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Assessment Of Factors Hindering Nebulization Therapy Effect For Mechanically Ventilated Critical Ill Patients

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Abstract

Background: *Nebulization therapy has several benefits over alternative delivery methods and is currently used for a variety of medications, including as corticosteroids and bronchodilators. Still, it has a lot of disadvantages.* ***Objective:*** *To identify factors hindering the effect of nebulization therapy among critically ill mechanically ventilated patients.* ***Settings:*** *four intensive care units at Makkah hospitals, Saudi Arabia.* ***Subjects:*** *A convenience sample of 60 adult critically patients on invasive MV and, all critical care nurses about 50 nurses who were involved in providing direct patient care and working in the three different shifts.* ***Tool:*** *"Factors hindering the effect of nebulization therapy among mechanically ventilated patients' assessment" was used to collect the needed data.* ***Results:*** *Findings of the current study revealed that there was a significant improvement in almost cardiovascular and respiratory parameters (p=<0.001* for all) after the nebulization therapy session with [1]4 hours, while Majority of the nurses had unsatisfactory level of performance regarding to nebulization therapy especially in the night shift with significant value for total score (p=0.006* for all).* ***Conclusion:*** *Larger diameter tracheal tubes, longer duty cycles, and slower inspiratory flow result in more efficient and effective nebulization..* ***Recommendations:*** *Before starting nebulization therapy, the ventilator's parameters and connections should be checked often. Nurses should also receive regular in-service training on the proper way to provide nebulization therapy.*

Keywords: *Factors, hindering, nebulization, therapy, effect, critically ill, mechanically ventilated patients.*

Introduction

MV is commonly used for critical ill patient to help their breathing. By maintaining appropriate tidal volumes and respiratory rates, MV can achieve its primary objectives of oxygenation and

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carbon dioxide removal (Warner and Patel, 2012). In the ICU, nurses frequently use the nebulizer on MV to give the patients on mechanical ventilation their prescriptions (Ellis et al., 2013).

It is thought that individuals on mechanical ventilation will benefit less from inhaled medications than those who breathe on their own. In a previous trial, when the dose was given without an artificial airway, 11.9% of the administered dose reached the distal airway, compared to just 2.9% in that case (Maccari et al., 2015).

A few studies address the factors that may impair the efficiency of nebulization therapy and the appropriate strategy for administering nebulization therapy to critically ill patients on mechanical ventilation (MV), despite the fact that various novel therapies and technologies have been published in the literature regarding nebulization therapy.

Aims of the Study

This study aims to identify factorshindering the effect of nebulization therapy among critically ill mechanically ventilatedpatients

Research Questions

What are the factors hindering the effect of nebulization therapy among critically ill mechanically ventilated patients?

Materials and Method

Materials

Research design:

A descriptive research design was used to conduct this study.

Settings:

This study was carried out at Makkah Hospital in four intensive care units

Subjects:

- A convenience sample of 60 adult critically ill hemodynamically stable patients on invasive MV and receiving nebulization therapy through mechanical ventilator for at least three days in the previously mentioned units were recruited for this study. Using the equal allocation method, a convenient sample of 50 nurses was selected from each of the previously mentioned settings.

- The patients were selected based on the poweranalysis using the Epi-info. Program to estimate the sample size using the following parameters: Population size =300 in three months, Expected frequency=50%, Expectable error=5%, Confidence coefficient =95%, Minimum sample size=180 patients.

- All critical care nurses from different nursing categories 50 nurses who were involved in providing direct patient care and working in the three different shifts (morning, evening, and night) in the previously mentioned units and welling to participate in this study.

Exclusion criteria:

All patients who have the following criteria were excluded from the study: Patient who needed nebulization therapy for less than three days, weaned from mechanical ventilator before three days, discharged to the hospital ward or transferred to another hospital, or died before three days.

Tools: In order to collect the necessary data for the study, one tool was used:

Factors hindering the effect of nebulization therapy among mechanically ventilated patients' assessment". The tool was developed by the researcher based on reviewing the related literatures (Ari andFink, 2010;and Fink andAri, 2017). This tool included two main Categories: the first category related to assessment of the factors hindering the effect of the nebulizationtherapy among mechanically ventilated patients; and the second category related to assessment of the patients' response to the nebulization therapy.

Method:

- An approval from the ethical committee, wasobtained.
- An official permission was obtained to conduct the study.
- An official approval was obtained from the hospital administrative authorities to collectthe necessary data from the selected settings after explanation of the aim of the study.
- The tool "**Factors hindering the effect ofnebulization therapy among mechanically ventilated patients' assessment**" wasdeveloped by the researcher after reviewing the related literatures.
- Content validity was done for the tool by a jury of seven experts in the field of the study, and suggestions of the jury members were reviewed and the tool was modified as indicated.
- Pilot study was carried out on five criticallyill patients and five critical care nurses to evaluate the clarity and applicability of thetool and necessary modifications were done accordingly.
- Reliability of the tool was done before conducting the study using Cronbach Alpha reliability, the reliability coefficient was (r = 0.880) which is reliable.
- Factors hindering the nebulization delivery during MV were assessed for each mechanically ventilated patient by using the six parts of the first category of the tool.
- Patients on invasive MV were enrolled in the study according to the previously mentioned inclusion criteria.

Statistical analysis:

- After data were collected, they werecoded and transferred into specially designed formats so as to be suitable for computer feeding. Following data entry, checking and verification processes were carried out to avoid any errorsduring data entry, frequency analysis,

crosstabulation and manual revision were all used to detect any errors. The statistical package for social sciences (SPSS version 25) was utilized forboth data presentation and statistical analysis of the results. The level of significance selected for this study was P equal to or less than 0.05.

Ethical considerations:

- Witness informed written consent wasobtained from head nurses for observation and intervention in this study after appropriate explanation of the study purpose.
- Written informed consent was obtained from patients' family for their participationand right to refuse of their patients' participation in the study was assured. Patients' privacy was respected.
- Anonymity and data confidentiality were assured during implementation of the study.

Results

Table I shows the distribution of thestudied critically ill patients according to their characteristics. It was noticed that a third of the patients' age was in the group between 18 to 30 years old. It was noticed that all patients were admitted with respiratory disease, about half of the patients were admitted with renal, and cardiovascular diseases (58.3 %, and 51.7 %, respectively). It was observed that about two thirds of the patients had GCS equal 3-8. A third of the patients had a length of stay equal 1-7 days.

Patient data	**No. (n=60)**	**%**
Demographic dataGender Male Female	 30 30	 50.0 50.0
Age 18 – 30 years 31 – 40 years 41 – 50 years 51 – 60 years	 20 10 15 15	 33.3 16.7 25.0 25.0
urrent Diagnosis Respiratory Cardiovascular Renal Neurological Endocrine	 60 31 35 22 26	 100.0 51.7 58.3 36.7 43.3
st Medical History Respiratory Cardiovascular Renal Endocrine	 28 30 35 26	 46.7 50.0 58.3 43.3
GCS score		

3 – 8 9 – 11	38 22	63.3 36.7
Length of stay in ICU 1 – 7 days 8 – 14 days 15 – 21 days 22 – 28 days >28 days	 20 16 5 12 7	 33.3 26.7 8.3 20.0 11.7

Table II presents the distribution of the critically ill patients according to ventilator parameters. It was observed that all patients were recruited to pressure control ventilation. The measured inspiratory flow in a half of the patients(50%) was more than 40 L/min. The calculated bias flow value in more than a half of the patients (58.3%) was 2 L/min or more. The calculated duty cycle value in majority of the patients (80%)was more than 0.30.

Ventilator parameters		**No. (n=60)**	**%**
Mode of MV			
Pressure Control mode	**BIPAP**	15	25.0
	PCV	13	21.7
	PSV	5	8.3
	SIMV + PSV	13	21.7
	CPAP + PSV	14	23.3
Inspiratory Flow			
<40 L/Min		25	41.7
40 L/Min		5	8.3
>40 L/Min		30	50.0
Bias flow			
<2 L/Min		25	41.7
≥2 L/Min		35	58.3
Duty Cycle			
<0.30		5	8.3
0.30		7	11.7
>0.30		48	80.0

Table III presents the distribution of the studied critically ill patients according to nebulization therapy. It was noticed that all the nebulization sessions were done using jet nebulizer device, that was positioned between the airway and the circuit in less than two thirds of the patients (60%). The received drugs were undiluted in more than a half of the patients (53.3%), and the fill volume of the drug in more than a half of the patients (55.7%) was 2cc. The duration of each nebulization therapy session in more than two thirds of the patients (71.7%) was 6-10 minutes. There was a residual volume of the nebulized drug in slightly less than a half of the patients (45%), and the measured residual volumeof the nebulized drug in near one quarter of

the patients (23.3%) was more than 2.5 ml.

Nebulization	**No. (n=60)**	**%**
Type of Aerosol Device Used During the Session		
Jet	60	100.0
Ultra sonic	0	00.0
Vibrating mesh	0	00.0
Pressurized metered dose inhalers	0	00.0
Position of The Device in The Circuit		
Between the ETT And the Circuit Inspiratory Limb 6	36	60.0
Inches From "Y" Shape	24	40.0
ution of the nebulized drug Diluted with 1 CC N. S		
Not diluted	28	46.7
	32	53.3
Fill Volume of the drug in the nebulizer device		
CC	34	56.7
CC	26	44.3
Duration of The Session		
Min	5	8.3
– 10 Min	43	71.7
11 – 15 Min	12	20.0
Presence of Residual volume from the Nebulized Drug	27	45.0
Present		
Absent	33	55.0
Residual Volume of the Nebulized Drug		
0.1 – 2.5 ml	13	21.7
>2.5 ml	14	23.3

Table IV represents the respiratory status of the patients before, immediately after, and 4 hours after nebulization therapy through the study days. It was noticed that a significant improvement in respiratory rate, tidal volume, and patient – ventilator synchronization 4 hours after session with significant difference (p= <0.001* for all). As regarding to **air entry on the right lung**, there was a significant improvement in the air entry on the right lung 4hours after the nebulization therapy session through the studied days, with a significant difference (p= 0.031*,0.012*, and 0.021* respectively). It was noticed that **the air entry on the left lung** has significantly improved 4hours after the nebulization therapy session through the studied days, with a significant difference (p= 0.042*,0.017*, and 0.004* respectively).

Respiratory status	1st day						Test of sig.(p1)	2nd day						Test of sig.(p2)	3rd day						Test of sig.(p3)
	Before Nebulization		mediately after nebulization		ter 4 hrs. from nebulization			Before Nebulization		mediately after nebulization		ter 4 hrs. from nebulization			Before Nebulization		mediately after nebulization		ter 4 hrs. from nebulization		
Respiratory Rate Mean ± SD.	22.98 ± 4.53		17.72 ± 1.51		18.17 ± 2.31		F=57.11* (<0.001*)	22.10 ± 4.73		17.47 ± 1.76		17.57 ± 1.99		F=43.80* (<0.001*)	22.25 ± 4.80		17.48 ± 1.78		17.67 ± 2.01		F=45.613* (<0.001*)
Air Entry																					
Right lung	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=6.936* (0.031*)	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=8.851* (0.012*)	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=7.731* (0.021*)
Normal	18	30.0	32	53.3	29	48.3		17	28.3	33	55.0	29	48.3		19	31.7	35	58.3	30	50.0	
Diminished	42	70.0	28	46.7	31	51.7		43	71.7	27	45.0	31	51.7		41	68.3	25	41.7	30	50.0	
Left lung	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=6.333* (0.042*)	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=8.190* (0.017*)	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=11.21* (0.004*)
Normal	23	38.3	35	58.3	34	56.7		25	41.7	39	65.0	37	61.7		22	36.7	38	63.3	37	61.7	
Diminished	37	61.7	25	41.7	26	34.3		35	58.3	21	35.0	23	38.3		38	63.3	22	36.7	23	38.3	
VT Mean ± SD.	543.1±86.37		696.8± 125		590.0± 58.7		F=40.18* (<0.001*)	543.2± 91.0		683± 110.2		602.6± 72		F=39.78* (<0.001*)	554.8± 91.2		690.1± 137		581.2± 74.9		F=31.557* (<0.001*)
Patient – ventilator synchronization	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=50.24* (<0.001*)	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=48.27* (<0.001*)	**No.**	**%**	**No.**	**%**	**No.**	**%**	Fr=58.80* (<0.001*)
No	35	58.3	22	36.7	2	3.3		32	53.3	24	40.9	2	3.3		38	63.3	31	51.7	3	5.0	
Yes	25	41.7	38	63.3	58	96.7		28	46.7	36	60.0	58	96.7		22	36.7	39	48.3	57	95.0	

Table V describes the distribution of the studied critical care nurses according to their characteristics. It was noticed that near two third of the nurses were in the age group (<25 years), slightly more than a half were males. About morethan a half of the nurses had a baccalaureate degree, near a half of the nurses (46.7%) had an experience in ICU5 years; and none of the nurses attend in service training regarding nebulization therapy.

Nurses' characteristics	**No. (n=60)**	**%**
Age (years)		
< 25	39	65.0
25 – 35	21	35.0
Gender		
Male	31	51.7
Female	29	48.3
Level of education		
Baccalaureate	34	56.7
Technical	14	23.3
Diploma	12	20.0
Years of Experience in Intensive care unit		
<1YR	20	33.3
1<5 YR	28	46.7
5<10 YR	12	20.0
endance of In-Service Education Regarding Nebulization Therapyyes	0	00.0
No	60	100.0

Table VI demonstrates the comparisonbetween the critical care nurses' level of performance of nebulization therapy during different working shifts. The table reveals that themajority of the nurses had unsatisfactoryperformance level related to nebulization therapy at night shift, with a significant total mean score and standard deviation of nebulization therapy steps in the different working shifts (p= 0.006*).

Nebulization therapy performance	**Morning shift**		**Evening shift**		**Night shift**		**Significance**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**Fr**	**p**
Total score								
<75% Unsatisfactory	50	83.3	56	93.3	58	96.7	10.400*	0.006*
≥75% Satisfactory	10	16.7	4	6.7	2	3.3		
Mean ± SD. Total score	60.23 ± 19.73		55.53 ± 13.05		53.82 ± 10.45		5.424*	0.006*
Mean ± SD. % Score	49.90 ± 16.14		45.99 ± 10.56		44.63 ± 8.45			

Discussion

Nebulized drug administration is becoming more common during mechanical ventilation (MV), and administering aerosolized drug therapy to patients suffering from pulmonary diseases is a standard therapeutic procedure. Bronchodilators and other drugs are frequently administered during mechanical ventilation (MV) using a jet nebulizer (McPeck et al., 2021).

According to the current study, every patient was chosen for pressure control ventilation since it was thought that this would prevent aerosol delivery from working as intended. This could be related to volume changes that occur during inspiration. This outcome is consistent with the findings of Patel et al. (2013) and Dugernier et al. (2016), who discovered that the ventilator circuit's deposition rate was lower for pressure control modes than for volume control modes. However, Vecellio et al. (2005) demonstrated that increased pressure volume had no influence on aerosol emission, contradicting the current result.
According to the current study, almost two thirds of the patients had elevated inspiratory flow and inspiratory bias flow, which make it more difficult to administer nebulization therapy. These findings are consistent with those of Li and Fink (2021), who demonstrated that a greater inspiratory flow can result in a lower patient delivery of bronchodilators. According to Emeryk et al. (2021), the inspiratory flow has a major impact on how much aerosol is dedeposited during inhalation therapy.

The calculated duty cycle value in majority of the studied patients was higher than 0.30. This may be attributed to the increasing inspiratorytime which gives longer duty cycle. this result is matching with Ari and Fink, (2010) who recommended that the duty cycle equal or higher than 0.30. Berlinski andWillis, (2015), and Ehrmann et al., (2020) demonstrated that higher duty cycle gives higher nebulizer output rate. On the other hand, the current results werecontradicted with Vecellio et al., (2005) who stated that there is a negative correlation between duty cycle, and the nebulizer output.

In the current study all the nebulization sessions to all the studied patients were done by using jet nebulizer device. The duration of each nebulization therapy session in more than two thirds of the patients was 6-10 minutes. It is not enough for delivering aerosolized medications. This may be attributed to the device's efficacy that influenced by the ventilator flow which led to incomplete drugdelivery. this result is in-line with Liu et al., (2019) who recommended increasing session duration and multiple used doses which is better to compensatethe poor delivery from the jet device.

In the current study the jet nebulizer was placed between the airway and the circuit in less than two thirds of the studied patients. The jet nebulizer which is too close for the airway todecrease the drug loss. The results of the current study were in line with Anderson et al., (2017);and Peng et al., (2018) who recommended placing the nebulizer device near ventilator, near humidifier inlet or outlet, or placing it before "Y" piece with 30 cm, which increase the nebulizer efficiency.
Since the nebulized medication was administered in the current study without being diluted, it has no impact. It might be explained by the inspired oxygen's ability to cause the medication to evaporate in the circuit more quickly. The findings of Saeed et al. (2018), who stressed that the nebulized medicine should be diluted to have effective nebulizer activity, run counter to the findings of the current investigation.

The current study showed that there was a residual volume of the nebulized drug in slightly less than a half of the patients, and the measured residual volume of the nebulized drug in near a quarter of the patients was more than 2.5 ml. Thismay be attributed to over dilution or placing the dose on old dose that may found in the nebulizer.

This result is in line with Yang et al., (2018) who showed that jet nebulizer has ahigher residual volume which make it the least efficient device comparable with other nebulization devices.

Regarding the hemodynamic and respiratory status related responses The current study found that following a 4-hour nebulization therapy session on the examined days, there was a

substantial drop in pulse, mean arterial pressure (MAP), respiratory rate, and enhanced air entry on both lungs. This suggests that the nebulized medications did not cause any cardiac or respiratory side effects. This could be explained by the fact that the nebulized drugs' localized action reduced the mechanically ventilated patients' respiratory effort without negatively affecting their hemodynamics.

These results are consistent with those of Moustafa et al. (2017) and Singla et al. (2018), who demonstrated that the nebulized medication was administered immediately after the hemodynamics and respiratory parameters improved somewhat. However, Bodet-Contentin et al., (2019) and Sahitia et al., (2018), who demonstrated that there was no change in the baseline hemodynamics and respiratory parameters following the session, contradict these results.

Regarding the tidal volume and the presence of patient and ventilator desynchrony, there was a significant decrease in the rate ofoccurrence of patient – ventilator desynchronyand increase in the inspired tidal volume. This result may be attributed to effect of the nebulized drug on decreasing the work of breathing, and thefighting between the patient and ventilator and increasing the tidal volume without any effort from the patients. The results of the current study is in line with Singla et al., (2018) who stated thatthe drug was effective in decreasing the breathing effort and increasing the respiratory capacity in the studied patients.

Regarding to the nurses' characteristics, the years of experience in ICU in near half of the nurses equal 1- < 5 years. However, none of the studied nurses attended in service education or training about nebulization therapy so almost of the nurses doesn't have any knowledge about the accurate administration procedure. Regarding to total mean score and standard deviation ofnebulization therapy steps in the different working shifts, the level of performance was unsatisfactory especially in the night work shift. This may be attributed to lack of the staff experience understaffing and work overload atnight shift with minimal resources for caring for the patients especially during administration ofperforming nebulization therapy.
This result is consistent with Zhang et al., (2021); and Zhang et al., (2019), who demonstrated that the nurses' performance and level of knowledge were inadequate because there were insufficient educational programs regarding the proper administration technique. This needs to be made up for by regular educational programs and assessments of the nurses' performance and knowledge levels. However, Ehrmann et al. (2016) and Shakor (2019) demonstrated that, when compared to the inadequate level of knowledge, the practice level was appropriate. This meant that the current study was inverted.

Conclusion

The results of this study suggest that ventilator settings should be examined before to nebulization therapy sessions because larger diameter tracheal tubes, longer duty cycles, and slower inspiratory flow result in more effective and efficient nebulization. During their morning and evening shifts, the nurses performed at a satisfactory level. After four hours of nebulization therapy, there was a noticeable improvement in respiratory metrics and hemodynamic state.

Recommendations

In line with the findings of the study, the following recommendations are made: Instruct the nurses to assess the ventilator data especially the inspiratory flow and the inspiratory time before the nebulization session., as well as, encouraging nursing staff to turn off the humidifier during the nebulizer.

The preferred position for placing jet nebulizer device is before the ETT and the circuit or 6 inches before the "Y" shape in the inspiratory limb. Provide frequent in-service training

programs for the critical care nurses regarding nebulization therapy devices with it is advantages and drawbacks and the correct application on mechanical ventilator and Assess barriers that affect the level of performance related to nebulization therapy at the night shift.

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