Iranian Journal of NEUROSURGERY

2024, Volume 10, E21

Research Paper

Tracheal Tube Cuff Pressure Measurement Methods in Lumbar Disc Surgery

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Citation Sanie Jahromi MS, Zarei M, Taheri L, Deylami M, Kalani N. Tracheal Tube Cuff Pressure Measurement Methods in Lumbar Disc Surgery. Iran J Neurosurg. 2024; 10:E21. http://dx.doi.org/10.32598/irjns.10.21

doi: http://dx.doi.org/10.32598/irjns.10.21

Article info:
Received: 03 Feb 2024
Accepted: 30 Jun 2024
Available Online: 27 Sep 2024

Keywords:
Intratracheal intubation, Manometry, Lumbar vertebrae, Surgical procedure

ABSTRACT

Background and Aim: Accurate tracheal tube cuff pressure measurement is crucial to prevent complications in patients undergoing mechanical ventilation. However, manual inflation methods, which are still commonly used in clinical practice, may lead to inaccurate cuff pressure measurements, compromising patient safety. Therefore, this study aims to compare the accuracy of manual and manometric methods for tracheal tube cuff pressure measurement in patients undergoing lumbar disc surgery in the prone position and to assess the safety implications of manual inflation methods.

Methods and Materials/Patients: This prospective analytical descriptive study was conducted on 60 patients undergoing lumbar disc surgery in the prone position. Tracheal tube cuff pressure was initially recorded in the supine position using both the manual method and the manometric method. Following the prone positioning of the patient, the cuff pressure was immediately recorded and adjusted by manometry. Subsequent recordings were made every 15 minutes until the conclusion of the surgery, using only the manometric method. Data were analyzed using descriptive statistics, including mean and percentage, as well as relevant statistical tests, such as repeated measurement and analysis of variance (ANOVA) using SPSS software, version 16.

Results: Significant differences were observed in tracheal tube cuff pressure measurements between the two instrumental (manometer) and manual methods in patients in the prone position ($P<0.001$). Tracheal tube cuff pressure, measured by both instrumental (manometer) and manual methods, exhibited significant differences at various time points (zero, 15 minutes, 30 minutes, 60 minutes, and 90 minutes) concerning body mass index in prone position patients ($P<0.05$). Additionally, a significant difference was observed in tracheal tube cuff pressure based on the duration of surgery ($P<0.05$), with the highest cuff pressure reported in patients with a surgical duration of 2 hours or more in the prone position.

Conclusion: The study results showed that tracheal tube cuff pressure measured by the instrumental method (manometer) was consistently lower than that measured by the manual method in patients placed in the prone position. Therefore, the manual approach may cause safety issues for patients.

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Highlights

- Manual method is inaccurate for cuff pressure measurement.
- Manometer method ensures safer cuff pressure readings.
- Prone position might affect tracheal tube cuff pressure.

Plain Language Summary

When patients are on a ventilator, it's crucial to ensure the air tube in their throat is properly inflated to prevent complications. However, the common method of manually checking the tube's pressure can be inaccurate, putting patients at risk. This study aimed to compare the accuracy of manual and electronic methods for measuring the pressure of the air tube in patients undergoing back surgery. The researchers studied 60 patients who were having back surgery while lying on their stomachs. They used both manual and electronic methods to measure the pressure of the air tube before and during the surgery. The results showed that the manual method consistently gave higher pressure readings than the electronic method. This means that patients may be at risk of complications due to overinflation of the air tube when the manual method is used. The study also found that the pressure of the cuff changed over time during the surgery, and that patients with longer surgeries or higher body mass indexes were at greater risk of complications. This is important because it highlights the need for accurate and regular monitoring of air tube pressure during surgery. The findings of this study matter because they have significant implications for patient safety. Inaccurate measurement of air tube pressure can lead to serious complications, such as damage to the throat or lungs. This study's results can inform healthcare policies and practices, ultimately leading to better outcomes for patients undergoing mechanical ventilation.

1. Introduction

Tracheal tubes are designed to establish a secure airway in adult patients, featuring a distal cuff that, when inflated, acts as a barrier to the tracheal wall. This inflation prevents pulmonary aspiration, ensuring the delivery of the intended flow volume to the lungs. The tracheal tube size is determined by its inner diameter, measured in millimeters; however, the relationship with the outer diameter varies across different production designs. The inflation of the tracheal tube cuff forms a barrier between the tube and the tracheal wall, eliminating air leakage during positive pressure ventilation and safeguarding the lungs against aspiration. Earlier tracheal tube cuffs, characterized by high pressure, exerted considerable force on tracheal mucus, leading to ischemia. Contemporary endotracheal tubes incorporate low-pressure cuffs to minimize pressure on the trachea, consequently reducing the risk of ischemia [1]. Maintaining cuff pressure within the range of 20-30 cm of water is crucial to minimize air leakage, preserve flow volume, and prevent damage to the tracheal mucosa [2]. Studies indicate that at a cuff pressure of 25 cm of water, tracheal blood flow remains normal, while pressures of 40 cm and 50 cm result in pale and white tracheal mucosa, respectively. A cuff pressure of 60 cm halts tracheal blood flow [3]. A linear relationship is observed between cuff volume and pressure, and insufficient cuff expansion (below 18 cm of water) can lead to pulmonary aspiration of upper airway secretions. To mitigate complications, it is imperative to periodically record the pressure inside the tracheal tube cuff and determine the optimal pressure with the appropriate volume [4-6]. Various methods, such as manual techniques (finger palpation and minimal leak) and automated approaches (direct manometry and continuous monitoring), are employed to assess tracheal tube cuff pressure. Common methods to assess cuff pressure accuracy include the manual minimal leak method and direct manometry [2]. Improper cuff pressure is considered a significant factor contributing to tracheal injury among various factors [8]. Some studies suggest that changing from a supine to a prone position affects cuff pressure, but the impact of lateral decubitus and prone positions on tracheal cuff pressure during surgery remains unexplored. Alterations in tracheal tube position or movement may influence cuff pressure due to the non-circular nature of the trachea along its length [7-11]. Hence, this study was conducted to investigate and compare tracheal tube cuff pressure using two instrumental methods (manometer) and manual methods in patients positioned prone during surgery.

Table 1. Demographic and anthropometric characteristics of patients with prone position

Characteristics		No. (%)
Age (y)	<30	16(26.7)
	40-30	13(21.7)
	50-41	8(13.3)
	60-51	11(18.3)
	≥60	12(20)
	Mean±SD	43.18±15.73
Sex	Male	26(43.3)
	Female	34(56.7)
Body mass index (BMI)	Normal	4(6.7)
	Overweight	36(60)
	Obese	20(33.3)
Surgery duration (h)	≤1.5	21(35)
	1.5-2	30(50)
	≥2	9(15)

SD: Standard deviation.

2. Methods and Materials/Patients

This prospective analytical study included 60 patients who underwent lumbar disc surgery in the prone position. The sample included all eligible patients referred to Peymaniyeh Hospital in Jahrom City, Iran, who underwent lumbar disc surgery in a prone position in 2022. The inclusion criteria included individuals aged 18 and above, undergoing general anesthesia in the prone position. The exclusion criteria included refusal to participate, head and neck injuries preventing bending, and inability to obtain consent. Induction of anesthesia involved midazolam (0.03-0.06 mg/kg), fentanyl (2-4 mg/kg), thiopental (5 mg/kg), and atracurium (0.06 mg/kg), with a subsequent administration of 0.1 mg/kg morphine. Intubation was conducted using a single attempt with an appropriately sized tracheal tube. Initially, in the supine position, cuff pressure inside the high-volume, low-pressure tracheal tube was recorded manually and then using a manometric method. Data, including demographic information and cuff pressure changes measured via manometry and manual methods, were collected using a researcher-made checklist. After positioning the patient in the prone position, the cuff pressure was immediately recorded and adjusted using manometry. Subsequent recordings were made every 15 minutes until the surgery's completion, utilizing only the manometric method. A German-made manometer (Mallinckrodt) was employed, connected to the tracheal tube cuff, and used to inflate the cuff. The pressure gauge displayed the pressure within the cuff, with the normal range being 20 to 30 cm of water. The tracheal tubes, low-pressure and high-volume, were manufactured by Iran's Supa factory and underwent pre-insertion testing for cuff leakage. Tracheal tube No. 8 was used for male patients, and 7.5 mm in internal diameter for female patients. An anesthetist proficient with the manometer conducted cuff pressure measurements. Data analysis utilized descriptive statistics (mean and percentage) and relevant statistical tests (repeated measurement and analysis of variance (ANOVA) through SPSS software, version 16.

3. Results

The present study encompassed a cohort of 60 patients ranging in age from 21 to 70 years undergoing lumbar disc surgery in the prone position. The mean age of the patients was 43.18±15.73 years, with nearly

Table 2. Comparison of two methods of tracheal tube cuff pressure measurement using two instrumental (manometer) and manual methods in patients with prone position

Time	Mean±SD	t	P
Manual	43.32±7.03		
Manometer 0	39.17±7.39		
Manometer 15 minutes	37.5±10.16		
Manometer 30 minutes	37.25±7.33		
Manometer 45 minutes	36.±6.97	84.62	0.001
Manometer 60 minutes	35.44±7.08		
Manometer 75 minutes	34.4±7.15		
Manometer 90 minutes	34.34±7.16		
Manometer 105 minutes	36.82±9.02		

half of them falling below the age of thirty years old (48.4%). Most participants were women, constituting 56.7%, while the remaining were men. Regarding body mass index, 60% of the patients were classified in the overweight range. The duration of surgery for half of the patients fell within the range of 1.5 to 2 hours (Table 1).

The tracheal tube cuff pressure at various time points did not adhere to a normal distribution (P<0.05). Consequently, Friedman's test was employed to compare the two methods of tracheal tube cuff pressure measurement, utilizing instrumental (manometer) and manual methods in patients positioned prone. Pairwise comparisons were conducted using the Wilcoxon test with Bonferroni correction. The results of Friedman's test revealed a significant difference between the two methods of measuring tracheal tube cuff pressure, employing both instrumental (manometer) and manual methods in patients in the prone position (P<0.001). Specifically, the pressure of the tracheal tube cuff measured instrumentally (manometer) was consistently lower than the manual prone position, exhibiting a decrease from 0 to 105 minutes post-operation. Further comparisons using the Wilcoxon test with Bonferroni correction demonstrated that tracheal tube cuff pressure in the manual method was significantly higher than the tracheal tube cuff pressure at 30 minutes (t=2.258, P=0.005), 45 minutes (t=3.091, P=0.001), 60 minutes (t=3.409, P=0.001), 75 minutes (t=4.621, P=0.001), 90 minutes (t=0.045, P=0.001), and 105 minutes (t=4.57, P=0.001) when measured using the manometer (Table 2).

The results of the Kruskal-Wallis test showed no significant difference between the two methods of measuring tracheal tube cuff pressure using two instrumental and manual methods in patients with Peron positions at different ages (P>0.05) (Table 3).

The results of the Kruskal-Wallis test showed a significant difference in tracheal tube cuff pressure by two instrumental methods (manometer) (at zero, 15 minutes, 30 minutes, 60 minutes, 90 minutes) and manual methods in patients with prone position according to body mass index (P<0.05). In manual and manometer methods at zero, 15 minutes, 30 minutes, 60 minutes, and 90 minutes, the highest tracheal tube cuff pressure was higher in obese patients than in other patients (Table 4).

The results of the Kruskal-Wallis test showed a significant difference in the tracheal tube cuff pressure in the traditional prone position method according to the length of surgery (P<0.05). In the manual method, the highest tracheal tube cuff pressure was in patients with a duration of surgery of 2 hours or more (Table 5).

4. Discussion

Tracheal tube cuff pressure management plays a pivotal role in airway management post endotracheal intubation, particularly in critically ill patients undergoing mechanical ventilation. Inadequate cuff pressure may lead to pulmonary aspiration, while excessive pressure can compromise tracheal capillary perfusion [12-15]. This study was conducted to compare two methods of

Table 3. Comparison of two methods of tracheal tube cuff pressure measurement using two instrumental and manual methods in patients with peron position based on age

Measured Pressure by Each Method	Mean±SD					P
	Age (y)					
	<30	30-40	41-50	51-60	60	
Manual	44.63±7.61	43±8.71	43.5±4.87	43±5.74	42.08±7.33	0.965
M0	41.5±8.69	37.54±9.2	40.38±5.18	37.45±4.82	38.58±6.64	0.507
M15 minutes	40.19±8.78	36±9.81	40.63±5.63	34.55±11.7	36.17±12.95	0.608
M30 minutes	38.81±7.43	34.92±8.64	39.5±7.03	35.36±4.34	37.92±8.08	0.445
M 45 minutes	37.25±7.93	35.38±8.12	38±5.98	33.45±4.34	36±7.14	0.536
M60 minutes	36.5±8.37	34.58±7.65	37.63±6.74	33.09±4.18	35.58±7.35	0.606
M75 minutes	35.88±9.04	34.25±6.44	36.63±8.18	31.8±4.59	33.25±6.18	0.660
M90 minutes	35.92±9.04	33.91±7.08	36±8.07	31.25±3.69	33.9±6.19	0.737
M105 minutes	37.7±9.97	35±7.07	41.33±11.6	31.71±2.36	38.6±10.71	0.595

M: Manometer.

tracheal tube cuff pressure measurement, using instrumental (manometer) and manual methods, on 60 patients aged 21 to 70 years in the prone position. A comparison of the two instrumental and manual methods in patients in the prone position revealed a significant difference in measuring tracheal tube cuff pressure. The instrumental method (manometer) demonstrated lower cuff pressure than the manual method in prone position patients, decreasing from 0 to 105 minutes post-operation. Various techniques, including manual

Table 4. Comparison of two methods of tracheal tube cuff pressure measurement using two instrumental and manual methods in patients with prone based on BMI

Measured Pressure by Each Method	Mean±SD			P
	BMI			
	Normal	Over Weight	Obese	
Manual	40±4.08	41.72±6.86	46.85±6.62	0.02
M0	35±4.08	37.61±6.17	42.80±8.65	0.037
M15 minutes	35±4.08	36.03±8.77	40.65±12.67	0.048
M30 minutes	32.75±5.25	36±6.69	40.40±7.9	0.043
M45 minutes	30.75±4.35	34.89±5.78	39.05±8.27	0.065
M60 minutes	30±4.08	33.94±5.95	39.42±7.88	0.012
M75 minutes	29.5±4.2	32.69±5.41	38.89±8.67	0.011
M90 minutes	29.33±1.15	32.74±5.25	38.38±9.2	0.033
M105 minutes	37.67±15.04	38.27±9.41	35.20±7.74	0.411

M: Manometer; BMI: Body mass index.

Table 5. Comparison of two methods of tracheal tube cuff pressure measurement using two instrumental and manual methods in patients with prone position based on the duration of surgery

Measured Pressure by Each Method	Mean±SD			P
	Surgery Duration			
	≤1.5 h	1.5-2 h	≥2 h	
Manual	43.52±6.75	41.23±6.36	49.78±6.34	0.009
M0	38.95±7.61	37.93±6.2	43.78±9.43	0.254
M15 minutes	37.14±11.37	35.97±9	43.44±9.77	0.202
M30 minutes	37.29±7.87	36.07±6.56	41.11±7.94	0.3
M45 minutes	35.24±7.71	35.27±5.72	40.22±8.20	0.234
M60 minutes	35.25±7.37	34.1±6.12	40.33±8.08	0.106
M75 minutes	34.21±6.72	33±6.32	39.44±9.06	0.077
M90 minutes	35.82±6.16	32.57±6.41	38.44±9.15	0.07
M105 minutes	34.91±5.8	37.69±12.01	37.89±7.72	0.315

M: Manometer.

and manual methods (minimal leak and finger palpation) and automatic methods (direct manometry and continuous monitoring), are used to check tracheal cuff pressure [2]. Studies exploring different methods of tracheal tube cuff pressure measurement have reported varying results. Sanaie et al. compared tracheal tube cuff pressure using constant volume techniques and the minimal leakage test method, both resulting in excessive intra-cuff pressure. However, the minimum leakage test method produced more acceptable pressure than constant volume techniques [16]. In the present study, cuff pressure measured by the manual method tended to be higher than manometer pressure, although both methods often recorded pressures higher than the normal range. White et al. compared four tracheal tube cuff pressure inflation techniques, favoring the use of a digital syringe over other methods and recommending the incorporation of a cuff manometer when employing alternative techniques [17]. Rahmani et al. found that touching the cuff balloon or using constant volume techniques was unsuitable for evaluating cuff pressure, emphasizing the need for control through a manometer [18]. In our study, the manometry method consistently measured and recorded tracheal tube cuff pressure throughout the procedure. Factors influencing tracheal tube cuff pressure include patient-related factors, environmental conditions, and care interventions, such as changes in position and therapeutic interventions. Studies have indicated that 25% to 80% of pressure in the abdominal and chest cavities can be transferred between them. Increased intra-abdominal pressure may elevate intra-thoracic pressure, resulting in increased airway pressure and endotracheal tube cuff pressure [19, 20, 10]. In our study, the highest tracheal tube cuff pressure was observed in obese patients, indicating elevated intra-abdominal and chest pressure. Furthermore, measuring cuff pressure by the manual method in the prone position revealed the highest cuff pressure in patients with a surgery duration of 2 hours or more. Research suggests that tracheal tube cuff pressure fluctuates over time. Diffusion of nitrous oxide into the endotracheal cuff during anesthesia leads to an immediate increase, while long-term surgical procedures (>4 hours) result in significant pressure changes [21, 22]. In our study, the surgical position used contributed to higher cuff pressure in a shorter timeframe.

5. Conclusion

According to the results of the current study, it is evident that the tracheal tube cuff pressure measured by the instrumental method (manometer) was consistently lower than that measured by the manual method in patients placed in the prone position. This underscores the importance of utilizing the manometry measurement method to accurately assess tracheal tube cuff pressure in various patient scenarios. The superiority of

the manometer in maintaining cuff pressures within the normal range suggests its critical role in airway management, particularly in situations where prone positioning is involved. Thus, it is recommended to adopt manometry as a standard practice for tracheal tube cuff pressure measurement to enhance precision and mitigate potential complications associated with improper cuff pressures.

Ethical Considerations

Compliance with ethical guidelines

This study was approved and registered by the Research Ethics Committee of Jahrom University of Medical Sciences, Jahrom, Iran (Code: IIR.JUMS.REC.1400.090).

Funding

This study was extracted from the doctoral residency dissertation of Meysam Zarei approved by the Department of Anesthesiology, Faculty of Medicine, Jahrom University of Medical Sciences, Jahrom, Iran.

Authors' contributions

Conceptualization and study design: Mohammad Sadegh Sanie Jahromi, and Navid Kalani; Data collection and writing the original draft: Mohammad Sadegh Sanie Jahromi, Lohrasb Taheri, Navid Kalani, and Meysam Zarei; Statistical analysis: Mansour Deylami and Navid Kalani Final approval: Mohammad Sadegh Sanie Jahromi and Navid Kalani.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgements

The authors would like to thank the Clinical Research Development Unit of Peymanieh Educational and Research and Therapeutic Center of Jahrom University of Medical Sciences, Jahrom, Iran for their help in revising the manuscript.

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