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Masterthesis

Narrative review on driving pressure guided ventilation in surgical patients

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Abstract

Background: **BackgroundPostoperative pulmonary complications (PPC) are common in surgical patients although a lung-protective ventilation strategy approach is used. Driving pressure (δP) is an important component of mechanical ventilation and the research in acute respiratory distress syndrome (ARDS) patients shows that an increase of δP is associated with increased mortality.**
Objective: **This review analyzes the impact of δP guided Positive End-expiratory Pressure (PEEP) in ventilated patient during general surgery.**
Methods: PubMed was searched using the keywords: "driving pressure", "mechanically ventilated patients", "surgery" and "anesthesia". Additional research was added using the references of appropriate studies.
Results: **Most studies suggest that δP guided PEEP lowers PPC, however there is no clear consensus depending on the type of surgery. More studies should use objective measurement of δP guided PEEP titration to have a better understanding of its impact on ventilation.**
Conclusion: **In recent years, personalized medicine has become more prominent. δP guided PEEP may guide personalized ventilator strategy and thus improve the outcome of the anesthetized patient by minimising PPC. More research should be done to understand the impact of δP on postoperative outcomes.**

Keywords (MeSH terms): **Positive-pressure respiration, respiratory mechanics, ventilator induced lung injury, postoperative complications.**

Introduction

Mechanical ventilation is very commonly used during general surgery and in the ICU. It is recommended to use lung protective ventilation parameters: low tidal volume (VT) (6-8ml/kg predicted body weight), moderate Positive End-expiratory Pressure (PEEP) of approximate 5cm H2O and when recruitment manoeuvres are performed, lowest effective pressure and shortest effective time or fewest number of breaths should be used[1]. The output ventilator parameters depend on ventilator adjustments and the patient's conditions, thus consisting in driving pressure (δP) (equal or lower than 15 cm H2O) and plateau pressure (PPLAT) (equal or lower than 20 cmH2O)2. Chest wall compliance (CCW) is 200 ml/cm H2O and lung compliance (CL) is 200 ml/H2O, thus respiratory system compliance (CRS) is 100 ml/cm H2O considering 1/CCW + 1/CL = 1/CRS.

δP is the difference between end-inspiratory PPLAT and PEEP which is easily measured clinically. δP includes two parts: transpulmonary δP (pressure applied to the lungs) and chest wall δP (pressure applied to chest wall)[3]. This is much more difficult to measure, and an esophageal balloon is required to define intrapleural pressure. δP is defined as the distending pressure above the applied end-expiratory pressure required to develop VT and is created by the elastic forces applied during inflation4. Consequently, δP represents the VT divided by the CRS (hence δP =VT/CRS) (see Figure 1). Therefore, δP can potentially be reduced by adjusting VT and/or CRS. Reducing VT and adjusting PEEP to a more favorable part of the compliance curve is easier than changing CRS unless changing the patient's position or applying intraperitoneal pressure during laparoscopy. According to Roca et al., δP can be measured during mechanical ventilation by doing a short

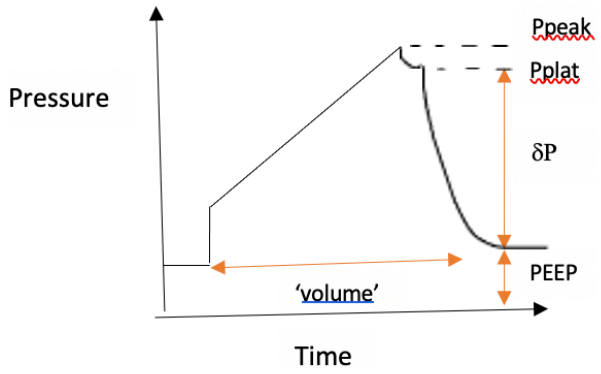

Fig. 1 — Diagram illustrating how driving pressure is correlated to lung strain, modified from Williams[5] et al. and Marini[31]
CRS: Respiratory system compliance, δP: driving pressure, FRC: functional residual capacity, PEEP: Positive end-expiratory pressure, Ppeak: Pressure peak, Pplat: Pressure plateau, VT: Tidal volume
Airway pressure profile during inflation with constant flow, where time reliably reflects inspired volume.
δP = Pplat – PEEP = transpulmonary pressure + Pressure applied to the chest wall. Therefore, δP= VT / CRS.
Strain is a measure of inspiratory lung deformation. And there is a linear correlation between CRS and FRC. Therefore δP is proportional to VT / FRC and δP is correlated to lung strain.

inspiratory pause of 0,2-0,3 seconds to measure PPLAT[4].

Stress represents the pressure applied to the lungs; the force applied divided by the surface5. Strain represents the variation of dimension, thus is a notion of deformation; strain is calculated by taking the sum of VT and PEEP-induced volume divided by the functional residual capacity (FRC). Strain is directly proportional to stress[5]. Lung injury is induced not only by the VT but also by the heterogeneity of lung expansion which can induce regional strains and systemic inflammation, amplifying the injurious effect of strain[5].

CRS = VT / (PPLAT – PEEP): therefore PPLAT – PEEP equals VT/CRS. Therefore δP is an indirect evaluation of VT divided by FRC; thus, an indication of the deformation caused by the VT and therefore of the dynamic strain. δP may reflect the change in lung stress which correlates with lung strain, which are both important factors related to ventilation induced lung injury (VILI) during prolonged ventilation: barotrauma, volutrauma, atelectrauma, biotrauma[3].

Extensive articles discuss the importance of δP in ARDS patients, but less in surgical patients whose lungs are usually healthy. According to Pistillo and Farina, safe levels of PPLAT and VT in ARDS patients did not always prevent atelectrauma, stress and strain, especially in patients with lower arterial oxygen partial pressure (PaO2) and fractional inspired oxygen (FiO2) ratio, lower end expiration lung volume, higher δP; but rather decreasing airway δP reduced the VILI risk[6]. Consequently, δP has clinical relevance and important practical implications during mechanical ventilation.

Amato et al.'s showed that in ARDS, δP is more strongly associated with survival than VT and PEEP; and the changes in VT and PEEP were associated with survival only when the changes induced a reduction in δP[7]. Chiumello et al.'s concluded that ARDS patients with high levels of δP presented significantly higher lung stress[8]. According to Barbas and Palazzo, PEEP titration to target transpulmonary positive end-expiratory pressures measured with esophageal manometry results in lower δP and lower 28-day mortality in ARDS patients[9]. And a high PPLAT and a δP higher than 15 cm are associated with increased mortality in ARDS patient[7,9]. Moreover, in surgical patients intraoperative high δP and changes in PEEP that elevate δP was associated with more post-operative pulmonary complication (PPC)9. It is recommended that PEEP should not follow a standard value (low, moderate, or high), but rather PEEP should be individualized for each patient by optimizing dynamic compliance, reducing δP or using tools such as ultrasound or thoracic electrical impedance tomography (EIT).

Therefore, this narrative review aims to examine the role of δP guided PEEP in the development of PPC during intraoperative mechanical ventilation in non-ARDS surgical patients. This review will focus mainly on PPC rather than VILI.

Methods

This narrative review researched available studies from PubMed from 2010 to September 2024 using the keywords: "driving pressure", "mechanically ventilated patients", "surgery" and "anesthesia".

The systematic literature search identified 760 records, after screening seven papers were selected for eligibility. Additional research was added using the references of appropriate studies. Ultimately 18 papers were used for this narrative review (see Figure 2). Inclusion criteria were RCTs, systematic reviews, meta-analysis, English language, adults undergoing surgery. Exclusion criteria were full texts not available, animal experiments and studies with missing results and methods. Table I summarizes the results of randomized controlled trials (RCT) by type of surgery. The results are presented by type of surgery and a separated section is devoted to meta-analyses.

Results

Meta-analysis results

Neto et al. have concluded that surgical patients showing intraoperative high δP or changes of PEEP inducing an increase in δP developed more PPC: barotrauma, postoperative lung injury, pulmonary infection or barotrauma (meta-analysis of 17 RCT until July 2015, 2250 patients)10. The limitations of this meta-analysis are that PPC are based on clinical criteria and no predictive scores were used. Li Y. et al. established that δP guided ventilation improved oxygenation index and decrease mortality (meta-analysis of seven RCT until September 2021, 1405 patients)[11]. Zhou et al. showed that during abdominal surgeries, laparoscopic surgeries, prone spinal surgeries there is a decrease in PPC (atelectasis, respiratory infection, hypoxemia) in the group with an individualized PEEP but no significant difference between the groups in the incidence of pleural effusion (systematic review and meta-analysis, 14 studies published from 2014 to 2021, 1105 patients)[12]. In their results, δP was significantly decreased in the individualized PEEP group[12].

Another systemic review and meta-analysis by Buonanno et al. (16 RCT until May 2022, 4993 patients) showed that low tidal volume and δP guided PEEP strategies compared with high tidal volume and fixed PEEP ventilation strategies were associated with a reduction in PPC: hypoxaemia (PaO2 less than 60mmHg or oxygen saturation less than 90%), bronchospasm, pulmonary infection, development of ARDS, aspiration pneumonitis, radiological findings of pulmonary infiltrate, atelectasis, pleural effusion, pneumothorax, and pulmonary oedema[13].

Gu et al. concluded that δP guided ventilation was associated with a lower risk of PPC in non-cardiothoracic surgery but not in cardiothoracic surgery (13 RCT, 3401 patients)[14]. This study used three RCT in thoracic surgery, one in cardiothoracic surgery and nine non-cardiothoracic surgery (predominantly abdominal surgery)[14]. The strengths of this recent study are that it is a multicenter RCT in various countries and it uses a rigorous method to analyse the RCTs. The limitations are that the various trials used different criteria to define PPCs and some included trials were small thus there might be publication bias.

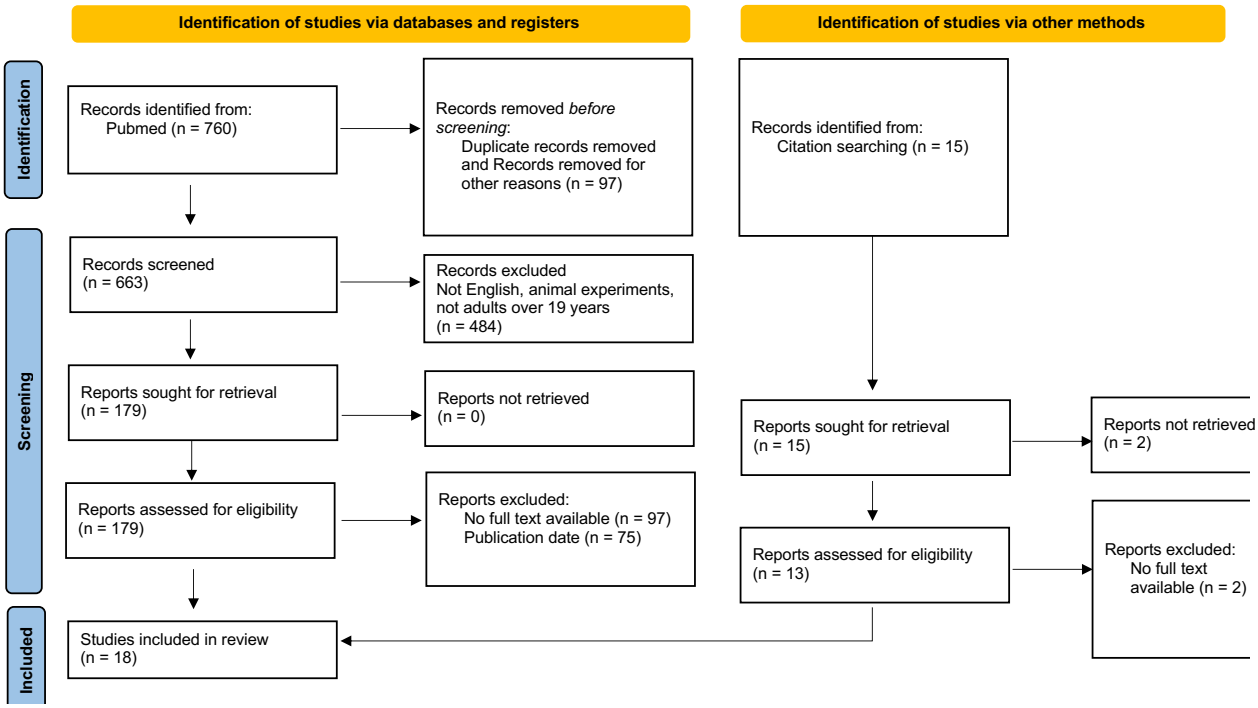

Fig. 2 — PRISMA 2020 flow diagram, Identification of studies included in review.

Table I. — Baseline characteristics of the included RCT studies.

First author	Year of publication	Study design	Sample size	Type of surgery	Comparison made	Types of PPC	Conclusions
Zhang[16]	2022	RCT single centre	48	Gynecological laparoscopy surgery	PEEP of 5 cm H_2O vs incremental PEEP titration producing the lowest dP	Atelectasis, lung injury biomarkers. EIT used.	dP-guided PEEP caused a more homogeneous ventilation, better gas exchange and C_{RS}
Kim[17]	2023	RCT single centre	363	Laparoscopic or robotic surgery	PEEP of 5 cm H_2O vs dP-guided incremental PEEP titration	Atelectasis, hypoxaemia, ARDS, pneumonia, pleural effusion, bronchospasm, pneumo- thorax, aspiration pneumonia, early extubation failure or requirement of reintubation, and postoperative requirements for rescue manoeuvres. Defined by pre- specified clinical and radiological criteria.	dP-guided PEEP did not decrease the incidence of PPC
Xu[18]	2022	RCT single centre	51 elderly patients	Laparoscopic surgery	PEEP of 6 cm H_2O vs decremental PEEP to the lowest dP	Postoperative atelectasis. Ultrasound score used.	Intraoperative titrated PEEP lower postoperative lung atelectasis
Pereira[19]	2018	RCT single centre	40	Open and laparoscopic abdominal surgery	PEEP of 4 cm H_2O vs EIT–guided PEEP	Postoperative atelectasis. EIT used.	Individualized PEEP settings with lower dP reduce postoperative atelectasis
Zhang[20]	2021	RCT single centre	148	Open upper abdominal surgery	PEEP of 6 cm H_2O vs incremental PEEP to the lowest dP	Hypoxemia, atelectasis, pleural effusion, dyspnea, pneumonia, pneumothorax, and ARDS. Chest computed tomography and EIT used.	Individualized PEEP based on minimum dP may weaken the severity of atelectasis, improve oxygenation, and reduce the incidence of PPC
Mini[21]	2021	RCT single centre	82	Abdominal surgery	PEEP of 5 cm H_2O vs incremental PEEP to the lowest dP	Postoperative atelectasis. Lung ultrasound score used.	Intraoperative titrated PEEP pressure diminished postoperative lung atelectasis
Ernest[22]	2023	RCT single centre	168	Emergency laparotomy	PEEP of 5 cm H_2O vs incremental PEEP to the lowest dP	Melbourne group scale: at least score four.	Similar results for PPC, duration of ICU stay, hospital stay and mortality
Li Xue-Fei[24]	2023	RCT single centre	694	On-pump cardiac surgery	PEEP of 5 cm H_2O vs incremental PEEP to the lowest dP	Acute respiratory distress syndrome, atelectasis pleural effusion, pneumonia, pneumothorax.	dP -guided ventilation did not decrease the risk of PPC compared to conventional lung-protective ventilation strategy
Park[25]	2019	RCT single centre	312	Thoracic one lung ventilation surgery	PEEP of 5 cm H_2O vs incremental PEEP to the lowest dP	Melbourne group scale: at least score four.	dP guided ventilation during one lung ventilation was associated with a lower incidence of PPC

First author	Year of publication	Study design	Sample size	Type of surgery	Comparison made	Types of PPC	Conclusions
Park[26]	2023	RCT multicentre	1170	Thoracic surgery: lung resection surgery	PEEP of 5 cm H_2O vs decremental PEEP to the lowest dP	Hypoxaemia (SpO2 <90%), oxygen therapy on postoperative day 2 or later, initial ventilator support longer than 24 h, re-intubation and mechanical ventilation, tracheostomy, pneumonia, empyema, atelectasis requiring bronchoscopy, ARDS, chest tube for 5 days or more owing to persistent air leak or pleural effusion, bronchopleural fistula, contralateral pneumothorax and pulmonary embolism.	dP-guided ventilation enhanced pulmonary mechanics intra-operatively but did not diminish PPC
Liu[28]	2023	RCT single centre	53	Supratentorial craniotomy	PEEP of 5 cm H_2O vs incremental PEEP to the lowest dP	Melbourne Group Scale: at least score 3. EIT and lung ultrasound used.	dP-guided ventilation did not contribute to postoperative homogeneous aeration but may cause better C_{RS} and decrease lung ultrasonography scores

C_{RS}: respiratory system compliance, EIT: Electrical impedance tomography, PEEP: Positive end-expiratory pressure, PPC: post-operative pulmonary complication, RCT: randomized controlled trials

General laparoscopic surgery and open abdominal laparotomy surgery results

Ahn et al. showed that individualized PEEP to reduce δP and the size of atelectasis detected in the lung CT scan, has beneficial repercussion on PPC especially in laparoscopy compared to open surgery[15]. The authors suggest using PEEP and VT titration to reduce δP and recommend recruitment before starting PEEP titration to keep recruited alveoli open[15].

Similarly, Zhang et al.'s RCT demonstrated that δP guided PEEP caused more homogeneous ventilation (showed by EIT), better gas exchange and CRS in patients undergoing gynecological laparoscopy[16]. This study also analyzed lung injury biomarkers (interleukin-10, neutrophil elastase, and Clara Cell protein-16) and did not show any difference in biomarkers between the two groups[16]. This single center randomized blinded study has a rigorous method of inclusion and exclusion criteria, anesthesia protocol and PEEP method titration. However, this single center study included only 48 healthy non-obese patients.

Kim et al. investigated the incidence of PPC in patients undergoing laparoscopic or robotic surgery ventilated with a δP guided PEEP strategy; this study showed that δP guided PEEP did not decrease the incidence of pulmonary complications within 7 days of the surgery[17]. Some limits of the study could explain these results: single center study, low and moderate risk patients, short intervention time[17]. The authors also question whether the benefits of individualized PEEP may disappear after extubation and not persist post-operatively and whether pneumoperitoneum and Trendelenburg positioning affects δP[17].

Xu et al. showed that intraoperative δP guided PEEP in a small sample of elderly patients undergoing laparoscopic surgery diminished postoperative lung atelectasis[18]. In this study, PEEP titration was decremented to the lowest δP and ultrasound scores were noted at the end of surgery and 15 min after the admission to the post-anesthesia care unit. The strength of this study is that it used an objective ultrasound score to compare the results. One limitation of this study is that pure O2 was used which may affect absorption atelectasis.

Pereira et al. analysed the effect of individualized PEEP settings on postoperative atelectasis during open and laparoscopic abdominal surgery and suggested that individualized PEEP settings with lower δP reduced postoperative atelectasis[19]. Their study used EIT to analyse atelectasis[19].

Similarly, Zhang et al. demonstrated that the use of individualized PEEP based on minimum δP

may weaken the severity of atelectasis, improve oxygenation, and reduce the incidence of PPC after abdominal surgery[20]. The strength of this study is using objective tools and measurements such as chest computed tomography and EIT to measure PPC. An incremental PEEP titration protocol was used in this study, thus further studies with decremental PEEP titration are needed to compare the outcomes. The limits of this study are that it's a single-centered study in one country, prolonged PEEP titration may cause recruitment which may affect the results and further investigations are needed to determine whether these findings can be extrapolated to other types of surgery.

Similarly, Mini et al. investigated the effect of δP guided PEEP titration on postoperative atelectasis in patients having major abdominal surgery[21]. This study measured atelectasis by lung ultrasound score, PEEP was increased incrementally, and no recruitment manoeuvre was used avoiding overdistension and haemodynamic instability. It is interesting that this study titrated PEEP multiple times during the surgery to account for change in CRS due to surgical tractors, fluid overload, atelectasis due to length of the surgery. Intraoperative titrated PEEP pressure diminished postoperative lung atelectasis, but the authors suggested more studies on PPC[21]. This is a single center study which used a very small sample size and further similar studies should be done with a bigger sample size.

Ernest et al. explored the effect of δP guided PEEP titration compared to a fixed PEEP of 5cm H2O on PPC in patients undergoing emergency laparotomy using the Melbourne group scale (at least four)[22]. The Melbourne group scale is a popular tool to predict PPC using clinical signs (high temperature, purulent sputum, blood oxygen saturation level below 90%), pathological biological results (high white cell count or use of antibiotics, positive microbiological sputum), pathological chest x-ray findings (atelectasis or consolidation) and re-admission or prolonged stay (more than 36 hours) in the intensive care or high dependency unit for respiratory problems[23]. The authors concluded that both groups had similar results for PPC, duration of ICU stay, hospital stay and mortality[22]. The strengths of this study are that a detailed mechanical ventilation was used, it included a large sample size of 168 patients without lost to follow up. The limitations of this single center study are that PEEP titration was not continued into the ICU in patients not extubated in the operating room. Furthermore, in the PEEP group, PEEP was titrated hourly arbitrarily, but compliance may change with time. Also, the location of the surgical incisions was not considered in the study and various types of procedures were performed which might affect the ventilation.

Cardiothoracic surgery results

Several studies examined the effect of δP guided PEEP during cardio-thoracic surgery. Li Xue-Fei et al. analyzed during on-pump cardiac surgery the effect of intraoperative δP guided ventilation using incremental PEEP compared to conventional lung protective ventilation on pulmonary complications (acute respiratory distress syndrome, atelectasis pleural effusion, pneumonia, pneumothorax)[24]. The authors concluded that δP guided PEEP did not decrease the risk of PPC compared to conventional lung-protective ventilation strategy[24]. The first disadvantage of this study is that it is single center with patients undergoing valve surgery and thus some patients may have pathological pulmonary artery pressure. The strength of this study is a large sample size of 694 patients, very little lost to follow-up and a detailed blind randomization was executed. Further investigations are needed in patients undergoing pump cardiac surgery for coronary artery bypass grafting. Moreover, a limitation of the study is that the recruitment manoeuvre was done through bag squeezing.

Park et al. compared δP guided PEEP during one lung ventilation with conventional protective ventilation in thoracic surgery, analyzing PPC (Melbourne Group Scale of at least 4) until postoperative day three25. They concluded that the application of δP guided PEEP during one lung ventilation was associated with a lower incidence of PPC[25]. This study had a large 312 sample size, but was done in a single center, intrinsic PEEP that majority of patients develop during one lung ventilation was not measured, PEEP trial was measured until 10 cm H2O thus effect on lung compliance was limited, high FiO2 was used which may have caused oxidative stress lung injury and atelectasis[25].

Park et al.'s clinical trial examined the δP guided PEEP and PPC in thoracic surgery specifically lung resection surgery and compared it to conventional protective ventilation[26]. The authors concluded that δP guided PEEP enhanced pulmonary mechanics intra-operatively but did not diminish PPC. In this multicenter randomised study, the protective ventilation group received recruitment manoeuvre then fixed PEEP, and the δP group received similar recruitment manoeuvre then PEEP was titrated in decremental manner[26]. The patients having lung resection surgery have increased risk of pulmonary complications because of pre-existing lung disease, injuries caused by one lung ventilation, surgical

aggression, loss of pulmonary parenchyma; thus, one of the interesting importance of this study is the relevance of δP guided ventilation on patient outcome[26]. Another strength of this trial is that it is a multicenter study in the same country with a large sample size (1170 patients), rigorous patients selection and detailed clinical analysis and results.

Li Xuan et al.'s systematic review and meta-analysis (seven studies with a total of 640 patients) analyzed the effect of δP guided PEEP during thoracic surgery in particular one-lung ventilation[27]. The conclusion was that δP orientated ventilation was linked to less PPC, improved perioperative oxygenation using PaO2/FiO2 ratio and better perioperative CRS[27]. The limitation of this study is the small sample size.

Neurosurgery results

Liu et al. concluded that δP on early postoperative lung gas distribution in supratentorial craniotomy did not contribute to postoperative lung aeration homogeneity but may induce better CRS and decrease lung ultrasonography scores[28]. PPC within 3 days post-operatively were assessed using the Melbourne Group Scale (score 3 or higher)[28]. The strength of this study is the detailed study protocol, objective measurements with EIT, lung ultrasound, arterial blood gas and use of the Melbourne Group Scale. The limitations are that EIT and lung ultrasound were only performed pre-induction, just after extubation and one hour after extubation, and lastly there was no evaluation of the link between the brain tumor and PPC[28].

Prospective literature

There are no studies analysing the impact of δP ventilation in obese patients during surgeries. Obese patients can cause a challenge during ventilation as the excess weight can have an impact on ventilation and increases pressure. Liou et al.'s retrospective review analyzes transpulmonary pressure guided PEEP titration for mechanical ventilation in class II and III obesity with ARDS using esophageal manometry and concluded that pressure guided PEEP titration in obese patients can be used to decrease δP and improve oxygenation[29]. According to Williams et al.'s study, measuring esophageal pressure or using EIT in obese patients could help to determine optimal levels of PEEP and guide lung recruitment[5]. Consequently, these findings can give future research possibilities in obese patients. There is currently a clinical trial by Yongtao Sun on the effects of δP guided PEEP in morbidly obese patients (Trial registration number NCT06181279).

Furthermore, there is no research for δP according to lung size, especially in pediatric patients, and when there is a degree of lung inhomogeneity due to pregnancy, aging, or pathology such as COPD, heart failure, surgical position and surgical traction. Therefore, it would be interesting to have more research on δP guided PEEP with various functional sizes and lung inhomogeneity.

Discussion

In this narrative review, δP guided PEEP during general surgery in non-ARDS patients is examined to provide insight for future research and optimise personalized mechanical ventilation. The main limitation of most studies is the small sample size, and they were done in a single center in the same country, thus questioning the generalisability of the study.

During laparoscopic surgery, a reduced δP has several benefits such as a more homogeneous ventilation, better gas exchange and CRS. However, several studies have contradicting conclusions concerning the duration of these effects after extubation. Therefore, more studies should examine whether the benefit of individualized PEEP persists after extubation. Moreover, studies should examine if δP is an accurate marker for lung strain during pneumoperitoneum and Trendelenburg positioning. Also, it should be noted that carbon dioxide during laparoscopic surgery affects CCW but not CL[17]. Two ongoing trial protocols might give more insight: Zhang et al.'s RCT involving patients undergoing laparoscopic surgery (Trial registration number NCT04374162) and Yoon et al's RCT on robot-assisted radical prostatectomy (Trial registration number NCT06909630).

In open abdominal surgery, studies suggest that individualized PEEP based on minimum δP may weaken the severity of atelectasis and improve oxygenation. More RCT are needed to analyse how δP is affected by the surgical retractors that induce CRS changes and how δP is affected by fluid overload and atelectasis due to length of the surgery. Schultz Marc et al. is currently doing an international multicenter study during minimally invasive abdominal surgery (Trial registration number NCT06101511).

Studies in cardiothoracic surgery, suggest that δP guided ventilation improves pulmonary mechanics, oxygenation, and compliance but there is no consensus whether δP guided ventilation decrease PPC. Thus, more studies should investigate the impact of δP on PPC in cardiothoracic surgery. Yong Lin et al. are currently doing a study in surgical repair of acute type A aortic dissection

(Trial registration number NCT06361420).

One study analyzed δP guided ventilation during craniotomy and concluded that it did not contribute to postoperative homogeneous aeration but may cause better CRS. More studies should be investigating the effect of δP during neurosurgery.

There are so far no studies that analyses the effect of reducing δP by reducing the tidal volume. It would be interesting to investigate the effect of tidal volume change on the δP and if there is an impact on ventilation, outcome and PPC.

In the studies presented some use δP guided incremental PEEP titration and others use decremental PEEP titration. It is not clear whether a PEEP derecruitment pattern or PEEP recruitment pattern is a better technique, and which causes the least disadvantages such as cardiovascular instability, need for repeat manoeuvre. Future studies should use a standardized recruitment manoeuvre and detail the technique used.

This narrative review focuses mainly on δP guided PEEP during general surgery and controlled ventilation, however it would be interesting to do a review on δP guided ventilation in spontaneously breathing patient during general surgery.

Conclusion

In the era of personalized medicine, δP guided PEEP may improve ventilation strategy and enhance patient recovery by minimising PPC through individualized ventilator strategies. Ideally further research should use standardized methods to qualify δP and PEEP titration and use objective measurements such as EIT or ultrasound. And more research should be conducted on various surgeries and surgical techniques.

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