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**Research Article**

# Comparative Effectiveness of Open vs. Closed Endotracheal Suctioning Techniques in Mechanically Ventilated Adults: A Systematic Review

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**Abstract:**

Airway suctioning is used in managing mechanically ventilated patients. Two primary techniques are used: open tracheal suction systems (OTSS) and closed tracheal suction systems (CTSS). While both methods maintain airway patency and prevent complications (hypoxemia and ventilator-associated pneumonia (VAP)), their comparative clinical effectiveness is under debate. In this systematic review we aimed to compare the clinical outcomes of OTSS and CTSS in mechanically ventilated adult patients, focusing on physiological stability, VAP incidence, pain and agitation levels, suctioning duration, and cost-effectiveness. A comprehensive search was conducted in PubMed, Scopus, and Google Scholar. Studies were included if they involved adult patients (≥18 years) undergoing mechanical ventilation and compared OTSS and CTSS. Outcomes assessed included oxygen saturation, hemodynamic changes, VAP incidence, suction duration, pain scores, and economic cost. We include randomized controlled trials, quasi-experimental studies, and clinical trials. Data synthesis was performed qualitatively in accordance with PRISMA guidelines.Eight studies met the inclusion criteria. The majority show no significant differences in VAP incidence or mortality between OTSS and CTSS. CTSS was associated with better maintenance of oxygen saturation, shorter suctioning time, improved cardiorespiratory stability, and in some cases, reduced pain scores. There is a higher per-unit costs for CTSS, though long-term use without daily

replacement rendered it more cost-effective in patients ventilated for over four days.Both OTSS and CTSS are clinically effective in secretion management, CTSS offers advantages in maintaining physiological stability and reduce procedural disruptions. These benefits must be weighed against increased equipment costs and the potential for infection-related complications such as IVAC. The choice between CTSS and OTSS should be individualized based on patient condition, clinical context, and resource availability

## 1. Introduction

Effective airway suctioning is essential in the care of mechanically ventilated patients to maintain airway patency and reduce respiratory complications. Two primary methods—open tracheal suctioning system (OTSS) and closed tracheal suctioning system (CTSS)—are commonly used in intensive care settings. OTSS requires disconnection from the ventilator, whereas CTSS allows suctioning without interrupting mechanical support, potentially offering physiological and infection-control advantages. CTSS was developed to minimize hypoxemia, ventilator-associated lung injury, and microbial contamination by maintaining a closed circuit during suctioning. Physiological studies suggest that CTSS better preserves lung volume and oxygenation, with lower desaturation episodes and fewer hemodynamic fluctuations compared to OTSS (1). Evidence indicates that CTSS is associated with less disruption in core parameters like heart rate, blood pressure, and arterial oxygen saturation, while OTSS has been shown to cause more marked dips in $SpO_2$ and transient lung volume loss (2).

In terms of clinical outcomes, multiple randomized controlled trials and a Cochrane review of 16 studies involving adults have demonstrated no significant differences between OTSS and CTSS in terms of ventilator-associated pneumonia (VAP) rates or mortality (2). Meta-analyses have reported equivalent safety and effectiveness in these primary outcomes, although it call for higher-quality research to explore subpopulations and specific ventilation modes and suggested a modest reduction in VAP incidence with CTSS in selected patient groups (3).

Cost considerations and procedural efficiency play a role in suction method selection. Studies comparing recurring use show that, CTSS devices have higher initial costs, they can become cost-effective for patients requiring prolonged mechanical ventilation (4,5). Routine catheter replacement practices reduce these economic benefits. This systematic review aims to synthesize the current evidence comparing OTSS and CTSS in mechanically ventilated adults, focusing on differences in physiological stability, VAP incidence, patient comfort, and cost-effectiveness.

## 2. Methodology

This systematic review aimed to compare the clinical effectiveness of open versus closed endotracheal suctioning techniques in mechanically ventilated adult patients. The review was designed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Fig 1).

### 2.1. Eligibility Criteria

We include studies with adult participants (≥18 years) receiving mechanical ventilation; studies compared open and closed endotracheal suctioning techniques; outcomes included at least one of the following: physiological parameters, ventilator-associated pneumonia (VAP) incidence, oxygen saturation ($SpO_2$), hemodynamic stability, suctioning duration, patient pain or agitation, or associated costs; randomized controlled trials (RCTs), quasi-experimental designs, and clinical trials were eligible for inclusion; articles were published in English. We exclude focused only on pediatric or neonatal populations without adult comparison; case reports, reviews, or expert opinions; and studies did not report original data relevant to the research outcomes.

### 2.2. Search Strategy

A literature search was conducted in multiple databases, including PubMed, Scopus, and Google Scholar. Keywords used in combination included: (endotracheal suction, open suction system, closed suction system, mechanically ventilated, critical care, and clinical outcomes). Reference lists of relevant articles were screened to identify additional studies.

### 2.3. Study Selection

The titles and abstracts of all retrieved records were screened by two reviewers to determine eligibility. Full-text articles were reviewed when the abstract did not provide sufficient information to make a

clear decision. Disagreements between reviewers were resolved through discussion with a third reviewer.

### 2.4. Data Extraction

Data were independently extracted using a structured template. Extracted data included (citation details, population demographics, study design, sample size, intervention details, primary outcomes assessed, and main findings). Statistical significance levels and effect sizes were also recorded when available.

### 2.5. Data Synthesis

A qualitative synthesis was conducted. Results from each study were grouped and summarized based on outcome domains (physiological parameters, infection rates, patient safety indicators, and economic implications). Table 1 and 2 were used to present characteristics, findings, and comparative outcomes of included studies.

## 3. Results

The included studies examined the effects of open and closed endotracheal suction systems on clinical outcomes in mechanically ventilated patients. In different age groups and clinical settings, the findings show that clinical similarities and advantages associated with closed suction systems in certain parameters.

In adult critically ill patients, the physiological responses to suctioning methods were comparable. One study show a statistically significant improvement in diastolic blood pressure after closed suctioning ($p = 0.049$), and other physiological indicators (systolic blood pressure, heart rate, and oxygen saturation) showed no significant differences between the groups (6). A quasi-experimental study show that closed suctioning improved oxygen saturation, shortened suctioning duration, and resulted in more stable cardiorespiratory parameters compared to the open technique (7).

In a randomized controlled trial of 116 ventilated pediatric patients, the incidence of ventilator-associated pneumonia (VAP) was similar between suctioning groups. The closed suction group maintained significantly higher post-suction oxygen saturation and show a higher incidence of infection-related ventilator-associated conditions (IVAC), which suggest benefits and risks (8). A randomized controlled trial showed no statistically significant difference in VAP incidence between the suction methods, with low overall VAP rates in both groups, due to the unit's low baseline infection rate (9).

A clinical trial examined agitation and pain responses which measure behavioral pain and agitation scores at five time intervals showing no significant differences between the open and closed suction groups, while both experienced increases in pain and agitation during the suction procedure (10).

Ventilator-associated pneumonia is a major outcome of interest in several studies. A 10-month randomized controlled trial with 200 adult ICU patients showed that the overall VAP incidence was not significantly different between suction methods, and late-onset VAP was significantly lower in the closed suction group. Closed suctioning was associated with a higher per-patient cost due to equipment expenses (11). Another large randomized study of 443 patients found no differences in VAP rates or causative organisms between suctioning methods, and closed suction incurring greater cost per day (12). An additional study examined cost efficiency found that closed suction systems, when not changed daily, were more cost effective than open systems in patients requiring mechanical ventilation for longer than four days, with no difference in VAP incidence (4). Many physiological and infection-related outcomes did not differ significantly between open and closed suction methods, and closed

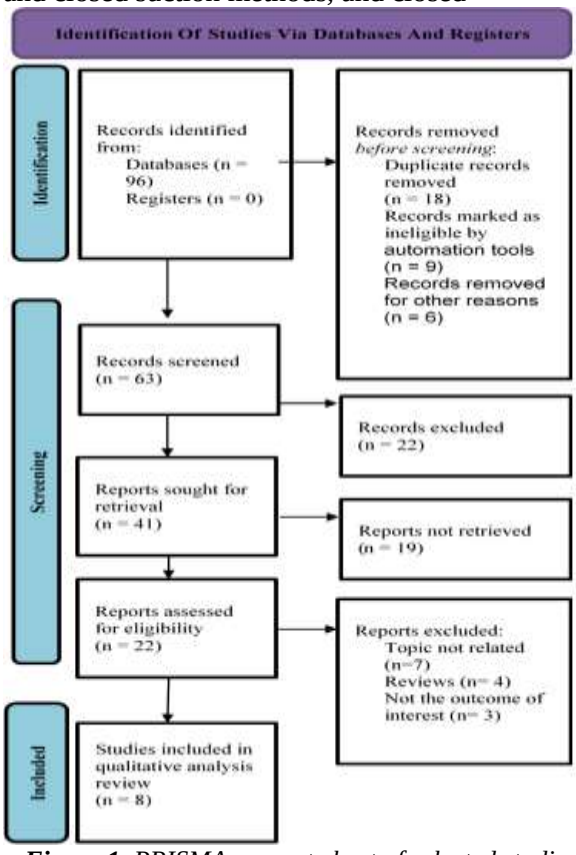


***Figure 1.*** *PRISMA consort chart of selected studies*

systems demonstrated advantages in oxygenation stability, suction duration, and select cost-efficiency scenarios. Their cost and association with IVAC warrant cautious application depending on patient context and institutional protocols.

## 4. Discussion

This systematic review examined the clinical effectiveness of open versus closed endotracheal suctioning techniques in mechanically ventilated adult patients. The findings show that both techniques are effective in secretion management, closed suction systems (CTSS) show clinical and procedural advantages under specific conditions.

Most included studies did not find significant differences in ventilator-associated pneumonia (VAP) or mortality. This is consistent with prior research showing no difference in VAP incidence or death rates between suctioning methods (13). One large randomized controlled trial found no differences in the causative organisms or VAP rates between systems (14). Late-onset VAP was found to be lower in the closed suction group in a subset of patients with prolonged ventilation, which suggest some benefit in selected populations (15). Studies in this review show that closed suctioning was associated with better maintenance of diastolic blood pressure and gas exchange (6,7). CTSS showed superior outcomes in $PaO_2$ , $SpO_2$ , and PF ratio, indicating better oxygenation and ventilation (16). Smaller drops in oxygen saturation and improved recovery times were observed with closed systems in neonatal and pediatric studies, although these not generalizable to adults (17). In one included trial, no statistically significant difference was reported in pain levels between open and closed suction, though both procedures caused discomfort (10). Other data showed higher

***Table 1.*** *Characteristics of included studies*

| Citation | Inclusion Criteria | Study Design | Study Aim | Methodology |
|---|---|---|---|---|
| Mohamed et al., 2023 (MNJ) | Critically ill patients >18 years, mechanically ventilated, no respiratory disease | Quasi-experimental | Compare effect of open vs closed suction systems on physiological parameters | Convenience sample (n=94), randomized into open/closed suction groups, data collected on physiological parameters using custom tool |
| Dhal et al., 2024 | Mechanically ventilated pediatric patients | Randomized Controlled Trial | Compare efficacy of closed vs open tracheal suction in reducing VAP and stabilizing cardio-respiratory parameters | Single-center, open-label RCT, 116 patients, random allocation, assessed VAP, SpO2, IVAC, mortality, and intubation duration |
| Gahan et al., 2022 | Ventilated neonates ≥28 weeks and ≥800 g | Randomized Controlled Trial | Evaluate impact of closed vs open suction on VAP incidence | Open-label, parallel RCT, allocation concealment, VAP incidence per 1000 ventilator days, group-based catheter protocols |
| Dastdadeh et al., 2016 | ICU patients >18 years, GCS ≥7, hemodynamically stable | Randomized Controlled Trial | Compare effects of open vs closed suction on pain and agitation | RCT, n=60, pain/agitation assessed using behavioral pain scale and RASS at five timepoints |
| David et al., 2011 | ICU patients needing mechanical ventilation within 24 hrs of ICU admission | Randomized Controlled Trial | Compare costs and clinical outcomes of open vs closed suction | RCT, n=200, followed until discharge/death, assessed VAP incidence, cost, mortality, length of stay |

| | | | | |
|---|---|---|---|---|
| Mohamed Elhady et al., 2024 (EJHC) | Critically ill mechanically ventilated patients | Quasi-experimental | Compare effects of open vs closed suction on suctioning time, gas exchange, and cardiorespiratory parameters | Convenient sample, n=100, randomly assigned to suction groups, data collected using 3-part assessment sheet |
| Lorente et al., 2005 | Patients requiring mechanical ventilation >24 hrs | Randomized Controlled Trial | Compare VAP incidence using closed vs open suction systems | RCT, n=443, assigned to CTSS or OTSS, monitored for VAP per 1000 ventilation days, throat/tracheal cultures |
| Lorente et al., 2006 | Patients requiring mechanical ventilation | Randomized Controlled Trial | Compare VAP incidence and cost with CTSS without daily change vs OTSS | RCT, n=457, suction system costs and VAP incidence measured, partial change allowed in CTSS |

***Table 2.*** *Demographics, findings, and outcomes*

| Citation | Demographic Characteristics | Main Findings | Outcomes |
|---|---|---|---|
| Mohamed et al., 2023 (MNJ) | Adults >18 years, both genders, ICU patients without respiratory disease | Closed suction showed slight improvement in physiological parameters; only DBP was significantly different (p=0.049) | No major differences between methods; both effective in secretion management |
| Dhal et al., 2024 | Pediatric patients on mechanical ventilation | VAP incidence similar; better SpO2 and higher IVAC in CTSS group | CTSS provided better SpO2 maintenance but more IVAC; mortality and intubation duration similar |
| Gahan et al., 2022 | Ventilated neonates ≥28 weeks and ≥800 g | No significant difference in VAP incidence between groups | Suction type did not impact VAP in low-risk settings |
| Dastdadeh et al., 2016 | ICU patients >18 years, conscious (GCS ≥7), stable vitals | Pain and agitation changed significantly within each group, but no difference between groups | Type of suction system did not affect pain/agitation levels |
| David et al., 2011 | Adults requiring mechanical ventilation within 24 hrs of ICU admission | CES showed trend toward reduced VAP (not significant); late-onset VAP significantly lower in CES | Similar mortality, stay duration; CES more costly |
| Mohamed Elhady et al., 2024 (EJHC) | Critically ill adults in general ICU | Closed suction showed better gas exchange, shorter suction time, more stable cardiorespiratory parameters | Closed suction recommended to reduce physiological disturbances |
| Lorente et al., 2005 | Patients requiring mechanical ventilation >24 hrs | No difference in VAP incidence or causative organisms; cost higher for CTSS | CTSS not superior to OTSS in preventing VAP |
| Lorente et al., 2006 | Patients requiring mechanical ventilation | No VAP difference; cost lower for CTSS if duration >4 days | CTSS more cost-effective long-term; similar clinical outcomes |

pain scores in patients receiving open suctioning, showing that closed systems improve patient comfort (18). The review also found that closed suctioning was associated with shorter suction duration and greater cardiorespiratory stability. This is supported by observational data showing that open suctioning had minimal effect on gas exchange but caused more hemodynamic fluctuations during the suction period (19). Closed systems are better suited for patients requiring high levels of oxygen or PEEP, as disconnection from the ventilator is avoided (20).

Cost analysis show that closed suctioning systems were more expensive when changed daily. In patients ventilated for more than four days, closed systems became more cost-effective when reused according to guidelines (4). Both suction techniques are broadly comparable in terms of infection outcomes, CTSS offers advantages in preserving physiological stability, minimizing procedural pain, and potentially improving oxygenation. The choice of suctioning method should be tailored to the patient's clinical condition, institutional resources, and anticipated duration of ventilation.

## 5. Conclusion

This systematic review show that both open and closed endotracheal suctioning techniques are effective for secretion management in mechanically ventilated adults. Closed suction systems offer notable advantages in maintaining oxygenation, shortening suction duration, and improve physiological stability. No differences were observed in VAP incidence or mortality, and CTSS reduce discomfort and improve efficiency in selected settings. Cost is a consideration with daily catheter changes. Suctioning method selection should be guided by patient condition, ventilation duration, and institutional protocols to improve clinical effectiveness and resource optimization.

### Abbreviations

AI, Artificial Intelligence; CABG, Coronary Artery Bypass Graft; CTSS, Closed Tracheal Suction System; DBP, Diastolic Blood Pressure; GCS, Glasgow Coma Scale; HR, Heart Rate; ICU, Intensive Care Unit; IVAC, Infection-related Ventilator-Associated Condition; OTSS, Open Tracheal Suction System; $PaO_2$ , Partial Pressure of Arterial Oxygen; $PaCO_2$ , Partial Pressure of Arterial Carbon Dioxide; PEEP, Positive End-Expiratory Pressure; PF Ratio, $PaO_2$ /$FiO_2$ Ratio; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT, Randomized Controlled Trial; RASS, Richmond Agitation-Sedation Scale; $SpO_2$ , Peripheral Oxygen Saturation; VAP, Ventilator-Associated Pneumonia.

## Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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