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Risk of Acute Respiratory Infection Transmission to Healthcare Workers During Aerosol-Generating Procedures

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Abstract

Introduction: The transmission of acute respiratory infections (ARIs) to healthcare workers (HCWs) during aerosol-generating procedures (AGPs) poses a significant risk, necessitating effective infection control measures. This systematic review aimed to evaluate the effectiveness of various interventions designed to mitigate the risk of ARI transmission to HCWs during AGPs.

Methods: A comprehensive search was conducted across PubMed, Embase, Scopus, and the Cochrane Library for interventional studies and clinical trials published in the last five years up to 2022. Studies were included if they assessed the risk of ARI transmission to HCWs during AGPs and evaluated the effectiveness of preventive measures. The primary outcomes included the incidence of ARI transmission, with adjusted risk ratios (aRRs) and confidence intervals (CIs) used to quantify the effectiveness of interventions.

Results: Seven studies met the inclusion criteria, encompassing a range of interventions including enhanced personal protective equipment (PPE), procedural modifications, engineering controls, and educational programs. Notably, the use of fitted N95 respirators significantly reduced ARI transmission risk compared to surgical masks (aRR = 0.22, 95% CI: 0.09-0.54). Implementing portable high-efficiency particulate air (HEPA) filters in AGP areas was associated with a lower incidence of ARI transmission (aRR = 0.53, 95% CI: 0.30-0.92). Educational interventions, although varied in design, consistently demonstrated a positive impact on reducing transmission risks.

Conclusions: This review highlights the effectiveness of a multifaceted approach to preventing ARI transmission to HCWs during AGPs. Enhanced PPE, specifically fitted N95 respirators, combined with engineering controls such as HEPA filters, and comprehensive educational programs, significantly reduce the risk of ARI transmission. These findings support the implementation of combined interventions to ensure the safety of HCWs in healthcare settings.

Keywords: Aerosol-Generating Procedures, Acute Respiratory Infections, Healthcare Workers, Personal.

Introduction

The risk of acute respiratory infection (ARI) transmission to healthcare workers (HCWs) during aerosol-generating procedures (AGPs) has long been a concern within the medical community. AGPs, which include intubation, bronchoscopy, and high-flow nasal oxygen therapy, among others, are essential for diagnosing and treating patients with various respiratory conditions. However, these procedures have the potential to release airborne particles that may contain infectious agents, posing a significant risk to HCWs. Studies have shown that HCWs involved in AGPs are at a higher risk of acquiring infections, with the transmission rates of ARIs significantly higher compared to non-aerosol-generating care activities, estimated at a 4.5-fold increase in infection risk [1]. This heightened risk underscores the need for effective infection control measures to protect HCWs from occupational exposure to infectious aerosols.

The prevalence of ARIs such as influenza, tuberculosis, and SARS-CoV-2 among healthcare settings further complicates the safety of HCWs during AGPs. For instance, during the COVID-19 pandemic, the transmission rate of SARS-CoV-2 to HCWs was alarmingly high, with some reports indicating that up to 29% of all COVID-19 cases were among healthcare personnel, significantly higher than the rate of transmission to the general population [2]. This elevated risk is partly attributed to the exposure of HCWs to high concentrations of viral particles during AGPs, especially in poorly ventilated spaces or when appropriate personal protective equipment (PPE) is not adequately used. Moreover, the variability in the efficacy of PPE, depending on the type and quality of the equipment used, can also influence the risk of transmission [3]. The impact of AGPs on the transmission of ARIs is not only limited to viral infections but extends to bacterial and fungal infections as well. Tuberculosis (TB), for example, remains a significant occupational hazard for HCWs, with studies indicating that HCWs are twice as likely to contract TB as the general population, with an even higher risk associated with exposure during AGPs [4]. The role of environmental factors, such as the adequacy of ventilation and air filtration systems in healthcare settings, further influences the risk of airborne transmission of infections during AGPs. Implementing effective infection control strategies, including engineering controls such as negative pressure rooms and high-efficiency particulate air (HEPA) filtration, has been shown to reduce the risk of transmission significantly [5]. Furthermore, the psychological impact of the perceived risk of infection can also affect the well-being and job performance of HCWs, with reports indicating a significant increase in stress and anxiety levels among HCWs performing AGPs during pandemic outbreaks [6-10]. The objective was to synthesize data on the prevalence, risk factors, and mitigation strategies associated with ARI transmission during AGPs in healthcare settings. By doing so, we sought to identify gaps in the current knowledge and provide evidence-based recommendations for protecting HCWs from occupational exposure to infectious aerosols.

Methods

For this systematic review, a comprehensive search strategy was developed to identify relevant studies that investigated the risk of acute respiratory infection (ARI) transmission to healthcare workers (HCWs) during aerosol-generating procedures (AGPs). The search was meticulously conducted across several electronic databases, including PubMed, Embase, Scopus, and the Cochrane Library. The search terms were carefully selected to encompass a broad range of keywords and MeSH terms related to ARIs, AGPs, healthcare workers, and risk of transmission. Examples of search terms used included "aerosol-generating procedures," "acute respiratory infections," "healthcare workers," "transmission," and "occupational exposure." The search strategy was designed to be as inclusive as possible to capture all potentially relevant studies. The search was limited to

studies published in the last five years, up to the year 2022, to ensure the review focused on the most current evidence regarding ARIs and AGPs. This time frame was chosen to reflect the most recent practices and guidelines in healthcare settings, especially considering the impact of the COVID-19 pandemic on healthcare protocols and infection control measures. The decision to focus on interventional studies was made to identify evidence of effective strategies to mitigate the risk of ARI transmission during AGPs, thereby providing actionable insights for healthcare facilities.

The inclusion criteria for the systematic review were strictly defined. Only interventional studies that assessed the risk of ARI transmission to HCWs during AGPs and evaluated the effectiveness of preventive measures were considered. Studies needed to provide clear data on infection rates among HCWs, types of AGPs involved, and the specific interventions implemented. Studies were required to be published in English and in peer-reviewed journals to ensure the reliability and quality of the evidence included. Exclusion criteria were also established to refine the search. Studies that did not focus on AGPs, those that were observational without any intervention component, case reports, reviews, and studies published in languages other than English were excluded from the review.

The study selection process followed a structured approach. Initially, two reviewers independently screened the titles and abstracts of the retrieved articles for relevance based on the predefined inclusion and exclusion criteria. This initial screening phase led to the identification of potentially relevant studies. Subsequently, the full texts of these selected articles were obtained and independently assessed by the same two reviewers. Disagreements between reviewers at any stage of the selection process were resolved through discussion or, if necessary, consultation with a third reviewer. This step ensured a high level of rigor in the study selection process. After the selection process, data extraction was performed by the reviewers using a standardized data extraction form. This form was designed to capture essential information from each study, including study design, population characteristics, details of the AGPs performed, the nature of the interventions evaluated, and the outcomes related to ARI transmission to HCWs. Attention was paid to extract data on the effectiveness of various interventions, such as the use of personal protective equipment (PPE), environmental controls, and vaccination, among others.

The methodological quality of the included studies was assessed using appropriate quality assessment tools tailored to the study designs of the included studies. This assessment aimed to identify potential biases and evaluate the strength of the evidence presented. The synthesis of findings from the included studies focused on summarizing the evidence on the effectiveness of different interventions in reducing the risk of ARI transmission to HCWs during AGPs. This systematic approach to literature search, study selection, data extraction, and quality assessment provided a comprehensive overview of the current evidence on the topic, laying the groundwork for evidence-based recommendations to enhance the safety of HCWs during AGPs.

Results and discussion

In the results section of this systematic review, seven interventional studies and clinical trials were included, providing valuable insights into the effectiveness of various interventions aimed at reducing the risk of acute respiratory infection (ARI) transmission to healthcare workers (HCWs) during aerosol-generating procedures (AGPs). The sample sizes across these studies varied significantly, ranging from as few as 30 participants to over 1,000 HCWs, reflecting a wide range of study settings and populations [11-17]. The interventions examined in these studies were diverse, encompassing the use of enhanced personal protective equipment (PPE), implementation of specific procedural modifications during AGPs, introduction of engineering controls such as portable high-efficiency particulate air (HEPA) filters, and educational interventions aimed at improving infection control practices among HCWs. One study focused on the efficacy of fitting N95 respirators compared to surgical masks, reporting a significant reduction in ARI transmission among HCWs with an adjusted risk ratio (aRR) of 0.22 and a 95% confidence

interval (CI) of 0.09-0.54 [11]. Another trial evaluated the impact of using powered air-purifying respirators (PAPRs) during high-risk AGPs, finding a risk reduction with an aRR of 0.32 (95% CI, 0.18-0.56) [12].

Procedural modifications, such as the use of protective barriers during endotracheal intubation, were investigated in another study, which reported a decrease in transmission risk with an aRR of 0.41 (95% CI, 0.24-0.69) [13]. The introduction of portable HEPA filters in AGP areas was associated with a lower incidence of ARI transmission in a clinical trial, showing an effectiveness with an aRR of 0.53 (95% CI, 0.30-0.92) [14]. Educational interventions, including simulation-based training on proper PPE use and AGP techniques, demonstrated a positive effect on reducing ARI transmission, although the results varied widely depending on the study design and outcome measures used [15].

Comparing these interventions, the studies highlighted the multifaceted approach required to effectively reduce the risk of ARI transmission to HCWs. While the use of enhanced PPE and engineering controls showed significant reductions in transmission rates, the effectiveness of these interventions was often influenced by the adherence to and the quality of the implementation. Educational interventions played a crucial role in supporting the effective use of PPE and adherence to infection control practices, suggesting that a combination of interventions is likely necessary to achieve optimal protection for HCWs during AGPs [16-17]. Overall, the included studies provided strong evidence that targeted interventions could significantly reduce the risk of ARI transmission to HCWs during AGPs. However, the variability in study designs, intervention types, and outcome measures underscore the complexity of evaluating and implementing infection control measures in healthcare settings. These findings underscore the need for comprehensive strategies that combine personal protective equipment, procedural modifications, engineering controls, and education to protect HCWs from ARI transmission during high-risk procedures. The discussion of the results from the included interventional studies and clinical trials highlights significant findings regarding the reduction of acute respiratory infection (ARI) transmission to healthcare workers (HCWs) during aerosol-generating procedures (AGPs). These findings reveal that targeted interventions, including enhanced personal protective equipment (PPE), procedural modifications, engineering controls, and educational strategies, can significantly mitigate the risk of transmission. Comparing the risk reduction observed in these studies to findings in the broader medical literature on other interventions provides an opportunity to evaluate the effectiveness and potential for integration of various strategies within healthcare settings.

The risk reductions reported in our review, with adjusted risk ratios (aRRs) ranging from 0.22 to 0.53 across different interventions [11-17], align with outcomes observed in other studies focusing on similar and additional preventive measures. For instance, studies examining the role of comprehensive infection control programs, including the systematic use of PPE, hand hygiene, and patient isolation, reported risk reductions in the transmission of ARIs with aRRs comparable to those found in our review [19,20]. This similarity underscores the critical importance of PPE and reinforces the need for adherence to established infection control practices.

Moreover, the effectiveness of engineering controls, such as the use of HEPA filters and negative pressure rooms, has been supported by other research, which reported aRRs indicating a substantial decrease in ARI transmission risk, comparable to the findings of the study included in our review that focused on HEPA filters [14,21,22]. These studies suggest that engineering controls play a vital role in reducing airborne particles and pathogens in healthcare settings, complementing the protective effects of PPE and procedural modifications. Educational interventions aimed at improving HCWs' knowledge and compliance with infection control measures have also been explored in the literature. Similar to the outcomes of the educational intervention study included in our review [15], other studies have shown varying levels of effectiveness, highlighting the challenges in measuring the direct impact of educational interventions on ARI transmission rates [23,24]. These findings suggest that while education is crucial, its

effectiveness may be enhanced when combined with other tangible interventions.

The integration of simulation-based training, as noted in one of the included studies [15], aligns with literature indicating improved compliance and technique among HCWs, potentially leading to lower ARI transmission rates [25,26]. This reflects the growing recognition of the value of hands-on, practical training in enhancing the efficacy of infection control measures. When comparing the numerical results of the included studies with those in the broader literature, it is evident that no single intervention is universally effective. The effectiveness of interventions varies based on the specific context, the pathogens involved, and the adherence to and quality of the implementation. This variability underscores the necessity for a multifaceted approach, combining multiple strategies to achieve the most effective protection against ARI transmission to HCWs during AGPs [27,28]. The findings from our systematic review are consistent with and supported by existing literature, reinforcing the importance of a comprehensive, layered approach to infection control in healthcare settings. The integration of enhanced PPE, procedural modifications, engineering controls, and educational initiatives is essential for minimizing the risk of ARI transmission to HCWs, particularly during AGPs. Future research should continue to explore the synergistic effects of combined interventions to establish the most effective and efficient strategies for protecting healthcare personnel.

The systematic review provides robust evidence supporting the overall effectiveness of physiotherapy interventions for individuals recovering from head and neck trauma. The inclusion of varied sample sizes and demographic characteristics, coupled with a broad spectrum of interventions, contributes to the generalizability of our findings. The calculated risk ratios consistently demonstrate significant improvements, including a substantial reduction in pain scores, a significant enhancement in range of motion, and a reasonable increase in functional outcomes. These results align with or surpass percentages reported in existing literature, affirming the positive impact of physiotherapy in this context. Despite acknowledged limitations, such as study heterogeneity and potential publication bias, our findings underscore the importance of tailored physiotherapeutic approaches based on the nature and severity of trauma. Moving forward, standardization of study designs and outcome measures is recommended to advance the comparability of research in this field. Clinically, our review advocates for the continued integration of physiotherapy, emphasizing a multifaceted strategy for optimizing outcomes in head and neck trauma rehabilitation[24] .

The systematic review presents several strengths that contribute significantly to its relevance and applicability in clinical practice. Firstly, its focus on interventional studies and clinical trials ensures that the evidence synthesized is based on interventions with potential for direct application in healthcare settings, offering practical insights into reducing the risk of acute respiratory infection (ARI) transmission to healthcare workers (HCWs) during aerosol-generating procedures (AGPs). The comprehensive search strategy, encompassing multiple databases and a wide range of keywords, enhances the review's thoroughness, capturing a broad spectrum of relevant literature. Furthermore, the inclusion of studies with varying designs and interventions allows for a comparative analysis, providing a nuanced understanding of the effectiveness of different strategies in mitigating transmission risks. This approach facilitates evidence-based decision-making, enabling healthcare facilities to implement tailored infection control measures that are supported by empirical evidence [25, 28].

However, the review also faces limitations that must be acknowledged. The variability in study designs, sample sizes, and intervention types across the included studies introduces challenges in directly comparing their outcomes, potentially affecting the consistency of the review's conclusions. Additionally, the restriction to studies published in English and within the last five years may have excluded relevant research, limiting the review's comprehensiveness. The focus on interventional studies, while valuable, may also overlook insights from observational studies that could offer additional perspectives on ARI transmission dynamics and the effectiveness of non-interventional prevention strategies.

Conclusions

This systematic review underscores the effectiveness of targeted interventions in reducing the risk of ARI transmission to HCWs during AGPs. Notably, the use of enhanced personal protective equipment (PPE), procedural modifications, and engineering controls like portable high-efficiency particulate air (HEPA) filters demonstrated significant risk reductions, with adjusted risk ratios (aRRs) ranging from 0.22 to 0.53. These findings highlight the importance of a multifaceted approach to infection control, combining multiple strategies to achieve optimal protection for healthcare personnel. As healthcare facilities continue to navigate the challenges of infectious disease outbreaks, the insights provided by this review offer valuable guidance for implementing effective preventive measures, ultimately contributing to safer healthcare environments.

Conflict of interests

The authors declared no conflict of interests.

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Table (1): Summary of the findings of the included studies that aimed to evaluate the effectiveness of various interventions designed to mitigate the risk of ARI transmission to HCWs during AGPs

Study ID	Sample Size	Population Characteristics	Type of intervention	Effectiveness of the intervention	Study conclusion
[11]	103	HCWs using N95 vs surgical masks during AGPs	Use of N95 respirators	Risk reduction: aRR = 0.22 (95% CI: 0.09-0.54)	N95 respirators significantly reduce ARI transmission to HCWs during AGPs.
[12]	251	HCWs using PAPRs during high-risk AGPs	Use of PAPRs	Risk reduction: aRR = 0.32 (95% CI: 0.18-0.56)	PAPRs are effective in protecting HCWs during high-risk AGPs.
[13]	75	HCWs with protective barriers during intubation	Protective barriers during intubation	Risk reduction: aRR = 0.41 (95% CI: 0.24-0.69)	Protective barriers during intubation decrease the risk of ARI transmission.
[14]	189	HCWs in areas with portable HEPA filters	Portable HEPA filters	Risk reduction: aRR = 0.53 (95% CI: 0.30-0.92)	Portable HEPA filters are associated with lower ARI transmission in AGP areas.
[15]	321	HCWs undergoing simulation-based training	Simulation-based training for PPE use	Improved compliance and technique, specific percentages not provided	Simulation-based training enhances PPE use effectiveness.
[16]	503	HCWs with enhanced hand hygiene practices	Enhanced hand hygiene	Decrease in ARI transmission, specific aRR not provided	Enhanced hand hygiene practices contribute to reduced ARI transmission.
[17]	87	HCWs using double gloving during patient care	Double gloving	Lower incidence of contamination, specific aRR not provided	Double gloving reduces the risk of hand contamination among HCWs.


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