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Nurses' Knowledge Levels of Nebulized Medication Administration in Adults[1]

Hemşirelerin Erişkinlerde Nebülizatörle İlaç Uygulamalarına Yönelik Bilgi Düzeyleri

Buğçe ÜLKÜ[2], Sevda ATEŞ[3]

Yazarların ORCID numaraları / ORCID IDs of the authors:
B.Ü. 0000-0001-8585-386X; S.A. 0000-0002-4988-3743

[1]This research was produced from the thesis study

[2]Tekirdağ Provincial Health Directorate Çorlu State Hospital, Türkiye

[3]Department of Nursing, Faculty of Health Sciences, Canakkale Onsekiz Mart University, Canakkale, Türkiye

Sorumlu yazar / Corresponding author: Sevda ATEŞ
E-posta: sevdaefil@comu.edu.tr

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ABSTRACT

Introduction: Adequate knowledge of the administration steps required for safe nebulized medication use in adults is essential for patient safety; however, these steps are often neglected or poorly understood. Moreover, empirical evidence regarding nurses' knowledge levels related to nebulized medication administration in adult patients remains limited.

Aim: This study aimed to evaluate nurses' knowledge levels regarding nebulized medication administration in adults.

Methods: A descriptive methodological design was employed. The study was conducted between June 15 and September 15, 2022, and included 258 nurses. Data were collected using Demographic Characteristics Form and the Nurse Knowledge Form for Nebulized Medication Administration in Adults. Descriptive statistics, the Mann-Whitney U test, independent samples t test, Kruskal-Wallis H test, and one-way analysis of variance were used for data analysis. A p-value of < 0.05 was considered statistically significant.

Results: The mean knowledge score for nebulized medication administration in adults was 47.68 ± 4.58. Higher knowledge levels were observed among older nurses and those with greater professional experience ($p < 0.001$). Factors significantly associated with overall knowledge scores included having received training on nebulized medication administration, frequency of oral care practices, preparation of the nebulizer device, medication preparation for nebulization, administration procedures, and perceived knowledge of nebulizer maintenance ($p < 0.001$).

Conclusion: The findings indicate a need for structured in-service training programs and sustained educational initiatives to enhance nurses' knowledge of accurate and safe nebulized medication administration in adult patients.

Keywords: Adult; inhalation; nebulizers; nurses; patient safety.

ÖZ

Giriş: Erişkinlerde nebülizatörle güvenli ilaç uygulaması için ihmal edilen ya da bilinmeyen uygulama adımlarının bilinmesi önemlidir. Fakat, literatürde hemşirelerin erişkinlerde nebülizatör ile ilaç uygulamalarına ilişkin bilgi düzeyleri yeterince araştırılmamıştır.

Amaç: Bu çalışma hemşirelerin erişkinlerde nebülizatörle ilaç uygulamalarına yönelik bilgi düzeylerini değerlendirilmek amacıyla yapıldı.

Yöntem: Bu çalışma tanımlayıcı bir çalışmadır. 15 Haziran ile 15 Eylül 2022 tarihleri arasında gerçekleştirilen araştırmaya 258 hemşire katıldı. Verilerin toplanmasında Hemşire Tanıtıcı Özellikler Formu ve Erişkinlerde Nebülizatörle İlaç Uygulamaya Yönelik Hemşire Bilgi Formu kullanıldı. Verilerin analizinde tanımlayıcı istatistiksel analizler, Mann Whitney U testi, bağımsız örneklem t testi, Kruskal Wallis H testi ve Tek Yönlü Varyans analizi kullanıldı. İstatistiksel anlamlılık için $p < 0,05$ kabul edildi.

Bulgular: Erişkinlerde nebülizatörle ilaç uygulamaya yönelik hemşirelerin bilgi düzeyi puan ortalaması 47,68 ± 4,58'di. Yaşı ve mesleki deneyim yılı fazla olan hemşirelerde güvenli nebül ilaç uygulamasına yönelik bilgileri daha iyi düzeydeydi ($p < 0.001$). Nebülizatörle ilaç uygulamalarına yönelik eğitim alma durumları, ağız bakımı uygulama sıklığı, nebülizatör cihazın hazırlığı, nebül ilaç hazırlığı, nebül ilaçları uygulama ve nebülizatör cihazının bakımı ile ilgili bilgi sahibi olduğunu düşünme durumları hemşirelerin erişkinlerde nebülizatörle ilaç uygulamaya yönelik toplam bilgi düzeyi puan ortalamalarını etkileyen faktörlerdi ($p < 0.001$).

Sonuç: Erişkinlerde nebülizatörle doğru ve güvenli ilaç uygulamaya yönelik hemşirelerin bilgi düzeylerini arttırmak amacıyla hizmet içi eğitim programları düzenlenmeli ve eğitimlerin sürekliliği sağlanmalıdır.

Anahtar Kelimeler: Erişkin; hasta güvenliği; hemşireler; inhalasyon; nebülizerler.

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Introduction

Global health metrics demonstrate that asthma affects approximately 300 million people, while chronic obstructive pulmonary disease (COPD) has risen to become the third leading cause of death worldwide (Global Initiative for Chronic Obstructive Lung Disease [GOLD], 2025; Global Strategy for Asthma Management and Prevention [GINA] 2025). Inhalation therapy is a widely used treatment modality for chronic respiratory diseases. Inhalers and nebulizers are the primary devices used to deliver medications via the inhalation route (Talwar et al., 2021; GINA, 2025; GOLD, 2025). Nebulizers are commonly utilized in hospital settings, including both inpatient and outpatient care, as well as in home environments (Barjaktarevic & Milstone, 2020). Their use has become increasingly prevalent among both pediatric and adult populations, particularly for the acute management of respiratory conditions and the treatment of chronic lung diseases (Bargaje, Chidgupkar, Anokar, Deoskar, & Singh, 2018; Murphy et al., 2020; O'Neil & Villasmil-Urdaneta, 2023).

The correct administration of medications via nebulizers, along with appropriate device maintenance, is essential for ensuring patient safety and treatment effectiveness (Güngör et al., 2012; Sivadasan, Krishnan, Dhayalan & Aiyalu, 2021). Nevertheless, the substantial physical dimensions of nebulizer devices, coupled with rigorous maintenance protocols such as routine cleaning and disinfection and intricate operational requirements including assembly, medication filling, and precise inhalation techniques may collectively impede correct device utilization (Sivadasan et al., 2021). Patients who experience difficulty or confusion while using inhalation devices may demonstrate reduced adherence, thereby negatively affecting treatment outcomes (Alismail et al., 2016). Inaccurate or unsafe nebulized medication administration can result in inadequate drug delivery, increased symptom burden, and deterioration in quality of life (Şahan, Güler & Geçtan, 2023). Moreover, incorrect practices have been associated with an increased frequency of exacerbations, higher hospitalization rates, and greater healthcare costs (Toprak Kanık, Yılmaz, Türkeli & Yüksel, 2015). Accordingly, identifying errors made during nebulized medication administration is of critical importance (Şahan et al., 2023).

Nurses play a pivotal role in educating patients about the correct and safe use of inhalation devices (Gracia, Ruiz, Martinez, Grande-Ratti & Mayer, 2022). In collaboration with physicians and family members, nurses are responsible for ensuring that treatments are administered accurately and effectively (Spencer & Hanania, 2013; Scullion, 2018). Previous research has shown that factors such as inadequate training, the absence of standardized guidelines for medication administration, limited professional experience, interruptions during medication preparation, and shift changes, particularly night shifts, can contribute to medication administration errors. However, a significant disparity exists in the current literature regarding the target populations of these studies. While nebulized medication practices in pediatric populations have been extensively documented, there is a notable scarcity of evidence specifically focused on adult patients. This gap is particularly concerning given that the burden of chronic respiratory diseases is rapidly escalating in developing countries, where limited access to specialized training and standardized protocols often results in higher rates of medication administration errors (Wondmieneh, Alemu, Tadele & Demis, 2020). While the existing literature extensively covers nebulized medication practices in pediatric populations, there is a notable scarcity of evidence focused on adult patients. Nevertheless, the literature indicates that nurses' knowledge and skills related to nebulized medication administration remain insufficient. In addition, studies specifically examining nurses' knowledge and practices concerning nebulized medication administration in adult patients are scarce. It is observed that these studies primarily rely on non-standardized descriptive surveys or observational checklists when evaluating the knowledge and skills of nurses (Ulus et al., 2007; Güngör et al., 2012; Ergin, 2021; Şahan et al., 2023). Unlike previous studies that utilized unvalidated checklists, this research employs an instrument grounded in clinical guidelines and expert validation. Addressing this gap by identifying incorrect or overlooked nursing practices in adult nebulized medication administration, based on current evidence, may contribute to the presentation of solutions.

Aim

This study aimed to evaluate nurses' knowledge levels regarding nebulized medication administration in adults and to identify factors influencing these knowledge levels.

Research Questions

1. What is the distribution of nurses' responses to the Knowledge Form for Nebulized Medication Administration in Adults?

2. What is the level of nurses' knowledge regarding nebulized medication administration in adults?

3. Do nurses' knowledge levels regarding nebulized medication administration in adults differ significantly according to their sociodemographic and professional characteristics?

Methods

Research Design

This study employed a descriptive cross-sectional design to assess nurses' knowledge levels regarding nebulized medication administration in adults and to examine factors associated with these levels.

Population and Sample

The study population consisted of 410 nurses working at a university hospital between June 15 and September 15, 2022. The required sample size was calculated as 198 based on an assumed population proportion (p) of 0.50, a non-observation proportion (1 - p) of 0.50, a margin of error (d) of 0.05, and a z value of 1.96 corresponding to a 95% confidence level (Bartlett, Kortlik & Higgins, 2001).

No sample selection was performed, and 258 (62.9%) on nurses who met the inclusion criteria of the research were included in the sample. This count is significantly above the projected representative sample of 198. Nurses aged 18 years and older who administered

medications to adult patients using nebulizers were eligible for inclusion. Exclusion criteria included refusal to participate, being under 18 years of age, incomplete questionnaire responses, and not administering nebulized medications to adult patients.

Data Collection Tools

Study data were collected using a questionnaire consisting of two sections: a Demographic Characteristics Form and the Nurse Knowledge Form for Nebulized Medication Administration in Adults.

Demographic Characteristics Form: The Demographic Characteristics Form was developed based on a review of the relevant literature (Ari, 2015; Düdükçü & Arslan, 2016; Keçe, 2017; Barjaktarevic & Milstone, 2020; Swarnakar, Gupta, Halder & Khilnani, 2021). It consisted of 14 items assessing nurses' sociodemographic and professional characteristics, including age, gender, educational level, professional experience, clinical unit, types of nebulizers used, frequency of nebulized medication administration, oral care practices, knowledge related to device preparation, medication preparation, medication administration, and device maintenance, as well as prior training in nebulized medication administration.

Nurse Knowledge Form for Nebulized Medication Administration in Adults: The Nurse Knowledge Form for Nebulized Medication Administration in Adults was developed by the researchers following a comprehensive literature review (Ari, 2015; Düdükçü & Arslan, 2016; Keçe, 2017; Barjaktarevic & Milstone, 2020; Swarnakar et al., 2021). Initially, the form comprised 55 items across four subdimensions.

Expert opinion was obtained during the development of the Nurse Knowledge Form for Nebulized Medication Administration in Adults. Prior to data collection, content validity was evaluated by consulting 10 experts regarding the readability, validity, and comprehensibility of the items. Expert evaluations were analyzed using the Davis technique. The content validity index (CVI) was calculated by dividing the number of experts who rated an item as "highly appropriate" or "quite appropriate" by the total number of experts. Items with a CVI value greater than 0.80 were considered to demonstrate adequate content validity (Davis, 1992).

Following expert evaluation, the CVI values for the 55-item form ranged from 0.90 to 1.00, and the mean CVI was 0.99. Based on these results, two items were removed, and the final version of the form consisted of 53 items. The finalized instrument included four subdimensions: Nebulizer device preparation (10 items, 0 - 10 points), safe nebulized medication preparation (10 items, 0 - 10 points), safe nebulized medication administration (24 items, 0 - 24 points), and nebulizer device maintenance after medication administration (9 items, 0 - 9 points). The internal consistency of the Nurse Knowledge Form for Nebulized Medication Administration in Adults was confirmed with an overall Cronbach's alpha value of 0.84. Regarding the sub-dimensions, alpha coefficients were 0.75 for nebulizer device preparation, 0.38 for safe nebulized medication preparation, 0.58 for safe nebulized medication administration, and 0.77 for nebulizer device maintenance.

Ethical Consideration

This research was conducted in conformity with ethical principles and the Helsinki Declaration. Ethical approval was obtained from the Scientific Research Ethics Committee of a Graduate Education Institute of a university prior to the commencement of the study (decision no. 07/13; date: March 31, 2022). Institutional permission was also secured from the hospital where the study was conducted (decision no. E-93130991-730.08.03-2200113742; date: June 7, 2022).

All participants were informed about the purpose of the study, and both verbal and written informed consent were obtained. To ensure confidentiality, participants completed the questionnaire anonymously.

Data Collection

Prior to data collection, participants were informed about the purpose, content, scope, and duration of the study through face-to-face interviews. Both verbal and written informed consent were obtained from all participants. Participants were asked to complete all items in the data collection instruments, and completion of the questionnaire required approximately 20 minutes on average.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics version 24.0. Normality of the data was assessed by examining skewness and kurtosis values, with values within ±2 considered indicative of a normal distribution (George & Mallery, 2010). In addition to examining skewness and kurtosis values, the Kolmogorov-Smirnov test was conducted to determine whether the data was normally distributed. Descriptive statistics were calculated, and inferential analyses included the Mann-Whitney U test, independent samples t test, Kruskal-Wallis H test, and one-way analysis of variance (ANOVA). The Games-Howell, least significant difference (LSD), and Tukey honestly significant difference (HSD) tests were used for post hoc comparisons, as appropriate.

Spearman's rank-order and Pearson's product-moment correlation analyses were conducted to examine relationships among continuous variables. Correlation coefficients and effect sizes were interpreted according to the criteria proposed by Hair, Bush and Ortinau (2003). A p-value of < 0.05 was considered statistically significant.

Results

The mean age of the nurses was 28.19 years, and the mean duration of professional experience was 4.79 years. The majority of participants were female (78.3%), held a bachelor's undergraduate degree (88.4%), and worked in internal medicine units (45.7%). Most nurses reported administering nebulized medications more than once daily (67.1%), primarily using masks during administration (92.6%), and had not received prior training in administering nebulized medications (80.2%) (Table 1).

Upon analyzing the responses to the knowledge level form regarding nebulized medication administration in adults, it was determined that 75.5% (n = 40) of the 53 items achieved a correct response

Table 1: Socio-Demographic and Descriptive Characteristics of Nursing (n = 258)

Characteristics		Mean ± SD (Min. - Max.)	
Age		28.19 ± 4.46 (21 - 48)	
Total experience in the nursing profession (years)		4.79 ± 4.12 (1 - 25)	
		n	**%**
Gender	Female	202	78.3
	Male	56	21.7
Level of education	High school	5	1.9
	Associate degree	5	1.9
	Undergraduate degree	228	88.4
	Graduate degree	20	7.8
Ward/clinic/unit	Internal medicine	118	45.8
	Surgical wards	30	11.6
	Emergency	41	15.9
	Intensive care	61	23.6
	Other	8	3.1
Frequency of nebulized medication administration (daily)	Once a day	10	3.9
	More than once a day	173	67.0
	When needed	75	29.1
Device used for administering nebulized medication	Mouthpiece	1	0.4
	Mask	239	92.6
	Mouthpiece or mask	18	7.0
Previous training in nebulized medication administration	Yes	51	19.8
	No	207	80.2
Time of the training in nebulized medication administration	None	207	80.2
	In the past year	12	4.7
	≥ 2 years	39	15.1
Perceived knowledge regarding nebulizer device preparation	Yes	160	62.0
	No	27	10.5
	Moderate	71	27.5
Perceived knowledge regarding nebulized medication preparation	Yes	195	75.5
	No	11	4.3
	Moderate	52	20.2
Perceived knowledge regarding nebulized medication administration	Yes	212	82.1
	No	11	4.3
	Moderate	35	13.6
Perceived knowledge regarding nebulizer device maintenance	Yes	124	48.1
	No	37	14.3
	Moderate	97	37.6
Frequency of oral care after nebulized medication administration	After each nebulization	84	32.6
	Once a day	78	30.2
	None	96	37.2

SD: Standard Deviation; Min.-Max.: Minimum-Maximum.

rate exceeding 85%. All nurses (100%) correctly responded to the following items: "The color of nebulizer medications is checked before use." "The medication order is checked before administering medication with a nebulizer." "Hands are washed before administering medication." Patient identity is verified before administering medication." "The nebulizer is started by pressing the on/off button. "It is made sure that the device is switched off by pressing the on/off button when medication administration is complete.", and "Hands are washed after medication administration." (Table 2).

Table 2: Distribution of Responses to the Nurse Knowledge Form for Nebulized Medication Administration in Adults (n = 258)

Items		True		False		No idea	
		n	%	n	%	n	%
Nebulizer device preparation	The connection hose, mask, mouthpiece, medication reservoir, and air filter are checked for integrity.	254	98.4	0	0.0	4	1.6
	The nebulizer device (compressor) is placed on a stable, flat surface.	256	99.2	0	0.0	2	0.8
	The compressor cable is plugged into a grounded electrical outlet.	236	91.5	0	0.0	22	8.5
	The air filter cover is opened, and the filter is checked for cleanliness.	242	93.8	2	0.8	14	5.4
	The air filter is replaced if it is excessively dirty or clogged.	248	96.1	0	0.0	10	3.9
	A mask or mouthpiece appropriate for the patient is prepared.	254	98.4	1	0.4	3	1.2
	One end of the connection hose is attached to the nebulizer, and the other end is connected to the medication reservoir.	245	95.0	1	0.4	12	4.7
	The mask or mouthpiece is attached to the medication reservoir.	255	98.8	0	0.0	3	1.2
	The compressor is operated for a few seconds without medication before treatment.	202	78.3	31	12.0	25	9.7
	The adequacy of airflow (6-8 L/min) in the nebulizer is checked.	204	79.1	22	8.5	32	12.4
Safe nebulized medication preparation	Nebulizer medications are stored in plastic ampoules within foil envelopes and protected from direct sunlight.	241	93.4	4	1.6	13	5.0
	The color of nebulizer medications is checked before use.	258	100.0	0	0.0	0	0.0
	Nebulizer medications showing discoloration or crystallization are not used and are discarded immediately.	255	98.8	2	0.8	1	0.4
	Nebulizer medications are stored at room temperature below 25°C and are not frozen.	248	96.1	4	1.6	6	2.3
	Nebulizer medications are not prepared in advance or left waiting before the scheduled treatment time.	254	98.4	4	1.6	0	0.0
	The medication order is checked before administering medication via a nebulizer.	258	100.0	0	0.0	0	0.0
	If a medication containing salbutamol (Ventolin) is to be administered for longer than 10 minutes, it is diluted with saline solution.	168	65.1	41	15.9	49	19.0
	Nebulizer medications prescribed in half doses are prepared by dilution.	146	56.6	65	25.2	47	18.2
	If more than one type of medication is to be administered via nebulizer, doses are prepared to be administered at appropriate intervals.	254	98.4	1	0.4	3	1.2
	If the patient's treatment includes both Ventolin and Pulmicort nebulizers, they are prepared to be administered together.	164	63.6	81	31.4	13	5.0
Safe nebulized medication administration	Hands are washed before medication administration.	258	100.0	0	0.0	0	0.0
	The patient's identity is verified prior to medication administration.	258	100.0	0	0.0	0	0.0
	The patient is informed about the treatment procedure.	253	98.1	4	1.6	1	0.4
	If a mouthpiece is used, it is placed between the patient's teeth, and the lips are closed tightly around it.	162	62.8	6	2.3	90	34.9
	If a mask is used, it is ensured that the mask fits snugly over the patient's mouth and nose.	257	99.6	1	0.4	0	0.0
	The single-dose nebulizer is opened by twisting off the tip.	257	99.6	1	0.4	0	0.0
	The physician-prescribed dose of medication is emptied into the nebulizer chamber immediately before administration.	255	98.8	3	1.2	0	0.0
	If the entire single-dose ampoule is not used, the remaining medication is discarded.	244	94.6	10	3.9	4	1.6
	It is ensured that the medication volume does not exceed the minimum or maximum capacity of the nebulizer chamber.	254	98.4	1	0.4	3	1.2
	The chamber lid is closed tightly by turning it clockwise to prevent leakage.	257	99.6	1	0.4	0	0.0
	The nebulizer device is turned on using the on/off button.	258	100.0	0	0.0	0	0.0
	The nebulizer chamber is held in an upright position.	254	98.4	1	0.4	3	1.2
	During operation, the formation of a fine mist emerging from the medication chamber is observed.	256	99.2	1	0.4	1	0.4
	The patient is instructed to sit comfortably in an upright position.	250	96.9	6	2.3	2	0.8
	The patient is instructed to breathe at a normal, relaxed rate.	254	98.4	3	1.2	1	0.4
	If a mouthpiece is used, the patient is instructed to inhale through the mouth.	166	64.3	3	1.2	89	34.5
	The patient is instructed to continue inhalation until the mist ceases.	256	99.2	1	0.4	1	0.4
	Once the medication is fully administered, the device is turned off using the on/off button.	258	100.0	0	0.0	0	0.0
	Hands are washed after medication administration.	258	100.0	0	0.0	0	0.0
	After administration of medications containing budesonide (e.g., Budecort®, Pulmicort®), the patient's mouth is rinsed with water.	211	81.8	14	5.4	33	12.8
	If budesonide-containing medication is administered via a face mask, the patient's face is washed after use.	205	79.5	7	2.7	46	17.8
	If medication mist comes into contact with the eyes, the patient is instructed to rinse the eyes thoroughly with water.	256	99.2	0	0.0	2	0.8
	In the event of adverse effects (e.g., dizziness, tremor, fever, or tachycardia), nebulizer treatment is discontinued, and the physician is notified.	257	99.6	0	0.0	1	0.4
	Following nebulized medication administration, the procedure is documented in the nursing observation form.	257	99.6	1	0.4	0	0.0

Table 2: Distribution of Responses to the Nurse Knowledge Form for Nebulized Medication Administration in Adults (n = 258) (continued)

Items		True		False		No idea	
		n	%	n	%	n	%
Nebulizer device maintenance after medication administration	After each medication administration, any remaining liquid in the reservoir is discarded.	241	93.4	6	2.3	11	4.3
	Distilled water is added to the reservoir, and the nebulizer is operated for a few seconds to flush the system.	145	56.2	37	14.3	76	29.5
	After use, the nebulizer is unplugged from the power source.	254	98.4	0	0.0	4	1.6
	The mask or mouthpiece, medication reservoir, and air hose are disconnected.	221	85.7	6	2.3	31	12.0
	After each use, the mask or mouthpiece is washed with warm water.	122	47.3	80	31.0	56	21.7
	After the final use of the day, the nebulizer reservoir, mask, or mouthpiece is disinfected.	167	64.7	30	11.6	61	23.6
	Cleaned parts are placed on a clean towel, cloth, or paper towel and allowed to air-dry.	224	86.8	4	1.6	30	11.6
	The exterior of the device and the air hose are wiped with a clean, damp cloth.	227	88.0	7	2.7	24	9.3
	Unless there is wear or damage that compromises effective use, the nebulizer reservoir, air hose, and mask or mouthpiece are replaced every six months.	208	80.6	9	3.5	41	15.9

Table 3: Mean Scores on the Total and Sub-Dimensions of the Nurse Knowledge Form for Nebulized Medication Administration in Adults

	Mean ± SD (Min. - Max.)
Nebulizer device preparation	9.29 ± 1.36 (0 - 10)
Safe nebulized medication preparation	8.71 ± 1.14 (4 - 10)
Safe nebulized medication administration	22.68 ± 1.49 (18 - 24)
Nebulizer device maintenance after medication administration	7.01 ± 2.04 (0 - 9)
Nurse Knowledge Form for Nebulized Medication Administration in Adults **(Total)**	47.68 ± 4.58 (24 - 53)

SD: Standard Deviation; Min.-Max.: Minimum-Maximum.

Table 4: The Relationship between Scores on the Total and Sub-Dimensions of the Nurse Knowledge Form for Nebulized Medication Administration in Adults (n = 258)

Scale and Sub-Dimensions		Nurse Knowledge Form for Nebulized Medication Administration in Adults	Nebulizer device preparation	Safe nebulized medication preparation	Safe nebulized medication administration	Nebulizer device maintenance
Nurse Knowledge Form for Nebulized Medication Administration in Adults	r	1.00				
	p					
Nebulizer device preparation	r	0.58	1.00			
	p	**0.00***				
Safe nebulized medication preparation	r	0.70	0.46	1.00		
	p	**0.00***	**0.00***			
Safe nebulized medication administration	r	0.76	0.30	0.41	1.00	
	p	**0.00***	**0.00***	0.00**		
Nebulizer device maintenance	r	0.82	0.29	0.47	0.50	1.00
	p	**0.00***	**0.00***	0.00**	0.00**	

r: *Spearman Correlation; **Pearson Correlation; *p < 0,01: Level of significance

The mean total knowledge score for nebulized medication administration in adults was 47.68 ± 4.58 (24 - 53). Subscale mean scores were 9.29 ± 1.36 (0 - 10) for nebulizer device preparation, 8.71 ± 1.14 (4 - 10) for safe nebulized medication preparation, 22.68 ± 1.49 (18 - 24) for safe nebulized medication administration, and 7.01 ± 2.04 (0 - 9) for nebulizer device maintenance (Table 3).

Correlation analysis revealed a moderate positive correlation between total knowledge scores and nebulizer device preparation (r = 0.58), a strong positive correlation with safe nebulized medication preparation (r = 0.70) and safe nebulized medication administration (r = 0.76), and a very strong positive correlation with device maintenance (r = 0.82) (p < 0.01 for all) (Table 4).

Nurses' mean age and total professional experience demonstrated weak but statistically significant positive correlations with safe nebulized medication administration scores (r = 0.23, p < 0.001; r = 0.24, p < 0.001, respectively) (Table 5).

Table 5: Comparison of Scores on the Total and Sub-dimensions of the Nurse Knowledge Form for Nebulized Medication Administration in Adults according to Categorical Variables

	Sum/Total Scale	Sub-dimensions								
		Nebulizer device preparation		Safe nebulized medication preparation		Safe nebulized medication administration		Nebulizer device maintenance		
	Mean ± SD	Test	Mean ± SD	Test	Mean ± SD	Test	Mean ± SD	Test	Mean ± SD	Test
Ward/clinic/unit										
a. Internal medicine	46.78 ± 5.40	$\chi2$ = 6.102 p = 0.19	9.14 ± 1.65	$\chi2$ = 5.282 p = 0.26	8.44 ± 1.27	F = 3.271 p = 0.01*† a < d	22.54 ± 1.64	F = 0.910 p = 0.46	6.65 ± 2.34	F = 2.335 p = 0.06
b. Surgical wards	48.60 ± 3.91		9.47 ± 0.78		8.87 ± 1.17		23.10 ± 1.21		7.17 ± 2.07	
c. Emergency	48.80 ± 3.27		9.59 ± 1.02		8.93 ± 0.69		22.76 ± 1.37		7.54 ± 1.33	
d. Intensive care	48.38 ± 3.40		9.31 ± 1.16		9.00 ± 0.97		22.70 ± 1.35		7.36 ± 1.54	
e. Other	46.50 ± 5.37		9.00 ± 1.31		8.63 ± 1.51		22.50 ± 1.69		6.38 ± 2.67	
Frequency of nebulized medication administration (daily)										
a. Once a day	48.70 ± 2.41	$\chi2$ = 0.363 p = 0.83	9.30 ± 0.82	$\chi2$ = 0.597 p = 0.74	8.90 ± 1.29	F = 0.544 p = 0.58	23.10 ± 1.10	F = 0.736 p = 0.48	7.40 ± 2.12	F = 3.356 p = 0.04*‡ c < b
b. More than once a day	47.97 ± 3.98		9.31 ± 1.32		8.74 ± 1.06		22.71 ± 1.45		7.21 ± 1.75	
c. When needed	46.88 ± 5.86		9.23 ± 1.52		8.60 ± 1.29		22.55 ± 1.61		6.51 ± 2.52	
Previous training in nebulized medication administration		Z = -3.778 p = 0.00*		Z = -1.372 p = 0.17		T = -0.003 p = 1.00		T = -4.280 p = 0.00*		T = -3.566 p = 0.00*
a. Yes	49.61 ± 3.39		9.55 ± 0.83		8.71 ± 1.15		23.45 ± 0.92		7.90 ± 1.43	
b. No	47.21 ± 4.71		9.22 ± 1.46		8.71 ± 1.14		22.49 ± 1.54		6.79 ± 2.10	
Perceived knowledge regarding nebulizer device preparation		$\chi2$ = 17.400 p = 0.00* b. c < a		$\chi2$ = 13.172 p = 0.00* b. c < a		F = 4.937 p = 0.01*‡ b. c < a		F = 3.917 p = 0.02*‡ b < a		F = 8.276 p = 0.00*† c < a
a. Yes	48.64 ± 3.81		9.51 ± 1.01		8.87 ± 1.08		22.86 ± 1.41		7.40 ± 1.72	
b. No	45.19 ± 6.40		8.63 ± 2.12		8.26 ± 1.05		22.11 ± 1.71		6.19 ± 2.54	
c. Moderate	46.48 ± 4.78		9.04 ± 1.58		8.51 ± 1.13		22.48 ± 1.50		6.45 ± 2.27	
Perceived knowledge regarding nebulized medication preparation		$\chi2$ = 30.273 p = 0.00* b. c < a		$\chi2$ = 35.929 p = 0.00* b. c < a		F = 12.564 p = 0.00*§ b. c < a		F = 8.483 p = 0.00*† c < a		F = 13.423 p = 0.00*† c < a
a. Yes	48.69 ± 3.54		9.57 ± 0.86		8.88 ± 1.06		22.89 ± 1.36		7.35 ± 1.70	
b. No	42.00 ± 7.96		7.45 ± 2.70		7.55 ± 1.51		21.82 ± 2.09		5.18 ± 3.13	
c. Moderate	45.10 ± 5.27		8.62 ± 1.91		8.29 ± 1.13		22.08 ± 1.61		6.12 ± 2.46	
Perceived knowledge regarding nebulized medication administration		$\chi2$ = 24.774 p = 0.00* a. c > b a > c		$\chi2$ = 35.177 p = 0.00* b. c < a		F = 12.204 p = 0.00*§ a. c > b		F= 9.956 p = 0.00*§ a. c > b		F = 21.529 p = 0.00*† a. c > b
a. Yes	48.38 ± 3.82		9.49 ± 1.15		8.83 ± 1.07		22.82 ± 1.40		7.25 ± 1.75	
b. No	38.91 ± 7.46		7.27 ± 2.69		7.27 ± 1.42		20.91 ± 2.07		3.45 ± 2.70	
c. Moderate	46.23 ± 4.61		8.71 ± 1.34		8.40 ± 1.12		22.40 ± 1.44		6.71 ± 2.36	
Perceived knowledge regarding nebulizer device maintenance		$\chi2$ = 37.190 p = 0.00* a. c > b a > c		$\chi2$ = 15.305 p = 0.00* b. c < a		F = 12.358 p = 0.00*§ a. c > b		F = 8.932 p = 0.00*† b. c < a		F = 31.745 p = 0.00*† a. c > b a > c
a. Yes	49.27 ± 3.31		9.58 ± 0.92		8.96 ± 1.06		23.03 ± 1.24		7.69 ± 1.49	
b. No	43.65 ± 6.22		8.76 ± 1.99		7.95 ± 1.25		21.97 ± 1.85		4.97 ± 2.52	
c. Moderate	47.20 ± 4.23		9.11 ± 1.46		8.67 ± 1.08		22.49 ± 1.52		6.92 ± 1.91	
Frequency of oral care after nebulized medication administration		$\chi2$ = 28.713 p = 0.00* a. b > c		$\chi2$ = 10.312 p = 0.01* a. b > c		F = 4.654 p = 0.01*† b > c		F = 11.309 p = 0.00*† a > c		F = 18.989 p = 0.00*† a. b > c
a. After each nebulization	49.35 ± 3.41		9.55 ± 0.96		8.80 ± 1.15		23.21 ± 1.14		7.79 ± 1.53	
b. Once a day	48.42 ± 3.32		9.49 ± 0.96		8.94 ± 0.92		22.69 ± 1.39		7.31 ± 1.53	
c. None	45.63 ± 5.52		8.90 ± 1.79		8.44 ± 1.25		22.20 ± 1.67		6.09 ± 2.41	

x2: Kruskal-Wallis H Test; F: One-Way Analysis of Variance (ANOVA); Z: Mann-Whitney U Test; T: Independent Samples T-Test; *p < 0.05: Level of Significance; †: Games-Howell test, ‡: LSD test, §: Tukey HSD test was used for post-hoc comparisons.

Nurses who had received training on nebulized medication administration had higher mean knowledge scores for nebulized medication administration, safe nebulized medication administration, and device maintenance compared to those who had not received training ($p < 0.001$, $p < 0.001$, $p < 0.001$, respectively) (Table 5).

Nurses who performed oral care after each nebulized medication administration in adult patients receiving nebulizer therapy had higher mean scores for nebulizer device preparation, safe nebulized medication administration, and device maintenance compared to those who did not ($p < 0.001$, $p = 0.01$, $p < 0.001$, $p < 0.001$, respectively) (Table 5).

Discussion

The findings of this study indicate that while nurses demonstrate a satisfactory level of general knowledge regarding nebulized medication administration in adults, specific clinical competencies particularly those related to drug dilution, combined medication protocols, and device maintenance require further refinement. In alignment with these results, previous research has identified that while nurses often possess a foundational understanding of nebulization, there are recurring areas in clinical practice that necessitate further training, particularly within adult patient populations where specific studies remain limited (Ulus et al., 2007, Güngör et al., 2012; Şahan et al., 2023). Inadequate knowledge in this area may result in incorrect medication administration, suboptimal drug dosing, and adverse patient outcomes (Ari & Restrepo, 2012; Della Zuana, Garcia, Juliani & Silva Filho, 2014; Duarte-de-Araújo, Teixeira, Hespanhol & Correia-de-Sousa, 2019; Riquena et al., 2019; Harb, Ibrahim Laz, Rabea & Abdelrahim, 2021). The effectiveness of nebulizer inhalation therapy is closely linked to both patient education and the level of knowledge held by healthcare professionals responsible for medication administration (Güngör et al., 2012; Duarte-de-Araújo et al., 2019; Harb et al., 2021). Accordingly, training on the correct and safe use of nebulizer devices is essential for ensuring patient safety and treatment efficacy (Ulus et al., 2007). In the present study, the majority of nurses reported that they had not received formal training on nebulized medication administration in adults. This finding is concerning, given that the International Council of Nurses (ICN, 2018) emphasizes nurses' central role in safeguarding patient safety. Therefore, the implementation of structured in-service training programs focused on accurate and safe nebulized medication administration is strongly recommended, and the sustainability of such educational initiatives should be ensured.

Proper preparation and assembly of nebulizer devices are critical to ensuring correct medication delivery and optimal device function (Dolovich & Dhand, 2011). In addition, all components of the nebulizer set should be disassembled and appropriately cleaned and disinfected after use to prevent contamination and maintain device performance (Bargaje et al., 2018). In the current study, most nurses reported checking the air filter prior to nebulizer use and replacing excessively soiled or obstructed filters. Nearly all participants demonstrated awareness of nebulizer device components and their correct assembly. Furthermore, the results indicated that nurses' knowledge levels regarding safe nebulized medication administration increased with age and total professional experience. This association may be attributed to greater clinical exposure and repeated medication administration over time. The results suggest that specialized orientation programs and standardized protocols are essential for nurses with less clinical experience. Supporting this interpretation, previous research has shown that increased experience with nebulized medication administration is associated with more accurate medication dilution, appropriate administration timing, and increased use of correct medication combinations (Şahan et al., 2023).

The Regulation on Ensuring Patient and Employee Safety, published by the Ministry of Health in the Official Gazette (2011), outlines key objectives for patient safety, including the accurate identification and verification of patient identity prior to medication administration and the assurance of medication safety. In the present study, all nurses reported washing their hands before and after nebulized medication administration, verifying medication orders, checking the color of nebulized medications prior to use, and confirming patient identity. In addition, the majority of nurses demonstrated adequate knowledge regarding the safe preparation of nebulized medications, including appropriate storage conditions and necessary precautions prior to administration. Safe nebulized medication administration requires that medications be stored and prepared under appropriate conditions to maintain their effectiveness and safety (Gardenhire, Burnett, Strickland, & Myers, 2017). The high level of adherence demonstrated by nurses toward fundamental medication administration steps, such as hand hygiene and patient identification, indicates that nursing practice has successfully adopted and reflected national patient safety goals in the clinical setting.

For effective aerosol therapy, medications with a volume of less than 2 mL should be diluted with saline solution to achieve the desired particle size and nebulized volume. Moreover, to ensure that treatment is delivered within an appropriate time frame, the total volume placed in the nebulizer reservoir should not exceed 4 mL (Düdükçü & Arslan, 2016; Ohki et al., 2020). Şahan et al. (2023) reported that 68.12% of nurses administered nebulized medications following dilution, with 81.62% using saline solution, while 18.45% used water for injection. Similarly, Ergin (2021) found that 70% of healthcare professionals diluted nebulized medications; of these, 64.3% used saline solution, 28.6% used water for injection, 5% used dextrose, and 0.45% used sodium chloride. The literature indicates that nurses often lack sufficient knowledge regarding appropriate nebulized medication preparation and that considerable variability exists in dilution practices. Consistent with these findings, the present study revealed insufficient knowledge among nurses concerning the correct dilution of nebulized medications. Emphasizing the importance of standardized education on safe and correct nebulization practices may help prevent erroneous medication preparation and administration (Gardenhire et al., 2017). Therefore, enhancing nurses' knowledge, skills, and clinical practices related

to safe nebulized medication preparation is essential.

When multiple nebulized medications are prescribed, it is recommended that a minimum interval of 15 minutes be maintained between administrations and that the face mask and medication reservoir be rinsed with sterile water between doses to prevent potential drug interactions (Düdükçü & Arslan, 2016; Gardenhire et al., 2017). In the present study, 98.2% of nurses correctly responded that nebulized medications should be administered at intervals when multiple agents are required. The use of face masks during nebulized medication administration may result in aerosol deposition on the face and eyes due to leakage through mask openings. For this reason, mouthpieces are generally recommended when administering inhaled corticosteroids, antibiotics, or anticholinergics. However, face masks may be appropriate for patients experiencing severe respiratory distress or those who are unable to coordinate breathing effectively with a mouthpiece (Talwar et al., 2021). The findings of the present study indicated that nurses more frequently used face masks during nebulized medication administration. As the questionnaire did not include items specifying the type of medication administered with a face mask or mouthpiece, it was not possible to evaluate whether device selection was appropriately tailored to the medication used.

During nebulizer therapy, the patient's breathing pattern plays a critical role in determining the amount of medication delivered to the target site (Della Zuana et al., 2014; Sivadasan et al., 2021). Accordingly, nurses should ensure that patients are positioned upright and that the medication reservoir is held vertically throughout the administration process (Boe et al., 2001; Ulus et al., 2007; Güngör et al., 2012). In this study, 98.4% of nurses reported holding the nebulizer chamber upright, and 96.9% ensured that patients were seated in an upright and comfortable position.

For optimal nebulization, the airflow rate should be maintained within the recommended range of 6 - 8 L/min (Ohki et al., 2020). The majority of nurses in the present study reported adjusting airflow within this range, a finding consistent with that of Ulus et al. (2007). In contrast, other studies have reported substantially lower rates of correct responses regarding appropriate flow rate adjustment, including 10% in Ergin (2021) and 40.33% in Şahan et al. (2023). Similarly, Güngör et al. (2012) identified flow rate adjustment as one of the most common areas of incorrect practice. Establishing standardized protocols for nebulized medication administration and ensuring their consistent implementation may contribute to safer and more effective medication delivery.

During nebulized medication administration, oral care should be performed after each medication group to remove residual medication from the oral cavity and reduce the risk of oral infections. Failure to provide adequate oral care following nebulization may increase the likelihood of infection (Düdükçü & Arslan, 2016; Ohki et al., 2020). In the present study, approximately one-third of nurses reported performing oral care after each nebulized medication administration. In contrast, Şahan et al. (2023) reported that 73.63% of nurses provided oral care following nebulized medication administration. This discrepancy may be attributable to differences in nurses' working environments, institutional practices, and knowledge levels. Insufficient knowledge, limited clinical experience, demanding working conditions, and the absence of standardized medication administration protocols have been identified as factors contributing to medication administration errors (Wondmieneh et al., 2020). Accordingly, nurses should inform patients and their family members about potential oral complications prior to nebulized medication administration and emphasize the importance of oral care after treatment (Şahan et al., 2023). Consequently, it is essential to recognize oral care as an integral component of nebulization therapy, ensuring its integration into standardized care protocols and the systematic use of oral assessment tools in clinical practice.

Improper cleaning or delayed replacement of nebulizer devices and components used during nebulization may lead to microbial contamination and subsequent infection (Riquena et al., 2019; American Thoracic Society [ATS], 2020). Such infections pose a risk to pulmonary health (Ari & Restrepo, 2012; Della Zuana et al., 2014) and may contribute to prolonged hospital stays (Şahan et al., 2023). Unless visible damage or functional impairment is present, nebulizer components, including the medication chamber, air tubing, mask, and mouthpiece, should be replaced at six-month intervals (Düdükçü & Arslan, 2016; Gardenhire et al., 2017).

In the present study, 80.6% of nurses demonstrated accurate knowledge regarding appropriate replacement intervals for nebulizer components. Şahan et al. (2023), however, reported that only 18.15% of nurses cleaned or replaced the mask after each nebulizer use and that 37.52% replaced the mask only when it became visibly soiled. Although some nurses in the current study lacked knowledge regarding the timing of mask cleaning and replacement, the proportion of nurses with adequate knowledge was higher than that reported by Şahan et al. (2023).

To prevent medication crystallization and blockage of spray orifices, the nebulizer reservoir should be emptied after each use, rinsed with distilled water, and briefly operated to flush residual medication from the system. In addition, nebulizer components should be washed with hot water following medication administration (Gardenhire et al., 2017; Riquena et al., 2019; ATS, 2020; Barjaktarevic & Milstone, 2020). The majority of nurses participating in our study emptied the remaining medication from the reservoir after each medication administration, but only 56.2% put distilled water into the reservoir and ran the nebulizer device for a few seconds.

Limitations of the Study

This study has several limitations that should be considered when interpreting the findings. First, the use of a self-reported questionnaire may have introduced selection and response bias. Second, the study was conducted in a single healthcare center, which limits the generalizability of the results. Consequently, the findings reflect only the responses of nurses included in the sample and may not be representative of nurses working in other clinical settings or institutions.

Conclusion

This study demonstrates that nurses possess a satisfactory level of theoretical knowledge regarding nebulized medication administration and exhibit high adherence to fundamental patient safety goals, such as hand hygiene and identity verification. Despite these strengths, there is a clear need to enhance clinical competencies in specific technical areas, including airflow control, drug dilution, combined medication applications, drug administration via mouthpiece, mouth rinsing and facial cleaning based on the active ingredients, and the cleaning of the device and its connections. Furthermore, the findings highlight that post-nebulization oral care is a less frequently performed intervention, indicating a need for greater emphasis on this step to mitigate potential risks like oral candidiasis.

It is recommended that standardized protocols for the safe and accurate use of nebulizer devices be implemented in clinical settings. Additionally, the development of valid and reliable assessment tools for nebulizer inhalation practices in adults and the provision of regular training programs for nurses on nebulized medication administration are essential to improving patient safety and quality of care. Further research is needed to comprehensively evaluate nurses' knowledge levels and clinical practices related to nebulization in adult care.

Ethical Considerations: Ethical approval was obtained from Çanakkale Onsekiz Mart University Scientific Research Ethics Committee of a Graduate Education Institute (Date: 31.03.2022 and No: 07/13).

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