

Comparison of Aerosol Delivery Methods in Mechanically Ventilated Patients: Evaluating Differences in Drug Deposition, Patient Outcomes, and Side Effects

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Abstract:

Background: Aerosol delivery methods vary in effectiveness and patient tolerance, particularly in mechanically ventilated patients. This study aims to compare Metered-Dose Inhalers (MDIs) with spacers, nebulizers, and Dry Powder Inhalers (DPIs) in terms of drug deposition, pulmonary function improvement, patient outcomes, and side effects.

Methods: A mixed-methods approach was used, combining quantitative analysis of drug deposition, pulmonary function tests (PFTs), patient outcome scores, and side effect reporting with qualitative interviews from patients and clinicians. Data were collected from a sample of 120 mechanically ventilated patients across three hospitals.

Results: Nebulizers demonstrated the highest mean drug deposition (45.8%) and pulmonary function improvement (22.3% change in FEV1), followed by MDIs with spacers (30.2% deposition, 15.5% improvement) and DPIs (25.0% deposition, 12.4% improvement). Nebulizers also had the highest patient outcome score (8.1), though with a higher incidence of side effects (22%). MDIs and DPIs had lower side effect rates (18% and 10%, respectively) and were preferred for their ease of use and quicker treatment times, despite lower efficacy.

Conclusion: Nebulizers are more effective in delivering medication and improving pulmonary function but are associated with higher side effects. MDIs and DPIs, while less effective, offer benefits in terms of side effect profiles and patient convenience. Clinicians should weigh these factors when choosing aerosol delivery methods for mechanically ventilated patients.

Keywords: Aerosol Delivery, Mechanically Ventilated Patients, Nebulizers, Metered-Dose Inhalers, Dry Powder Inhalers, Drug Deposition, Pulmonary Function, Patient Outcomes, Side Effects

Introduction

Aerosol therapy is a cornerstone in the management of respiratory conditions in mechanically ventilated patients. Effective aerosol delivery is crucial for optimizing therapeutic outcomes, minimizing drug wastage, and reducing adverse effects. Mechanically ventilated patients, due to their altered respiratory mechanics, present unique challenges for aerosol administration. Consequently, selecting an appropriate aerosol delivery method is essential for ensuring adequate drug deposition and improving patient outcomes.

Several aerosol delivery methods are commonly used in mechanically ventilated patients, including metered-dose inhalers (MDIs) with spacers, nebulizers, and dry powder inhalers (DPIs). MDIs are widely utilized due to their portability and ease of use, but their efficacy can be influenced by the use of spacers. Nebulizers, which convert liquid medication into a mist, offer a high level of drug delivery but can be cumbersome and

time-consuming. Dry powder inhalers, while efficient in drug delivery, are less commonly used in mechanically ventilated patients due to their reliance on patient inhalation effort.

Previous studies have shown variability in drug deposition and clinical outcomes across these different delivery methods. For instance, nebulizers have been reported to achieve higher lung deposition compared to MDIs, but they may also pose risks of side effects such as systemic drug absorption and contamination (Tashkin et al., 2007; Zarogoulidis et al., 2013). On the other hand, MDIs, especially when used with spacers, offer a more controlled drug delivery but may suffer from lower deposition rates (Dhand, 2008).

Despite the existing body of research, there remains a need for a comprehensive comparison of these aerosol delivery methods specifically in mechanically ventilated patients. Understanding how different methods impact drug deposition, patient outcomes, and side effects can guide clinical practice and improve patient care.

This study aims to compare the efficacy of various aerosol delivery methods in mechanically ventilated patients by evaluating differences in drug deposition, patient outcomes, and side effects. The findings will provide insights into the optimal aerosol delivery approach for this patient population, potentially leading to enhanced therapeutic strategies and better management of respiratory conditions.

Literature Review

Aerosol Delivery Methods in Mechanically Ventilated Patients

Effective aerosol delivery is essential for managing respiratory diseases in mechanically ventilated patients. This literature review examines the various aerosol delivery methods used in these patients, focusing on drug deposition, patient outcomes, and side effects.

1. Metered-Dose Inhalers (MDIs)

MDIs are commonly used for delivering inhaled medications due to their convenience and efficiency in non-ventilated patients. When used with spacers, MDIs can improve drug delivery efficiency. However, in mechanically ventilated patients, MDIs face challenges related to airflow patterns and ventilator settings, which can affect drug deposition. Research has shown that while MDIs can be effective, their delivery efficiency may be compromised in mechanically ventilated patients compared to other methods (Tashkin et al., 2007; Zarogoulidis et al., 2013).

2. Nebulizers

Nebulizers convert liquid medication into an aerosol mist, which can be directly inhaled. They are often used in mechanically ventilated patients due to their ability to deliver larger doses of medication and their independence from patient inhalation effort. Studies indicate that nebulizers generally provide higher lung deposition rates compared to MDIs, particularly in patients with severe respiratory conditions (Ehrmann et al., 2017; Dhand, 2008). However, nebulizers can be associated with longer treatment times, higher drug wastage, and potential for system contamination (Hassan et al., 2017).

3. Dry Powder Inhalers (DPIs)

DPIs rely on the patient's inspiratory effort to disperse medication. They are less commonly used in mechanically ventilated patients due to the necessity for adequate patient inhalation, which is often compromised in this population. While DPIs offer high efficiency in drug delivery and minimal drug wastage, their reliance on patient effort limits their effectiveness in mechanically ventilated patients (Lee et al., 2018; Dhand, 2008).

4. Comparative Studies and Outcomes

Comparative studies have highlighted the differences in drug deposition among these aerosol delivery methods. Research suggests that nebulizers typically achieve better lung deposition compared to MDIs, but at the cost of increased drug exposure and potential side effects (Tashkin et al., 2007). Conversely, MDIs, especially when used with spacers, offer a more controlled delivery but may result in lower deposition rates. DPIs, while efficient in non-ventilated patients, are not ideal for mechanically ventilated individuals due to their dependence on patient inhalation (Lee et al., 2018; H Zarogoulidis et al., 2013).

5. Side Effects and Clinical Outcomes

Side effects associated with aerosol delivery methods include systemic absorption of medications, local airway irritation, and potential for infection due to nebulizer use (Ehmann et al., 2016). The choice of aerosol delivery method can also impact clinical outcomes, including the effectiveness of medication and overall patient comfort. Understanding these side effects and their implications is crucial for optimizing aerosol therapy in mechanically ventilated patients (Zarogoulidis et al., 2013; Dhand, 2008).

6. Gaps in Current Research

While existing studies provide valuable insights into aerosol delivery methods, there is a need for further research specifically focusing on mechanically ventilated patients. Most studies have concentrated on non-ventilated populations, and there is limited data on how different aerosol delivery methods compare in terms of drug deposition and clinical outcomes in this unique patient group.

Methodology

Study Design

This research utilized a comparative, cross-sectional study design to evaluate the efficacy of different aerosol delivery methods in mechanically ventilated patients. The study aimed to assess drug deposition, patient outcomes, and side effects associated with each delivery method.

Participants

The study included 120 mechanically ventilated patients from the ICU of a tertiary hospital. Inclusion criteria were:

- Adults aged 18 years or older
- Receiving mechanical ventilation for at least 48 hours
- Prescribed aerosol therapy as part of their treatment regimen

Exclusion criteria included:

- Pregnancy
- Presence of contraindications for aerosol therapy
- Participation in other clinical trials affecting aerosol therapy

Aerosol Delivery Methods

Participants were randomly assigned to receive aerosol therapy through one of the following methods:

1. Metered-Dose Inhalers (MDIs) with Spacers: MDIs were used with an appropriate spacer device to ensure optimal drug delivery.
2. Nebulizers: Jet nebulizers were employed to administer the medication, with settings adjusted according to the manufacturer's recommendations.

3. Dry Powder Inhalers (DPIs): DPIs were used where feasible, though their use was limited to patients with sufficient inspiratory effort.

Outcome Measures

1. Drug Deposition

- Measured using a gamma scintigraphy technique to visualize and quantify medication deposition in the lungs.
- Pulmonary function tests (PFTs) were also conducted to assess the functional impact of drug deposition.

2. Patient Outcomes

- Respiratory parameters (e.g., oxygenation, ventilation, and respiratory rates) were monitored and recorded.
- Clinical improvement was assessed using validated scales such as the Respiratory Severity Score and patient-reported outcomes.

3. Side Effects

- Documented based on patient reports and clinical observations.
- Included both systemic side effects (e.g., cardiovascular effects) and local effects (e.g., airway irritation).

Data Collection

Data were collected over a 6-month period. Drug deposition data were gathered during scheduled ventilation settings, while respiratory parameters and side effects were continuously monitored. Data collection forms were used to record all relevant information.

Data Analysis

Quantitative data were analyzed using statistical software (e.g., SPSS). Descriptive statistics were used to summarize baseline characteristics and outcomes. Comparative analyses were performed using ANOVA and post-hoc tests to determine differences in drug deposition, clinical outcomes, and side effects between delivery methods. Qualitative data from patient and clinician feedback were analyzed thematically to identify common experiences and challenges.

Ethical Considerations

The study was approved by the ethics committee. Informed consent was obtained from all participants or their legal representatives. All data were anonymized and handled confidentially to ensure patient privacy and compliance with ethical standards.

Findings

The study aimed to compare the effectiveness of different aerosol delivery methods in mechanically ventilated patients. The findings are presented below in a tabular format for quantitative data and thematic analysis for qualitative data.

Quantitative Findings

Aerosol Delivery Method	Drug Deposition (Mean %)	Pulmonary Function Improvement (Mean Change in FEV1%)	Patient Outcome Score (Mean Score)	Reported Side Effects (%)

Metered-Dose Inhalers (MDIs) with Spacers	30.2%	15.5%	7.2	18%
Nebulizers	45.8%	22.3%	8.1	22%
Dry Powder Inhalers (DPIs)	25.0%	12.4%	6.8	10%

Key Observations:

- Drug Deposition: Nebulizers had the highest mean drug deposition (45.8%), followed by MDIs with spacers (30.2%), and DPIs (25.0%).
- Pulmonary Function Improvement: Patients using nebulizers showed the greatest improvement in pulmonary function (mean change in FEV1 of 22.3%), compared to MDIs with spacers (15.5%) and DPIs (12.4%).
- Patient Outcome Scores: Nebulizer users reported the highest average outcome score (8.1), indicating better overall satisfaction with therapy.
- Reported Side Effects: The percentage of patients reporting side effects was highest with nebulizers (22%), followed by MDIs with spacers (18%), and lowest with DPIs (10%).

Qualitative Findings

Theme 1: Effectiveness of Delivery Methods

- Sub-theme: Perceived Efficacy
 - Participants' Replies: Many patients and clinicians reported that nebulizers were perceived as the most effective in delivering medication, with statements like, “The nebulizer seems to get the medication into my lungs better than the MDI” and “I notice a significant improvement in breathing after nebulizer treatments.”
- Sub-theme: Comparisons with MDIs and DPIs
 - Participants' Replies: Some expressed concerns about the MDI's efficiency, noting, “Using the MDI with a spacer feels less effective compared to nebulizers,” while DPIs were rarely used due to their reliance on patient effort.

Theme 2: Side Effects

- Sub-theme: Local Effects
 - Participants' Replies: Side effects such as throat irritation were frequently mentioned with MDIs and nebulizers. One participant noted, “I experience a sore throat after using the nebulizer, but it's worth it for the relief it provides.”
- Sub-theme: Systemic Effects
 - Participants' Replies: Systemic side effects, such as increased heart rate, were more commonly reported with nebulizers. One patient reported, “The nebulizer sometimes makes me feel jittery, which I don't experience with the MDI.”

Theme 3: Patient Satisfaction and Comfort

- Sub-theme: Ease of Use
 - Participants' Replies: Nebulizers were often described as easier to use, especially for patients who were critically ill. “The nebulizer requires less effort and feels more comfortable,” was a common remark.
- Sub-theme: Treatment Duration

- Participants' Replies: MDIs and DPIs were preferred by some for their quicker treatment times. A participant stated, “The DPI is fast and convenient, but it doesn’t seem as effective as the nebulizer.”

Discussion

This study aimed to evaluate and compare different aerosol delivery methods—MDIs with spacers, nebulizers, and DPIs—in mechanically ventilated patients. The findings provide valuable insights into drug deposition, patient outcomes, side effects, and overall satisfaction associated with each method.

Drug Deposition and Pulmonary Function

The study found that nebulizers resulted in the highest mean drug deposition (45.8%) compared to MDIs with spacers (30.2%) and DPIs (25.0%). This is consistent with the existing literature, which suggests that nebulizers, due to their ability to deliver medication in the form of a fine mist, are more effective in reaching the lower airways and achieving higher drug deposition (Zarogoulidis et al., 2013). The significant improvement in FEV1 observed with nebulizers (22.3%) supports their superior efficacy in enhancing pulmonary function compared to MDIs (15.5%) and DPIs (12.4%). This aligns with previous studies indicating that nebulizers can lead to greater clinical benefits in terms of respiratory improvement (Ehrmann et al., 2017).

Patient Outcomes and Satisfaction

Nebulizer users reported the highest average patient outcome score (8.1), indicating better overall satisfaction with the therapy. The ease of use and effectiveness of nebulizers contribute to this higher satisfaction. Conversely, DPIs, despite being quick and convenient, were associated with lower patient outcome scores (6.8) due to their reliance on adequate inspiratory effort, which may not be feasible for all mechanically ventilated patients (Lee et al., 2018).

Side Effects

The percentage of patients reporting side effects was highest with nebulizers (22%), followed by MDIs with spacers (18%) and lowest with DPIs (10%). Nebulizers were linked to systemic side effects such as jitteriness, while MDIs and DPIs primarily caused local effects like throat irritation. These findings are consistent with the literature, which highlights that nebulizers, while effective, can be associated with higher incidence of side effects due to their delivery mechanism (Dhand, 2008).

Qualitative Insights

Qualitative feedback revealed that patients and clinicians perceived nebulizers as the most effective and comfortable method for aerosol delivery. This is supported by comments such as “The nebulizer seems to get the medication into my lungs better than the MDI” and “It requires less effort.” However, nebulizers were also noted to cause more side effects, particularly throat irritation and systemic symptoms. This aligns with existing research that emphasizes the trade-off between effectiveness and side effects for nebulizer use (Hassan et al., 2017).

Comparison with Existing Literature

The results corroborate findings from other studies indicating that nebulizers are generally more effective in drug deposition and improving pulmonary function compared to MDIs and DPIs (Tashkin et al., 2007). However, the higher incidence of side effects with nebulizers suggests the need for careful monitoring and management of adverse effects, as highlighted by the observed systemic and local reactions.

Implications for Clinical Practice

These findings suggest that while nebulizers offer superior drug deposition and pulmonary function improvement, the associated side effects need to be managed appropriately. MDIs with spacers, though less effective in drug delivery, may be preferred in scenarios where side effects are a concern. DPIs, despite being less effective for mechanically ventilated patients, remain a viable option for patients with adequate inspiratory effort.

Future Research Directions

Further research could focus on exploring strategies to minimize the side effects associated with nebulizer use while maintaining its effectiveness. Additionally, investigating alternative delivery systems or modifications to existing devices could provide new insights into optimizing aerosol therapy for mechanically ventilated patients.

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