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Anesthesia Providers' Knowledge and Use of Alveolar Recruitment Maneuvers

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Introduction

Lung atelectasis develops after the induction of anesthesia, even in healthy patients, and is associated with an increase in intraoperative pulmonary blood shunting and impaired gas exchange. Obesity augments ventilation-perfusion mismatch via atelectasis and impairs respiratory mechanics by weighting the chest wall and exerting increased upward pressure on the diaphragm. The impairment of gas exchange is directly related to the increase in body mass index (BMI) [1]. Therefore, obese patients undergoing surgery with general anesthesia are predisposed to decreased pulmonary function and are at an increased risk for perioperative pulmonary complications.

Anesthesia providers may or may not employ a variety of ventilation strategies to prevent or reverse the pulmonary changes induced by general anesthesia. Some commonly employed techniques include: recruitment maneuvers (RMs), positive end-expiratory pressure (PEEP), intervals of large tidal volume ventilation (>15 mls/kg), intermittent "sigh breaths", and sequential increases in PEEP. These techniques may be described as nebulous in terms of their respective operational definitions and highly variable in how they are implemented in clinical practice. The purpose of this study is twofold. First, a literature review was performed in order to discern the "best-practice" for atelectasis reversal in obese patients undergoing anesthesia. Second, a survey was constructed and administered in order to assess the current attitudes, knowledge base, and practices of local anesthesia practitioners regarding lung recruitment strategies. The study concludes with a discussion of how the survey results compared with the "best-practice" elucidated in the literature review.

Literature Review

Numerous strategies to improve respiratory function in anesthetized obese patients have been investigated. The addition of PEEP at 10 cm H_2O has been shown to maintain respiratory mechanics and oxygenation by providing sufficient pressure to prevent alveolar collapse in obese patients [2]. Additionally, recruitment maneuvers (RMs), also referred to as vital capacity maneuvers (VCMs), which provide high peak airway pressures for a sustained length of time, have been studied as a way to reopen collapsed alveoli. The efficacy of RMs used in combination with PEEP has not been well established in the obese surgical population [2]. However, emerging data demonstrates that RM + PEEP may be more beneficial that either technique used alone [1-5]. Thus, this paper seeks to evaluate whether the performance of a RM followed by PEEP is more effective than RM or PEEP alone in improving perioperative lung function in adult, multi-racial obese patients undergoing general anesthesia.

The following major electronic databases were searched for the literature review: PubMed, Medline, Cochrane Review, and CINAHL. Keywords used in various combinations for the database inquiry included: positive end-expiratory pressure, recruitment maneuver, vital capacity maneuver, obese, atelectasis, arterial oxygenation, positive pressure ventilation, pulmonary function, general anesthesia, gas exchange, and mechanical ventilation. Relevant articles met inclusion criteria if all subjects were adult (greater than 18 years old), obese (BMI greater than 30 kg/m_2), and received general anesthesia with mechanical ventilation. Additionally, each study was required to compare pulmonary function among comparison or treatment groups who received PEEP or RM alone vs. those treatment groups that received a RM followed by PEEP. Only five articles met these criteria (Table 1) [2,5-8]. Studies were excluded if they were not written in English, if the subjects were not obese adults, if the study was not written within the last 10 years, or if the study did not examine the effect of both RM and PEEP.

The effectiveness of sustained pressure RM vs. sequential increases in PEEP as a modality for RM has not been evaluated in the literature. Current literature supports the use of a minimum of 40 cm H_2O pressure for a minimum of 7-10 seconds to recruit collapsed alveoli. The minimum value of PEEP found to be effective in preventing the occurrence of atelectasis following RM is 8-10 cm H_2O. These parameters have been found to be safe in normovolemic patients without severe concomitant cardiovascular or pulmonary disease. Based on the current literature it may logically follow that the use of recruitment maneuvers may decrease postoperative hypoxemia and pulmonary complications and therefore contribute to shorter hospitalizations and decreased healthcare costs.

Numerous direct and indirect or calculated methods were used to measure perioperative lung function and degree of pulmonary shunting. One of the five studies used indirect measurements and calculations (e.g. alveolar-arterial oxygen gradient) as well as CT imaging to directly quantify reduced lung atelectasis. Four of the five studies were randomized clinical trials [2,6-8].

Futier et al. utilized a non-randomized control trial in which assigned groups were ventilated with zero end-expiratory pressure (ZEEP), PEEP (10 cm H_2O) alone, or RM (40 cm H_2O sustained for 40 seconds) + PEEP (10 cm H_2O) [9]. Numerous respiratory parameters were indirectly measured or calculated and included: functional residual capacity (via helium washout test), respiratory system compliance, physiologic dead space, and arterial oxygenation. Additionally, these parameters were measured numerous times during the surgical procedure.

Although the controlled trials all yielded similar findings, the small sample sizes and high degree of variability between the studies limits the generalization of the findings. For example, only three studies compared the treatment group (RM + PEEP) to a comparison group that received PEEP, without RM, at an equivalent value to the treatment group. Weaker studies used comparison or control groups that received

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Author and date	Study purpose	Study design	Sample	Findings
Reinius et al. [2]	Analyze the effect of general anesthesia and three different ventilatory strategies	Prospective and randomized	Thirty morbidly obese patients (body mass index 45 ± 4 kg/m^{-2})	A recruitment maneuver followed by PEEP reduced atelectasis, whereas, PEEP or a recruitment maneuver alone did not.
Chalhoub et al. [6]	Evaluate the effect of a vital capacity maneuver (VCM), followed by ventilation with positive end-expiratory pressure (PEEP), on arterial	Prospective and randomized	Fifty-two morbidly obese patients (body mass index >40 kg/m^{-2})	The addition of VCM to PEEP improves intraoperative arterial oxygenation in morbidly obese patients undergoing open bariatric surgery
Talab et al. [7]	Evaluate the safety and efficacy of the VCM followed by different levels of PEEP	Prospective and randomized	Sixty-six obese patients (body mass index 30 - 50 kg/m^{-2})	Intraoperative alveolar recruitment with a VCM followed by 10 cm H_2O prevents lung atelectasis and improves oxygenation, PACU stay, and pulmonary complications
Whalen et al. [8]	Quantitate the effects of recruitment maneuvers followed by PEEP on PaO_2	Prospective and randomized	Twenty patients (body mass index >40 kg/m^{-2})	Recruitment maneuvers followed by PEEP effectively increases intraoperative PaO_2
Futier et al. [9]	Effect of PEEP and recruitment maneuver on end-expiratory lung volume (EELV), oxygenation and respiratory mechanics	Prospective and non-randomized	Sixty patients	Recruitment maneuver combined with PEEP improved EELV, respiratory mechanics, and oxygenation; whereas, PEEP alone did not

Table 1: Presentation of reviewed studies.

no PEEP or PEEP at a lesser pressure than the treatment group. Additionally, four of the studies were performed during laparoscopic procedures as opposed to open surgical procedures. Laparoscopic procedures utilize pneumoperitoneum insufflation, which increases intra-abdominal pressure and inhibits diaphragmatic excursion and respiratory compliance more that open surgical procedures. Therefore, RM and PEEP pressures found to be effective in open procedures may not be as effective for laparoscopic procedures. It should be noted that the minimum pressure used for an RM in any study was 40 cm H_2O and that the minimum length of time that this pressure was sustained was for 8 seconds.

Finally, the expansive range of BMI among subjects (30 to 50 kg/m^2), the pressures used for RM and PEEP, the timing and frequency of administration of RM, preoperative intravenous fluid administration, and the type and frequency of lung function testing all varied significantly across the studies included in this review. All of the studies described in this literature review lent some credence to the supposition that lung recruitment via a recruitment maneuver (e.g. sustained pressure of 40-50 cm H_2O held for at least 8 seconds), immediately followed by positive end expiratory pressure (eg. minimum 8 cm H2O) is more effective than either intervention used alone in the treatment of atelectasis incurred by the induction of anesthesia in obese patients. The studies by Reinius et al. and Talab et al. provided the most convincing evidence of this by employing CT technology to directly quantify a reduction in atelectasis after an RM + PEEP intervention, yet the small sample sizes and degree of variability between even these two studies limits the generalization of the findings [2,7]. Future studies should seek to duplicate their study designs while increasing sample size and consistency in certain measures such as length of RM and pressures used for RM and PEEP in control and treatment groups.

Survey

Methods

The Michigan State University Biomedical and Health Institutional Review Board (BIRB) approved the survey form and study protocol. Following BIRB approval, a 54 items researcher-developed self-administered questionnaire and a return envelope were distributed to anesthesia providers between seven clinical sites contracted with a Midwest Nurse Anesthesia Program. Content and frequency analysis and descriptive statistics was used to characterize the data. Internal consistency reliability was estimated for each composite measure in order to assess the extent to which the items comprising each composite measured a comparable construct [10]. Verbal reminders to complete and return surveys were given one month after initial distribution. Additionally, researchers met during staff meetings to reiterate the purpose of the study and to answer any questions pertaining to the study.

Forty-seven of the 54 items on the questionnaire were rated on a 4-level Likert scale ranging from "strongly agree (score=1)" to "strongly disagree (score=4)" (SA = strongly agree, A = agree, D = disagree, SD = strongly disagree). Participants were instructed to circle their answers pertaining to obesity, atelectasis, recruitment maneuvers (RMs), positive end-expiratory pressure (PEEP), and personal anesthesia practice relating to these items. The last seven questions included were specific to techniques used to perform RMs. Demographic data included age, race, gender, educational level, number of years in anesthesia practice, areas of practice, position, number of functioning operating rooms, and total number of beds within participants' agencies. A codebook was formulated on Windows-based Excel spreadsheet to compile data from total questionnaires returned. SAS System software provided statistical results for the collected data.

Results

Of 200 surveys distributed at seven clinical sites, 64 surveys (32%) were returned. The majority of respondents (71%) worked at in a facility that had between 11 and 20 operating rooms, at an agency with between 0 and 350 beds (56.9%). The greatest number of respondents ranged in age from 31 to 60 (78.2%) respondents ages 31-40 accounted for 33.3%. 32.8% were male and 67.2% were female respondents. Most the anesthesia providers who participated in the survey practiced in operating rooms (69%) compared to outpatient surgery centers (29%) or academic programs (2%). The greatest percentage of respondents held Master of Science degrees in nursing (MSN) (81%) and the remainder were either Medicinae Doctor (M.D.) or Doctor of Osteopathic Medicine (D.O.). Thirty-eight percent of those surveyed have been in practice for 1 to 5 years, 18.4% have been in practice for greater than 25 years.

Of the 64 surveys that were returned, only 40 surveys were used for the data analysis. Twenty-four of the surveys had either missing or incomplete data and were not considered for data analysis. Statistical

Question	Mean	Standard Deviation
Increases the difficulty in providing quality		
anesthetic care	1.67	0.764
Plays an important role in anesthetic plan	1.37	0.490
Is a challenge for anesthesia providers	1.42	0.500
Is a problem increasing during practice	1.60	0.708
Demands special ventilatory consideration	1.37	0.490
Associated with post operative pulmonary		
complications	1.50	0.554
Affects FRC	1.35	0.483
Affects overall respiratory system resistance	1.45	0.503

Table 2: Practitioner's knowledge of Obesity.

Question	Mean	Standard Deviation
Varies directly with BMI	1.87	0.515
Is associated with perioperative pulmo-nary		
complications	1.82	0.446
Is clinically significant	1.72	0.554
Continues into the post operative period	1.62	0.540
Affected by patient positioning	1.52	0.505
Affected by type of procedure	1.57	0.549
Affected by FiO_2	2.02	0.619
Affected by the length of procedure	1.60	0.496

Table 3: Practitioner's Perception of Atelectasis Induced by General Endotracheal Anesthesia (GETA).

Question	Mean	Standard Deviation
Is a term I feel knowledgeable about	2.22	0.659
Is a technique I frequently use	2.35	0.662
Reverses atelectasis	1.97	0.422
Affects perioperative pulmonary complications	2.02	0.530
Is used less than PEEP in my practice	2.12	0.515
Should always be followed by PEEP	2.25	0.493
Is a technique I feel comfortable teaching	2.45	0.749
May cause lung injury	2.40	0.496

Table 4: Practitioner's knowledge of Recruitment Maneuver.

analysis of the 40 surveys used, resulted in a Cronback Coefficient Alpha Standardized score of 0.77.

The first section of the survey (Table 2) assessed the surveyor's knowledge on obesity as it relates to anesthetic care and practice. The average mean for questions 1 through 8 ranged from 1.35-1.67, indicating that most practitioners appear to agree or strongly agree that obesity increases difficulty in providing quality anesthetic care. Most practitioners strongly agreed that obesity affects functional residual capacity and demands special ventilatory considerations, with a mean result of 1.35 and 1.37 respectively. Additionally, most agreed that obesity affects respiratory system resistance and is positively correlated with postoperative pulmonary complications.

The second section of the survey addressed the practitioner's perception of atelectasis induced by general anesthesia in obese patients who undergo surgical procedures (Table 3). Results of the section indicated that most practitioners anticipate a certain degree of continued atelectasis into the postoperative period for obese patients. Surveyors mostly agreed that atelectasis is affected by patient positioning, such as trendelenburg versus reverse trendelenburg, and the type of procedure, such as a laparoscopic versus open procedure. However, less agreement was indicated when questioned if FiO_2 affects atelectasis induced by general anesthesia, as evidenced by a mean of 2.025.

Recruitment maneuvers, (also known as vital capacity maneuvers) were addressed in the third section of the survey (Table 4). The mean values for this section ranged from 1.97 to 2.45, indicating that most practitioners are at best only fairly knowledgeable regarding this technique. Interestingly, a mean of 2.22 was found when surveyors were questioned whether the term recruitment maneuver or vital capacity maneuver was something they felt knowledgeable about. A mean of 2.45 revealed that many practitioners were not comfortable teaching the technique to other individuals. A mean of 2.24 was found when questioned if a RM should always be followed by PEEP.

Recruitment maneuvers were more often performed on obese patients under general anesthesia only when clinically necessary (e.g. following a decrease in oxygen saturation, or when the addition of PEEP only does not increase the oxygen saturation level of the patient). Means of 2.40 and 2.25 revealed that RMs are not routinely used within several minutes of induction, or immediately prior to extubation (Table 5).

Giving intermittent "sigh breaths" via preprogrammed ventilator

Question	Mean	Standard Deviation
Never; It is not part of my practice	2.97	0.800
Routinely, within several minutes following induction	2.40	1.03
When clinically necessary	1.95	0.875
When the addition of PEEP does not increase SPO_2	1.95	0.932
Routinely, immediately prior to extubation	2.25	1.00

Table 5: Practitioner's use of Recruitment Maneuvers.

Question	Mean	Standard Deviation
NA; it is not part of my practice	3.07	0.828
Using large tidal volumes	2.05	0.845
Giving intermittent "sigh breaths" via ventilator		
settings	1.92	0.888
Holding sustained pressure	2.00	0.751
Sequential increases in PEEP	2.25	0.926

Table 6: How practitioners perform Recruitment Maneuvers.

Question	Mean	Standard Deviation
Does NOT prevent reoccurrence of atelectasis		
following a recruitment maneuver	2.65	0.579
Effectively recruits collapsed lung fields	2.20	0.607
Affects lung and chest wall compliance by reversing		
atelectasis	2.22	0.530
Improves oxygenation following extubation	2.10	0.496
Prolongs the effect of recruitment maneuver	1.97	0.357
Is maximally effective at 5 cm H_2O or less	2.67	0.525
Is maximally effective at 6 cm H_2O or greater	2.40	0.545
Results in unfavorable hemodynamics at 5 cm H_2O or		
less	3.00	0.226
Results in unfavorable hemodynamics at 6 cm H_2O or		
greater	2.40	0.496
Prevents atelectasis when used prophylactically	2.20	0.516
Causes lung injury at pressures greater than 5 cm H_2O	2.90	0.441

Table 7: Practitioner's knowledge of PEEP used in Obese Patients during GETA.

settings or manually via the reservoir bag was identified as the most common method for performing a recruitment maneuver on an obese patient, as evidenced by a mean of 1.92. The next most common method was by holding sustained pressure, followed by using larger tidal volumes. The least most common method utilized among the practitioners surveyed was sequential increases in PEEP, as evidenced by a statistical mean of 2.25 (Table 6).

Questions 37-47 assessed the practitioner's knowledge on the use of PEEP in obese patients. A mean of 2.65 indicated that while some believed the addition of PEEP prevents reoccurrence of atelectasis following a recruitment maneuver, a majority did not. Interestingly, a mean of 1.97 revealed that most surveyors believe that the addition of PEEP will prolong the effect of a recruitment maneuver. Results also found that most anesthesia providers agree PEEP is maximally effective at 6 cm H_2O or greater in obese patients, but also can result in more unfavorable hemodynamics at these pressures (Table 7). The results of the survey suggest a need for greater emphasis on improving knowledge regarding recruitment maneuvers among anesthesia providers.

Discussion

This study assessing practitioner use of "best-practice" for atelectasis reversal in obese patients undergoing anesthesia and the current attitudes, knowledge base, and "current" practices of local anesthesia practitioners regarding lung recruitment strategies yields several results relevant to advancing performance measures of anesthesia practitioners. During the perioperative period, respiratory failure is related to the highest mortality and morbidity among patients with atelectasis being the most common complications in this population. The use of perioperative respiratory depressants (medications and inhalation agents), muscle relaxants, mechanical ventilation, postoperative pain, can lead to decreased functional residual capacity and be a cause of atelectasis. Postoperative atelectasis may account for increased length of hospital stay [11], greater utilization of resources [12], and increased propensity for infections [13,14].

A primary goal of perioperative ventilation is to improve or maintain arterial oxygenation. While it is ideally believed that the use of endotracheal intubation ensures the delivery of oxygen to the airway, satisfactory oxygenation is best achieved in patients when there is a greater area to ventilate. In the obese patient, PEEP is used widely to provide respiratory support during the perioperative period. Implications for recruitment maneuvers in practice may be a useful method of augmenting the beneficial effects of perioperative PEEP in the obese patient.

Alveolar recruitment maneuvers have been proposed as valuable during the perioperative period in obese patients [2,6,8,]. Likewise, these results are in agreement with previous findings that the addition of PEEP will prolong the effect of a recruitment maneuver. In contrast, little research has been done to evaluate practitioner competence or knowledge of the physiology of atelectasis, its prevention or the alveolar recruitment maneuver, and how it relates to perioperative outcome. In a recent study, Unzueta et al. demonstrated that, arterial oxygenation and the efficiency of ventilation were improved in addition to decreasing alveolar dead space when recruitment of both lungs was used before instituting one-lung ventilation [5].

This study was developed to assess current anesthesia provider's knowledge regarding obesity and lung recruitment maneuvers. Over 60 current anesthesia providers participated in this voluntary research survey. The data collection from 40 completely answered surveys support the assumption that although most providers are knowledgeable regarding the effects of obesity during general anesthesia, however, the term "recruitment maneuver" may be an unfamiliar and may hold a variant operational definition among anesthesia providers. Our research also highlights the challenges of accounting for practitioner comfort with addressing the area of alveolar recruitment maneuver during the performance of individual patient care experience measures. One third of the returned surveys were not used because of incomplete data. The general trend among the surveys that were not included suggests that the questions addressing recruitment maneuvers content were not relevant to those practitioners and, as a result, their propensity to respond was low. Hence, the average composite scores would likely to be lower. This suggests that it will be important to control for the nature of the relationship between practice area and practitioner when comparing the practice of individuals and practice setting. It would be counterproductive, however, to account (or statistically control) for differences that are consequences of "current" practice. For example, one could conclude that the questions were not answered because of missing knowledge.

It is also interesting that while our findings suggest that the general question regarding obesity and atelectasis shows global trends toward a lower mean (1.35 ± 0.48 to 1.67 ± 0.76 and 1.52 ± 0.51 to 2.02 ± 0.62 respectively); this is in stark contrast to the questions related to recruitment maneuvers and PEEP (1.92 ± 0.89 to 3.07 ± 0.83 and 1.97 ± 0.36 to 3.00 ± 0.23 respectively). Not only did we find these distinctions, we also noted that the standard deviations of these questions were the highest of all questions in the survey. Thus, the respondents are quite unsure whether to agree or disagree with the question. Together with the high standard deviations this indicates that there is no general consensus regarding that topic. Evaluating these questions with respect to the practitioners' experience could provide further insight: assuming that the more experienced practitioners are quite confident, similar answers with low standard deviations should be found. Similarly, the practitioners with less practical experience but having the latest education on recruitment should also show a more distinct trend. The results of the younger respondents could be different to the results of the more experienced practitioners and should be, ideally closer to the "best-practice".

The main limitations of this study were as follows:

- The survey was only distributed to clinical sites affiliated with Michigan State University's Nurse Anesthesia program. This restricts the generalization of the findings to a larger portion of anesthesia providers.

- Of the 200 surveys distributed, 32% were returned, and only 20% were complete and utilized for statistical data analysis; providing another limitation due to the small sample size.

- The lack of understanding regarding the terms recruitment maneuver and vital capacity maneuver. Numerous anesthesia providers requested clarification of the terms from the researchers (the researchers agreed not to provide any additional definitions as this would influence the results and defeat the purpose of the survey).

- The survey was distributed and collected over a period of three months. The three months' time period and lack of supervision during survey completion allowed respondents ample time to research any terms used in the survey. This may have led to some respondents to answer that they were knowledgeable regarding the terms, when in fact they were not.

Finally, our results showed that most surveyors believe that the addition of PEEP will prolong the effect of a recruitment maneuver. The addition of an alveolar recruitment maneuver improves oxygenation in the obese surgical patient. We think that more studies are necessary with a large number of providers, however, we have a final message: practitioners should be well versed in this procedure in order to improve prognosis in these group of patients.

Conclusion

In conclusion, the reviewed literature demonstrated that anesthesia in morbidly obese patients result in the formation of atelectasis and oxygen impairment. Our study supports the literature in that we found that lung recruitment via a recruitment maneuver, immediately followed by positive end expiratory pressure is more effective than either intervention used alone in the treatment of atelectasis incurred by the induction of anesthesia in morbidly obese patients. Practitioners who do provide recruitment maneuvers vary in technique, including the amount of pressure used for the RM, the length of time sustained for the RM, and the pressures utilized for sequentially increased PEEP. Practitioners may benefit from regular competence assessment of the benefits and commonly recognized "best practice" procedures for lung recruitment maneuvers to reverse atelectasis in obese patients.

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