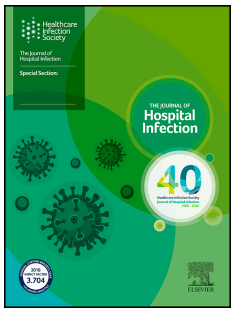
Journal Pre-proof



Impact of non-ventilator healthcare-associated pneumonia on mortality and additional length of stay in adults admitted to an acute care hospital: A systematic review

M.A. Chalker, K. Browne, P.L. Russo, B.G. Mitchell

PII: S0195-6701(26)00034-4

DOI: https://doi.org/10.1016/j.jhin.2026.01.013

Reference: YJHIN 7738

To appear in: *Journal of Hospital Infection*

Received Date: 12 September 2025

Revised Date: 10 December 2025

Accepted Date: 15 January 2026

Please cite this article as: Chalker MA, Browne K, Russo PL, Mitchell BG, Impact of non-ventilator healthcare-associated pneumonia on mortality and additional length of stay in adults admitted to an acute care hospital: A systematic review, *Journal of Hospital Infection*, https://doi.org/10.1016/j.jhin.2026.01.013.

This is a PDF of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability. This version will undergo additional copyediting, typesetting and review before it is published in its final form. As such, this version is no longer the Accepted Manuscript, but it is not yet the definitive Version of Record; we are providing this early version to give early visibility of the article. Please note that Elsevier's sharing policy for the Published Journal Article applies to this version, see: https://www.elsevier.com/about/policies-and-standards/sharing#4-published-journal-article. Please also note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2026 The Author(s). Published by Elsevier Ltd on behalf of The Healthcare Infection Society.

Journal Pre-proof

Impact of non-ventilator healthcare-associated pneumonia on mortality and additional length of stay in adults admitted to an acute care hospital: A systematic review

M.A. Chalker [a], K. Browne [a], P.L. Russo [a, b, c], B.G. Mitchell [a, b, d, e]

[a] Avondale University, Lake Macquarie, New South Wales, Australia

[b] Monash University, Melbourne, Victoria, Australia

[c] Cabrini Health, Malvern, Victoria, Australia

[d] Central Coast Local Health District, Gosford, New South Wales, Australia

[e] Hunter Medical Research Institute, Newcastle, New South Wales, Australia

*Corresponding author:

Michelle Chalker

Email: michelle.chalker@avondale.edu.au

Keywords:

Infection control; Healthcare-associated pneumonia; Cross-infection; Length of stay; Mortality; Systematic review; Health services.

Journal Pre-proof

Summary/Abstract

Background: Non-ventilator-associated pneumonia (NV-HAP), a subset of healthcare-associated pneumonia (HAP), is common and significantly increases patient mortality and hospital stay. However, no systematic review has been undertaken to synthesise the impact of NV-HAP on these outcomes.

Aim: To undertake a review of the evidence on the impact of NV-HAP on mortality and additional length of stay in adults admitted to an acute care hospital.

Methods: We performed a systematic search to identify research exploring and evaluating the impact of NV-HAP on mortality and additional length of stay in adults admitted to an acute care hospital. The electronic databases MEDLINE and CINAHL were searched, for peer-reviewed articles published between January 2004 and August 2025. An assessment of the study quality and risk of bias of included articles was conducted using the ROBINS-E and ROBINS-I tool.

Findings: 6324 studies were initially identified with 49 articles included in the review following the screening and full-text review. Twenty-six papers identified both mortality and additional length of stay results, 21 papers identified mortality results only and two papers reported additional length of stay results only. Inpatient mortality following NV-HAP ranged from 3.1 – 73.9%. Additional length of stay associated with NV-HAP was extended between 10 - 47.5 days.

Conclusions: This systematic review highlights the impact of NV-HAP on patients admitted to hospital. NV-HAP was associated with patient mortality and additional length of stay. Results of this study will inform a larger planned program of research.

Journal Pre-proof

Introduction

Healthcare-associated pneumonia (HAP) refers to a respiratory infection which develops in hospitalised patients 48 hours or more after admission, which was not present at the time of hospital admission [1, 2]. HAP is further classified into ventilator-associated pneumonia (VAP) and non-ventilator healthcare-associated pneumonia (NV-HAP) [3]. Point prevalence studies undertaken in Singapore, the United States, Australia and Europe, identified the most common HAI [4-7]. Point prevalence studies conducted in the United States and Europe, HAP was the most common HAI at 21.8% and 19.4% [5, 6]. Studies conducted in Singapore and Australia report HAP as the second most common healthcare-associated infection at 24.8% and 18.0% [4, 7]. Point prevalence studies are limited to a specific population at a single point in time. These point prevalence studies do not identify the impact of HAP on patient outcomes such as mortality and additional length of stay. Reporting of the incidence of HAP in the literature is limited.

It has been suggested that one in 12 deaths following NV-HAP are potentially preventable [8]. Prevention strategies for NV-HAP focus on addressing risk factors including improved oral care, early mobilisation, elevation of the head of bed during meals, hand hygiene, identification and management of dysphasia [9, 10]. A Swiss study implemented a range of NV-HAP prevention strategies, including oral care, dysphagia screening and management, early patient mobilisation, discontinuation of non-indicated proton-pump inhibitors and respiratory therapy. This study reported a decrease in NV-HAP from 1.45 cases per 1,000 patient days to 0.90 cases per 1,000 patient days. A strong understanding of the incidence of NV-HAP and the burden it places on patients, and the healthcare system is important when undertaking research about the effectiveness of NV-HAP prevention strategies.

The aim of the systematic review is twofold. First, to explore the impact of NV-HAP on mortality. Second, the impact of NV-HAP on additional length of stay in hospital. The two research questions informing this aim are:

1. In an acute care hospital, does NV-HAP impact patient mortality compared to those without NV-HAP?
2. In an acute care hospital, does NV-HAP impact patient length of stay compared to those without NV-HAP?

Methods

The systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. [11] A protocol was developed to guide this

systematic review and was registered with PROSPERO International Prospective Register of Systematic reviews (available at https://www.crd.york.ac.uk/prospero/ with registration number: CRD42024556950). Ethics was not sought because this review used data from published studies.

Information sources and search strategy

A systematic search was conducted using the electronic databases MEDLINE (PubMed) and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) to search for articles published between January 2004 and August 2025. The timeframe was chosen to include the most current NV-HAP data and to provide contemporary data. To identify articles from MEDLINE and CINAHL, two search strategies were used. The first strategy was used to identify articles on the impact of NV-HAP on length of stay, while the second focussed on the impact of NV-HAP on patient mortality. A combination of Medical Subject Headings (MeSH) and free-text terms were used. The identification of keywords were based on a previous review of MeSH Tree Structures and literature. For the eligible articles, the reference lists were reviewed to identify any additional articles.

The first search involved the following terms: ('pneumonia' or 'hospital acquired pneumonia' or 'healthcare associated pneumonia' or 'hap') AND ('hospital' or 'acute setting' or 'ward') AND 'length of stay'. The keywords used for the second search were ('pneumonia' or 'hospital acquired pneumonia' or 'healthcare associated pneumonia' or 'hap') AND ('nosocomial infection' or 'cross infection' or 'healthcare associated infection') AND ('hospital' or 'acute setting' or 'ward') AND 'mortality'). These terms were searched using an ALL TEXT search. Results from both searches were combined.

Study inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) cohort, case control, cross sectional, observation, case reports or randomised controlled trials; (2) published between January 2004 and August 2025; (3) contained data on NV-HAP length of stay and/or mortality outcomes; (3) English language articles; (4) peer reviewed articles; (5) adult population > 18 years old; (6) participants admitted to any ward in an acute care hospital; (7) for studies that reported data from both intervention and control groups, control group data was separated.

Studies examining VAP or community-acquired pneumonia, all grey literature, non-peer-reviewed literature, participants admitted to a rehabilitation hospital, aged care facility or mental health facility and participants aged < 18 years old were excluded. Studies that measured the effectiveness of all oral antimicrobials (excluding topical medication and mouth wash), studies evaluating

treatment intervention (excluding prophylactic treatment) of NV-HAP and comparative studies where control group data could not be separated were also excluded.

Definitions

For this review, we accepted the definition(s) of NV-HAP, length of stay and mortality outcomes as stated in the paper.

Selection process

All papers retrieved using the search strategies in the electronic databases were uploaded to Covidence, a web-based collaboration software platform that streamlines the production of systematic review and other literature reviews [12]. The titles, abstracts and keywords of all identified papers were examined and assessed for relevance and appropriateness inclusion and exclusion criteria. Any duplicate papers were removed, and irrelevant studies were excluded. The study selection process was performed by one author (MC). Articles deemed to have data relevant to the systematic review were included. A randomly selected 5% of all original articles retrieved were cross-checked against the study eligibility criteria by an independent reviewer. If discrepancies are identified, a second review of all abstracts was to be conducted by a member of the research team. No discrepancies were identified. Two members of the research team conducted a full text review of articles (MC, KB). Any conflicts in the application of either the inclusion or exclusion criteria, was resolved by a third member of the research team (BM).

Data collection and data items

One reviewer (MC) carried out data extraction by creating a data extraction sheet in Microsoft Excel. For each eligible study, the following data was extracted: author(s); year of publication, country of study, study design, study setting, study population, definition used for HAP, main results for length of stay and mortality, hospital and study participant demographics, HAP definition and time-dependent bias for length of stay. No attempt was made to contact the authors of papers that contained missing data or unclear information.

Risk of bias

An assessment of the study quality and risk of bias in the articles included in this review was conducted using the Cochrane ROBINS-I tool (Risk of bias in non-randomized studies) which aims to assess the risk of bias in a specific result from an individual non-randomized study that examines the effect of an intervention on an outcome [13]. Risk of bias assessments were conducted by one

member of the research team (MC), with a random selection cross checked another researcher (BM). Any discrepancies were resolved by a third member of the research team.

Data synthesis

Extracted data from the included studies were synthesised and summarised in evidence tables.

Results

Overview of search results

An abstract and title search was conducted for 6324 articles, with 155 articles progressing to full text review. Forty-nine studies met the eligibility criteria and were included in this review. The PRISMA flow chart describing the papers identified from the search strategy is presented in Figure 1. Twenty-six papers identified both mortality and additional length of stay results, 21 papers identified mortality results only and two papers reported additional length of stay results only.

Characteristics of included studies

Characteristics of the 49 studies identified by the literature search are given in Table 1. Studies included were conducted in 24 countries. The United States had the most studies (n = 9) in the systematic review [14-22]. Fourteen countries had 1 article included in this review [15, 19, 23-34]. Thirty studies were conducted in a single hospital [14, 16, 23-25, 27, 28, 30, 32, 33, 35-54] and 19 studies were conducted in multiple hospitals [14, 15, 17, 18, 20-22, 26, 29, 31, 34, 55-62]. Study hospital demographics were reported in 13 studies [18, 19, 28, 33-36, 47, 51, 53, 54, 56, 58].

Definitions of included studies

There were eight different definitions used to define NV-HAP in the included studies, as depicted in Table 2. The most common definitions used were the International Classification of Diseases (ICD-9) and (ICD10) codes (n = 9) [15-18, 20-22, 40, 44] and American Thoracic Society/Infectious Diseases Society of America (ATS/IDSA) (n=9) [19, 30, 33, 37, 39, 45, 52, 59, 61], followed by Centers for Disease Control and Prevention/ National Healthcare Safety Network (CDC/HNSN) (n=8) [25, 26, 32, 34, 48, 49, 53, 55]. Sixteen studies did not specifically name the source definition but did provide a written description of the requirements [14, 23, 27, 29, 31, 38, 41, 43, 46, 47, 50, 51, 56-58, 62]. The differences in definitions used has implications for the ability to make direct comparisons between studies.

Mortality

Forty seven of the 49 studies reported mortality results (*Table 2*) [14-47, 49-53, 55-64]. There were several (n = 11) measurements of mortality used in the included studies (*Table 2*). Sixteen studies reported hospital mortality rates which ranged from 11.7 – 51.5% [14, 19, 20, 24, 29-33, 35, 40, 41, 44, 45, 57, 62]. 30-day mortality was reported in 7 studies which ranged from 18.5 – 34.5 % [17, 29, 38, 55, 56, 60, 64]. Four studies reported 1-year mortality following NV-HAP diagnosis which ranged from 47.3 – 73.9% [17, 29, 33, 45]. Other measures of mortality included in these studies reported 28-day mortality, 5-year mortality, 6-week crude mortality and overall case fatality rate. A broad variation in mortality outcomes remains the same in different part of the world except for in South America (*Supplementary Table 1*). From the 2 studies conducted in South America, mortality outcomes reported ranged from 53.0 – 73.0% [23, 34]. Additionally, the broad variation in mortality outcomes remains consistent when comparing studies using NV-HAP definitions (*Supplementary Table 2*).

Length of stay

Twenty-eight studies reported hospital data on additional length of stay due to HAP (*Table 2*) [14, 15, 17-20, 22-24, 28-30, 32, 34, 39, 40, 45-52, 54, 57, 59, 62]. Patients with NV-HAP had an increased hospital length of stay between 10 - 47.5 [14, 18, 19, 22-24, 28-30, 32, 34, 45, 46, 50, 51, 59, 62]. When reviewing additional length of stay due to HAP in different parts of the world, a broad range of results were reported in studies conducted in 14 European countries 3.1 – 47.5 days [19, 25, 26, 28-31, 33, 35, 36, 40, 43, 45-49, 56, 57, 59, 62] but reported a narrower range of results in studies conducted in Asia, North America and South America 12.6 - 31.0 days [14-23, 27, 32, 34, 37-39, 41, 42, 44, 52-55, 58, 60, 61] (Supplementary Table 1). Furthermore, a broad variation in additional length of stay results were reported using the several NV-HAP definitions except for studies using the CDC/HNSN and ICD- 9 or 10 codes [15-18, 20-22, 25, 26, 32, 34, 40, 44, 48, 49, 53, 55] (Supplementary Table 2). None of the 28 studies which reported additional length of stay results discussed accounting for time-dependent bias in their analysis.

Risk of bias assessment

Forty-two articles were assessed using the ROBINS-E tool (Risk of Bias in Non-randomized Studies – of Exposures). Seven articles were assessed using the ROBINS-I V2 tool (Risk of Bias in Non-randomized Studies – of Interventions). Supplementary Table 3 provides an overview of the risk of bias assessment for each study.

Discussion

In this systematic review, we comprehensively and systematically explored the impact of NV-HAP on mortality and additional length of stay in adults admitted to an acute care hospital. Several studies identified NV-HAP as being associated with increased mortality [14-47, 49-53, 55-64] and that NV-HAP contributes to increased length of stay in hospital [14, 15, 17-20, 22-24, 28-30, 32, 34, 39, 40, 45-52, 54, 57, 59, 62]. However, there was considerable heterogeneity on the reporting mortality outcomes, definitions used, study designs and settings. The same heterogeneity exists for studies reporting the additional length of stay associated with NV-HAP. Differences in these definitions limit the ability to directly compare studies and perform a meta-analysis. Grouping of studies by NV-HAP definition (*Supplementary Table 2*) was not part of the initial aim of this review but was provided to help clarify reported data.

In our review, several studies indicated that NV-HAP was associated with patient mortality [14-47, 49-53, 55-64]. Mortality is one measure to identify the major impact of a health problem and can be used to inform future prevention strategy interventions against competing priorities [65, 66]. A consistent mortality measure is important in NV-HAP research to assess the effectiveness of NV-HAP prevention strategy interventions. This review found that mortality is higher in patients with NV-HAP compared to those without NV-HAP, highlighting the need for effective NV-HAP prevention strategies to reduce the impact.

In our review, several studies indicated that NV-HAP was associated with increased length of stay in hospital [14, 15, 17-20, 22-24, 28-30, 32, 34, 39, 40, 45-52, 54, 57, 59, 62]. Prolonging hospital stay not only impacts the patient, but the broader hospital and community through reducing the availability of beds for new patients [67]. Accurately determining attributable length of stay due to an infection is important and requires careful consideration of the timing of the infection during hospitalisation. Infections may prolong hospitalisation, but time in hospital is also a risk factor for acquiring an infection. Failure to account for the timing of infection leads to time-dependent bias [68]. None of the studies included in this review appear to have accounted for time-dependent bias

in their calculation of additional length of stay. Therefore, there may be over estimations of length of stay associated with NV-HAP in the included studies.

This review has several strengths including a large number of studies and the diversity of study settings from multiple countries, thus increasing the generalizability of results. The review also has weaknesses. The diversity of information contained in studies, including the use of different diagnostic criteria for NV-HAP identification, measures of mortality, in addition to a diversity in the population of comparator groups limited to the opportunity for a meaningful meta-analysis. Currently there is no gold standard for the definition of NV-HAP. This may lead to inconsistent identification of cases in NV-HAP surveillance [66, 69].

The findings of this study highlight the major impact that NV-HAP has on mortality and additional length of stay in hospital. Additionally, from a methodological perspective, there is a need for a standardisation in three key areas: (1) a unified NV-HAP definition for accurate case identification (2) consistent measures of mortality and (3) improved study designs that account for time-dependent bias. Future research addressing these gaps will be crucial in developing evidence-based interventions to reduce NV-HAP and improve patient outcomes.

Journal Pre-proof

Acknowledgements

Conflict of interest statement

None declared.

Ethics

Not required

Funding sources

BM is a recipient of a National Health and Medical Research Council Grant (GNT2008392) and Medical Research Future Fund Grant (MRF2022645) administered by Avondale University. MC is a recipient of a PhD scholarship administered by Avondale University.

References

[1] Tarsia P, Aliberti S, Cosentini R, Blasi F. Hospital-acquired pneumonia. Breathe. 2005;1(4):296-301.
[2] Shebl E, Gulick PG. Nosocomial Pneumonia. StatPearls. 2023. doi: https://www.ncbi.nlm.nih.gov/books/NBK535441/.
[3] Niederman MS. Hospital-acquired pneumonia, health care-associated pneumonia, ventilator-associated pneumonia, and ventilator-associated tracheobronchitis: definitions and challenges in trial design. Clinical infectious diseases. 2010;51(Supplement_1):S12-S7.
[4] Cai Y, Venkatachalam I, Tee NW, Tan TY, Kurup A, Wong SY, et al. Prevalence of healthcare-associated infections and antimicrobial use among adult inpatients in Singapore acute-care hospitals: results from the first national point prevalence survey. Clinical Infectious Diseases. 2017;64(suppl_2):S61-S7.
[5] European Centre for Disease Prevention and Control. Surveillance of healthcare-associated infections and prevention indicators in European intensive care units 2017.
[6] Magill SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, et al. Multistate point-prevalence survey of health care–associated infections. New England Journal of Medicine. 2014;370(13):1198-208.
[7] Russo PL, Stewardson AJ, Cheng AC, Bucknall T, Mitchell BG. The prevalence of healthcare associated infections among adult inpatients at nineteen large Australian acute-care public hospitals: a point prevalence survey. Antimicrobial Resistance & Infection Control. 2019;8:1-8.
[8] Tatara AM, Apostolopoulou A, Agan AA, DelloStritto L, Rhee C, Klompas M. Preventability of Hospital Deaths in Patients With Non-Ventilator Hospital-Acquired Pneumonia. Clinical Infectious Diseases. 2024;79(5):1269-76.
[9] Mitchell BG, Russo PL, Cheng AC, Stewardson AJ, Rosebrock H, Curtis SJ, et al. Strategies to reduce non-ventilator-associated hospital-acquired pneumonia: a systematic review. Infection, disease & health. 2019;24(4):229-39.
[10] Pássaro L, Harbarth S, Landelle C. Prevention of hospital-acquired pneumonia in non-ventilated adult patients: a narrative review. Antimicrobial Resistance & Infection Control. 2016;5:1-11
[11] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi: 10.1136/bmj.n71.
[12] Covidence systematic review software. Melbourne, Australia Veritas Health Innovation n.d.
[13] Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. bmj. 2016;355.
[14] Micek ST, Chew B, Hampton N, Kollef MH. A Case-Control Study Assessing the Impact of Nonventilated Hospital-Acquired Pneumonia on Patient Outcomes. CHEST. 2016;150(5):1008-14. doi: 10.1016/j.chest.2016.04.009. PubMed PMID: 118998953. Language: English. Entry Date: 20170512. Revision Date: 20200328. Publication Type: Journal Article.
[15] Thompson DA, Makary MA, Dorman T, Pronovost PJ. Clinical and economic outcomes of hospital acquired pneumonia in intra-abdominal surgery patients. Annals of surgery. 2006;243(4):547-52. doi: 10.1097/01.sla.0000207097.38963.3b. PubMed PMID: 16552208.
[16] Warren C, Medei MK, Wood B, Schutte D. A Nurse-Driven Oral Care Protocol to Reduce Hospital-Acquired Pneumonia. AJN American Journal of Nursing. 2019;119(2):44-51. doi: 10.1097/01.NAJ.0000553204.21342.01. PubMed PMID: 134327396. Language: English. Entry Date: 20190131. Revision Date: 20190712. Publication Type: Journal Article.
[17] Carey E, Blankenhorn R, Chen P, Munro S. Non-ventilator associated hospital acquired pneumonia incidence and health outcomes among U.S. veterans from 2016-2020. American journal of infection control. 2022;50(1):116-9. doi: 10.1016/j.ajic.2021.06.001. PubMed PMID: 34116083.

[18] Kollef MH, Shorr A, Tabak YP, Gupta V, Liu LZ, Johannes RS. Epidemiology and outcomes of health-care-associated pneumonia: results from a large US database of culture-positive pneumonia. CHEST. 2005;128(6):3854-62. doi: 10.1378/chest.128.6.3854. PubMed PMID: 106005141. Language: English. Entry Date: 20080229. Revision Date: 20200423. Publication Type: Journal Article.
[19] Micek ST, Kollef MH, Torres A, Chen C, Rello J, Chastre J, et al. Pseudomonas aeruginosa nosocomial pneumonia: impact of pneumonia classification. Infection control and hospital epidemiology. 2015;36(10):1190-7. doi: 10.1017/ice.2015.167. PubMed PMID: 26190444.
[20] Zilberberg MD, Nathanson BH, Puzniak LA, Shorr AF. Descriptive Epidemiology and Outcomes of Nonventilated Hospital-Acquired, Ventilated Hospital-Acquired, and Ventilator-Associated Bacterial Pneumonia in the United States, 2012-2019. Critical care medicine. 2022;50(3):460-8. doi: 10.1097/CCM.0000000000005298. PubMed PMID: 34534129.
[21] Giuliano KK, Baker D, Thakkar-Samtani M, Glick M, Restrepo MI, Scannapieco FA, et al. Incidence, mortality, and cost trends in nonventilator hospital-acquired pneumonia in medicaid beneficiaries, 2015-2019. American journal of infection control. 2023;51(2):227-30. doi: 10.1016/j.ajic.2022.06.016. PubMed PMID: 35732253.
[22] Giuliano KK, Baker D, Quinn B. The epidemiology of nonventilator hospital-acquired pneumonia in the United States. American Journal of Infection Control. 2018;46(3):322-7. doi: 10.1016/j.ajic.2017.09.005. PubMed PMID: 128126716. Language: English. Entry Date: 20180301. Revision Date: 20191114. Publication Type: Journal Article.
[23] Souza de Oliveira AB, Hirassawa Sacillotto G, Balthazar Neves MF, Nora da Silva AH, Adriane Moimaz T, Villafanha Gandolfi J, et al. Prevalence, outcomes, and predictors of multidrug-resistant nosocomial lower respiratory tract infections among patients in an ICU. Brazilian Journal of Pulmonology/Jornal Brasileiro de Pneumologia. 2023;49(1).
[24] Gardiner W, Brown K, Richardson H, Pretorius N, Heales L. The incidence, characteristics and in-hospital mortality of non-ventilator-associated hospital-acquired pneumonia in regional Queensland: A retrospective descriptive study. Australian Journal of Rural Health. 2023;31(1):138-43. doi: 10.1111/ajr.12923. PubMed PMID: 162014106. Language: English. Entry Date: 20230301. Revision Date: 20240201. Publication Type: Journal Article.
[25] Yakoub M, Elkhwsky F, El Tayar A, El Sayed I. Hospital-acquired pneumonia pattern in the intensive care units of a governmental hospital: A prospective longitudinal study. Annals of African medicine. 2023;22(1):94-100. doi: 10.4103/aam.aam_178_21. PubMed PMID: 36695229.
[26] Wójkowska-Mach J, Bulanda M, Rózańska A, Kochan P, Heczko PB. Hospital-acquired pneumonia in the intensive care units of Polish hospitals. Infection control and hospital epidemiology. 2006;27(7):784-6. doi: 10.1086/504447. PubMed PMID: 16807862.
[27] Bhadade R, Harde M, deSouza R, More A, Bharmal R. Emerging trends of nosocomial pneumonia in intensive care unit of a tertiary care public teaching hospital in Western India. Annals of African medicine. 2017;16(3):107-13. doi: 10.4103/aam.aam_7_17. PubMed PMID: 28671150.
[28] Taušan Đ, Rančić N, Kostić Z, Ljubenović N, Rakonjac B, Šuljagić V. An assessment of burden of hospital-acquired pneumonia among abdominal surgical patients in tertiary university hospital in Serbia: A matched nested case-control study. Frontiers in medicine. 2022;9:1040654. doi: 10.3389/fmed.2022.1040654. PubMed PMID: 36569168.
[29] van Vught LA, Scicluna BP, Wiewel MA, Hoogendijk AJ, Klein Klouwenberg PMC, Franitza M, et al. Comparative Analysis of the Host Response to Community-acquired and Hospital-acquired Pneumonia in Critically Ill Patients. American journal of respiratory and critical care medicine. 2016;194(11):1366-74. doi: 10.1164/rccm.201602-0368OC. PubMed PMID: 27267747.
[30] Karhu J, Ala-Kokko TI, Ylipalosaari P, Ohtonen P, Laurila JJ, Syrjälä H. Hospital and long-term outcomes of ICU-treated severe community- and hospital-acquired, and ventilator-associated pneumonia patients. Acta Anaesthesiologica Scandinavica. 2011;55(10):1254-60. doi: 10.1111/j.1399-6576.2011.02535.x. PubMed PMID: 104602012. Language: English. Entry Date: 20120330. Revision Date: 20200708. Publication Type: Journal Article.

[31] Gonçalves Pustiglione Campos C, Pacheco A, Dagmar da Rocha Gaspar M, Arcaro G, Martim Reche P, Mendes Nadal J, et al. Analysis of diagnostic criteria for ventilator-associated pneumonia: a cohort study. Revista Brasileira de Enfermagem. 2021;74(6):1-7. doi: 10.1590/0034-7167-2019-0653. PubMed PMID: 152172043. Language: English. Entry Date: 20210903. Revision Date: 20210903. Publication Type: Journal Article.
[32] Juan C-H, Fang S-Y, Chou C-H, Tsai T-Y, Lin Y-T. Clinical characteristics of patients with pneumonia caused by Klebsiella pneumoniae in Taiwan and prevalence of antimicrobial-resistant and hypervirulent strains: a retrospective study. Antimicrobial resistance and infection control. 2020;9(1):4. doi: 10.1186/s13756-019-0660-x. PubMed PMID: 31911832.
[33] Feet JA, Müller KE, Grewal HM, Ulvestad E, Heggelund L. A retrospective study of non-ventilator hospital-acquired pneumonia in a Norwegian hospital: a serious medical condition in need of better and timelier microbiological diagnostics. Infectious Diseases. 2024;56(11):965-73.
[34] Rosenthal VD, Guzman S, Migone O, Safdar N. The attributable cost and length of hospital stay because of nosocomial pneumonia in intensive care units in 3 hospitals in Argentina: a prospective, matched analysis. American journal of infection control. 2005;33(3):157-61. doi: 10.1016/j.ajic.2004.08.008. PubMed PMID: 15798670.
[35] Burton LA, Price R, Barr KE, McAuley SM, Allen JB, Clinton AM, et al. Hospital-acquired pneumonia incidence and diagnosis in older patients. Age and ageing. 2016;45(1):171-4. doi: 10.1093/ageing/afv168. PubMed PMID: 26683049.
[36] Edis EC, Hatipoglu ON, Yilmam I, Eker A, Tansel O, Sut N. Hospital-acquired pneumonia developed in non-intensive care units. Respiration. 2009;78(4):416-22. doi: 10.1159/000232392. PubMed PMID: 105280218. Language: English. Entry Date: 20100205. Revision Date: 20200708. Publication Type: Journal Article.
[37] Feng D-Y, Zhou Y-Q, Zou X-L, Zhou M, Wu W-B, Chen X-X, et al. Factors influencing mortality in hospital-acquired pneumonia caused by Gram-negative bacteria in China. Journal of infection and public health. 2019;12(5):630-3. doi: 10.1016/j.jiph.2019.02.014. PubMed PMID: 30824328.
[38] Feng D-Y, Zhou Y-Q, Zou X-L, Zhou M, Zhu J-X, Wang Y-H, et al. Differences in microbial etiology between hospital-acquired pneumonia and ventilator-associated pneumonia: a single-center retrospective study in Guang Zhou. Infection and drug resistance. 2019;12:993-1000. doi: 10.2147/IDR.S204671. PubMed PMID: 31118705.
[39] Lee H, Park JY, Lee T, Lee YJ, Lim H-J, Park JS, et al. Intermediate risk of multidrug-resistant organisms in patients who admitted intensive care unit with healthcare-associated pneumonia. The Korean journal of internal medicine. 2016;31(3):525-34. doi: 10.3904/kjim.2015.103. PubMed PMID: 26968189.
[40] Loubet P, Voiriot G, Houhou-Fidouh N, Neuville M, Bouadma L, Lescure F-X, et al. Impact of respiratory viruses in hospital-acquired pneumonia in the intensive care unit: A single-center retrospective study. Journal of clinical virology : the official publication of the Pan American Society for Clinical Virology. 2017;91:52-7. doi: 10.1016/j.jcv.2017.04.001. PubMed PMID: 28494435.
[41] Maruyama T, Niederman MS, Kobayashi T, Kobayashi H, Takagi T, D'Alessandro-Gabazza CN, et al. A prospective comparison of nursing home-acquired pneumonia with hospital-acquired pneumonia in non-intubated elderly. Respiratory medicine. 2008;102(9):1287-95. doi: 10.1016/j.rmed.2008.03.027. PubMed PMID: 18602805.
[42] Ohi H, Yanagihara K, Miyazaki Y, Hirakata Y, Tomono K, Kadota J-i, et al. Hospital-acquired pneumonia in general wards of a Japanese tertiary hospital. Respirology (Carlton, Vic). 2004;9(1):120-4. doi: 10.1111/j.1440-1843.2003.00530.x. PubMed PMID: 14982613.
[43] Oznur E, Guzeldag S, Cakir N. Evaluating causative agents, mortality factors, and laboratory data of hospital-acquired pneumonia patients. Revista da Associacao Medica Brasileira (1992). 2021;67(12):1846-51. doi: 10.1590/1806-9282.20210764. PubMed PMID: 34909960.
[44] Poovieng J, Sakboonyarat B, Nasomsong W. Bacterial etiology and mortality rate in community-acquired pneumonia, healthcare-associated pneumonia and hospital-acquired

pneumonia in Thai university hospital. Scientific reports. 2022;12(1):9004. doi: 10.1038/s41598-022-12904-z. PubMed PMID: 35637232.
[45] Putot A, Tetu J, Perrin S, Bailly H, Piroth L, Besancenot JF, et al. Impact of microbiological samples in the hospital management of community-acquired, nursing home-acquired and hospital-acquired pneumonia in older patients. European journal of clinical microbiology & infectious diseases : official publication of the European Society of Clinical Microbiology. 2016;35(3):489-95. doi: 10.1007/s10096-015-2565-9. PubMed PMID: 26753994.
[46] Solmaz İ, Kalın BS. Assessment of antibiotic resistance of infectious agents in patients with pneumonia in tertiary critical care unit and effect on clinical outcomes. International journal of clinical practice. 2021;75(4):e13872. doi: 10.1111/ijcp.13872. PubMed PMID: 33247984.
[47] Sopena N, Heras E, Casas I, Bechini J, Guasch I, Pedro-Botet ML, et al. Risk factors for hospital-acquired pneumonia outside the intensive care unit: A case-control study. American Journal of Infection Control. 2014;42(1):38-42. doi: 10.1016/j.ajic.2013.06.021. PubMed PMID: 104130362. Language: English. Entry Date: 20140114. Revision Date: 20200708. Publication Type: Journal Article.
[48] Stolbrink M, McGowan L, Saman H, Nguyen T, Knightly R, Sharpe J, et al. The Early Mobility Bundle: a simple enhancement of therapy which may reduce incidence of hospital-acquired pneumonia and length of hospital stay. The Journal of hospital infection. 2014;88(1):34-9. doi: 10.1016/j.jhin.2014.05.006. PubMed PMID: 25063011.
[49] Ucgun I, Dagli CE, Kiremitci A, Yildirim H, Ak G, Aslan S. Effects of isolation rooms on the prevalence of hospital acquired pneumonia in a respiratory ICU. European review for medical and pharmacological sciences. 2013;17 Suppl 1:2-8. PubMed PMID: 23436659.
[50] Werarak P, Kiratisin P, Thamlikitkul V. Hospital-acquired pneumonia and ventilator-associated pneumonia in adults at Siriraj Hospital: etiology, clinical outcomes, and impact of antimicrobial resistance. Journal of the Medical Association of Thailand = Chotmaihet thangphaet. 2010;93 Suppl 1:S126-S38. PubMed PMID: 20364567.
[51] Yalçınsoy M, Salturk C, Takır HB, Kutlu SB, Oguz A, Aksoy E, et al. Case fatality rate related to nosocomial and ventilator-associated pneumonia in an ICU: a single-centre retrospective cohort study. Wiener klinische Wochenschrift. 2016;128(3-4):95-101. doi: 10.1007/s00508-015-0884-6. PubMed PMID: 26542131.
[52] Zhang Z, Duan J. Nosocomial pneumonia in non-invasive ventilation patients: incidence, characteristics, and outcomes. Journal of Hospital Infection. 2015;91(2):153-7. doi: 10.1016/j.jhin.2015.06.016. PubMed PMID: 109357270. Language: English. Entry Date: 20160603. Revision Date: 20180705. Publication Type: Journal Article.
[53] Zheng Y-l, Wan Y-f, Zhou L-y, Ye M-l, Liu S, Xu C-q, et al. Risk factors and mortality of patients with nosocomial carbapenem-resistant Acinetobacter baumannii pneumonia. American journal of infection control. 2013;41(7):e59-e63. doi: 10.1016/j.ajic.2013.01.006. PubMed PMID: 23523521.
[54] Zhong X, Wang D-L, Xiao L-H. Research on the economic loss of hospital-acquired pneumonia caused by Klebsiella pneumonia base on propensity score matching. Medicine. 2021;100(15):e25440-e. doi: 10.1097/MD.0000000000025440. PubMed PMID: 150922577. Language: English. Entry Date: 20210618. Revision Date: 20221006. Publication Type: Journal Article.
[55] Chung DR, Song J-H, Kim SH, Thamlikitkul V, Huang S-G, Wang H, et al. High prevalence of multidrug-resistant nonfermenters in hospital-acquired pneumonia in Asia. American journal of respiratory and critical care medicine. 2011;184(12):1409-17. doi: 10.1164/rccm.201102-0349OC. PubMed PMID: 21920919.
[56] Herkel T, Uvizl R, Doubravska L, Adamus M, Gabrhelik T, Htoutou Sedlakova M, et al. Epidemiology of hospital-acquired pneumonia: Results of a Central European multicenter, prospective, observational study compared with data from the European region. Biomedical papers of the Medical Faculty of the University Palacky, Olomouc, Czechoslovakia. 2016;160(3):448-55. doi: 10.5507/bp.2016.014. PubMed PMID: 27003315.
[57] Ibn Saied W, Mourvillier B, Cohen Y, Ruckly S, Reignier J, Marcotte G, et al. A Comparison of the Mortality Risk Associated With Ventilator-Acquired Bacterial Pneumonia and Nonventilator ICU-

Acquired Bacterial Pneumonia. Critical care medicine. 2019;47(3):345-52. doi: 10.1097/CCM.0000000000003553. PubMed PMID: 30407949.
[58] Jiao J, Li Z, Wu X, Cao J, Liu G, Liu Y, et al. Risk factors for 3-month mortality in bedridden patients with hospital-acquired pneumonia: A multicentre prospective study. PloS one. 2021;16(3):e0249198. doi: 10.1371/journal.pone.0249198. PubMed PMID: 33784317.
[59] Uvizl R, Kolar M, Herkel T, Vobrova M, Langova K. Possibilities for modifying risk factors for the development of hospital-acquired pneumonia in intensive care patients: results of a retrospective, observational study. Biomedical papers of the Medical Faculty of the University Palacky, Olomouc, Czechoslovakia. 2017;161(3):303-9. doi: 10.5507/bp.2017.019. PubMed PMID: 28461706.
[60] Watanabe A, Yanagihara K, Kohno S, Matsushima T. Multicenter survey on hospital-acquired pneumonia and the clinical efficacy of first-line antibiotics in Japan. Internal medicine (Tokyo, Japan). 2008;47(4):245-54. doi: 10.2169/internalmedicine.47.0577. PubMed PMID: 18277024.
[61] Yin Y, Zhao C, Li H, Jin L, Wang Q, Wang R, et al. Clinical and microbiological characteristics of adults with hospital-acquired pneumonia: a 10-year prospective observational study in China. European journal of clinical microbiology & infectious diseases : official publication of the European Society of Clinical Microbiology. 2021;40(4):683-90. doi: 10.1007/s10096-020-04046-9. PubMed PMID: 33029764.
[62] Giannella M, Pinilla B, Capdevila JA, Martínez Alarcón J, Muñoz P, López Álvarez J, et al. Pneumonia treated in the internal medicine department: focus on healthcare-associated pneumonia. Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases. 2012;18(8):786-94. doi: 10.1111/j.1469-0691.2011.03757.x. PubMed PMID: 22284436.
[63] Fang W-F, Yang K-Y, Wu C-L, Yu C-J, Chen C-W, Tu C-Y, et al. Application and comparison of scoring indices to predict outcomes in patients with healthcare-associated pneumonia. Critical care (London, England). 2011;15(1):R32. doi: 10.1186/cc9979. PubMed PMID: 21247444.
[64] Iwata K, Igarashi W, Honjo M, Oka H, Oba Y, Yoshida H, et al. Hospital-acquired pneumonia in Japan may have a better mortality profile than HAP in the United States: a retrospective study. Journal of infection and chemotherapy : official journal of the Japan Society of Chemotherapy. 2012;18(5):734-40. doi: 10.1007/s10156-012-0411-x. PubMed PMID: 22491995.
[65] von Cube M, Timsit J-F, Schumacher M, Motschall E, Schumacher M. Quantification and interpretation of attributable mortality in core clinical infectious disease journals. The Lancet Infectious Diseases. 2020;20(12):e299-e306. doi: https://doi.org/10.1016/S1473-3099(20)30485-0.
[66] Jones BE, Sarvet AL, Ying J, Jin R, Nevers MR, Stern SE, et al. Incidence and outcomes of non–ventilator-associated hospital-acquired pneumonia in 284 US hospitals using electronic surveillance criteria. JAMA Network Open. 2023;6(5):e2314185-e.
[67] Rojas-García A, Turner S, Pizzo E, Hudson E, Thomas J, Raine R. Impact and experiences of delayed discharge: A mixed-studies systematic review. Health Expectations. 2018;21(1):41-56.
[68] Barnett AG, Beyersmann J, Allignol A, Rosenthal VD, Graves N, Wolkewitz M. The time-dependent bias and its effect on extra length of stay due to nosocomial infection. Value in Health. 2011;14(2):381-6.
[69] Kalil AC, Metersky ML, Klompas M, Muscedere J, Sweeney DA, Palmer LB, et al. Management of adults with hospital-acquired and ventilator-associated pneumonia: 2016 clinical practice guidelines by the Infectious Diseases Society of America and the American Thoracic Society. Clinical infectious diseases. 2016;63(5):e61-e111.

Journal Pre-proof

Table 1: Characteristics of the included studies

Author(s)	Year of publication	Country of study	Study design	Number of hospitals	Study population	Hospital demographics	Outcome of interest
Bhadade et al. [36]	2017	India	Prospective observational cohort	1	Age 18-90 years Medical ICU	Not reported	Mortality
Burton et al. [11]	2016	United Kingdom	Prospective survey	1	Aged ≥65 years All hospital	Hospital 1 - Acute Medical and Medicine for the elderly wards & 3 Orthopaedic wards Hospital 2 - 4 sub-acute Medicine for the Elderly wards	Mortality
Carey et al. [26]	2022	USA	Retrospective cohort analysis	Not reported	U.S Veterans All hospital	Not reported	Mortality and length of stay
Chung et al. [58]	2011	Korea	Prospective surveillance	73	Adults All hospital	Not reported	Mortality
Edis et al. [42]	2009	Turkey	Prospective cohort	1	Adults All hospital	936 bed capacity	Mortality
Feet et al. [40]	2024	Norway	Retrospective cohort	1	Aged ≥ 18 years All hospital	344 bed capacity	Mortality
Feng et al. [43]	2019	China	Retrospective	1	Aged ≥ 18 years All hospital	Not reported	Mortality
Feng et al. [44]	2019	China	Retrospective observational	1	Aged > 18 years All hospital	Not reported	Mortality
Gardiner et al. [33]	2023	Australia	Retrospective	1	Aged >17 years All hospital	Not reported	Mortality and length of stay
Giannella et al. [12]	2011	Spain	Prospective	72	Age >16 years Internal medicine department	Not reported	Mortality and length of stay
Giuliano et al. [30]	2023	USA	Retrospective review of Medicaid Database	Not reported	Adults With Medicaid insurance	Not reported	Mortality
Giuliano et al. [31]	2018	USA	Retrospective case-control	Not reported	Aged >18 years All hospital	Not reported	Mortality and length of stay
Gonçalves-Pereira et al. [38]	2021	Portugal	Retrospective review of records	100	Adult patients All hospital	Not reported	Mortality
Herkel et al. [59]	2016	Czech Republic	Prospective observational	4	Aged ≥ 18 years ICU	Clinical center 1 - 4 Department of anaesthesiology and intensive care medicine	Mortality

Journal Pre-proof

Ibn Saied et al. [60]	2019	France	Longitudinal prospective	23	Aged > 18 years ICU	Not reported	Mortality and length of stay
Jiao et al. [61]	2021	China	Prospective	25	Aged >18 years All hospital	6 tertiary, 12 non-tertiary and 7 community hospitals	Mortality
Juan et al. [39]	2020	Taipei	Retrospective	1	Aged > 20 years All hospital HAP caused by *Klebsiella pneumoniae*	Not reported	Mortality and length of stay
Karhu et al. [37]	2011	Finland	Prospective observational	1	All patients Mixed ICU	Not reported	Mortality and length of stay
Kollef et al. [27]	2005	USA	Retrospective cohort	59	All patients All hospital Culture positive pneumonia	16 teaching hospitals & 43 non-teaching hospitals	Mortality and length of stay
Lee et al. [45]	2016	Korea	Retrospective cohort	1	All patients Medical ICU	Not reported	Mortality and length of stay
Loubet et al. [46]	2017	France	Retrospective	1	All patients Medical ICU mPCR assay for RVs	Not reported	Mortality and length of stay
Maruyama et al. [47]	2008	Japan	Prospective cohort	1	Aged > 65 years All hospital	Not reported	Mortality
Micek et al. [28]	2015	USA, France, Germany, Italy & Spain	Retrospective	12	Aged ≥ 18 years All hospital HAP caused by *Pseudomonas aeruginosa*	Not reported	Mortality and length of stay
Micek et al. [23]	2016	USA	Retrospective case-control	1	Aged > 19 years All hospital	1300 bed	Mortality and length of stay
Ohi et al. [48]	2004	Japan	Retrospective review of medical records	1	All patients All hospital	Not reported	Mortality
Oznur et al. [49]	2021	Turkey	Retrospective registry review	1	All patients Chest Diseases ICU	Not reported	Mortality
Poovieng et al. [50]	2022	Thailand	Retrospective cohort	1	Aged ≥ 18 years All hospital	Not reported	Mortality
Putot et al. [51]	2016	France	Retrospective review of records	1	Aged > 75 years Geriatrics, pneumology, infectious disease,	Not reported	Mortality and length of stay

Journal Pre-proof

					internal medicine and ICU		
Rosenthal et al. [41]	2005	Argentina	Matched cohort	3	All patients ICU	Hospital 1 - Public 250 bed hospital with 1 medical/surgical ICU (10 beds) and I coronary ICU (10 beds) Hospital 2 - Private 150 bed hospital with 1 medical/surgical ICU (17 beds) and 1 coronary ICU (15 meds) Hospital 3 - Private 180 bed hospital with 1 medical/surgical ICU (10 beds) and 1 coronary ICU (10 beds)	Mortality and length of stay
Solmaz et al. [52]	2020	Turkey	Retrospective cohort	1	Aged ≥ 18 years ICU	Not reported	Mortality and length of stay
Sopena et al. [53]	2014	Spain	Incident case-control	1	Aged ≥18 years All hospital	600-bed tertiary hospital with 20,000 annual admissions	Mortality and length of stay
Souza de Oliveira et al. [32]	2023	Brazil	Prospective observational cohort	1	Age ≥ 18 years ICU Multidrug-resistant nosocomial lower respiratory tract infection	Not reported	Mortality and length of stay
Stolbrink et al. [54]	2014	United Kingdom	Prospective clustered design intervention	1	All patients Elderly care & respiratory wards	Not reported	Length of stay
Taušan et al. [14]	2022	Serbia	Matched nested case-control	1	All patients Abdominal surgery	1,000 bed tertiary healthcare center	Mortality and length of stay
Thompson et al. [24]	2006	USA	Retrospective review of national inpatient sample database	Not reported	Aged ≥ 18 years Intra-abdominal surgery	Not reported	Mortality and length of stay
Ucgun et al. [55]	2013	Turkey	Cohort	1	All patients ICU	Not reported	Mortality and length of stay
Uvizl et al. [62]	2017	Czech Republic	Retrospective observational	2	Aged > 18 years ICU	Not reported	Mortality and length of stay
van Vught et al. [9]	2016	Netherlands	Prospective observational cohort	2	Age ≥ 18 years ICU	Not reported	Mortality and length of stay

Journal Pre-proof

Warren et al. [25]	2019	USA	Nurse-driven oral care protocol intervention	1	Adults All hospital	Not reported	Mortality
Watanabe et al. [63]	2008	Japan	Prospective observational	254	All patients Internal medicine or respiratory wards	Not reported	Mortality
Werarak et al. [10]	2010	Thailand	Prospective hospital-based active surveillance	1	Age ≥ 18 years All hospital	Not reported	Mortality and length of stay
Wójkowska-Mach et al. [35]	2006	Poland	Retrospective review of National Nosocomial Infections Surveillance System	Not reported	Adults ICU	Not reported	Mortality
Yakoub et al. [34]	2023	Egypt	Prospective longitudinal	1	Adults ICU	Not reported	Mortality
Yalçinsoy et al. [13]	2016	Turkey	Retrospective cohort	1	Adults ICU	22 beds Level III medical non-surgical, non- obstetrical adult intensive care unit	Mortality and length of stay
Yin et al. [64]	2021	China	Prospective observational	15	Aged ≥18 years All hospital	Not reported	Mortality
Zhang & Duan. [15]	2015	China	Prospective observational	1	Aged >18 years Respiratory ICU	Not reported	Mortality and length of stay
Zheng et al. [56]	2013	China	Retrospective cohort	1	All patients nosocomial carbapenem-resistant *Acinetobacter baumannii* pneumonia	1500 beds	Mortality
Zhong et al. [57]	2021	China	Retrospective case-control	1	All patients All hospital HAP caused by *Klebsiella pneumonia*	Average annual inpatient population of 80,000	Length of stay
Zilberberg et al. [29]	2022	USA	Retrospective cohort	253	Aged ≥ 18 years All hospital	Not reported	Mortality and length of stay

Journal Pre-proof

Table 2: Overview of mortality and length of stay results

Author(s)	HAP Definition	Reported mortality	Reported additional length of stay (days)	Comparative length of stay results	Accounted for Time-dependent bias
Bhadade et al. [36]	Not named	Individual with HAP who die^: n = 3, 10%	Not measured		N/A
Burton et al. [11]	ECDC	In-hospital death rate^ in patients with clinically confirmed HAP: 29%	Not measured		N/A
Carey et al. [26]	ICD-10 codes	30-day mortality: n = 2,157, 19.1% 1-year mortality: n = 5,346, 47.3%	Not measured	Veterans who developed NV-HAP compared to those who did not was 27.3 days (22 days longer)	Not reported
Chung et al. [58]	CDC/HNSN	Non-ICU mortality^ due to pneumonia: n = 208, 23.9% ICU mortality due to pneumonia: n = 64, 18.7%	Not measured		N/A
Edis et al. [42]	Turkish Thoracic Society	6-week crude mortality: 51%	Not measured		N/A
Feet et al. [40]	ATS/IDSA	In-hospital mortality^: n = 25, 21% 30-day mortality: n = 33, 27.7% 1-year mortality: n = 47, 39.5%	Not measured		N/A
Feng et al. [43]	Not named	Overall mortality rate^: n = 39, 14.4%	Not measured		N/A
Feng et al. [44]	ATS/IDSA	30-day mortality due to pneumonia: 18.5%	Not measured		N/A
Gardiner et al. [33]	Business Analysis and Decision Support (BADS) report & medical record review	In-hospital mortality rate^ for NV-HAP cases: 18.9%	Length of stay due to NV-HAP = 13.0, IQR 12.0		Not reported
Giannella et al. [12]	Not named	In-hospital mortality^ due to HAP: n= 28, 26.9%	Hospital stay due to HAP = 11, Range 6-16		Not reported
Giuliano et al. [30]	ICD-10 codes	5-year mortality rate due to NV-HAP: 7.76%	Not measured		N/A
Giuliano et al. [31]	ICD-9 codes	Patients who died^ due to NV-HAP: 13.1%	Length of stay due to NV-HAP = 13.1		Not reported
Gonçalves-Pereira et al. [38]	Not named	Mortality of patients^ with HAP was higher in patients with stroke (OR, 1.2; 95% CI, 1.1–1.3)	Not measured		N/A
Herkel et al. [59]	Not named	30-day mortality rate for HAP: 29.9%	Not measured		N/A
Ibn Saied et al. [60]	Not named	ICU mortality rate due to HAP: n = 45, 25.6% Hospital mortality rate^ due to HAP: n = 63, 35.8%	ICU length of stay due to ICU-HAP = 13.5, Range 6-28 Hospital length of stay due to ICU-HAP = 26, Range 14-52		Not reported
Jiao et al. [61]	Not named	Mortality rate^ due to HAP: 16.56%	Not measured		N/A
Juan et al. [39]	CDC/HNSN	28-day mortality due to HAP: n = 53, 39.6% In-hospital mortality^ due to HAP: n = 65, 48.5%	Length of stay due to HAP = 16.0, Range 6.0 – 39.3		Not reported
Karhu et al. [37]	ATS/IDSA	ICU mortality due to HAP: n = 5, 7.6% 28-day mortality due to HAP: n = 14, 21.2% Hospital mortality^ due to HAP: n =15, 22.7%	ICU length of stay due to HAP = 3.1 Hospital length of stay due to HAP = 19		Not reported
Kollef et al. [27]	ICD-9 codes	Mortality rate^ due to HAP: 18.8%	Length of stay due to HAP = 15.2		Not reported
Lee et al. [45]	ATS/IDSA	28-day mortality due to HAP: n = 14, 31.1% ICU mortality due to HAP: n = 20, 43.5%	ICU length of stay due to HAP = 12.65		Not reported

Journal Pre-proof

Loubet et al. [46]	ICD-10 codes	In-hospital mortality^ due to HAP: n = 38, 40% 28-day mortality due to HAP: n = 40, 42%	ICU length of stay after HAP diagnosis in patients alive at discharge = 14, Range 4-26		Not reported
Maruyama et al. [47]	Not named	In-hospital mortality^ due to HAP: 51.5%	Not measured		N/A
Micek et al. [28]	Not named	Hospital mortality^ due to HAP: n = 65, 40.1%	Hospital length of stay due to HAP = 24.5, Range 12.0 – 41.0		Not reported
Micek et al. [23]	ATS/IDSA	Hospital mortality^ due to HAP: n = 27, 15.5%	Hospital length of stay due to HAP = 15.9, Range 9.8 – 26.3	Patients with NV-HAP have a longer hospital length of stay = 15.9 vs 4.4 days; P < .01	Not reported
Ohi et al. [48]	Japanese Respiratory Society (JRS)	Mortality rate^ due to HAP: 6.5%	Not measured		N/A
Oznur et al. [49]	Not named	Mortality rate^ due to HAP: 16.9%	Not measured		N/A
Poovieng et al. [50]	ICD-10 codes	In-hospital mortality rate due to HAP: 1.48 (95% CI 1.04-2.05) per 100 person-days 28-day mortality due to HAP: 2.40 (95% CI 1.58-3.49) per 100 person-days	Not measured		N/A
Putot et al. [51]	ATS/IDSA	In-hospital mortality^ due to HAP: 43.5% 1-year mortality due to HAP: 73.9%	Hospital duration due to HAP = 47.5		Not reported
Rosenthal et al. [41]	CDC/HNSN	Mortality^ due to HAP: n = 195, 63.51%	Length of stay due to HAP = 19.68, Range 11-24		Not reported
Solmaz et al. [52]	Not named	Mortality^ due to HAP: n = 17, 73.9%	ICU length of stay due to HAP = 11, Range 5-23 Hospital length of stay due to HAP = 14, Range 10-25	In patients with HAP had a higher hospital length of stay days = 14 (10-25) vs 7 (5-11), P = .001	Not reported
Sopena et al. [53]	Not named	Mortality attributable to HAP: 27.7%	Not measured	The mean length of stay was significantly greater in cases compared with controls when adjusted by severity of underlying disease and Charlson comorbidity index, with a difference in mean length of stay of 26.35 ± 2.38 days	Not reported
Souza de Oliveira et al. [32]	Not named	In-hospital mortality^ due to multidrug-resistant pathogen negative (MDRP–) LRTI: n = 48, 53.0% In-hospital mortality^ due to multidrug-resistant pathogen positive (MDRP+) LRTI: n = 106, 73.0%	ICU length of stay due to MDRP- LRTI: 16, Range 10-24 ICU length of stay due to MDRP+ LRTI: 23, Range 15-33 Hospital length of stay due to MDRP- LRTI: 26, Range 15-41 Hospital length of stay due to MDRP+ LRTI: 31, Range 21-51	MDRP+ LRTI patients had a longer ICU length of stay (median: 23 [15-33] days vs. 16 [10-24] days MDRP+ LRTI patients had a longer hospital length of stay (median: 31.0 [21.0-50.5] days vs. 26.0 [15.0-41.0] days; P = 0.004)	Not reported
Stolbrink et al. [54]	CDC/HNSN	Not measured		Length of stay was significantly longer in patients who had HAP = 11.7 vs 33.4 days: P = 0.01	Not reported
Taušan et al. [14]	ECDC	All-cause mortality rate in patients with HAP: 52.1%	Length of hospital stay in patients with HAP = 38, Range 23.5–56 ICU length of stay in patients with HAP = 15, Range 3–28.75		Not reported

Journal Pre-proof

Thompson et al. [24]	ICD-9 codes	Mortality rate^ due to HAP in patients following intra-abdominal surgery: n = 1421, 10.7%	Not measured	Hospital length of stay for intra-abdominal surgery patients who developed HAP was significantly greater compared with intro-abdominal surgery patients who did not develop HAP = 17.10 days (SD, 18.66 days) vs 6.07 days (SD, 5.37) (P < 0.001)	Not reported
Ucgun et al. [55]	CDC/HNSN	Crude mortality for patients with HAP: n = 67, 66.3%	Not measured	The length of ICU stay was significantly longer in patients with HAP (8.8 days vs. 23.6 days; p < 0.001)	Not reported
Uvizl et al. [62]	ATS/IDSA	Overall mortality^: 24%	ICU length of stay for patients with HAP: 7.6 Hospital length of stay for patients with HAP: 23.5		Not reported
van Vught et al. [9]	Not named	ICU mortality in patients with HAP: n = 47, 21.2% Hospital mortality^ in patients with HAP: n = 78, 35.1% 30-day mortality in patients with HAP: n = 64, 28.8% 90-day mortality in patient with HAP: n = 89, 40.1% 1-year mortality in patients with HAP: n = 118, 53.2%	ICU length of stay due to HAP: 8, IQR 5–18 Hospital length of stay due to HAP: 21, Range 9-39	Patients with HAP had a longer ICU length of stay (6 [3 – 11] vs. 5 [2-11] for patients with CAP; P = 0.04)	Not reported
Warren et al. [25]	ICD-9 and ICD-10 codes	Baseline group NV-HAP deaths^: n = 20 Intervention group NV-HAP deaths^: n = 4	Not measured		N/A
Watanabe et al. [63]	Japanese Respiratory Society (JRS)	30-day mortality in patients with HAP: n = 93, 34.7%	Not measured		N/A
Werarak et al. [10]	Not named	30-day mortality in patients with HAP: n = 16, 44.4%	ICU length of stay due to HAP: 47.5, Range 25-70 Hospital length of stay due to HAP: 16, Range 1-136		Not reported
Wójkowska-Mach et al. [35]	CDC/HNSN	Mortality rate^ in patients with NV-HAP: 3.1%	Not measured		N/A
Yakoub et al. [34]	CDC/HNSN	Overall fatality rate in patients with HAP: 74%	Not measured		N/A
Yalçinsoy et al. [13]	Not named	Crude ICU case fatality rate in patients with HAP: 41% Overall case fatality rate in patients with HAP: 84.1% ICU case fatality rate in patients with HAP: 45.5% Short-term case fatality rate^ in patients with HAP: 27.3% Long-term case fatality rate^ in patients with HAP: 11.4%	Length of hospital stay due to HAP: 10, Range 5–21 ICU length of stay due to HAP: 14, Range 10–24		Not reported
Yin et al. [64]	ATS/IDSA	All-cause mortality rate associated with HAP: 13.7%	Not measured		N/A

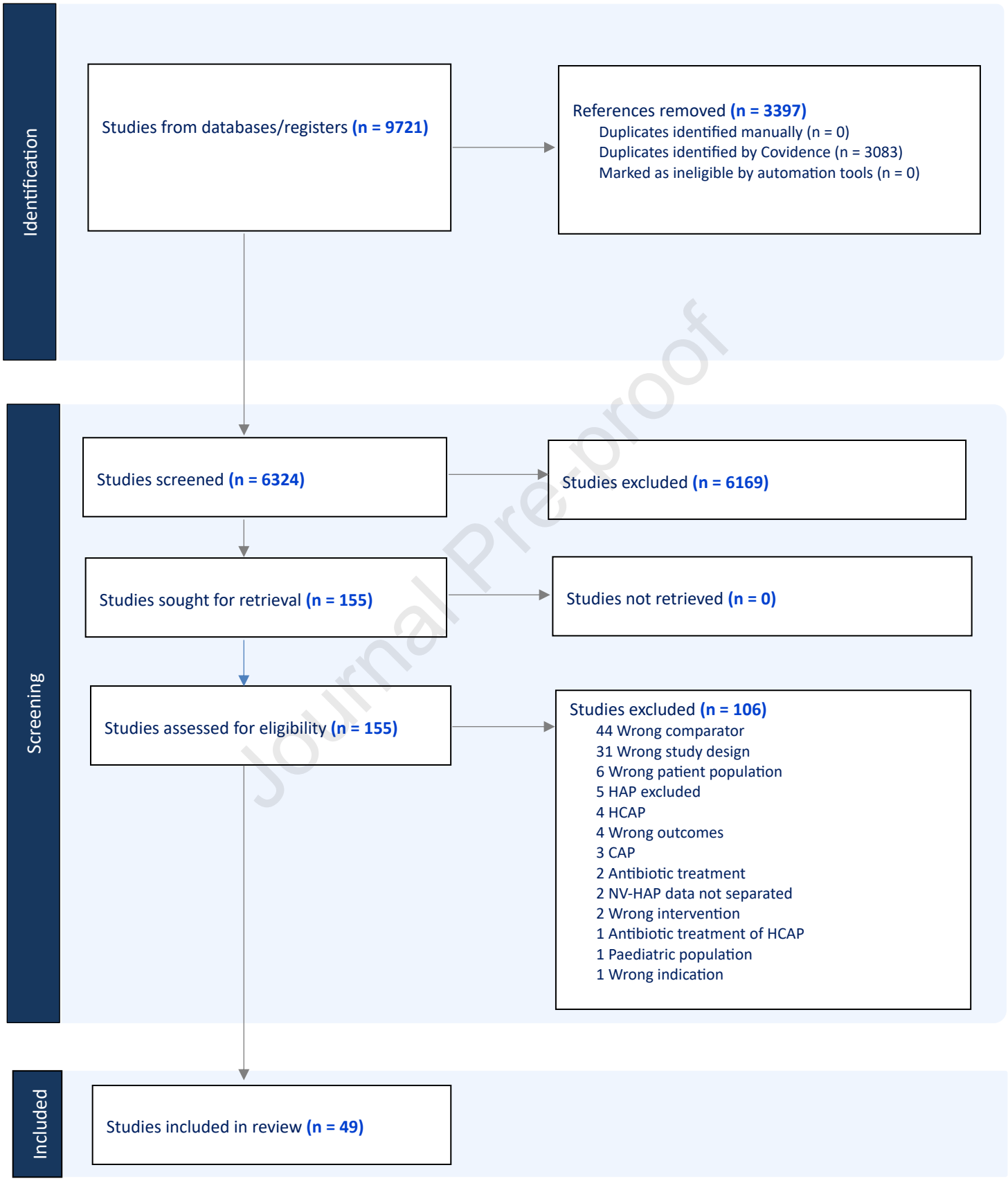
Journal Pre-proof

Zhang & Duan. [15]	ATS/IDSA	Hospital mortality^ due to HAP: n = 5, 31.3%	Hospital length of stay due to HAP: 25.9, Range 12.3 - 34.1 ICU length of stay due to HAP: 10.9, Range 7.7 - 16.8	Compared to patients without nosocomial pneumonia, nosocomial pneumonia patients had a longer ICU stay (median: 10.8 vs 7.9 days; P = 0.007) and longer hospital stay (median: 25.9 vs 15.3 days; P = 0.04)	Not reported
Zheng et al. [56]	CDC/HNSN	Mortality rate^ of patients with nosocomial *Acinetobacter baumannii* pneumonia: n = 68, 28.1%	Not measured		N/A
Zhong et al. [57]	National Health Commission of the People's Republic of China	Not measured	Length of stay due to HAP caused by *Klebsiella pneumonia*: 22, IQR 14 – 29 Length of stay due to HAP caused by extended-spectrum beta-lactamases producing *Klebsiella pneumonia*: 26.5, Range 19 - 29 Length of stay due to HAP caused by extended-spectrum beta-lactamases negative *Klebsiella pneumonia*: 19, Range 12 - 29		Not reported
Zilberberg et al. [29]	ICD-9 & ICD-10 codes	Hospital mortality^ in patients with nonventilated hospital-acquired bacterial pneumonia: - n = 553, 11.70%	Hospital length of stay due to nonventilated hospital-acquired bacterial pneumonia: 17, Range 11–27		Not reported

^ The type of mortality was not described or unclear.

Journal Pre-proof

Figure 1. PRISMA flow diagram for study selection



Journal Pre-proof