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Research Article

THE EFFECT OF CHANGE IN POSITION AND CARBON DIOXIDE INSUFFLATION ON TRACHED TUBE CUFF PRESSURE DURING LAPAROSCOPIC SURGERIES.

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A B S T R A C T

In general anaesthesia patients are intubated with an endotracheal tube during controlled ventilation. In laproscopic surgeries a pneumoperitoneum is created by insufflating gas into the patients' abdominal cavity. Various factors such as change in position of patient during surgery, cuff volume, use of nitrous oxide, temperature and high altitude affect the endotracheal tube cuff pressure.In our study we have observed the changes in endotracheal tube cuff pressure and airway pressures tube in laparoscopic surgeries in trendelenberg position and their corelation with post operative laryngotracheal morbidity, in an attempt to improve patient recovery in the immediate post operative period.

We observed increased cuff pressures and airway pressures increased at intubation which further increased at abdominal insufflation and head down position peaking at 15 minutes after positional changes. There was no further increase thereafter till the end of the surgery. The incidence of sore throat, hoarseness and stridor 2 hours post operatively is 86%, 66% and 18% which reduces to 22%, 4% and 0% 24 hours post operatively, respectively. Hence post-operative sore throat was the most common laryngotracheal morbidity followed by hoarseness of voice. In conclusion, monitoring and adjustment of endotracheal tube cuff pressures within the recommended safe limits (25-40 cm H20) intra-operatively will help reduce post-operative laryngotracheal moribidity and increase patient comfort and recovery in the immediate post operative period.

INTRODUCTION

In patients undergoing general anaesthesia the purpose of intubation with an endotracheal tube is essentially for the maintenance of a patent airway. The cuff of an endotracheal tube is used to prevent gas leak and pulmonary aspiration by creating a seal in intubated patients during controlled ventilation.

The endotracheal tube cuff pressure changes with a change in position of patient during surgery (Godoy AC et al., 2008; Yildirim Z et al., 2011), head position (Brimacombe J et al., 1999), cuff position (Bernhard W et al., 1985), cuff volume (Sengupta P et al., 2004) , use of nitrous oxide (Mitchell V et al., 1999), temperature (Saleh Moghaddam AR et al., 2013) and high altitude (Mann C et al., 2007) .

Lateral wall pressure is thought to be the most important factor contributing to the morbidity of intubation. High Volume Low Pressure (HPLV) cuffs may have ideal characteristics and can produce clinical seal with low lateral wall pressures. Nevertheless, these cuffs may easily be overinflated, generating excessive lateral wall pressures (Black A et al., 1981; Lewis F et al., 1979).

Thus, despite the use of High Volume Low Pressure cuffs, patients remain at risk for cuff-induced laryngo-tracheal morbidity, even with short-duration anaesthesia. The main symptom reported after tracheal intubation is sore throat, but patients also report hoarseness, dysphagia and blood streaked sputum.

Although the exact pathophysiology of post-intubation airway symptoms is not fully known, mucosal damage occurring at the cuff level is thought to be an important causative factor for tracheal morbidity.

Tracheal arterial capillary pressure decreases when the cuff exerts pressure greater than 40 cm H_2O, causing tracheal ischemia proportional to the pressure exerted by the cuff and the duration of exposure (Seegobin RD et al., 1984).

While there is no single number, the consensus regarding an acceptable maximum endotracheal tube intra-cuff pressure ranges from 25 to 40 cm of H_20 (Seegobin RD et al., 1984; Stewart SL et al., 2003; Stoelting RK et al., 2000; O'Donnell JH, 1995; Morgan GE, 1966). The length of time needed for an elevated cuff pressure to cause these complications is unclear,

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but mucosal damage has been demonstrated after only 15 minutes in an animal model (Nordin U, 1976).

At the same time, subinflation of the cuff puts patients at risk for microaspiration of subglottic secretions. This microaspiration is considered the major pathogenic mechanism for ventilator-associated pneumonia (Lizy C et al., 2014).

Table No. 1 Ideal, high and low intra-cuff pressures of endotracheal tube (Stewart SL et al., 2003).

Intra cuff pressure	cm of H_2O	mm of Hg
Ideal	25-40	18-30
High	>40	>30
Low	<25	<18

Although palpation of the endotracheal tube pilot balloon is a common practice, several studies have demonstrated the inability to accurately determine endotracheal tube cuff pressure by palpation alone (Ganner C, 2001). So, measuring pressure in the endotracheal tube cuff with a small aneroid cuff pressure manometer has been advocated (Stewart SL et al., 2003).

In our study we used an aneroid manometer - Portex Cuff Pressure Indicator (CE0473, for low pressure cuffs, Germany) to measure endotracheal tube intracuff pressure.

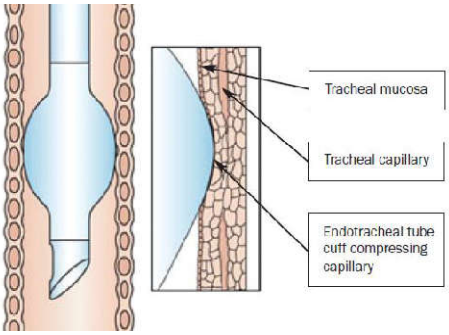

Figure No. 1 Diagram showing lateral pressure over the tracheal wall due to inflated cuff. (Sultan P et al., 2011)

Laparoscopic surgery has become very popular over past few decades and has been shown to decrease postoperative pain, shorten hospital stay and have an earlier return to normal activities which results in overall reduction in medical costs (Gerges F et al., 2006). Laparoscopic surgery is performed under general anesthesia with mechanical ventilation, and a high volume low pressure endotracheal tube with a sealing cuff pressure about 20 to 30 cmH_2O is commonly used for a proper seal and avoidance of over-inflation (Wu C et al., 2014). Carbon dioxide pneumoperitoneum is the most common method used to obtain abdominal distension for laparoscopic surgery (Casati A et al., 1997).

This study concentrates on the question whether we should be concerned about intra-cuff pressure of endotracheal tube, especially in laparoscopic surgeries in trendelenberg position which involve creation of pneumoperitoneum in an attempt to avoid post-operative laryngo-tracheal morbidity like sore throat, hoarseness of voice and dysphagia.

MATERIALS AND METHODOLOGY

Sample Size: **50**
Sample Size Justification

Based on the literature "Changes in endotracheal tube cuff pressures during laparoscopic surgery in head up or head down position" (Wu C et al., 2014)), it was found that changes in mean endotracheal tube cuff pressure during laparoscopic surgery in head down position from baseline (mean ± SD) 33 ± 5 to 35 ± 5 cm H_2O and after abdominal insufflation the mean cuff pressures increased from the baseline values of 27 ± 3 to 33 ± 5. Expecting mean difference from baseline will be 2 with standard deviation 5, during cuff pressure laparoscopic surgery in head down position, with 80% power and 5% level of significance, we will be required to take 50 patients.

Sample Size Calculation

Sample size was calculated using the formula:

$$n = \frac{[Z(\alpha/2)+Z\beta]^2 * \sigma^2}{d^2} = \frac{[1.96 + 0.84]^2 * 25}{4} = \sim 50$$

Where,
z =abscissa of normal curve = 1.96 for α = 5% (type 1 error)
β (type II error) = 80% = 0.84
σ^2 (standard deviation) = 5*5 = 25
d^2 (standardised difference) =2*2 = 4

Study Design

It is a prospective observational open study which was conducted between August 2016 and December 2016 in in Department of Anaesthesiology, Kokilaben Dhirubhai Ambani Hospital, Mumbai, after obtaining ISEB and Ethical Committee clearance.

Inclusion criteria is as follows

- ASA (American Society of Anesthesiologist) classification I–II
- Patients undergoing elective and emergency laparoscopic hysterectomy under general anesthesia receiving 30^o head low with carbon dioxide abdominal insufflation.
- Patients of age 30 to 75 years were included in the study.

Exclusion Criteria is as follows

- ASA III and above patients
- Difficult intubation
- Patients requiring pressure controlled ventilation and/or positive end expiratory pressure to maintain normocapnia
- Patients with respiratory diseases which are likely to affect lung compliance and/or airway resistance.
- Core temperature less than 35 degrees Celcius or greater than 37.5 degrees Celsius (Saleh Moghaddam AR et al., 2013).
- Patients with BMI >35 (morbid obesity)

Instruments Used

The **Portex Cuff Pressure Indicator** (CE0473, for low pressure cuffs, Germany) was used to obtain intra-cuff pressure readings from the endotracheal tube cuff pilot balloon.

Portex endotracheal tube with high volume and low pressure cuff no. 7 (with internal diameter of 7 mm) for females was used for intubation.

10 ml Luer lock BD syringe was used for inflating the cuff through pilot balloon with air.

A standard protocol was followed for all the patients. Each patient was visited a day prior to surgery in the wards. A detailed history and examination was taken. The procedure to be done was explained to the patient and a written informed consent was obtained for the general anaesthesia to be given. Blood investigations were carried out as per the requirement of the surgery.

Anaesthesia Technique

After arrival in the operating room, patients were placed in the supine position. After securing an intravenous line, standard anaesthesia monitors were attached and baseline hemodynamic parameters like heart rate, systolic blood pressure, diastolic blood pressure, and oxygen saturation were taken.

- All patients were premedicated with intravenous glycopyrolate, midazolam and fentanyl and received general anaesthesia with propofol and atracurium after preoxygenation with 100% oxygen for 3 minutes.
- After direct larygoscopy, intubation was done with a Portex endotracheal tube was used (high volume, low pressure) size 7.0mm for all patients. Lignocaine jelly or spray was not used. The endotracheal tube cuff was inflated with 6-8 ml of air to achieve a minimum cuff pressure between 20 – 30 cm H_20 using an aneroid manometer such that the cuff provided an adequate air seal.
- Mechanical ventilation was carried out in each patient with tidal volume of 8-10ml/kg at a respiratory rate between 8 to 14 per minute to maintain normocapnia without the use of positive end expiratory pressure. If the airway pressures increased beyond 35 cm H_2O which required a change to pressure control ventilation to ensure adequate ventilation of the patient, then such a patient was excluded from the study.
- For maintenance of anesthesia 1:1 mixture of air and oxygen was used. Nitrous oxide was not used. General anaesthesia was maintained with a constant MAC of sevoflurane.
- After the patient was painted and draped for surgery, the surgical ports were inserted. The patient's abdomen was insufflated with carbon dioxide (at 25 minutes post intubation) in the supine position to maintain intra-abdominal pressure between 10 to 15 mmHg.
- 30° Head-down position was given to the patient for laparoscopic hysterectomy (measured using a protractor by an observer who did not participate in this study)
- The endotracheal tube cuff pressure and airway pressures were measured and recorded at 5 minutes intervals from the time of intubation till 60 minutes post-intubation during the end expiratory phase with patient's head and neck in the neutral position and the occiput on a same type of pillow.
- The patient was followed up at 2,12 and 24 hours after the surgery and complaints of either soreness of throat, stridor, hoarseness in voice or blood streaked expectoration were noted.

Table No 2 Comparison of Cuff Pressures [Pre- Abdominal Insufflation (At Intubation) and Post- Abdominal Insufflation, Post - Positioning, 20 Minutes Post Positioning, 30 Minutes Post Positioning] (Normality Test (Shapiro-Wilk) Failed (P < 0.05), Thus Wilcoxon Signed Ranks Test Applied.)

Cuff pressure (mm Hg)	N	Mean	Std. Deviation	Median	IQR	Wilcoxon Signed Ranks Test	P Value
At intubation (0 minutes)	50	25.06	2.68	24.00	4.00	-6.239	0.000
At abdominal insufflation (25 minutes)	50	30.22	3.46	30.00	6.00	Difference is significant	
At positioning (30 minutes)	50	35.16	3.62	34.00	6.00	Difference is significant	
20 minutes post positioning (50 minutes)	50	37.98	3.33	38.00	4.00	Difference is significant	
30 minutes post positioning (60 minutes)	50	37.90	3.31	38.00	4.00	Difference is significant	

Table No 3 Comparison of Airway Pressures [Pre- Abdominal Insufflation (At Intubation) and Post-Abdominal Insufflation, Post-Positioning, 20 Minutes Post Positioning, 30 Minutes Post Positioning] (Normality Test (Shapiro-Wilk) Failed (P < 0.05), Thus Wilcoxon Signed Ranks Test Applied.)

Airway Pressure (cm H_2O)	N	Mean	Std. Deviation	Median	IQR	Wilcoxon Signed Ranks Test	P Value
At intubation (0 minutes)	50	15.66	2.02	15.00	3.00	-6.202	0.000
At abdominal insufflation (25 minutes)	50	20.16	2.87	19.00	4.25	Difference is significant	
At positioning (30 minutes)	50	23.98	2.95	23.00	3.25	Difference is significant	
20 minutes post positioning (50 minutes)	50	26.26	2.65	26.00	3.00	Difference is significant	
30 minutes post positioning (60 minutes)	50	26.24	2.56	26.00	3.00	Difference is significant	

Table no 4 Incidence of post-operative complains at 2 hours, 12 hours, 24 hours

Post - operative complains	**Incidence in our study (%)**		
	2 hours	**12 hours**	**24 hours**
Sore throat	86.00%	86.00%	86.00%
Hoarseness	66.00%	66.00%	66.00%
Stridor	18.00%	18.00%	18.00%
Blood Streaked sputum	0.00%	0.00%	0.00%

RESULTS

- ***Cuff pressure*** - It increased from 25.06 ± 2.68 mm Hg to 30.22 ± 3.46 mm Hg at abdominal insufflation, which further increased to 35.16 ± 3.62 mm Hg at head low

positioning of the patient. The cuff pressure peaked (37.98 ± 3.33 mm Hg) at 15 minutes post positioning (45 minutes post intubation). The pressures remained at that level (37.90 ± 3.31 mm Hg) 60 minutes post intubation. The difference is significant ($p<0.001$) (Table No. 2)

- ***Airway pressure*** - It changed from 15.66 ± 2.02 cm H_2O to 20.16 ± 2.87 cm H_2O at abdominal insufflation (25 minutes post intubation), which further increased to 23.98 ± 2.95 cm H_2O at head low positioning of the patient. The airway pressure peaked (26.26 ± 2.65 cm H_2O) at 15 minutes post positioning (45 minutes post intubation). The pressures remained at that level (26.24 ± 2.56 cm H_2O) 60 minutes post intubation. The difference is significant ($p<0.001$) (Table No. 3)

- ***Post - operative complications***

1. ***Sore throat*** - The incidence post-operatively at 2 hours was 43/50 (86%) which reduced to 34/50 (68%) at 12 hours post-operatively and further, 11/50 (22%) at 24 hours post-operatively. (Table No. 4)
2. ***Hoarseness*** - The incidence post-operatively at 2 hours was 33/50 (66%) which reduced to 16/50 (32%) at 12 hours post-operatively and further, 2/50 (4%) at 24 hours post-operatively.(Table No. 4)
3. ***Blood streaked sputum*** - The incidence post-operatively at 2 hours was 0/50 (0%) which remained the same at 12 and 24 hours post-operatively. (Table No. 4)
4. ***Stridor*** - The incidence post-operatively at 2 hours was 9/50 (18%) which reduced to 0/50 (0%) at 12 and 24 hours post-operatively. (Table No. 4) Hence, we can conclude that in the given 50 patients, sore throat and hoarseness are common post-operatively.
    - Incidence of post operative larygotracheal morbidity can be correlated with increased intraoperative endotracheal tube cuff pressures.
    - Since we considered all patients with a body mass index (BMI) less than or equal to 35 kg/m^2 in our study, the results achieved in this study is applicable to obese as well as non obese patients.(normal range – 18.50-24.99; pre-obese 25.00-29.99; obese – 30.00-35) (Park K, 2009)

DISCUSSION

Our study was designed to concentrate on the question whether we should be concerned about monitoring the intra-cuff pressure of endotracheal tube, especially in laparoscopic surgeries in trendelenberg position which involve creation of pneumoperitoneum to avoid post-operative laryngo-tracheal morbidity like sore throat, hoarseness of voice and dysphagia.
The major finding of our study is that the endotracheal tube cuff pressure and airway pressure increases with abdominal insufflation and head-down position during laparoscopic hysterectomy.

Various studies have concluded that pneumoperitoneum, change in position of the patient and use of air to inflate the cuff during nitrous oxide anaesthesia are factors causing increase in endotracheal tube intra-cuff pressure(Godoy AC et al., 2008; Yildirim Z et al., 2011; Lizy C et al., 2014; Wu C et al., 2014).

Hence, increase in endotracheal tube cuff pressures has been attributed to the following factors:

Patient position

Changes in body position (Godoy AC et al., 2008) and head position (Lizy C et al., 2014; Brimacombe J et al., 1999) can cause significant cuff pressure variations in patients under mechanical ventilation.

In our study, all patients were positioned in a tredelenberg position (head low) of 30 degrees with head in neutral position. The cuff pressures and airway pressures increased at positioning with a continued increase which peaked at 15 minutes after positioning with no further increase thereafter.

Over inflation of cuff (Volume of cuff)

There is a linear relationship between the measured cuff pressure and the volume of air retrieved from the cuff. The regression equation indicated that injected volumes between 2 and 4 ml usually produce cuff pressures between 20 and 30 cmH2O independent of tube size for the same type of tube. However, there was considerable patient-to-patient variability in the required air volume. Measuring actual cuff pressure thus appears preferable to injecting a given volume of air (Sengupta P et al., 2004; Hoffman RJ et al., 2006). In our study, at intubation, the endotracheal tube cuff pressure was inflated with 6-8ml of air to achieve a cuff pressure between 20 – 30 cm of H_2O (measured using an aneroid manometer).

Type of cuff

Since different types of cuffs of the endotracheal tube have varying effects on the tracheal mucosa, a uniform PVC endotracheal tube with 'Low pressure, high volume' cuff is used for all patients included in our study.

Nitrous oxide anaesthesia

Nitrous oxide, when used as a inhalation agent, diffuses easily into the endotracheal tube cuffs, increasing the cuff pressure (Dullenkopf A et al., 2004). The increase in cuff pressure varies directly with the partial pressure of nitrous oxide, the permeability of the cuff wall and time (Dorsch J et al., 2008)

Beydon et al evaluated the risk of over inflation of endotracheal tube cuffs when used with nitrous oxide and observed that the pressure in the cuff rose sharply upto more than 40 cm H_2O (Beydon L et al., 2011).

Due to these facts, we did not use nitrous oxide. We used a fixed concentration of air and oxygen in the ratio of 50:50 for all patients included in the study

Creation of pneumoperitoneum

Wu C *et al* observed that after insufflation, the cuff pressure increased from 27 ± 3 to 33 ± 5 cmH_2O in patients undergoing laparoscopic colorectal tumor resection ($p < 0.001$). The head-down tilt further increased cuff pressure from 33 ± 5 to 35 ± 5 cmH_2O ($p < 0.001$). (Wu C et al., 2014)

Yildirim *et al* showed that the cuff pressure of endotracheal tube progressively increased during pneumoperitoneum in group I (patients who underwent laparoscopic cholecystectomy), as the pressure increased from 29 to 35 cm H_2O (Yildirim Z et al., 2011).

However, they did not analyze the effect of change in position of patient and correlations of cuff pressure to body mass index, whereas, in our study, we considered the change in cuff pressure in head low position. We also considered all patients

with a body mass index (BMI) less than equal to 35 kg/m^2, and observed that an excessive cuff pressure during laparoscopic surgery was found not only in obese but also non-obese patients.

Our results were comparable to both the above mentioned studies, since there is significant increase ($p<0.001$) in cuff pressures from 25.06 ± 2.68 cm H_2O at intubation to 30.22 ± 3.46 cm of H_2O after abdominal insufflation.

We also observed that there was an increase in airway pressures, from 15.66 ± 2.02 cm H_2O at intubation to 20.16 ± 2.87 cm H_2O at abdominal insufflation. This difference is significant ($p<0.001$). It is known that the insufflation of carbon dioxide into the abdomen during pneumoperitoneum affects the intrathoracic pressure by approaching the diaphragm upward. The increase in airway pressure is a reflection of increased intrathoracic pressures.

Laryngo-tracheal morbidity

Various factors affect laryngotracheal morbidity, such as follows:

1. ***Sex*: P**ostoperative sore throat is significantly higher in females than in males. Hence, in our study, the study population consists of only female patients (Biro P et al., 2005).
2. ***Endotracheal tube size*:** The incidence of laryngo-tracheal morbidity was much lower when endotracheal tube size 7.5 for males & 6.5 for females was used; instead of 9 and 7.5 respectively. Hence, in our study, all patients were female patients and were intubated using a endotracheal tube size 7 (Stout D et al., 1987).
3. ***Intra cuff pressure*:** Lower incidence of sore throat was noticed in patients with cuff pressures maintained < 20 CmH_20 (Suzuki N et al., 1999; Mandoe H et al., 1992). In our study, post-operative laryngotracheal morbidity can be correlated with higher intracuff pressures.
4. ***Duration*:** Increased duration of tracheal intubation and duration of surgery is associated with increased incidence of symptoms (Liu J et al., 2010; Kloub R, 2001). Hence, by limiting our study to one particular type of surgery (laparoscopic hysterectomies), we have standardized the duration of surgery.
5. ***Lidocaine spray and lidocaine jelly*:** Post-operative sore throat and hoarseness is more common after use of lidocaine spray and lidnocaine jelly on the mucous membranes of the mouth (Kori K et al., 2009). Hence, in our study, we have not used lidnocaine jelly or spray during intubation.

Wu C *et al* reported that postoperative sore throat is at its peak in the early postoperative period, 2 to 6 hours after extubation, but the incidence decreases rapidly with time (Wu C et al., 2014). In our study also it was seen that complaints of postoperative sore throat and postoperative hoarseness was maximum at 2 hours post operatively which decreased considerably at 24 hours after surgery.

The limitations of the study of Wu C (Wu C et al., 2014) was that their study design was not able to correlate cuff pressure and specific clinical outcome such as postoperative sore throat, that was associated with multiple factors, such as numbers of attempt to intubate, use or no use of a intubating stylet, operating time and type of lubrication of endotracheal tube cuff. Each factor should be considered and analyzed to clarify the correlation between the specific factor - cuff pressure and postoperative sore throat.

In our study we avoided other external factors known to affect laryngotracheal morbidity by using the same size of endotracheal tube, by observing all patients for a set duration of time, avoiding lignocaine jelly and spray, avoiding repeated attempts at intubation and gas diffusion by nitrous oxide.

CONCLUSION

Thus, from our study, we found endotracheal tube cuff pressure rises intraoperatively in laparoscopic surgeries which involve creation of pneumoperitoneum, which further rises after head low positioning. It leads to increased incidence of postoperative laryngo-tracheal morbidity.

Therefore, objective assessment and adjustment of endotracheal tube intra-cuff pressure with an aneroid manometer should be made mandatory and should be routinely done in laparoscopic surgeries in Trendelenberg position to decrease the incidence of postoperative laryngo-tracheal morbidity associated with inadvertent increase in endotracheal tube cuff pressure.

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