Etiology of health care associated pneumonia in different hospital settings

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Abstract: Healthcare-associated infections are one of the most common complications among hospitalized patients. Hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) are severe nosocomial infections leading to high morbidity and mortality. Despite the achievement in reducing burden of AP/VAP during the last years, these conditions are still linked with significant morbidity and mortality, prolonged duration of hospital stays, and substantial health-care costs. Information about local epidemiology and permanent microbiological surveillance is critical for improving patient's outcome and approaches to empirical antibiotic treatment. This review summarizes the recent studies in epidemiology and etiology HAP/VAP in adult and children that can lead the correct and effective management of these infections.

Keywords: Healthcare-associated infections, hospital acquired pneumonia, ventilator associated pneumonia, etiology, epidemiology

Introduction

Healthcare-associated infections (HAI) also referred to as nosocomial infections (NI) are considered as the most frequent complications in hospitalized patients. HAI are infections acquired by patients during their stay in a hospital or another healthcare setting. Some of these infections can be managed easily, but others may have more serious impact on patient's health, prolonged their stay in the medical facilities and increase treatment costs.

Healthcare-associated infections first of all include Hospital-acquired Pneumonia (HAP) and Ventilator-associated Pneumonia (VAP), as well as central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI) and surgical site infections (SSI) [1].

More than 3.5 million cases of healthcare-associated infections are estimated diagnosed in the European Union and European Economic Area (EU/EEA) each year, result in more than 90,000 deaths and corresponding to about 2.5 million disability adjusted life years (DALYs). This burden is more than the cumulative number of other infections including influenza and tuberculosis in the EU/EEA. Moreover, HAIs account for 71% of cases of infections with antibiotic-resistant bacteria, including bacteria resistant to carbapenem-resistant Enterobacter ales. It's important to note that up to 50% of HAIs are considered as preventable. That's why the implementation of infection prevention and control programs in healthcare settings is essential to prevent HAIs. Intensive care units (ICUs) are the hospital wards with the highest prevalence of healthcare-associated HAIs. Most HAIs in critical care units are associated with invasive devices, and a significant proportion of these HAIs can be considered as preventable. In addition, the rate of antimicrobial resistance is high in ICUs, mostly due to the frequent use of antibiotics and different infection prevention and control protocols. Implementation of the antimicrobial stewardship program and infection

prevention and control practices are crucial measures to prevent hospital infections and spread of antimicrobial resistance [2].

According to the WHO, today, out of every 100 patients in acute-care hospitals, seven patients in high-income countries and 15 patients in low- and middle-income countries will acquire at least one health care-associated infection (HAI) during their hospital stay. Usually, one out of ten affected patients will die from HAI. Patients in critical care units and newborns are specifically at risk. Over one fourth of patients affected by health care-associated sepsis and more than half of those patients treated in ICU die annually. Deaths are increased twice when causative bacteria is resistant to antibiotics. If compare data from the 2017–18 and the 2021–22 surveys, it will be clear, that the percentage of countries presented a national infection prevention program remains almost the same. According to the WHO survey in 2019 only 15.2% of health care facilities fulfill the IPC minimum requirements [3].

Epidemiology and etiology of health care associated pneumonia is different in different countries and in different hospital settings. Countries' income also plays an important role. The microorganisms responsible for HAP/VAP and their drug resistance vary between individual hospitals wards, between regions of a country and across world.

In Nepal four hundred and thirty-eight patients were enrolled in the study. 46.8% (205/438) of the patients required intubation. Pneumonia was common in both intubated (94.14%) and non-intubated (52.36%) patients. Intubated patients with pneumonia in the ICU had longer days of stay in the ICU (median of 10, IQR 5–15) to compare to non-intubated pneumonia patients (median of 4, IQR 3–6). VAP incidence rate was 20% and incidence density was 16.45 cases per 1,000 ventilator days. Mortality rate was significantly higher in patients with VAP (44.6%) than patients with pneumonia not requiring intubation (10.7%). Gram negative *Klebsiella* and *Acinetobacter* species were the dominant bacteria in both VAP and non-VAP patients. Multi-drug resistance was highly prevailing in bacterial strains linked with VAP (90%) and non-VAP categories (81.5%). Hospital-acquired Pneumonia and Ventilator-associated Pneumonia presented as the most prevalent HAIs [4].

In Benin 3.353 blood culture bottles (BCB) were sampled, corresponding to 3.140 blood cultures and 3.082 suspected bloodstream infection (BSI) episodes. Most of these cultures (78.7%) were sampled in children <15 years of age. Pathogens were recovered from 383 (12.4%) cultures, corresponding to 381 confirmed BSI. *Klebsiella pneumoniae* (15.6%), *Salmonella Typhi* (15.3%) and *Staphylococcus aureus* (13.5%) were the most prevalent bacteria. Antimicrobial resistance rates were high among Enterobacterales, with resistance to third-generation cephalosporins in 77.6% of *K. pneumoniae* isolates (n = 58), 12.8% of *Escherichia coli* isolates (n = 49) and 70.5% of *Enterobacter cloacae* isolates (n = 44). Methicillin resistance was present in 22.4% of *S. aureus* isolates. It was concluded, that high rates of AMR among Gram-negative bacteria against commonly used antibiotics demonstrates the clinical importance of bacteriology laboratories in hospital settings [5].

The burden of HAP/VAP in the African region is twice that of developed settings. Overall, only 37.9% of HAIs had documented positive microbiological culture result and the pathogens identified include bacteria and fungi. Gram negative bacteria: Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa, Acinetobacter baumannii and Citrobacter were the most common microorganisms. This was followed by gram positive bacteria such as Staphylococcus aureus, enterococci and streptococci, and fungi such as Candida albicans and Aspergillus fumigatus which account for 21.7–50% and 1.8–21.7%, respectively [6]. Hospital-acquired infections contribute significantly to hospital morbidity and mortality, cost of healthcare, and reduce health-related quality of life [7].

In China 2,773 cases of bloodstream infections (BSI) were investigated. A total of 2,773 cases of BSIs were found and a majority (97.3%) of them were monomicrobial. Out of 2,773 case 38.4% were classified as community-acquired BSIs (CABSIs), and 61.6% as a hospital-acquired BSIs (HABSIs). Of the 2,861 BSI isolates, 67.5% were Gram-negative bacteria, 29.6% - Gram-positive, and 2.9% - fungi. The most common BSI pathogens were *Escherichia coli, Klebsiella pneumoniae,* coagulase-negative *Staphylococci* (CNS), *Staphylococcus aureus*, Enterococci, and *Acinetobacter baumannii*. *K. pneumoniae* and *Escherichia coli* isolates showed low susceptibility to cephalosporins (13.1% susceptible), and ampicillin-sulbactam (43.4% susceptible); moderate susceptibility (about 60% susceptible) to ceftazidime, cefepime, and aztreonam; and high susceptibility (>90%) to β-lactam/β-lactamase antibiotics, except *K. pneumoniae* strains to piperacillin-tazobactam (59.2% susceptible). HABSIs were associated with higher prevalence of carbapenem-resistant and extended-spectrum β-lactamases-producing *K. pneumoniae*, methicillin-resistant *S. aureus*,

and ampicillin-resistant *Enterococci* than CABSIs. In general, 42.0% of the BSI due to *S. aureus* strains were resistant to methicillin [8].

In Ukraine 1,579 HAIs were observed. The most frequent of HAI types were pneumonia (38.4%), surgical site infection (34.2%), urinary tract infection (18.1%) and bloodstream infection (9.3%). *Klebsiella pneumoniae* were most commonly reported, accounting for 25.1% of all organisms, followed by *Escherichia coli* (17.6%), *Staphylococcus aureus* (9.9%), *Pseudomonas aeruginosa* (8.9%), *Acinetobacter baumannii* (8.5%), coagulase-negative staphylococci (6.8%), and *Streptococcus spp*. (5.5%). In total, 76.3% isolates from neurosurgical patients were MDRs. Antimicrobial resistance in Ukraine varies greatly by bacterial species, antimicrobial group, and region [9].

In Bulgaria, the frequency, characteristics and risk factors for the occurrence of VAP in newborns hospitalized in intensive care unit was analyzed. Out of 507 neonates, followed up prospectively, 107 were on mechanical ventilation for ≥48 h. Ventilator-associated Pneumonia was diagnosed in 33 neonates (31%). The incidence rate of VAP was 35.06/1.000 ventilator days. The average length of stay of patients with VAP in the NICU was significantly longer to compare the hospital stays of non-VAP patients. In newborns with VAP, the duration of mechanical ventilation was significantly longer to compare with patients without VAP. Among VAP patients the prevalence of Gram-negative bacteria was 91% to compare with Gram-positive bacteria (9%). The most common causative agent of VAP was *Klebsiella pneumoniae* ESBLs+(27%), followed by *Acinetobacter baumannii (14%), Pseudomonas aeruginosa* (12%) and *Escherichia coli* (12%). Mechanical ventilation more than 7 days was showed as an independent risk factor for VAP development. The findings of the study emphasize that VAP remains a serious problem in pediatric and neonatal intensive care units and the birth weight, gestational age, and duration of hospital stay have a significant association with VAP [10].

In Saudi Arabia device-associated nosocomial infections in intensive care units were studied. The device-associated infection (DAI) rates such as central line-associated blood-stream infection (CLABSI), catheter-associated urinary tract infection (CAUTI), ventilator-associated pneumonia (VAP) and ventilator-associated event (VAE) in critical care unit was studied. In general, during the study period 4.29 CLABSI events per 1000 central line days were described. The highest CAUTI rate was presented in the pediatric surgical intensive care unit, while the neonatal ICU and adult surgical ICU showed the lowest. The overall VAP rate ranged from 0.33 to 2.21 cases per 1000 ventilator days. The highest VAP rate was in the pediatric medical-surgical ICU, while the neonatal ICU showed the lowest rate. The authors unveil that the most frequent DAIs in this region is CLABSI and CAUTI [11].

In the USA a multicenter retrospective cohort study of hospitalized patients with culture-positive nonventilated hospital-acquired bacterial pneumonia (nvHABP), ventilated hospital-acquired bacterial pneumonia (vHABP) and ventilator-associated bacterial pneumonia (VABP) was conducted. Out of 17,819 patients 26.5% had nonventilated hospital-acquired bacterial pneumonia, 25.6% ventilated hospital-acquired bacterial pneumonia, and 47.9% ventilator-associated bacterial pneumonia. vHABP was linked with the highest comorbidity and VABP with lowest. Paralysis and neurologic disorders were substantially more common comorbidities in vHABP than nvHABP, and in VABP than in vHABP. *S. aureus* was the most commonly isolated organism, but methicillin-resistant *S. aureus* (MRSA) was prevalent in nvHABP and methicillin-susceptible *S. aureus* (MSSA) was most common in VABP. *P. aeruginosa* was most common in patients with vHABP. *E. coli* was one-third and one-fourth less common in VABP than in vHABP and nvHABP, respectively. *A. baumannii*, although rare across types, was about two times more common in VABP than in other two conditions. Ventilator-associated bacterial pneumonia (17.8%) was more likely than either ventilated hospital-acquired bacterial pneumonia (15.2%) or nonventilated hospital-acquired bacterial pneumonia (11.7%) to be polymicrobial [12].

In Spain etiology of HAP was analyzed using a new molecular platforms and imaging techniques. *Pseudomonas aeruginosa* (18.2%) and *Staphylococcus aureus* (12.2%) were the main pathogens causing HAP. *Klebsiella pneumoniae* was presented in 6.9% of cases and *Escherichia coli* in 6.7%. Ventilator-associated pneumonia was diagnosed in 35% of the infections acquired in the ICU. The most common pathogens were *P.aeruginosa* (17.5%), *S.aureus* (12.1%), and *K. pneumoniae* (10.3%), followed by *E. coli* (7.5%), *Enterobacter cloacae* (7.3%), and *Serratia marcenscens* (7%). Finally, among the bacterial pathogens, *Stenotrophomonas maltophilia* and *Acinetobacter baumannii* were particularly relevant in ICU patients, causing 5.5% and 0.7%, respectively, of VAP. It was noted that in Eastern European countries the frequency of *A. baumannii* can be as high as 20% [13].

In Poland the observational study was carried out. The incidence of ventilator-associated pneumonia was 8.0%. The most common bacteria causing VAP were *Enterobacteriaceae* and non-fermenting Gram-negative bacteria. The causative bacteria's isolation was depending on the diagnostic method: if using PNEU-1, *Staphylococcus aureus* (21.3%) and *Klebsiella pneumoniae* (12.5%) were the dominant organisms, whereas in other VAP cases, *Acinetobacter baumannii* (23.8%) was commonly observed. In cases diagnosed with PNEU-1 the length of antibiotic treatment was shorter than for other VAP cases (7.2 vs. 9.1 days), as was the duration of hospitalization (49 vs. 51.8 days). For *A.baumannii* isolates antibiotic resistance was a particular problem. *A.baumannii* was highly resistance to imipenem (70.6%) and meropenem (52.9%). *K. pneumoniae* strains were highly resistance to ampicillin (90.3%), ceftazidime (71.0%) and third-generation cephalosporins (74.2%) [14].

In Portugal, VAP epidemiology was assessed. Early-onset ventilator-associated pneumonia was diagnosed in 24.9% of the VAP patients. Late-onset VAP was more common and accounted 75.1% of cases. The causative microorganisms were significantly different in the two groups: *S. aureus* was predominant in early-onset VAP, while *P. aeruginosa* was more commonly isolated in late-onset VAP. *K. pneumoniae* was almost similarly isolated in both groups. In both groups *P. aeruginosa* and *S. aureus* were the most prevalent strains. Out of 33 episodes 26 (79%) were caused by *P. aeruginosa*. It should be noted that initial empirical antibiotic therapy was inappropriate in 44% and 31% of *S. aureus* and *P. aeruginosa* cases, respectively [15].

In Turkey, the retrospective study was conducted from July 1, 2021, to June 30, 2023. Adult patients on mechanical ventilation for more than 48 hours were studied. The most frequent pathogens were *Escherichia coli* (42%), *Acinetobacter baumannii* (23%), *Klebsiella pneumoniae* (13%), *Pseudomonas aeruginosa* (12%) and *Staphylococcus aureus* (12%) [16].

In Gulf Cooperation Council (GCC) countries the incidence and pathogens associated with HAP/VAP in hospitals were summarize. It was shown a general reduction in VAP rates over time, but Gram-negative bacteria *Acinetobacter baumannii, Pseudomonas aeruginosa,* and *Klebsiella pneumoniae* remains the most commonly isolated pathogens. MDR cases among *A. baumannii, K. pneumoniae, Escherichia coli and P. aeruginosa* isolates was frequently reported. In Saudi Arabia, between the period 2015- 2019, carbapenem resistance among Gram-negative bacteria were 19–25% and antimicrobial resistance rates in *Acinetobacter* species were 60–89% [17].

In Korea etiology, antibiotic resistance pattern, and clinical outcomes in patients with CAP, HCAP, and HAP were studied. In patients with CAP and HCAP, *Streptococcus pneumoniae* (7.4% vs. 5.7%) and *P. aeruginosa* (9.2% vs. 18.6%) were the most frequent gram-positive and gram-negative bacteria. In the HAP group *Staphylococcus aureus* (methicillin-resistant, 2.7%; methicillin-susceptible, 2.4%) and carbapenem resistant *Acinetobacter baumannii* (20.5%) were the most common Gram-positive and Gram-negative bacteria, respectively. High susceptibility to levofloxacin was reported in CAP and HCAP isolates [18].

In a study from Spain, it was stated that precise information of local epidemiology is important for improving effectiveness of empirical antimicrobial treatment. The local prevalence of MDR pathogens among different medical centers varies significantly. The medical facilities should clarify their local epidemiological data and not rely on national statistics. The MDR bacteria most commonly isolated in Ventilator-associated pneumonia were methicillin-resistant Staphylococcus aureus (MRSA), Acinetobacter baumannii, carbapenemase-producing Enterobacteriaceae (CPE), extended spectrum beta-lactamase-producing Enterobacteriaceae (ESBL-E), and P.aeruginosa [19].

In a recent narrative review [20] it was underline, that in the last years new microbiological technics, like molecular tests based on rapid immunoassay or nucleic acids using amplifications tests, with high sensitivity and specificity have been introduced. New β-lactam/β-lactamase inhibitor combinations are available with significant activities against MDR bacteria. To get microbiological culture in patients with ventilator-associated pneumonia is relatively easy through the endotracheal tube. Collection of specimens is more difficult in patients with hospital acquired pneumonia, that's why microbial etiologies remain poorly documented. In general, HAP can be caused by a wide spectrum of bacteria, and in some cases, can be polymicrobial. The most frequent pathogens are methicillin-resistant *Staphylococcus aureus* (MRSA), *Pseudomonas aeruginosa, Klebsiella pneumoniae*, *Escherichia coli* and *Acinetobacter baumannii*. Besides, in postoperative patients requiring mechanical ventilation, viruses can cause pneumonia, while in immunocompromised patients, both viruses and fungi can cause the infection [21].

To summarize, in this review we presented latest publications concerning the epidemiology and causative organisms of HAP and VAP in pediatric and adult hospitals in different countries of the world. Hospital acquired pneumonia is more common in patients outside of PICU. At the same time the risk of HAP development is higher in patients on mechanical ventilation. Based on available data the most frequent pathogens in patients with VAP are Gram-negative MDR Acinetobacter species, Pseudomonas species, Klebsiella species and Enterococcus species. Isolation of organisms causing VAP depends on length of hospital stay, and antibiotic use in previous months. It is generally considered that early-onset VAP is usually caused by non-MDR bacteria. In contrast, in the late-onset VAP, MDR pathogens are mostly isolated. The types of bacteria in patients with HAP/VAP are different in different countries. The review indicates the extremely important role of microbiological diagnostic methods in infection control programs.

References

1. Boev C, Kiss E. Hospital-Acquired Infections: Current Trends and Prevention. Crit Care Nurs Clin North Am. 2017 Mar;29(1):51-65. doi: 10.1016/j.cnc.2016.09.012.
2. European Centre for Disease Prevention and Control. Healthcare-associated infections. Accessed March 29, 2024. https://www.ecdc.europa.eu/en/healthcare-associated-infections
3. WHO launches first ever global report on infection prevention and control, 6 May 2022. Accessed March 23, 2024. https://www.who.int/news/item/06-05-2022-who-launches-first-ever-global-report-on-infection-prevention-and-control
4. Dongol S, Kayastha G, Maharjan N, Pyatha S, K C R, Thwaites L, Basnyat B, et al. Epidemiology, etiology, and diagnosis of health care acquired pneumonia including ventilator-associated pneumonia in Nepal. PLoS One. 2021 Nov 17;16(11):e0259634. doi: 10.1371/journal.pone.0259634
5. Ombelet S, Kpossou G, Kotchare C, Agbobli E, Sogbo F, Massou F, et al. Blood culture surveillance in a secondary care hospital in Benin: epidemiology of bloodstream infection pathogens and antimicrobial resistance. BMC Infect Dis. 2022 Feb 3;22(1):119. doi: 10.1186/s12879-022-07077-z.
6. Abubakar U., Amir O., Rodríguez-Baño J. Healthcare-associated infections in Africa: a systematic review and meta-analysis of point prevalence studies. J Pharm Policy Pract. 2022; 15:1–16. doi: 10.1186/s40545-022-00500-5
7. Melariri H, Freercks R, van der Merwe E, Ham-Baloyi WT, Oyedele O, Murphy RA, Claasen C, et al. The burden of hospital-acquired infections (HAI) in sub-Saharan Africa: a systematic review and meta-analysis. EClinicalMedicine. 2024 Apr 8; 71:102571. doi: 10.1016/j.eclinm.2024
8. Hu F, Yuan L, Yang Y, Xu Y, Huang Y, Hu Y, Ai X, et al. A multicenter investigation of 2,773 cases of bloodstream infections based on China antimicrobial surveillance network (CHINET). Front Cell Infect Microbiol. 2022 Dec 15; 12:1075185. doi: 10.3389/fcimb.2022.1075185.
9. Salmanov AG, Shchehlov DV, Mamonova M, Bortnik IM, et al. Healthcare-associated infections after neurosurgical procedures in Ukraine: a multicentre study (2020-2022). Wiad Lek. 2024;77(1):17-24. doi: 10.36740/WLek202401102
10. 1Rangelova VR, Raycheva RD, Kevorkyan AK, Krasteva MB, Kalchev YI. Ventilator-Associated Pneumonia in Neonates Admitted to a Tertiary Care NICU in Bulgaria. Front Pediatr. 2022 Jun 28; 10:909217. doi: 10.3389/fped.2022.909217.
11. AlSaleh E, Naik B, AlSaleh AM. Device-Associated Nosocomial Infections in Intensive Care Units at Al-Ahsa Hospitals, Saudi Arabia. Cureus. 2023 Dec 8;15(12):e50187. doi: 10.7759/cureus.50187
12. 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. Crit Care Med. 2022 Mar 1;50(3):460-468. doi: 10.1097/CCM.0000000000005298
13. Candel FJ, Salavert M, Estella A, Ferrer M, Ferrer R, Gamazo JJ, et al. Ten Issues to Update in Nosocomial or Hospital-Acquired Pneumonia: An Expert Review. J Clin Med. 2023 Oct 14;12(20):6526. doi: 10.3390/jcm12206526
14. Wałaszek M, Różańska A, Wałaszek MZ, Wójkowska-Mach J; Polish Society of Hospital Infections Team. Epidemiology of Ventilator-Associated Pneumonia, microbiological diagnostics and the length of antimicrobial treatment in the Polish Intensive Care Units in the years 2013-2015. BMC Infect Dis. 2018 Jul 6;18(1):308. doi: 10.1186/s12879-018-3212-8

15. Mergulhão P, Pereira JG, Fernandes AV, Krystopchuk A, et al. Epidemiology and Burden of Ventilator-Associated Pneumonia among Adult Intensive Care Unit Patients: A Portuguese, Multicenter, Retrospective Study (eVAP-PT Study). Antibiotics. 2024; 13(4):290. doi: 10.3390/antibiotics13040290
16. Semet C. The ongoing challenge of ventilator-associated pneumonia: epidemiology, prevention, and risk factors for mortality in a secondary care hospital intensive care unit. Infect Prev Pract. 2023 Oct 31;5(4):100320. doi: 10.1016/j.infpip.2023.100320
17. Abdalla JS, Albarrak M, Alhasawi A, Al-Musawi T, Alraddadi BM, et al. Narrative Review of the Epidemiology of Hospital-Acquired Pneumonia and Ventilator-Associated Pneumonia in Gulf Cooperation Council Countries. Infect Dis Ther. 2023 Jul;12(7):1741-1773. doi: 10.1007/s40121-023-00834-w
18. Hyun H, Song JY, Yoon JG, Seong H, Noh JY, Cheong HJ, Kim WJ. Risk factor-based analysis of community-acquired pneumonia, healthcare-associated pneumonia and hospital-acquired pneumonia: Microbiological distribution, antibiotic resistance, and clinical outcomes. PLoS One. 2022 Jun 29;17(6):e0270261. doi: 10.1371/journal.pone.0270261.
19. Plata-Menchaca EP, Ferrer R. Current treatment of nosocomial pneumonia and ventilator-associated pneumonia. Rev Esp Quimioter. 2022 Oct;35 Suppl 3:25-29. doi: 10.37201/req/s03.06.2022.
20. Bussini L, Pascale R, Rinaldi M, Bartoletti M. Diagnosis, management and treatment of nosocomial pneumonia in ICU: a narrative review. Journal of Emergency and Critical Care Medicine. 2022; 6 (10):22-32. doi: 10.21037/jeccm-22-3.
21. Miron M, Blaj M, Ristescu AI, Iosep G, Avădanei AN, Iosep DG, Crişan-Dabija R, Ciocan A, Perţea M, Manciuc CD, Luca Ş, Grigorescu C, Luca MC. Hospital-Acquired Pneumonia and Ventilator-Associated Pneumonia: A Literature Review. Microorganisms. 2024 Jan 20;12(1):213. doi: 10.3390/microorganisms12010213.