Comparison of Manual and Manometric Methods for Tracheal Tube Cuff Pressure Measurement in Prone Position Patients Undergoing Lumbar Disc Surgery: A Prospective Analytical Descriptive Study

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Abstract

Background and Aim: Accurate tracheal tube cuff pressure measurement is crucial for preventing 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. So, we performed this study 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 involved 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 analysis employed descriptive statistics, including mean and percentage, as well as relevant statistical tests such as repeated measurement and ANOVA using SPSS version 16 software.

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, there was a significant difference 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 shows 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. So the manual approach might cause safety issues for patients.

Keywords: Tracheal tube cuff pressure, manometer, Peron position, manual cuff pressure measurement

Introduction

Tracheal tubes are designed to establish a secure airway in adult patients, featuring a distal cuff that, when inflated, acts as a barrier with 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 for minimizing air leakage, preserving flow volume, and preventing 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). There exists a linear relationship 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 for assessing cuff pressure accuracy include the manual minimal leak method and direct manometry (7). 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 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 (12,13). Hence, this study aims to investigate and compare tracheal tube cuff pressure using two instrumental methods (manometer) and manual methods in patients positioned prone during surgery.

Methods and Materials/Patients:

This prospective analytical study involved 60 patients who underwent lumbar disc surgery in the prone position. The sample included all eligible patients referred to Peymaniyeh Hospital in Jahrom city, who underwent lumbar disc surgery with a prone position in the year 2022. Inclusion criteria comprised individuals aged 18 and above, undergoing general anesthesia in the prone position. Exclusion criteria included refusal to participate, head and neck injuries preventing bending, and inability to obtain consent. Induction of anesthesia involved midazolam (0.03-0.06mg/Kg), fentanyl (2-4 microg/Kg), thiopental (5mg/kg), and atracurium (0.06mg/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, encompassing 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 (Malinckrodt) 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 No. 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 ANOVA) through SPSS software version 16.

Results

The present study encompassed a cohort of 60 patients ranging in age from 21 to 70 undergoing lumbar disc surgery in the prone position. The average age of the patients was 43.18±15.73 years, with nearly half of them falling below the age of thirty (48.4%). A majority of the participants were female, constituting 56.7%, while the remaining were male. 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).

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

		N	%
Age	<30	16	7.26%
	40-30	13	7.21%
	50-41	8	3.13%
	60-51	11	3.18%
	≥60	12	0.20%
	Mean±SD	43.18±15.73	
Sex	Male	26	3.43%
	Female	34	7.56%
BMI	Normal	4	7.6%
	Over weight	36	0.60%
	Obese	20	3.33%

Surgery duration	≤1.5	21	0.35%
	1.5-2	30	0.50%
	≥2	9	0.15%

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 Benferroni 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 Benferroni 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).

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-value
Manual	32.43	7.03	84.62	0.001
Manometer 0	17.39	7.39		
Manometer 15 minutes	50.37	10.16		
Manometer 30 minutes	25.37	7.33		
Manometer 45 minutes	36	6.97		
Manometer 60 minutes	44.35	7.08		
Manometer 75 minutes	40.34	15.7		
Manometer 90 minutes	34.34	16.7		
Manometer 105 minutes	82.36	9.02		

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

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

Age	<30		40-30		50-41		60-51		>60		p-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
manual	63.44	61.7	00.43	71.8	50.43	87.4	00.43	74.5	08.42	33.7	0.965
M*0	50.41	69.8	54.37	20.9	38.40	18.5	45.37	82.4	58.38	64.6	0.507
M15 minutes	19.40	78.8	00.36	81.9	63.40	63.5	55.34	70.11	17.36	95.12	0.608
M30 minutes	81.38	43.7	92.34	64.8	50.39	03.7	36.35	34.4	92.37	08.8	0.445
M 45 minutes	25.37	93.7	38.35	12.8	00.38	98.5	45.33	34.4	0[illegible].36	14.7	0.536
M60 minutes	50.36	37.8	58.34	65.7	63.37	74.6	09.33	18.4	58.[illegible]5	35.7	0.606
M75 minutes	88.35	04.9	25.34	44.6	63.36	18.8	80.31	[illegible]9.4	25.33	18.6	0.660
M90 minutes	92.35	04.9	91.33	08.7	00.36	07.8	25.[illegible]	[illegible]9.3	90.33	19.6	0.737
M105 minutes	70.37	97.9	00.35	07.7	33.41	6[illegible].11	71.31	36.2	60.38	71.10	0.595

*M= Manometer

The results of the Kruskal-Wallis test showed that there is 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 other patients (Table 4).

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

BMI	Normal		Over weight		obese		p-value
	Mean	SD	Mean	SD	Mean	SD	
manual	00.40	08.4	72.41	86.6	85.46	62.6	0.02
M*0	00.35	08.4	61.37	17.6	80.42	65.8	0.037
M15 minutes	00.35	08.4	03.36	77.8	65.40	67.12	0.048
M30 minutes	75.32	25.5	00.36	69.6	40.40	90.7	0.043
M 45 minutes	75.30	35.4	89.34	78.5	05.39	27.8	0.065
M60 minutes	00.30	08.4	94.33	95.5	42.39	88.7	0.012
M75 minutes	50.29	20.4	69.32	41.5	89.38	67.8	0.011

M90 minutes	33.29	15.1	74.32	25.5	38.38	20.9	0.033
M105 minutes	67.37	04.15	27.38	41.9	20.35	74.7	0.411

*M=Manometer

The results of the Kruskal-Wallis test showed that there is 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).

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

Surgery duration	**Normal**		**Over weight**		**Obese**		**p-value**
	Mean	SD	Mean	SD	Mean	SD	
Manual	52.43	75.6	23.41	36.6	78.4[illegible]	34.6	0.009
M*0	95.38	61.7	93.37	[illegible]0.6	78.43	43.9	0.254
M15 minutes	14.37	37.11	97.35	00.9	44.43	77.9	0.202
M30 minutes	29.37	87.7	07.3[illegible]	5[illegible].6	11.41	94.7	0.300
M 45 minutes	24.35	71.7	27.3[illegible]	72.5	22.40	20.8	0.234
M60 minutes	25.35	37.7	10.[illegible]4	12.6	33.40	08.8	0.106
M75 minutes	21.34	72.6	[illegible].33	32.6	44.39	06.9	0.077
M90 minutes	82.35	1[illegible].6	[illegible]7.32	41.6	44.38	15.9	0.070
M105 minutes	91.34	[illegible]0.5	69.37	01.12	89.37	72.7	0.315

*M=Manometer

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 (14-17). This study aimed to compare two methods of tracheal tube cuff pressure measurement—using instrumental (manometer) and manual methods—on 60 patients aged 21 to 70 years in the prone position. 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 and manual methods (minimal leak and finger palpation) and automatic methods (direct manometry and continuous monitoring), are used to check tracheal cuff pressure (18). Studies exploring different methods of tracheal tube cuff pressure measurement have reported varying results. Sanaie et al. (2019) 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 (19). 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. (2020) 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 (20). Rahmani et al. (2017) 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 (21). 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 (23, 24). 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 (25, 26). In our study, the surgical position used contributed to higher cuff pressure in a shorter timeframe.

Conclusion:

In light of the findings from 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 for accurately assessing 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, the adoption of manometry as a standard practice for tracheal tube cuff pressure measurement is recommended to enhance precision and mitigate potential complications associated with improper cuff pressures.

Ethical Considerations

Compliance with ethical guidelines:

Ethical Code:

IR.JUMS.REC.1400.090

Funding: None.

Authors' Contributions

All authors contributed toward data analysis, drafting, and revising the article and agreed to be responsible for all aspects of this work.

Conflict of Interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank the Clinical Research Development Unit of Peymanieh Educational and Research and Therapeutic Center of Jahrom University of Medical Sciences for the revise manuscript.

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