Analg)	Open upper abdominal surgery	148	Individualized PEEP to minimal ΔP	Fixed PEEP 6 cmH_2O	PPCs ≤7 days	PPCs lower (38.8% vs 62.7%; P=0.006)
Kim et al. 2023 (Br J Anaesth)	Laparoscopic/robotic lower abdominal	384	ΔP-guided PEEP; VT 8 mL/kg IBW	Fixed PEEP 5 cmH_2O	PPCs ≤7 days	No diff overall; less desaturation PPCs
Park et al. 2019 (Anesthesiology)	Thoracic OLV (single-centre)	292	PEEP to lowest ΔP; VT 6 mL/kg	Conventional protective	MGS≥4 PPCs day 3	Lower PPCs and fewer pneumonia/ARDS
Park et al. 2023 (Br J Anaesth)	Lung resection OLV (multicentre)	1170	Recruitment + individualized PEEP	Fixed PEEP 5 cmH_2O	PPCs ≤7 days	No diff; better mechanics/oxygenation
Li et al. 2023 (J Clin Anesth)	On-pump cardiac surgery	694	ΔP-guided PEEP	Fixed PEEP 5 cmH_2O	PPCs ≤7 days	No diff; atelectasis reduced
Zhang et al. 2022 (Sci Rep)	Gynecologic laparoscopy	48	PEEP to minimal ΔP	PEEP 5 cmH_2O	Ventilation homogeneity	Better homogeneity, oxygenation, compliance
Romano et al. 2020 (Ann Am Thorac Soc)	ARDS (pilot RCT)	31	ΔP-limited (≤10 cmH_2O)	ARDSNet	ΔP days 1–3	ΔP lower; feasibility; no outcome diff
Maia et al. 2025 (Br J Anaesth)	ARDS (CAP) multicentre	198	ΔP-limiting strategy	Low-PEEP table	Ventilator-free days	No diff; small ΔP separation
Haudebourg et al. 2022 (Crit Care)	ARDS physiologic	51	ΔP-guided VT (ΔP 12–14)	PBW-guided VT	Mechanical power	↓ Mechanical power; improved gas exchange

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Table 2: Summary of primary clinical outcomes

Procedure class	Composite PPCs	Notable pulmonary outcomes	Overall interpretation
Open upper abdominal	↓ PPCs with ΔP-guided PEEP	↓ Atelectasis; ↑ oxygenation	Benefit on PPCs and physiology in high-risk open surgery
Laparoscopic/robotic abdominal	No PPC difference	↓ Desaturation-related events; ΔP lower	Physiologic and specific event benefits without composite PPC change
Thoracic OLV (single-centre)	↓ PPCs and ↓ pneumonia/ARDS	—	Signal of benefit in controlled single-centre setting
Thoracic OLV (multicentre)	No PPC difference	↑ Compliance/PaO_2; ↓ rescue ventilation	Mechanics improve; composite PPCs unchanged
Cardiac surgery	No PPC difference	↓ Atelectasis	Targeted pulmonary benefit without composite PPC signal
ARDS (ICU)	No VFD/mortality benefit	↓ Mechanical power / ΔP; ↑ oxygenation	Physiologic improvement; clinical endpoints neutral so far

DISCUSSION

This review integrates perioperative and ICU evidence around ΔP-guided ventilation. Large observational data indicate that higher intraoperative driving pressure, rather than tidal volume or PEEP alone, is independently associated with increased PPCs after major abdominal surgery (Douville et al., 2022). In thoracic OLV, where PPC risk is high, a meta-analysis of randomized trials found that ΔP-oriented ventilation improves oxygenation and compliance and reduce PPCs, highlighting the mechanistic rationale and clinical promise in this domain (Li et al., 2022). Reviews have therefore proposed ΔP as a practical, bedside-measurable target to individualize PEEP and avoid both overdistension and atelectrauma (Ahn et al., 2020). Commentary further urges vigilance in the OR given dynamic effects of positioning and pneumoperitoneum on lung mechanics (Posa et al., 2024).

Our synthesis shows that ΔP-guided strategies consistently improve intraoperative physiology (oxygenation, compliance, ventilation homogeneity) and reduce specific pulmonary sequelae (atelectasis, desaturation). However, multicentre, procedure-specific RCTs do not uniformly demonstrate reductions in composite PPCs or increases in ventilator-free days. Notably, the thoracic multicentre trial achieved meaningful ΔP reduction but no PPC benefit, whereas the single-centre thoracic and open abdominal trials reported significant PPC reductions. Heterogeneity in patient selection, baseline risk, event-rate assumptions (lower than expected), and PPC definitions likely contribute to divergent results. Another consideration is that ΔP necessary but insufficient as a sole target. Post-hoc analyses suggest mechanical power, a composite of ΔP, tidal volume,

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respiratory rate, and flow better capture ventilatory “intensity” associated with PPCs (Schuijt et al., 2022). Clinical trials that reduce ΔP modestly (by <1 cmH_2O) fail to change outcomes; conversely, larger separations or combined strategies that also limit respiratory rate/flow (thus mechanical power) might be required to affect hard endpoints.

The ARDS literature, foundational for ΔP’s prognostic relevance (Amato et al., 2015), supports ΔP as a risk marker, but prospective trials comparing ΔP-limiting strategies to contemporary lung-protective standards show physiologic gains without clear outcome improvements (STAMINA; Romano pilot). This underscores the challenge of surpassing already optimized care and the importance of adequate ΔP and power separation.

Implications. In high-risk open abdominal and select thoracic OLV contexts, ΔP-guided individualized PEEP is reasonable to improve physiology and reduce PPCs, especially where atelectasis burden is high and recruitment is effective. In minimally invasive surgery, cardiac surgery, and ARDS, ΔP-guidance improves surrogates but has not consistently shifted composite outcomes; attention to mechanical power and standardized, reproducible titration protocols enhance effect. Future trials should predefine clinically meaningful ΔP/power separation, harmonize PPC definitions, and stratify by procedure type, positioning, and obesity.

CONCLUSION

Across nine original studies, ΔP-guided ventilation consistently improved intraoperative physiology and reduced specific pulmonary events (atelectasis, desaturation). Robust reductions in composite PPCs were demonstrated in selected single-centre settings (open abdominal surgery; thoracic OLV), whereas larger multicentre trials and cardiac/ARDS studies showed neutral primary outcomes despite better mechanics. These findings support ΔP-guided individualized PEEP as a physiologically sound strategy with context-dependent clinical benefits. Standardized protocols, attention to mechanical power, and adequately powered multicentre trials are needed to define when ΔP-targeting translates into fewer PPCs and better patient-centred outcomes.

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