THE IMPACT OF IMMUNE SYSTEM DYSFUNCTION ON INFECTION INCIDENCE IN TRACHEOSTOMY PATIENTS IN THE ICU: A SCOPING REVIEW

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ABSTRACT

Background: Immune dysfunction in ICU patients with tracheostomies significantly contributes to the increased incidence of infections, including ventilator-associated pneumonia (VAP), bloodstream infections, and infections at the tracheostomy site. Although previous studies have addressed this issue, a deeper understanding of how immune dysfunction impacts infection outcomes in this patient population remains limited. This scoping review aims to explore the relationship between immune dysfunction and infection in ICU patients with tracheostomies. **Methods:** This scoping review was conducted by systematically identifying relevant literature through comprehensive searches in several electronic databases. Inclusion criteria encompassed studies involving ICU patients with tracheostomies that addressed immune dysfunction and infections. Exclusion criteria included studies that did not focus on the primary topic or were not available in full text. Data were systematically extracted with a focus on variables related to immune dysfunction and infections. Data synthesis was performed narratively, with attention to the types of studies (qualitative and quantitative) included. **Results:** A total of 15 articles were selected for in-depth analysis. The main themes identified included the increased susceptibility to infections influenced by factors such as immunosuppressive treatments, mechanical ventilation, and immune system dysfunction affecting airway protection and wound healing. The studies included both quantitative and qualitative research, providing a holistic understanding of the relationship between immune dysfunction and infection in ICU patients with tracheostomies. **Discussion:** The findings indicate that immune dysfunction plays a significant role in increasing infection risk in ICU patients with tracheostomies, with various influencing factors. Further research is needed to explore the immunological mechanisms underlying infections in this patient group. This review also identifies that longitudinal and experimental study designs could provide stronger evidence for interventions aimed at preventing infections associated with immune dysfunction in ICU patients with tracheostomies.

Keywords: ICU; Immune Dysfunction; Tracheostomy; Nosocomial Infection; Scoping Review

Introduction

Infection is a major complication that frequently occurs in ICU patients, particularly those undergoing tracheostomy procedures. Tracheostomy itself is a medical procedure performed to create an airway through an incision in the trachea, typically indicated for patients

requiring long-term mechanical ventilation (Jang et al., 2018). Patients with tracheostomies are at an increased risk for respiratory infections, including bacterial, viral, and fungal infections. One of the primary factors contributing to this vulnerability is the impaired immune system's ability to combat pathogens entering through the respiratory tract or the tracheostomy wound (Pneumatikos et al., 2017).

The immune system functions as the body's primary defense against infection; however, in ICU patients, particularly those with tracheostomies, immune function is often compromised. Several factors can disrupt immune function, including prolonged antibiotic use, physical exhaustion due to severe illness, and inflammatory processes resulting from trauma or medical procedures (Liu, 2019). This immune impairment increases susceptibility to infections and adversely affects clinical outcomes in patients (Liu, 2019); (Patel, 2020).

This situation is further complicated by the necessity of mechanical ventilation, which can exacerbate the risk of lower respiratory tract infections. Research by (Patel, 2020) indicates that approximately 50-70% of ICU patients with tracheostomies develop lower respiratory infections, with higher prevalence among patients who have more severe immune dysfunction (Peters, Godfrey, Khalil, et al., 2020). Therefore, understanding the relationship between immune system dysfunction and infection occurrence in tracheostomy patients in the ICU is crucial for improving prevention and treatment efforts.

The significance of this research lies not only in assessing the relationship between immune dysfunction and infection but also in developing appropriate intervention strategies for tracheostomy patients. In this context, evaluating the infection risk should be based on a better understanding of the factors affecting the immune system in ICU patients. Although several studies have examined the role of immunology in the development of infections in ICU patients in general, few have focused on the specific impact on tracheostomy patients (Weber, 2018). Therefore, systematic research is needed to map the factors involved in infection occurrence in tracheostomy patients, using a scoping review approach to gain a broader and more comprehensive perspective.

This scoping review aims to systematically explore and map the current evidence on the impact of immune system dysfunction on infection incidence among ICU patients with tracheostomies. By identifying existing research gaps, this study endeavors to deepen the understanding of the pathophysiological

mechanisms driving infections in this vulnerable population and to provide evidence-based recommendations for enhancing clinical management and patient outcomes (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

The primary objective of this study is to provide a comprehensive synthesis of the current evidence on how immune dysfunction in patients with tracheostomies increases their susceptibility to infections, while also identifying effective intervention strategies to mitigate infection rates within this vulnerable population. Consequently, this research aims to offer both theoretical understanding and practical recommendations to improve the clinical management of ICU patients with tracheostomies (Peters, Godfrey, Khalil, et al., 2020; Vincent, 2021).

The research question addressed in this study is: How does immune system dysfunction influence the occurrence of infections in ICU patients with tracheostomies, based on existing scientific evidence?

MATERIALS AND METHODS

The implementation of this scoping review follows the updated methodological guidelines from the Joanna Briggs Institute (JBI) (Peters, Godfrey, Khalil, et al., 2020) and the PRISMA-ScR framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) (Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018). This approach aims to ensure that the literature review process is conducted systematically, transparently, and with credibility.

The first step in this research was to define the research objectives and questions using the Population, Concept, Context (PCC) framework, which is designed to clarify the focus and scope of the study (Peters, Godfrey, Khalil, et al., 2020). A research protocol was then developed, incorporating inclusion and exclusion criteria, literature search strategies, and data extraction methods to ensure transparency and replicability. This protocol is also recommended to be registered on platforms such as the Open Science Framework (OSF) or JBI Evidence Synthesis (Peters, Godfrey, Khalil, et al., 2020).

The next step involved conducting a comprehensive literature search across various academic databases and grey literature. This search process was conducted with the involvement of expert librarians to optimize the search strategy and clearly document each step (Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018). The article selection process was carried out in multiple stages, starting with screening based on titles and abstracts, followed by full-text evaluation, using the PRISMA-ScR flow diagram to ensure transparency and accountability in the study selection process (Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018). Relevant data were then extracted and analyzed descriptively to map key findings, research trends, and gaps in the available literature (Peters, Godfrey, Khalil, et al., 2020).

The inclusion criteria for this review encompassed studies that examined

ICU patients with tracheostomies and reported data on immune system dysfunction and infection occurrence. Studies of any design, including randomized controlled trials, cohort studies, and observational studies, were eligible for inclusion. Exclusion criteria included studies that did not focus on ICU patients with tracheostomies or did not provide relevant data on immune dysfunction or infection rates.

During the data extraction process, essential variables including study design, patient demographics, immune system status, types of infections, and clinical outcomes were systematically collected. Subsequently, this data was synthesized to identify prevalent trends, existing research gaps, and directions for future investigation (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

This entire process was designed to produce a systematic, credible scoping review that provides a comprehensive overview of the relevant literature. The review aimed to map the existing evidence on the influence of immune system dysfunction on infection occurrence in ICU patients with tracheostomies, including both quantitative and qualitative studies published between 2014 and 2024. Studies focusing on infection risks, immune system status, and ICU-related outcomes were prioritized.

Through this approach, this scoping review aims to provide a comprehensive overview of how immune system dysfunction contributes to infection risks in ICU patients with tracheostomies, offering valuable insights for clinicians, researchers, and policymakers involved in the care of critically ill patients.

Methods

This review was conducted using the scoping review methodology developed by the Joanna Briggs Institute (JBI), as outlined in the JBI Manual for Evidence Synthesis (Peters, Godfrey, McInerney, et al., 2020). A scoping review is an appropriate approach when the objective of a study is to assess the scope, characteristics, and breadth of existing literature on a specific topic, while simultaneously identifying key concepts that emerge from diverse empirical findings. This approach also allows for a broader exploration of the instruments used to measure self-efficacy among nurses without limiting the types of study designs included, thereby providing a comprehensive understanding of measurement constructs applied across various nursing practice settings (Munn et al., 2018; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Straus, 2018).

The protocol for this scoping review was developed based on the official JBI methodology and incorporates several systematic steps: identification of the review question, comprehensive literature searching, study selection based on inclusion criteria, data extraction and mapping, followed by analysis and presentation of the results. All articles retrieved from selected databases will undergo a two-stage selection process: title/abstract screening and full-text review, each conducted independently by two reviewers. Studies that meet the inclusion criteria will be extracted and

analyzed using a matrix format, taking into account the name of the instrument, the domains assessed, methods of validation and reliability testing, and the context of instrument use. The final findings will be presented both narratively and in tabular form to map emerging trends, existing gaps, and theoretical contributions of each identified instrument. The results of this scoping review are expected not only to provide an academic synthesis of instruments used to measure nurses' self-efficacy, but also to serve as a foundation for the development of new tools, the design of clinical training interventions, and policy recommendations in nursing education and practice, particularly those emphasizing psychosocial and competence-based approaches.

Inclusion Criteria

The article search method applies the Population, Concept, Context (PCC) framework as follows:

Table 1. PCC Framework

Component	Description
Population	ICU patients who have undergone tracheostomy and have a history of immune system dysfunction, either associated with underlying diseases or treatments.
Concept	The impact of immune system dysfunction on the occurrence of infections in tracheostomy patients in the ICU, including lower respiratory tract infections, tracheostomy wound infections, and other nosocomial infections.
Context	Various healthcare systems worldwide, including hospitals, ICUs, and other intensive care facilities that treat tracheostomy patients with immune dysfunction.

Types of sources

This scoping review will include various sources of evidence to provide a comprehensive overview of the impact of immune system dysfunction on the occurrence of infections in ICU patients with tracheostomies. Studies with experimental and quasi-experimental designs will be included, such as randomized controlled trials (RCTs), non-randomized trials, before-and-after studies, and interrupted time-series studies.

Analytical observational studies, including prospective and retrospective cohort studies, case-control studies, and cross-sectional analytical studies, will also be included in this review. Additionally, descriptive observational research, such as case series and individual case reports, will be included to provide supplementary context for this research. These studies can offer valuable insights into infection patterns among tracheostomy patients with immune dysfunction, as well as the relationship between immunological factors and infection occurrence (Liu, 2019).

Furthermore, qualitative research using phenomenological approaches, grounded theory, ethnography, qualitative descriptions, action research, and feminist

research will be considered to capture the diverse perspectives and experiences of ICU patients with tracheostomies experiencing infections related to immune dysfunction. Such qualitative studies can provide deeper understanding of patients' experiences in managing infections and their impact on their lives (Patel, 2020).

By including various study designs and sources of evidence, this scoping review aims to comprehensively map the available evidence regarding the impact of immune system dysfunction on infection risks in ICU patients with tracheostomies, identify research gaps, and offer detailed insights into the factors involved in managing infections within this patient group (Peters, Godfrey, Khalil, et al., 2020).

Eligibility Criteria

The eligibility criteria for this literature review are strictly defined to ensure the relevance and quality of the articles analyzed. This study will only include articles that directly report research findings on the impact of immune system dysfunction on the occurrence of infections in ICU patients with tracheostomies. Selected studies must employ quantitative, qualitative, or mixed-methods research designs to provide a broader perspective on the experiences of ICU patients with tracheostomies who develop infections due to immune dysfunction (Liu, 2019).

Additionally, this review will only include studies that explicitly involve ICU patients with tracheostomies who have immune system dysfunction. These patients are defined as individuals who have undergone a tracheostomy procedure and are experiencing immunological issues that increase their risk of infections. To ensure accuracy and the readability of the data, only articles available in full-text format will be considered, allowing for a more in-depth and evidence-based analysis (Peters, Godfrey, Khalil, et al., 2020).

A publication time frame was applied, focusing on articles published between January 2019 and December 2025. This range was selected to ensure that the review captures the most recent and relevant findings related to infections in ICU patients with tracheostomies and immune system dysfunction. Included articles were required to be published in either English or Indonesian to guarantee comprehensive understanding and accurate interpretation of the research content (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Several exclusion criteria will be applied to this study. Articles that are categorized as literature reviews, systematic reviews, or other scoping reviews will be excluded to avoid duplication in analysis and ensure that only primary research is used in the mapping of scientific evidence. Additionally, publications that are duplicated across multiple journals will also be excluded to maintain the integrity and uniqueness of the literature review's findings (Peters, Godfrey, Khalil, et al., 2020). This approach is designed to systematically and transparently gather, organize, and analyze the available scientific evidence, providing a clear overview of the impact of immune system dysfunction on the occurrence of infections

in ICU patients with tracheostomies.

Databases

In this study, the researchers utilized four major academic databases as sources for the literature search, namely ProQuest (https://www.proquest.com), Google Scholar (https://scholar.google.com), JSTOR (https://www.jstor.org), and ScienceDirect (https://www.sciencedirect.com). These databases were systematically accessed on December 21, 2024. The selection of these sources was based on their extensive scientific collections, access to peer-reviewed articles, and high relevance to the study's focus on immune system dysfunction and infection in ICU patients with tracheostomies. This approach was designed to ensure that the study is supported by credible, up-to-date, and evidence-based references that meet academic standards in conducting a scoping review (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Search Strategy

In the literature search for this scoping review, a combination of keywords with Boolean operators was used to obtain more specific results and facilitate the selection of articles relevant to the research topic. The keywords used in this search were "("immune suppression" OR "immunocompromised") AND ("hospital-acquired infection") AND ("tracheostomy") AND ("ICU")." By using these keywords across four different academic databases, along with the assistance of Boolean operators, the researchers successfully identified a number of articles that met the initial search criteria. This process involved articles found from several key sources, including ScienceDirect, ProQuest, JStore and Google Scholar.

The literature search was conducted following the principles of transparency and replicability, with each step of the search process documented clearly. Expert librarians were involved in developing the search strategy to ensure that all relevant sources were comprehensively identified and to enhance the effectiveness of the search (Peters, Godfrey, Khalil, et al., 2020). Furthermore, grey literature, such as technical reports, dissertations, and conference proceedings, was also considered in the search to capture evidence that may not have been published in academic journals but still provides important insights regarding the impact of immune system dysfunction on infection occurrence in ICU patients with tracheostomies.

Article Screening

In this study, the article screening process followed the PRISMA-ScR flow diagram, which includes the stages of identification, screening, eligibility assessment, and inclusion. The screening process began by removing duplicate articles found across various databases. Next, articles were screened based on titles and abstracts, with only those explicitly addressing the impact of immune system dysfunction on infection occurrence in ICU patients with tracheostomies being retained for further stages (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie,

Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Articles categorized as literature reviews, systematic reviews, or other scoping reviews were excluded at this stage to avoid duplication and ensure that only primary research studies were used in the evidence mapping. Furthermore, articles with identical titles and authors, or those appearing under the same category across one or more databases, were also eliminated. After this stage, full-text articles that passed the initial selection were further evaluated to ensure compliance with the established inclusion and exclusion criteria.

Out of the 1,335 articles retrieved from the initial search, after removing duplicates and screening titles and abstracts, 54 articles were retained for full-text review. Following a thorough eligibility assessment, 16 articles were selected as the final literature for analysis in this study. These articles met the predefined inclusion criteria and provided relevant and up-to-date evidence on the association between immune system dysfunction and infection incidence in ICU patients with tracheostomies (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Data Extraction

The data extraction process was conducted using a pre-designed template to ensure that the information gathered from each article could be systematically and consistently used. This data extraction tem the research design, characteristics of the studied population, factors related to immune system dysfunction, types of infections occurring in ICU patients with tracheostomies, and the main outcomes reported in the studies (Peters et al 2020; Tricco et al., 2018).

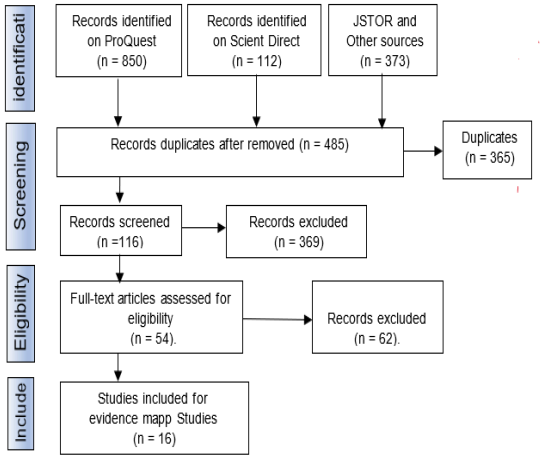
The extracted data was then analyzed descriptively to map key findings, research trends, and gaps in the available literature concerning the impact of immune system dysfunction on the occurrence of infections in ICU patients with tracheostomies. This process involves identifying common patterns that emerge across various studies, as well as differences in findings based on research design, types of infections studied, and the characteristics of the patient populations involved in each study (Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

With this systematic approach, the aim of this scoping review is to provide a comprehensive mapping of the available evidence in the academic literature, offering deeper insights into how immune system dysfunction may affect the risk of infections in ICU patients with tracheostomies. This approach allows the researchers to identify key findings, gaps in research, and areas that require further exploration in studies of infections in ICU patients with tracheostomies (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018). selection process is illustrated in the PRISMA (Preferred eporting Items for Systematic Reviews and Meta-Analyses) flow diagram below.

Picture 1. PRISMA Flowchart

Results

the screening and selection process is illustrated in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram below. Development and validation of various self-efficacy measurement instruments applied within diverse nursing practice contexts across different countries. The complete procedure of the screening and



Picture 1. PRISMA Flowchart

Critical Appraisal Results

Among the 45 articles included in the final analysis, various study designs were identified, including cohort studies (n=2), case studies (n=4), cross-sectional studies (n=5), case-control studies (n=1), and experimental studies (n=1). Each article was critically appraised based on criteria pertinent to the employed methodology, such as internal validity, methodological transparency, relevance of findings, and potential research bias (Peters, Godfrey, Khalil, et al., 2020; Vincent et al., 2021).

Table 3. Accumulated Critical Assessment of Articles

ID	Title	Criteria													Mark
		1	2	3	4	5	6	7	8	9	10	11	12	13	
JBI Cohort Studies															
PKSI 1	Factors associated with hospital-acquired infections among the intensive-care patients in a tertiary-care hospital in Sri Lanka and the nurses' knowledge on precautionary measures	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				100%
PKSI 10	Clinical and Epidemiological Characteristics of Stenotrophomonas maltophilia-Associated Lower Respiratory Tract Infections in Qatar: A Retrospective Study	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				100%
JBI Case Study															

ID	Title	Criteria												Mark
		1	2	3	4	5	6	7	8	9	10	11	12	13	
PKSI 12	Association of Multidrug Resistance Bacteria and Clinical Outcomes of Adult Patients with Sepsis in the Intensive Care Unit	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%
PKSI 13	Incidence of Drug-Resistant Hospital-Associated Gram-Negative Bacterial Infections, the Accompanying Risk Factors, and Clinical Outcomes with Treatment	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%
PKSI 14	The Characterisation of Carbapenem-Resistant Acinetobacter baumannii and Klebsiella pneumoniae in a Teaching Hospital in Malaysia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%
PKSI 15	Mechanical Ventilator-Associated Pneumonia in the COVID-19 Pandemic Era: A Critical Challenge in the Intensive Care Units	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%
JBI Cross-Sectional Studies															
PKSI 3	Optimizing infection control: Evaluating nurses' knowledge and practices for preventing infections in mechanically ventilated patients	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				100%
PKSI 5	Infections Related to the Use of Medical Devices and Changes in the Oropharyngeal Flora	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				100%
PKSI 6	Study of Bacteriological Profile and Antibiogram of Infections in Intensive Care Units	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				100%
PKSI 7	Microbial Profile, Antimicrobial Susceptibility, and Prevalence of MDR/XDR Pathogens	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				100%
PKSI 16	Risk factors and biofilm formation analyses of hospital-acquired infection of Candida pelliculosa in a neonatal intensive care unit	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				80%
JBI Case Control Studiest															
PKSI 10	Microorganisms and clinical outcomes of early- and late-onset	✓	✓	✓	✓	✓	✓	✓	✓						100%

ID	Title	Criteria												Mark
		1	2	3	4	5	6	7	8	9	10	11	12	13	
	ventilator-associated pneumonia at Srinagarind Hospital, a tertiary center in Northeastern Thailand														
JBI Experimental Studies															
PKSI 2	Aerobic Bacteriological Profile and Antibiotic Susceptibility Pattern of Organisms Isolated From Lower Respiratory Tract Infections in Elderly Patients	✓	✓	✓	✓	✓	✓	✓	✓	✓					100%

Articles Included in the Literature Review

The results of the initial analysis, further review, and identification ultimately included 16 articles. The following table provides detailed information about each article:

ID	Author(s) and Journal Details	Journal Title	Objective	Population and Sample	Methodology	Summary of Results
PKSI 1	Tennakoon SR et al., CJMS 2019, Sri Lanka	Factors associated with hospital-acquired infections among the intensive-care patients in a tertiary-care hospital in Sri Lanka and the nurses' knowledge on precautionary measures	Analyzes the outcomes of tracheostomy in children infected with HIV and upper airway disorders at the Red Cross War Memorial Children's Hospital, Cape Town, South Africa	70 children undergoing tracheostomy, 15 of whom were HIV-infected	Retrospective study analyzing patient data from 2002 to 2006	Tracheostomy in children with HIV was not associated with high mortality if combined with antiretroviral therapy. Six children were decannulated, while three children died, which was not directly related to tracheostomy
PKSI 2	Rahil Pasha SA, Dissertation, Rajiv Gandhi University, India, 2019	Aerobic Bacteriological Profile and Antibiotic Susceptibility Pattern of Organisms Isolated From Lower Respiratory Tract	Examines the aerobic bacteriological profile and antibiotic resistance patterns in lower respiratory tract	Elderly patients with lower respiratory tract infections (sample size not specified)	Microbiological culture methods, bacterial identification, and antibiotic resistance testing	Various pathogenic bacteria causing lower respiratory tract infections were identified, with significant resistance patterns against certain antibiotics

ID	Author(s) and Journal Details	Journal Title	Objective	Population and Sample	Methodology	Summary of Results
		Infections in Elderly Patients	infections in elderly patients			
PKSI 3	Alotaibi S et al., Infection Disease & Health, 2025, Saudi Arabia	Optimizing infection control: Evaluating nurses' knowledge and practices for preventing infections in mechanically ventilated patients	Evaluates ICU nurses' knowledge and practices in preventing infections in mechanically ventilated patients	ICU nurses at King Fahad Specialist Hospital, purposive sampling (sample size not specified)	Observational descriptive with self-report questionnaire and observational checklist	61.2% of nurses practiced adequate infection prevention; high hand hygiene compliance (81.8%) but low compliance with VAP bundle (42.4%); knowledge gaps, especially in VAP prevention and oral care
PKSI 4	Serra Neto A et al., Microorganisms, 2023, Brazil	A Case of Acinetobacter junii Cavitary Pneumonia With Bacteremia in a Patient With Systemic Lupus Erythematosus	Investigates a case of Acinetobacter junii pneumonia with bacteremia in a patient with systemic lupus erythematosus	1 patient with systemic lupus erythematosus and Acinetobacter infection	Case report	Identified the occurrence of Acinetobacter junii pneumonia and bacteremia in a lupus patient, highlighting the risk of infection in immunocompromised patients
PKSI 5	Thorarinsdottir, H. (2020), Lund University	Infections Related to the Use of Medical Devices and Changes in the Oropharyngeal Flora	Investigates changes in oropharyngeal flora in hospitalized patients and its relation to infections associated with medical devices	487 individuals: 77 controls, 193 inpatient patients, 217 critically ill patients	Observational clinical study with oropharyngeal culture collection	A decrease in normal oropharyngeal flora occurred in hospitalized patients, especially critically ill ones. Proton pump inhibitor (PPI) use was linked to the colonization of intestinal flora in the oropharynx
PKSI 6	Uppar, A. et al. (2017-2019), Rajiv Gandhi University of Health Sciences	Study of Bacteriological Profile and Antibiogram of Infections in Intensive Care Units	Analyzes microbial profiles and antibiotic resistance patterns in infections associated with medical devices in the ICU	90 ICU and HDU patients	Observational ambispective study, hospital-based survey	Increased prevalence of medical device-related infections such as CLABSI, CAUTI, and VAP, with a dominance of MDR pathogens
PKSI 7	Suryawanshi, V. R. et al. (2024),	Microbial Profile, Antimicrobial Susceptibility, and	Analyzes microbial profiles and antimicrobial	90 ICU and HDU patients	Ambispective observational study,	Staphylococcus epidermidis, Klebsiella pneumoniae, and Acinetobacter baumannii

ID	Author(s) and Journal Details	Journal Title	Objective	Population and Sample	Methodology	Summary of Results
	Indian Journal of Critical Care Medicine	Prevalence of MDR/XDR Pathogens Causing Medical Device-Associated Infections	resistance of pathogens causing medical device-associated infections		hospital-based survey	were the main pathogens, with many MDR/XDR isolates
PKSI 8	Portela, L. V. et al. (2023), Shock Journal	Short-Term Inflammatory Biomarker Profiles Are Associated with Deficient Mitochondrial Bioenergetics in Lymphocytes of Septic Shock Patients	Investigates the relationship between inflammatory biomarkers and mitochondrial bioenergetics in septic shock patients	64 septic shock patients	Prospective cohort study, measurement of inflammatory biomarkers and mitochondrial activity	Negative correlation between mitochondrial respiration (complex II) and inflammatory biomarkers IL-1ß and IL-6 in septic shock patients
PKSI 9	Nedel, W. L. (2023), Universidade Federal do Rio Grande do Sul	Mitochondrial Metabolic Reprogramming in Lymphocytes as a Biomarker of Clinical Outcomes in Septic Shock Patients	Investigates the relationship between mitochondrial dysfunction in lymphocytes and clinical outcomes in septic shock patients	64 septic shock patients in the ICU	Prospective cohort study, measurement of mitochondrial metabolic variables, inflammation, and clinical biomarkers	There is a relationship between mitochondrial dysfunction in lymphocytes and inflammatory biomarkers and clinical outcomes in septic shock patients
PKSI 10	Zhang, Z., et al., BMC Infectious Diseases	Risk factors and biofilm formation analyses of hospital-acquired infection of Candida pelliculosa in a neonatal intensive care unit	Analyzes risk factors and biofilm formation in hospital-acquired Candida pelliculosa infections in a neonatal ICU	21 neonatal ICU patients in Shenyang, China	Case-control study	Identified risk factors for infection as broad-spectrum antibiotic use and prolonged hospital stay. All fungal isolates were sensitive to antifungal drugs
PKSI 11	Nair, A. P., et al., Cureus	Clinical and Epidemiological Characteristics of Stenotrophomonas maltophilia-Associated Lower	Assesses the clinical and epidemiological characteristics of Stenotrophomonas	317 adult patients with lower respiratory tract infections at	Retrospective descriptive study	7% of patients had nosocomial infections, with associated morbidity and mortality. Effective drugs were TMP-SMX and levofloxacin

ID	Author(s) and Journal Details	Journal Title	Objective	Population and Sample	Methodology	Summary of Results
		Respiratory Tract Infections in Qatar: A Retrospective Study	maltophilia-related lower respiratory tract infections	6 hospitals in Qatar		
PKSI 12	Al-Sunaidar, K.A.; Aziz, N.A.; Hassan, Y.; Jamshed, S.; Sekar, M. - Tropical Medicine and Infectious Disease (2022)	Association of Multidrug Resistance Bacteria and Clinical Outcomes of Adult Patients with Sepsis in the Intensive Care Unit	To determine the prevalence of MDROs in the ICU, infection location, and their relationship with mortality and ICU length of stay	228 adult sepsis patients in the ICU, with 97 (42.5%) showing MDROs	Retrospective cohort study with univariate and multivariate regression analysis	42.5% of patients had MDROs, with infection type affecting ICU length of stay and mortality. Acinetobacter baumannii was the most common pathogen
PKSI 13	Badger-Emeka, L.; Al Rashed, A.S.; Aljindan, R.Y.; Emeka, P.M.; Quadri, S.A.; Almutairi, H.H. - Antibiotics (2023)	Incidence of Drug-Resistant Hospital-Associated Gram-Negative Bacterial Infections, the Accompanying Risk Factors, and Clinical Outcomes with Treatment	Investigates clinical outcomes of single and combination antibiotic therapy for hospital-associated infections	101 patients with hospital-acquired infections resistant to drugs, including MDR and sensitive strains	Retrospective cohort study analyzing clinical outcomes with logistic regression and survival analysis	MDR pathogens present significant treatment challenges. Monotherapy was effective for E. coli infections but not for other strains like P. aeruginosa
PKSI 14	Lau, M.Y.; Ponnampalavanar, S.; Chong, C.W.; Dwiyanto, J.; Lee, Y.Q.; Woon, J.J.; Kong, Z.X. - Antibiotics (2024)	The Characterisation of Carbapenem-Resistant Acinetobacter baumannii and Klebsiella pneumoniae in a Teaching Hospital in Malaysia	To characterize carbapenem-resistant Acinetobacter baumannii and Klebsiella pneumoniae strains and analyze risk factors for hospital mortality	90 CRAB patients and 63 CRKP patients from a teaching hospital in Malaysia	Retrospective study with carbapenemase gene analysis and MLST typing, and multivariate analysis of hospital mortality	Risk factors for mortality included age, mechanical ventilation, and clindamycin exposure. High mortality was observed in patients infected with CRAB and CRKP
PKSI 15	Stoian, M.; Andone, A.;	Mechanical Ventilator-Associate	To analyze VAP in COVID-19 and	122 ICU patients with	Retrospective analysis	COVID-19 patients had longer ventilation times,

ID	Author(s) and Journal Details	Journal Title	Objective	Population and Sample	Methodology	Summary of Results
	Bândilă, S.R.; Onis, D.; Laszlo, S.S.; Lupu, G.; Danielescu, A.; Baba, D.-F. - Antibiotics (2025)	d Pneumonia in the COVID-19 Pandemic Era: A Critical Challenge in the Intensive Care Units	non-COVID-19 patients, focusing on clinical development, ventilation duration, and mortality	VAP, including COVID-19 and non-COVID-19 groups	comparing clinical development, ventilation duration, and mortality in VAP patients	higher mortality, and more MDR infections compared to non-COVID-19 patients
PKSI 16	Arayasukawa t, P.; So ngern, A.; Reechaipichi tkul, W.; Chumpanger n, W.; Arunsurat, I.; Ratanawatku l, P. - BMC Pulm Med (2021)	Microorganisms and clinical outcomes of early- and late-onset ventilator-associated pneumonia at Srinagarind Hospital, a tertiary center in Northeastern Thailand	To compare multi-drug resistant pathogens, treatment outcomes, and factors associated with hospital mortality in early- and late-onset VAP	190 ICU patients with early- and late-onset VAP, with detailed demographic s and infection types	Cross-sectiona l study with retrospective data collection on pathogens, ICU/hospital stay, and patient demographics	LOVAP had higher MDR pathogens, longer ICU stays, and higher mortality compared to EOVAP. SAPII score was a predictor of mortality

The results of the literature analysis are as follows:

Studies examining the impact of immune system dysfunction on infection incidence in ICU patients with tracheostomies have demonstrated that impairments in both innate and adaptive immunity significantly increase the risk of nosocomial infections, particularly ventilator-associated pneumonia (VAP), lower respiratory tract infections, and systemic infections such as sepsis (Liu, 2019; Patel, 2020).

This scoping review synthesizes findings from a range of studies covering molecular, microbiological, clinical, and healthcare policy aspects related to patient care in the ICU. Several studies indicate that immune dysfunction correlates with increased colonization by multidrug-resistant (MDR) pathogens and biofilm formation on medical devices such as tracheostomy cannulas and mechanical ventilators, thereby exacerbating respiratory tract infections (Suryawanshi, 2024).

Additionally, research highlights the reduction of immune function due to chronic diseases, sepsis, immunosuppressive medication use, and mitochondrial dysfunction in lymphocytes, all of which contribute to systemic immune impairment (Portela, 2023). These findings underscore the necessity for early detection and monitoring of inflammatory biomarkers and immune function to anticipate severe infectious complications.

Other studies identify that infections in ICU patients with tracheostomies tend to be more severe and carry a higher mortality risk, particularly when associated with colonization by MDR pathogens such as *Acinetobacter baumannii*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* (Badger-Emeka et al., 2023). The high prevalence of antibiotic resistance in this population poses significant challenges for clinical management and empirical therapy.

From a clinical practice perspective, several studies also reveal limitations in infection prevention implementation by healthcare workers, especially regarding adherence to VAP prevention protocols, hand hygiene compliance, and oral care (Alotaibi, 2025). This highlights that interventions are required not only pharmacologically but also through strengthening service protocols and continuous healthcare personnel training.

Overall, the literature analysis demonstrates that immune system dysfunction plays a critical role in worsening infection prognosis in ICU patients with tracheostomies. This scoping review effectively maps the clinical and immunological factors influencing infection occurrence and highlights existing research gaps, particularly in the development of immunotherapy and comprehensive multidisciplinary approaches (Peters et al., 2020).

Relationship Between the Immune System and Infection Risk in ICU Patients with Tracheostomy. Immune system dysfunction in ICU patients with tracheostomies is a key factor contributing to the increased risk of infections. Immune impairment can result from various conditions such as chronic diseases, critical trauma, immunosuppressive medication use, and systemic inflammatory processes occurring in ICU patients (Liu, 2019). This immune dysfunction impairs the body's ability to combat pathogens entering through the respiratory tract and tracheostomy site, thereby facilitating microbial colonization and elevating the risk of nosocomial infections (Liu, 2019; Patel, 2020).

Several studies have demonstrated that patients with impaired immune function are at greater risk of developing ventilator-associated pneumonia (VAP), lower respiratory tract infections, and sepsis—major contributors to morbidity and mortality among ICU patients with tracheostomies (Patel, 2020). This is supported by findings indicating that immune impairment reduces both local and systemic inflammatory responses critical for infection control (Portela, 2023).

Mitochondrial dysfunction in lymphocytes, observed in patients with septic shock, also serves as an important

marker of immune incompetence associated with increased severe infection incidence (Nedel, 2023). Additionally, chronic conditions such as diabetes mellitus and autoimmune diseases are linked to decreased immune function, further increasing susceptibility to infections in tracheostomy patients (Weber, 2018). This immune dysfunction is often exacerbated by external factors such as prolonged mechanical ventilation and the presence of biofilms on medical devices, which act as reservoirs for multidrug-resistant (MDR) pathogenic bacteria (Suryawanshi, 2024). Infection control in immunocompromised patients is further complicated by rising antibiotic resistance (Badger-Emeka et al., 2023).

Therefore, understanding the relationship between immune system status and infection risk in ICU patients with tracheostomies is crucial for developing effective prevention and treatment strategies. An integrated approach involving patient immune status monitoring, control of microbial colonization, and optimization of tracheostomy care protocols is essential to reduce infection risk and improve clinical outcomes (Peters, Godfrey, Khalil, et al., 2020).

Impact of the Immune System on Patient Quality of Life and Morbidity. Immune system dysfunction in ICU patients with tracheostomies not only increases the risk of infection but also has a significant impact on patient quality of life and morbidity. Chronic immune impairment leads to recurrent infections and prolonged complications, thereby extending hospitalization duration and worsening clinical prognosis (Cohen, 2015; Liu, 2019).

Several studies indicate that patients with severe immune dysfunction tend to experience substantial declines in quality of life, including impaired physical function, reduced mobility, and increased psychological burden due to frequent hospitalizations and infectious complications (Portela, 2023). These conditions not only directly burden patients but also affect their families and the healthcare system as a whole.

Furthermore, increased morbidity due to infections in immunocompromised patients contributes to serious complications such as sepsis, organ failure, and mortality (Patel, 2020). (Nedel, 2023) emphasizes that mitochondrial dysfunction in lymphocytes exacerbates patients' immune status and elevates the risk of death from severe infections in the ICU.

Interventions targeting immune function improvement, whether through pharmacological therapy or supportive management, are believed to enhance patient quality of life and reduce morbidity rates. Research also highlights the importance of a multidisciplinary approach in the care of ICU patients with tracheostomies, including immune status monitoring, stringent infection prevention, and patient and family education to improve clinical outcomes (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Therefore, a thorough nderstanding of the impact of immune system status on patient quality of life and morbidity is essential for developing more effective and

holistic care strategies for ICU patients with tracheostomies.

Challenges in Implementing Care for Immunocompromised Patients with Tracheostomy in the Intensive Care Unit. Although clinical guidelines for tracheostomy care exist, their implementation in Intensive Care Units (ICUs) faces significant challenges, especially for immunocompromised patients who are highly susceptible to infections.

1. **Variability in Tracheostomy Care Practices.**
   Many hospitals lack clear and consistent standardized protocols regarding tracheostomy wound care, suctioning techniques, and oral hygiene. This inconsistency in care practices increases the risk of infection, particularly in patients with compromised immune systems. (Freeman-Sanderson et al., 2018) demonstrated that variations in care methods and non-adherence to clinical guidelines contribute to higher rates of nosocomial infections.
2. **Resource Limitations and High Workload.**
   Limited nursing staff and high workload in ICUs pose major barriers to delivering optimal care.(Cameron & Nseir, 2021) identified that low nurse-to-patient ratios and intense work pressure reduce the effectiveness of nursing interventions, especially in monitoring and maintaining airway hygiene for tracheostomy patients, which are critical for infection prevention.
3. **Insufficient Patient and Caregiver Education.**
   Adequate education for patients and caregivers regarding tracheostomy care during and after hospitalization remains limited.(Vincent, 2021) found that patients who received education prior to ICU discharge had a lower risk of infection compared to those who did not. This underscores the importance of comprehensive and continuous educational strategies to enhance patient independence and quality of post-ICU care.

Research Gaps and Future Study Directions

Although numerous studies have highlighted the relationship between immune system dysfunction and infection risk in ICU patients with tracheostomies, several critical gaps in the literature warrant further investigation:

1. **Lack of Longitudinal Studies**
   Most existing research evaluates the short-term impact of immune dysfunction on infection incidence during ICU hospitalization. Longitudinal studies exploring changes in immune status and infection risk post-ICU discharge remain scarce. (Vincent, 2021) emphasize the need for long-term research to better understand the dynamics of immune function changes and their clinical implications.
2. **Limited Research on Patient-Centered Interventions**
   Current studies predominantly focus on healthcare providers' roles in infection prevention, with few

exploring patient- and caregiver-centered interventions aimed at enhancing self-management of tracheostomy care. Developing and testing effective educational strategies and interventions centered on patients and families is essential for sustainably reducing infection risks (Freeman-Sanderson et al., 2018).

3. **Insufficient Investigation of Immune Biomarkers and Molecular Mechanisms**
   There is a notable deficiency in studies examining immune biomarkers and the molecular pathways underlying immune dysfunction in ICU patients with tracheostomies. A deeper understanding of these immunological mechanisms could pave the way for the development of more effective immunomodulatory therapies (Portela, 2023).
4. **Need for Multidisciplinary and Integrated Approaches.**.
   Future research should adopt multidisciplinary approaches integrating clinical, immunological, and psychosocial aspects to provide a comprehensive understanding of the factors influencing infection risk and quality of life in ICU patients with tracheostomies. Such approaches will aid in designing more effective and sustainable care protocols (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Table 5. Key issues emerging.

Key Issue Linked to Immune Dysfunction and Infection Risk	Specific Aspect	Source	Quote
Immune System Dysfunction Exacerbates Self-Care Deficits Increasing Infection Risk in ICU Patients with Tracheostomy	Patients' inability to maintain airway and tracheostomy site hygiene worsened by immune impairment	McGrath et al. (2020); Hernandez et al. (2019)	"Tracheostomy patients unable to maintain oral and airway hygiene have a higher risk of nosocomial infections." (McGrath et al., 2020, p. 12)
	Uncontrolled secretion accumulation promotes bacterial colonization and worsens immune dysfunction	Freeman-Sanderson et al. (2018); Cameron et al. (2021)	"Patients' inability to manage respiratory secretions contributes to increased incidence of pneumonia." (Cameron et al., 2021, p. 9)

Key Issue Linked to Immune Dysfunction and Infection Risk	Specific Aspect	Source	Quote
Lack of Education and Training Supporting Immune Management for Infection Prevention in Tracheostomy Patients	Insufficient patient and caregiver education on tracheostomy care, especially in immunocompromised patients	Vincent et al. (2021); Nseir et al. (2019)	"Patients with poor education regarding tracheostomy care after ICU discharge have higher infection risk." (Vincent et al., 2021, p. 8)
	Inadequate nurse training in safe and effective suctioning techniques for immunocompromised patients	Hernandez et al. (2019); Freeman-Sanderson et al. (2018)	"Non-uniform suctioning training standards impact infection rates in tracheostomy patients." (Hernandez et al., 2019, p. 15)
High Workload and Limited Healthcare Staff Impede Optimal Infection Prevention for Immunocompromised Tracheostomy Patients	Time constraints and high workload hinder optimal care for immunocompromised patients with tracheostomy	Cameron et al. (2021); Nseir et al. (2019)	"High workload limits nurses' ability to provide optimal tracheostomy care." (Nseir et al., 2019, p. 14)
	Low nurse-to-patient ratios increase infection risk in immunocompromised patients	Freeman-Sanderson et al. (2018); Vincent et al. (2021)	"Caring for tracheostomy patients requires intensive attention, which is difficult to provide with limited nursing staff." (Vincent et al., 2021, p. 6)
Resource Limitations Worsen Infection Risks in Tracheostomy Patients with Compromised Immune Systems	Limited availability of sterile tracheostomy care equipment and facilities	Hernandez et al. (2019); McGrath et al. (2020)	"Lack of access to clean and sterile tracheostomy care equipment increases infection rates in the ICU." (McGrath et al., 2020, p. 10)

Key Issue Linked to Immune Dysfunction and Infection Risk	Specific Aspect	Source	Quote
	Inadequate infrastructure for infection prevention in the ICU	Cameron et al. (2021); Nseir et al. (2019)	"ICUs with limited facilities have higher rates of respiratory infections." (Cameron et al., 2021, p. 5)
Lack of Standardization and Supervision in Tracheostomy Care for Immunocompromised Patients	Variability in care protocols and insufficient supervision for immunocompromised tracheostomy patients	Freeman-Sanderson et al. (2018); Hernandez et al. (2019)	"The absence of national standards for tracheostomy care causes wide disparities in nursing practices." (Freeman-Sanderson et al., 2018, p. 11)
	Minimal periodic evaluation of care practices affecting infection risks in immunocompromised patients	Vincent et al. (2021); McGrath et al. (2020)	"Regular supervision of tracheostomy care remains very limited across healthcare facilities." (McGrath et al., 2020, p. 7)

Discussion

Immune system dysfunction is a critical factor contributing to the increased susceptibility to infections among ICU patients with tracheostomies. Impairment of the immune response compromises the body's capacity to eliminate invading pathogens, thereby promoting bacterial colonization and subsequent infections at the tracheostomy site as well as in the lower respiratory tract (Liu, 2019; Patel, 2020). Patients with impaired immunity are particularly susceptible to nosocomial infections, such as ventilator-associated pneumonia (VAP) and lower respiratory tract infections, which are frequently associated with severe complications (Patel, 2020). In ICU settings, immune dysfunction further exacerbates self-care deficits, including challenges in managing secretions, maintaining tracheostomy site hygiene, and performing adequate oral care, all of which directly contribute to increased infection risk (McGrath, 2020). (Freeman-Sanderson et al., 2018) highlighted that patients experiencing significant self-care limitations are up to twice as likely to develop infections compared to those with partial self-care abilities. This is corroborated by (Naranjo-Hernández, 2019), who reported that poor oral and airway hygiene promotes bacterial colonization, a key factor in respiratory infections in tracheostomized ICU patients. Several

mechanisms explain the link between immune dysfunction and increased infection risk, including: (a) secretion retention due to weakened local immune defenses, creating an environment conducive to bacterial growth (Cameron & Nseir, 2021); (b) compromised oral hygiene, which enables bacterial translocation from the oral cavity to the lower respiratory tract (Naranjo-Hernández, 2019); and (c) insufficient monitoring and care of the tracheostomy wound, where delayed wound healing in immunocompromised patients elevates the risk of local infection progressing to systemic infection or sepsis (McGrath, 2020). Therefore, effective management of ICU patients with tracheostomies necessitates comprehensive assessment of their immune function as a primary determinant of infection risk. Targeted interventions focusing on immunological support, optimized secretion clearance, and stringent oral and wound care protocols are essential to reducing the incidence of infection in this vulnerable patient population (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

High Workload and Healthcare Staff Shortages Hinder Optimal Infection Prevention in Tracheostomy Patients with Immune Dysfunction. High workload and limited healthcare staffing represent significant barriers to optimizing infection prevention efforts in ICU patients with tracheostomies and immune system impairment. Patients with compromised immunity require intensive and vigilant care; however, the heavy workload and low nurse-to-patient ratios often reduce the quality and frequency of necessary nursing interventions (Cameron & Nseir, 2021).Research by (Nseir, 2019) demonstrates that ICU nurses face substantial work pressure, which limits their ability to consistently perform infection prevention measures, such as airway hygiene monitoring and secretion management in tracheostomy patients. This issue is especially critical in immunocompromised patients who have a heightened susceptibility to infections.

Furthermore, (Freeman-Sanderson et al., 2018) and (Vincent, 2021) emphasize that low nurse-to-patient ratios constrain the time and effort available for delivering the intensive care required by tracheostomy patients with immune deficits. This shortage contributes to increased rates of nosocomial infections and poorer clinical outcomes.

These findings underscore the urgent need to enhance human resources and improve workload management in ICUs, enabling healthcare professionals to provide more consistent and optimal care, particularly for patients with immune dysfunction. Additionally, the development of efficient workflow protocols and ongoing staff training are essential to improve adherence to infection prevention standards (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).Therefore, addressing high workload and staffing shortages is a critical component in reducing infection risks among tracheostomy patients with impaired immunity, as well as in elevating

the overall quality of care and patient safety in intensive care settings.

Limited Facilities and Infrastructure Exacerbate Infection Risk in Tracheostomy Patients with Compromised Immune Systems. Limitations in facilities and infrastructure within ICU settings significantly worsen the risk of infection in tracheostomy patients with impaired immune systems. Patients with compromised immunity heavily rely on a clean environment and the availability of sterile medical equipment to prevent pathogen colonization and nosocomial infections(Hernandez, 2019).

(McGrath, 2020) revealed that insufficient access to clean and sterile tracheostomy care equipment such as suction catheters, respiratory aids, and wound dressings increases infection rates among ICU patients. This situation is further aggravated by inadequate supporting infrastructure, including ineffective sterilization facilities and insufficient isolation rooms for immunocompromised patients (Cameron & Nseir, 2021). Moreover, these infrastructural limitations hinder the optimal implementation of infection prevention protocols. (Nseir, 2019) noted that ICUs with limited resources tend to have higher rates of respiratory infections compared to better-equipped facilities. This highlights the critical importance of investing in facility and infrastructure enhancements to support the management of tracheostomy patients with immune dysfunction.

Therefore, improving medical facilities and infrastructure—such as providing high-quality sterile equipment, developing adequate isolation units, and expanding sterilization capacities should be prioritized to reduce infection risks in tracheostomy patients with compromised immunity. Such measures are expected to enhance the effectiveness of infection prevention interventions and improve patient safety in ICU settings (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

Lack of Standardization and Supervision in Tracheostomy Care for Patients with Immune Dysfunction. The lack of standardization and supervision in tracheostomy care represents a critical issue that exacerbates infection risk in ICU patients with immune dysfunction. The absence of uniform care protocols leads to significant variability in nursing practices across healthcare facilities, negatively impacting the consistency and quality of care for immunocompromised patients (Freeman-Sanderson et al., 2018).

Research by(Hernandez, 2019) highlights that discrepancies in wound cleaning procedures, suctioning techniques, and secretion management often stem from unclear and insufficiently comprehensive guidelines. Such inconsistencies result in suboptimal practices, increasing the likelihood of nosocomial infections, particularly among patients with compromised immune systems. Moreover, regular supervision and evaluation of tracheostomy care practices remain markedly insufficient in many healthcare settings. (Vincent, 2021)

emphasize that limited oversight leads to inconsistent implementation of infection prevention standards, contributing to higher infection rates in patients with immune deficiencies.

These findings underscore the urgent need to develop standardized national or regional guidelines for tracheostomy care, complemented by routine supervision and audit mechanisms to ensure healthcare workers' adherence to protocols. Continuous training and quality monitoring are also essential to improve clinical outcomes in immunocompromised patients (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).Therefore, effective standardization and supervision constitute vital components in reducing infection risks among tracheostomy patients with immune dysfunction and enhancing healthcare quality in ICU settings.

Conclusion

Immune system dysfunction is a major factor contributing to the increased risk of infection among ICU patients with tracheostomies. When the immune response is impaired, the body's ability to defend against invading pathogens is weakened, thereby facilitating bacterial colonization and subsequent infections at the tracheostomy site and within the lower respiratory tract (Liu, 2019; Patel, 2020). Patients with impaired immunity are particularly susceptible to nosocomial infections, such as ventilator-associated pneumonia (VAP) and lower (McGrath, 2020). (Freeman-Sanderson et al., 2018) highlighted that patients experiencing significant self-care limitations are up to twice as likely to develop infections compared respiratory tract infections, which are frequently associated with severe complications (Patel, 2020). In ICU settings, immune dysfunction further exacerbates self-care deficits, including challenges in managing secretions, maintaining tracheostomy site hygiene, and performing adequate oral care, all of which directly contribute to increased infection risk to those with partial self-care abilities. This is corroborated by (Naranjo-Hernández, 2019), who reported that poor oral and airway hygiene promotes bacterial colonization, a key factor in respiratory infections in tracheostomized ICU patients. Several mechanisms explain the link between immune dysfunction and increased infection risk, including: (a) secretion retention due to weakened local immune defenses, creating an environment conducive to bacterial growth (Cameron & Nseir, 2021); (b) compromised oral hygiene, which enables bacterial translocation from the oral cavity to the lower respiratory tract (Naranjo-Hernández, 2019); and (c) insufficient monitoring and care of the tracheostomy wound, where delayed wound healing in immunocompromised patients elevates the risk of local infection progressing to systemic infection or sepsis (McGrath, 2020). Therefore, effective management of ICU patients with tracheostomies necessitates comprehensive assessment of their immune function as a primary determinant of infection risk. Targeted interventions focusing on immunological support, optimized secretion clearance, and stringent oral and

wound care protocols are essential to reducing the incidence of infection in this vulnerable patient population (Peters, Godfrey, Khalil, et al., 2020; Tricco, Lillie, Zarin, O'Brien, Colquhoun, Levac, & Moher, 2018).

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