doi.org/10.36721/PJPS.2026.39.4.REG.14378.1

Factors contributing to in-hospital infections in elderly ICU patients post-antibiotics: A risk prediction model

Rongting Bian*# and Lixia Fan#
EICU, Nanjing First Hospital, Nanjing Medical University, Nanjing, Jiangsu, China

Abstract: **Background**: Early identification of high-risk individuals is essential to guide infection-prevention strategies and optimize antibiotic stewardship in this vulnerable population. **Objectives**: To identify independent risk factors associated with hospital-acquired infections in elderly ICU patients following antibiotic use and to develop and internally validate a clinical risk prediction model for early infection detection. **Methods**: A retrospective cohort study was conducted in the ICU of Nanjing First Hospital, Nanjing Medical University. A total of 120 patients aged ≥65 years, with ICU stay >48 hours, no documented infection at ICU admission and antibiotic exposure within 48 hours before or at ICU admission were included. Demographic data, comorbidities, Sequential Organ Failure Assessment (SOFA) scores, antibiotic exposure characteristics, invasive device use and nutritional support were collected from electronic health records. **Results**: Hospital-acquired infections occurred in 46 patients (38.3%). Independent predictors included advanced age (odds ratio [OR] 1.08 per year), higher SOFA score (OR 1.25 per point), diabetes mellitus (OR 1.45), chronic kidney disease (OR 1.65), use of central venous catheters (OR 1.75), mechanical ventilation (OR 1.85), Foley catheterization (OR 1.55), broad-spectrum antibiotic use (OR 1.50), longer antibiotic duration (OR 1.20 per day) and prolonged ICU stay (all $p<0.05$). The prediction model demonstrated good discrimination (AUC-ROC = 0.82), which improved slightly after variable refinement (AUC-ROC = 0.83). Cross-validated performance remained robust (AUC = 0.80). **Conclusion**: A multivariable risk prediction model using routinely available clinical parameters demonstrated good internal validity and may assist clinicians in early identification of high-risk patients, enabling targeted infection prevention and improved antibiotic stewardship.

Keywords: Antibiotic; ICU acquired infection; Infection control; Risk assessment tool

Submitted on 02-04-2025 – Revised on 16-07-2025 – Accepted on 09-12-2025

INTRODUCTION

Hospital-acquired infections, especially in elderly Intensive Care Unit (ICU) patients, are quite problematic to manage as this patient category is at a higher risk of getting infections and complications resulting from the administration of antibiotics. Ageing patients, basically, those with an age of 65 and above, have declined immune competence resulting from comorbid conditions, age related immunosenescence and others, making them vulnerable to developing nosocomial infections (Smith *et al*., 2021). Therefore, in the ICU environment the risk is heightened by invasive devices, extended lengths of stay and liberal antibiotic usage and comprises the delicate balance of factors that recognise infection prevention and control while enhancing patient outcomes (Johnson *et al*., 2023). Nevertheless, when necessary, antibiotic therapy increases the rate of developing antibiotic resistance, which plays an essential role in the development of nosocomial infections (Brown *et al*., 2022). Hospital-acquired infections, particularly those occurring in the intensive care unit, are associated with increased morbidity and mortality; therefore, identifying their contributing risk factors is essential to improve care delivery and patient outcomes (Garcia *et al*., 2021).

Various factors relevant to jeopardized in-hospital elderly ICU patients have been identified concerning antibiotic usage. One of the key causes is therefore immune frailty, a progressive decline in immune effectiveness linked with very old age that hinders the body's capacity to mount a satisfactory defense against disease causing pathogens (Anderson *et al*., 2022). Such immune deterioration, combined with the immunos SF-36 uppressive agents use by the majority of ICU patients, results in creating an environment that is permissive of infections (Hernandez *et al*., 2023). In addition, there are compelling primary diseases such as diabetes, chronic renal disease and coronary disease, which are much more common in the elderly population and which also compromise the immunity of the aging population, thereby making them prone to infections (Chen *et al*., 2020). The problem of antibiotic resistance plays an important role in infections related to intensive care units. The elderly ICU patients often present a history of multiple antibiotic courses leading to selective pressure, a scenario where only resistant strains are present and continue to grow (Martinez *et al*., 2022). Hence, the recently emerged clinical variants like methicillin-resistant *Staphylococcus aureus (*MRSA), vancomycin-resistant Enterococci (VRE), or multidrug resistant Gram-negative bacteria appear to be especially worrisome in this setting (Wilson *et al*., 2024). Research

**Corresponding author:* e-mail: BJY02508286@hotmail.com
#These authors contributed equally; therefore, they are the co-first authors.

has shown that broad spectrum antibiotics alter the normal flora and this creates an opportunity for pathogenic and resistant organisms to fully evolve (Clark *et al*., 2021). Since the emergence of COVID, elderly patients admitted to ICUs with COVID have faced unique risks for hospital-acquired infections due to virus-induced immune dysfunction, high rates of invasive procedures and extensive antibiotic use. Therefore, this study specifically focuses on elderly ICU patients infected with COVID to identify risk factors contributing to in-hospital infections and to develop a predictive model for infection risk in this population.

Another important determinant of illness acquisition in ICU comprises the utilization of invasive devices like central venous lines (CVLs), endotracheal tubes (ETs) and urinary catheters (UCs). These devices act as potential sources to let pathogens undermine the immune system of the body and give place for diseases to spread in immunocompromised patients (Thomas *et al*., 2023).

Antibiotic stewardship programs (ASPs) are intended to address antibiotic usage plans, decrease resistance and decrease infections. Nevertheless, some problems should be considered when applying ASPs in elderly ICU patients. Due to the increased susceptibility of infections in these patients, sometimes clinicians treatment is based on the least likelihood of resistance, even if the culture samples do not indicate an infection at a specific site (Jackson *et al*., 2023). While it may be required under some circumstances, this approach raises the probability of overusing it and leads to resistance. Research shows that when ASP is implemented appropriately, the rate of infections and outcomes can be improved due to the cutting of unnecessary prescriptions of antibiotics (Sullivan *et al*., 2021). However, striking an ideal balance between the proper use of drugs to treat and the potential harm of using drugs inappropriately is a major factor that has not been given adequate attention (Lee *et al*., 2023). Co-morbid conditions like diabetes, chronic obstructive pulmonary disease (COPD) and renal insufficiency add on to the challenges involved in managing infection in elderly. Each of these conditions alone raises the infection risk and may require additional medications adding up to polypharmacy (Garcia *et al*., 2023). Multiple medication taking is defined as use of more than four different drugs at the same time; this has negative interaction effects that can even compromise the immune synergy or the antibiotic course (White *et al*., 2024). The fact remains that the patient density issues, contact frequency of the personnel and constant unit mobilization enhance the possibility of pathogen spread (O'Neill *et al*., 2020). Moreover, ample studies indicate that ICU surfaces and equipment, if not properly cleaned and disinfected, can become reservoirs of resistant organisms, a concern for patients' outcomes (Stevens *et al*., 2021). New knowledge about the genomics of elderly patients has enabled researchers to ascertain how genetic determinants work in risking infections and reacting to antibiotics among the elderly (Perez *et al*., 2023). Additionally, there is some evidence that patients with advanced age and a particular set of genetic characteristics may undergo microbiome disturbances due to antibiotics more rapidly, which may lead to infections (Sharma *et al*., 2022).

Thus, nutritional status quite sensibly comes second to immunological susceptibilities as a determinant of infection risk in elderly ICU patients. The patients suffering from malnutrition are the ones likely to present with compromised immunity and therefore are likely to respond poorly to antibiotics and become prone to infections (Smith *et al*., 2023). Multiple sources have indicated that post antibiotic related infections can easily develop in malnourished patients due to the poor immunity of their bodies in fighting infections (Johnson *et al*., 2024). Enteral nutrition support is required in ICU patients; nevertheless, achieving adequate nutrition is difficult, particularly in geriatric patients with GI morbidity (Chen *et al*., 2023).

Psychosocial antecedents are now more understood, especially because the elderly population's health is strongly linked to such factors. Older patients suffers from social isolation, anxiety and depression, which may worsen whenever they are in the ICU where people are allowed to visit rarely (Martinez *et al*., 2023). Such psychosocial factors have been associated in some way with poor immunological functioning, indicating that mental ailments, despite their physical manifestations, might make people more exposed to infections (Wilson *et al*., 2023). Several measures have been recommended, including counseling and permission to have family visits that have been postulated to enhance mental health and possibly to reduce risk of infection (Clark *et al*., 2024). More studies should be carried to identify the complete extent of psychosocial effects on infection incidences among elderly ICU patients (Garcia *et al*., 2024).

The study of in-hospital infections such as pneumonia and catheter related blood Stream in elderly ICU patients is not a simple immunology, but a clinical, environmental and genetic/epigenetic problem. Despite these requirements, antibiotics need only be prescribed to reduce the incidences of bacterial resistance and interferences with the regular conversation of flora.

MATERIALS AND METHODS

Design and patients' recruitment

In this article, we have employed a retrospective cohort study carried out in the ICU of Nanjing First Hospital, Nanjing Medical University, located in Nanjing, Jiangsu Province, China. The current research focused on creating a model that will help TO identify causes of in-hospital acquired infections in elderly ICU patients after

administering antibiotics. The 120 elderly patients used in this study were aged 65 years or above. For this purpose, the study population comprised patients who were admitted to ICU for more than 48 hours, free from documented infection at ICU admission and initiating antibiotic therapy at any time within 48 hours prior to, or at the time of ICU admission. Patients with active infections on admission to the ICU and patients with HIV/AIDS, active cancer or other immunosuppressive diseases were excluded, as were patients with missing records.

Methodology

Information retrieved from the Electronic Health Record **(**EHR) sources was the patient's demographics (age, sex, comorbidity status), clinical features (length of the ICU stay, main diagnosis, illness severity) and laboratory results. Data on antibiotic types, doses and periods of administration before and after ICU admissions were also collected. Selected details of post-antibiotic in-hospital infections, including the onset time, type of infection and microbiological results, were collected and checked by two investigators. Some of the other variables which were documented were – central venous catheterisation, endotracheal intubation, nutritional support in the form of total enteral or parenteral nutrition, physical and functional status assessment.

Outcome measures

The main endpoint was the acquisition of a hospital-associated infection subsequent to antibiotic therapy in the ICU. Other endpoints were measured to establish the effects of infections on the overall health of the patients. On the patient level, we defined ICU LOS as the number of days from admission to discharge for the ICU stay and overall hospital LOS, which included ICU and non-ICU stays, to assess the period of time to recover from infection and resource utilization. For this study, the mortality rate inside the ICU was measured by the proportion of patients who died during their ICU stay; we also divided the sample by the type of infection and the timing of the onset. Details of the type and the timing of the infection relative to the antibiotic commencement were recorded to evaluate the relationship with the outcome for each infection. Intention to treat rate was used as a measure and it focused on the readmission rate, which means admission back to the ICU or hospital within 30 days of discharge. Antibiotic resistant organisms were followed in bacterial cultures of the cases and resistant strains, including MRSA, VRE and ESBL producers, were recorded to look into the correlation between severity of the infection and the developed resistance. Organ dysfunction was measured using the Sequential Organ Failure Assessment (SOFA) score and for this analysis, emphasis was made on effects on the main systems, which include respiratory, renal and cardiovascular. Functional decline was measured by the Barthel Index (BI) before and after ICU stay in order to determine the extent of change in daily living activities as a result of infection (Caronni *et al*., 2025). Details on patients' QoL were collected through follow-up questionnaires of 1, 3 and 6 months after discharge and the SF-36 was used to evaluate the long-term consequences (Garcia *et al*., 2024).

Statistical analysis

The descriptive methods were then used in presenting cross sectional characteristics of health status and illness rates and the results of medical treatment. Details of post-antibiotic hospital-acquired infections were collected and univariate analyses were performed to identify associated risk factors. Variables with $p < 0.05$ were subsequently entered into a multivariable logistic regression model to develop the risk prediction model. Each predictor was measured by odds ratios (ORs) with 95% confidence intervals (CIs). Model performance was evaluated using discrimination and calibration measures: discrimination was measured by means of the area under the ROC curve (AUC-ROC) and calibration was studied by calculating the Hosmer-Lemeshow goodness of fit test (Surjanovic *et al*, 2024). Other diagnostic statistics included in the evaluation of the final model were sensitivity, specificity, positive predictive value and negative predictive value. All statistical tests were conducted in SPSS 26.0 statistical software and considered statistically significant when $p < 0.05$.

Sample size calculation

The required sample size was calculated using a power analysis for logistic regression. Assuming a significance level (α) of 0.05, a power (1–β) of 0.80 and an expected infection incidence of approximately 35% based on prior studies, a minimum of 110 patients was estimated to detect an odds ratio of 1.8 for major risk factors. To account for potential exclusions or incomplete data, we recruited 120 elderly ICU patients.

RESULTS

Demographic and baseline characteristics of patients

Table 1 describes demographic and baseline variables of patients in a study on identifying predictors of hospital infections in elderly patients in ICU.

Age and gender distribution

The mean age of the total population of the elderly ICU cohort is 74.3 years, with no statistical differences between the mean ages of the infected at 75.1 ± 7.9 and the noninfected group at 73.4 ± 8.5 ($p = 0.231$), thus pointing out that mere age cannot be used to distinguish the infection risk amongst the elderly ICU population. Nevertheless, as for gender distribution, there is a significant difference because 58.33% of patients infected with COVID are male, whereas 41.67% of patients not infected with COVID are male ($p = 0.045$), which confirms

that more males are affected by COVID than females. Additionally, comorbidities differed by gender: among male patients, the most common conditions were diabetes and chronic kidney disease, while among female patients, hypertension and chronic obstructive pulmonary disease were more prevalent. These findings highlight potential gender-based vulnerabilities to infection and comorbid conditions in elderly ICU patients.

Co-morbid diseases and pre-existing illnesses

Among comorbidities, hypertension stands out in 66.67% of the total group, however highest among infected – 62.5% and lowest among non-infected – 37.5 % – p = 0.031. Diabetes mellitus is also more frequent in the infected group (63.64%) compared to the non-infected group (36. 36%) (p = 0.029); this implies that the risk of being infected can be significantly associated with diabetes. The same goes for Chronic kidney disease, with 62.5% of infected and 37.5% non-infected patients with KD+, p-value = 0.018, which implies that there was a significant relationship with infectious disease.

Clinical indicators: These variables include SOFA score, ICU stay and hospital stay

Specifically, the illness severity according to SOFA score is significantly higher among infected patients (8.2 ± 2.1) vs. non-infected patients (6.9 ± 2.5; p = 0.009), suggesting that severe illness at ICU admission may be comparatively more susceptible to infection. Moreover, patients admitted to the ICU who have a diagnosis of infection have a longer length of stay, 15.1 days compared to 10.3 median days for those who are not infected, p = 0.002. Infectious complications may explain this prolonged ICU stay, while members of the extended ICU exposure may have infectious effects on the critical care interventions. Again, each overall hospital length of stay has been found to be significantly increased in infected patients, which is 25.3 days, compared with the non-infected group, which is 16.8 days, with p < 0.001. This increased hospital stay in infected patients shows not only the disease burden within patient-treated infection, but also the burden within healthcare, for patients requiring extra procedures and days in hospital to heal.

Antibiotic exposure details

The more nuanced results of the antibiotic exposure for the ICU patients, as described in table 2, indicate more distinctions between the infected and non – infected patients' characteristics.

Antibiotic type and therapy management

A greater proportion of the total patients (70.83%) received broad-spectrum antibiotics; infected patients were given broad-spectrum antibiotics significantly more frequently than non-infected patients (64.71% vs 35.29% p = 0.015). Broad-spectrum antibiotics, on the other hand, were prescribed more frequently in the non-infected group (57.14%) than the infected (42.86%), with a p-value of 0.027. The results point to an undesirable effect of broad-spectrum antibiotic use, with an increased infection risk, resulting from the broader interference with the micro biome, which can encourage resistant organisms to develop. The type of therapy they underwent also differed a great deal across the groups. Co-administration of greater than one antibiotic was significantly higher among infected patients, 70.00% than non-infected patients 30.00%; p = 0.022. Single antibiotic therapy, however, was more evenly distributed, although marginally more in the infected group (57.14%) than in the non-infected group (42.86%) (p=0.029). These results suggest that combination therapy might be associated with a higher infection risk perhaps because of its higher selective pressure to the bacterial population.

Length and time of antibiotic treatment

The duration of antibiotic use was significantly higher in infected patients who received an average of 12.4 days of antibiotics, compared to 8.1 days in non-infected patients overall, with a highly statistically significant value of p<0.001. This implies that staying for long on the antibiotics could lead to more infections since the setting probably favors antibiotic resistant microbes (Table 2). The timing of antibiotic initiation relative to ICU admission was also significantly different. Examining antibiotic prescription within the first 24 hours, a significantly higher proportion of patients with infection (66.67%) was given the medication compared to non-infected patients (33.33%); p = 0.012. Similar direction was observed during 48 hours: 55,56 % of infected patients were given antibiotics while 44,44 % of non-infected patients (p = 0,038). Collectively, these observations suggest that early administration of antibiotics to ICU patients may be linked to some increased risk of infection, perhaps by altering the clarity of the intrinsic microbiota or promoting the selection of antibiotic-resistant microorganisms (Table 2).

PMD, EE and targeted antibiotic therapy

Infected patients received prophylactic antibiotics at a higher percentage of 66.67% than the non-infected patients, who received the drug at a percentage of 33.33% (p = 0.041). In the same way, empiric antibiotic therapy, which was given before culture results, was used in 70.00% of infected patients and only 30.00% of non-infected patients, p = 0.018. Another analysed variable was targeted therapy, which is performed depending on the culture results and also more frequently among infected patients (62,50%) than in non-infected ones (37,50%), p <0.026. Such tendencies indicate that even the preventive and early treatment-based antibiotic administration practices, where antibiotic pre-emption or limited course empiric therapy is administered to prevent or quickly control infections in critical care units, may indeed fuel the emergence of infections caused by resistant bacterial strains in ICU patients (Table 2).

Table 1: Demographic and baseline characteristics of patients

Characteristic	Total (n = 120)	Infected with COVID (n = X)	Non-infected with COVID (n = Y)	p-value (ANOVA)
Age (mean ± SD)	74.30 ± 8.20	75.10 ± 7.90	73.40 ± 8.50	0.231
Gender (male, %)	60 (50.00%)	35 (58.33%)	25 (41.67%)	0.045
Gender (female, %)	60 (50.00)	25 (41.67%)	35 (58.33%)	0.031
Hypertension (%)	80 (66.67%)	50 (62.50%)	30 (37.50%)	0.031
Diabetes mellitus (%)	55 (45.83%)	35 (63.64%)	20 (36.36%)	0.029
Chronic kidney disease (%)	40 (33.33%)	25 (62.50%)	15 (37.50%)	0.018
SOFA Score (mean ± SD)	7.50 ± 2.30	8.20 ± 2.10	6.90 ± 2.50	0.009
ICU length of stay (days, mean ± SD)	12.40 ± 6.80	15.10 ± 5.90	10.30 ± 6.30	0.002
Hospital length of stay (days, mean ± SD)	20.10 ± 9.50	25.30 ± 10.10	16.80 ± 8.70	<0.001

Table 2: Antibiotic exposure details

Antibiotic parameter	Total (n = 120)	Infected with COVID (n=X)	Non-infected with COVID (n = Y)	p-value (ANOVA)
Broad-spectrum antibiotics (%)	85 (70.83%)	55 (64.71%)	30 (35.29%)	0.015
Narrow-spectrum antibiotics (%)	35 (29.17%)	15 (42.86%)	20 (57.14%)	0.027
Combination therapy (%)	50 (41.67%)	35 (70.00%)	15 (30.00%)	0.022
Single antibiotic therapy (%)	70 (58.33%)	40 (57.14%)	30 (42.86%)	0.029
Antibiotic duration (days, mean ± SD)	10.20 ± 3.60	12.40 ± 3.20	8.10 ± 3.80	<0.001
Antibiotic initiation relative to ICU admission				
Within 24 hours (%)	60 (50.00%)	40 (66.67%)	20 (33.33%)	0.012
Within 48 hours (%)	45 (37.50%)	25 (55.56%)	20 (44.44%)	0.038
Prophylactic use of antibiotics (%)	30 (25.00%)	20 (66.67%)	10 (33.33%)	0.041
Empiric antibiotic therapy (%)	50 (41.67%)	35 (70.00%)	15 (30.00%)	0.018
Targeted therapy post-culture (%)	40 (33.33%)	25 (62.50%)	15 (37.50%)	0.026
IV antibiotic administration (%)	90 (75.00%)	60 (66.67%)	30 (33.33%)	0.014
Oral antibiotic administration (%)	30 (25.00%)	15 (50.00%)	15 (50.00%)	0.033

Table 3: Clinical characteristics and invasive device use

Clinical characteristic / Device	Total (n = 120)	Infected with COVID(n=X)	Non-infected with COVID (n = Y)	p-value (ANOVA)
Central venous catheter (%)	70 (58.33%)	45 (64.29%)	25 (35.71%)	0.019
Endotracheal tube (%)	85 (70.83%)	60 (70.59%)	25 (29.41%)	0.004
Foley catheter (%)	60 (50.00%)	40 (66.67%)	20 (33.33%)	0.021
Arterial line (%)	45 (37.50%)	30 (66.67%)	15 (33.33%)	0.028
Continuous renal replacement therapy (CRRT) (%)	25 (20.83%)	18 (72.00%)	7 (28.00%)	0.032
Mechanical ventilation (%)	90 (75.00%)	65 (72.22%)	25 (27.78%)	0.008
Non-invasive ventilation (%)	30 (25.00%)	18 (60.00%)	12 (40.00%)	0.039
Enteral nutrition (%)	65 (54.17%)	40 (61.54%)	25 (38.46%)	0.034
Parenteral nutrition (%)	30 (25.00%)	20 (66.67%)	10 (33.33%)	0.041
Surgical drain (%)	20 (16.67%)	15 (75.00%)	5 (25.00%)	0.025
Urinary stent (%)	15 (12.50%)	10 (66.67%)	5 (33.33%)	0.047
Tracheostomy (%)	10 (8.33%)	8 (80.00%)	2 (20.00%)	0.015
Hemodialysis (%)	25 (20.83%)	15 (60.00%)	10 (40.00%)	0.036
Vasopressor support (%)	50 (41.67%)	35 (70.00%)	15 (30.00%)	0.013

Route of administration

All the types of administration methods, intravenous (IV), were the most frequently used, with a record high of 75% of the patients who received antibiotics intravenously. Of the infected patients, 66.67% was given IV antibiotics compared to 33.33% of the non-infected patients, indicating that the infection was associated with a higher risk with the use of IV (p = 0.014). Oral antibiotic administration was less common than other routes, accounting for only 25% of cases overall, with an equal distribution between infected and non-infected patients (50% each); however, the difference remained statistically significant (p = 0.033).Table 2).

Use of invasive devices

Central venous catheters, endotracheal tubes and Foley catheters were the most common invasive devices identified amongst the involved patients in the study and there was significant variability in the use of the devices in the infected and non-infected subjects. Overall central venous catheters were used by 58.33% of the total patients; infection 64.29% and non-infection 35.71% with p = 0.019. Likewise, use of endotracheal tubes was higher in the infected group (70.59%) compared to the non-infected group (29.41%) and (p = 0.004) of ICU patients s, implying that these devices could be the entry point of infections in ICU. Foley catheters were inserted in 27 patients (50.00%) while the other 27 patients did not undergo catheterisation before developing the infection; Foley catheterisation was significantly higher in the infected group (66.67%) than in the non-infected group (33.33%); (p 0.021) thus supporting the hypothesis that catheter use increased the risk of the infection (Table 3).

Other procedures that may be invasive

Mechanical ventilation and arterial lines were also independently associated with infection among the patients. Arterial lines were utilized more in the infected cohort (66.67%) than in the non-infected (33.33%), with a statistically significant difference (p = 0.028). Of all the risk factors examined here, mechanical ventilation used in 75% of the total cycle cohort had the highest infection risk, with 72.22% of infected patients requiring this intervention compared to only 27.78% of non-infected patients (p = 0.008). Less commonly applied (25% overall), NIV usage also revealed a statistically significant difference: 60% of infected patients received NIV, while only 40% of non-infected patients did so (p = 0.039). These findings imply that both entubation and non-entubation invasive and non–invasive ventilation may be risks for infections, possibly through airway access (Table 3).

Dialysis and nutrition

Specific to infection, both enteral and parenteral nutritional support were found to be independently associated with infection. Enteral nutrition was given in 54.17% of patients; the patients in infected group received the enteral nutrition more frequently than non-infected patients (61.54%) (<50.00%) (p = 0.034). The delivery method parenteral nutrition was used in the present study with an overall frequency of only 25% of the total cohort and yet, it was administered significantly more to the infected group (66.67%) compared to the non-infected group minority (33.33%) (p = 0.041). These results imply that though essential, nutritional support may increase the risk of infection, likely because of handling and preparing processes. The other variables were continuous renal replacement therapy (CRRT) and hemodialysis. CRRT was prescribed to 20.83% of the patients, infected patients being prescribed CRRT more often (72.00%) than non-infected patients (28.00%) (p = 0.032). Hemodialysis was also statistically significant; infected patients were 60% requiring hemodialysis as compared to 40.00% in the non-infected patients (p = 0.036). This implies that, unlike cases where renal replacement therapies delayed the development of infection, these treatments expose the patient to multiple access points, increasing the likelihood of getting an infection (Table 3).

Surgery and other supports

Surgical drains, urinary stents, tracheostomies and vasopressor support were also shown to be associated with infection. Surgical drains were used in 16.67% of patients in general; however, infected patients had surgeries more frequently than non-infected patients (75% vs 25%) (p = 0.025). Infection with urinary stents was found in 50% of patients with stents in comparison to 25% of patients without it; hence, usage of urinary stents was documented in 12.5% of cases; p = 0.0047. Likewise, tracheostomy was a very low incidence (8.33 %), but its infection rate was (80%) among those who underwent the operation (p = 0.015). Another factor was vasopressor support, which was needed in 41.67% of total patients, though more required it if infected (70.%) compared to the non-infected group (30.%) (p = 0.013) (Table 3).

Infection type, onset timing and related outcomes

The types of infection, onset timing and antibiotic resistance regarding ICU patients and compare the characteristics of the infected and non-infected patient groups as well as the risk factors that are more associated with infection (Table 4).

Types of infections

Of all the observed infection types, respiratory infections turned out to be the most widespread – 37,50% overall. Among the infected patients, 66.67% reported respiratory infections, while the rest of the patients, 33.33%, had no infection, according to the calculated p-value of 0.017. Another complained illness was the urinary tract infection that was experienced by 29.17% of the patients. When evaluating the prevalence of UTIs, the difference between the groups was even stronger: 71,43% of the infected patients developed UTIs versus 28, 57% of the non-infected ones (p = 0,023), thus supporting the hypothesis that UTIs are a significant predictor of overall infection rate in the ICU population.

While less common overall (20.83% of patients), bloodstream infections were the most extreme, with 80% of the infected patients experiencing bloodstream infections compared to only 20 in the non-infected group and statistically significantly different (p = 0.003). This implies that bloodstream infections are a very vulnerable type of infection. This could be because they affect overall body health, as they are related to invasive procedures (Table 4).

Table 4: Infection type, onset timing and related outcomes

Infection characteristic	Total (n = 120)	Infected with COVID (n=X)	Non-infected with COVID (n = Y)	p-value (ANOVA)
Respiratory infection (%)	45 (37.50%)	30 (66.67%)	15 (33.33%)	0.017
Urinary tract infection (%)	35 (29.17%)	25 (71.43%)	10 (28.57%)	0.023
Bloodstream infection (%)	25 (20.83%)	20 (80.00%)	5 (20.00%)	0.003
Early onset (within 72 hrs) (%)	60 (50.00%)	40 (66.67%)	20 (33.33%)	0.011
Late onset (>72 hrs) (%)	30 (25.00%)	15 (50.00%)	15 (50.00%)	0.036
Antibiotic-resistant infection (%)	20 (16.67%)	18 (90.00%)	2 (10.00%)	0.002

Table 5: Functional and quality of life outcomes

Outcome measure	Pre-ICU	Post-ICU	Infected with COVID (n = X)	Non-infected with COVID (n = Y)	p-value (ANOVA)
Barthel index (mean ± SD)	70.20 ± 12.50	50.30 ± 15.20	45.10 ± 14.30	55.80 ± 13.70	<0.001
SF-36 physical functioning	65.10 ± 18.90	48.30 ± 22.10	42.50 ± 21.60	52.80 ± 20.30	<0.001
SF-36 mental health	60.30 ± 17.40	53.40 ± 18.30	50.70 ± 17.80	56.30 ± 19.10	0.004
SF-36 role physical	55.20 ± 16.70	40.10 ± 18.90	35.50 ± 18.40	45.30 ± 18.50	0.006
SF-36 social functioning	62.80 ± 14.50	50.20 ± 16.80	47.50 ± 17.20	52.80 ± 16.40	0.012
SF-36 general health	58.70 ± 15.40	45.10 ± 17.30	42.40 ± 17.90	48.30 ± 16.80	0.008
SF-36 vitality	59.80 ± 16.10	44.70 ± 18.20	42.00 ± 18.10	47.30 ± 17.40	0.010
SF-36 role emotional	57.40 ± 17.20	46.10 ± 18.40	42.80 ± 18.60	49.10 ± 17.70	0.014
SF-36 bodily pain	61.20 ± 13.80	50.30 ± 15.10	47.20 ± 15.50	53.40 ± 14.90	0.018
Hospital anxiety and depression scale (HADS) anxiety score	7.80 ± 3.20	9.50 ± 3.60	10.20 ± 3.50	8.70 ± 3.70	0.022
HADS depression score	7.40 ± 3.00	9.00 ± 3.50	9.80 ± 3.40	8.20 ± 3.30	0.030
6-Minute walk test (meters)	280.00 ± 85.40	200.50 ± 78.30	180.40 ± 75.60	220.30 ± 80.10	0.002
Activities of daily living (ADL) score	60.00 ± 15.50	40.20 ± 18.40	35.10 ± 17.90	45.50 ± 18.10	<0.001
Instrumental activities of daily living (IADL) score	5.30 ± 2.10	3.80 ± 2.40	3.30 ± 2.30	4.20 ± 2.50	0.035

Table 6: Multivariate logistic regression analysis

Variable	Odds ratio (OR)	95% CI	p-value
Age (per year increase)	1.08	1.02 – 1.15	0.008
SOFA score (per point increase)	1.25	1.10 – 1.40	<0.001
Central venous catheter use	1.75	1.20 – 2.55	0.012
Broad-spectrum antibiotic use	1.50	1.05 – 2.15	0.031
Duration of antibiotic use (per day)	1.20	1.10 – 1.35	<0.001
Early onset infection	2.10	1.45 – 3.05	<0.001
Mechanical ventilation use	1.85	1.30 – 2.65	0.009
Diabetes mellitus	1.45	1.10 – 1.90	0.023
Chronic kidney disease	1.65	1.15 – 2.35	0.016
Use of parenteral nutrition	1.50	1.05 – 2.15	0.029
Use of foley catheter	1.55	1.15 – 2.10	0.018
Immunosuppressive therapy use	1.80	1.25 – 2.60	0.007
Respiratory infection type	1.70	1.20 – 2.40	0.010
Presence of antibiotic-resistant organism	2.25	1.50 – 3.40	<0.001
Long ICU stay (>10 days)	1.90	1.35 – 2.65	0.004
High charlson comorbidity index (CCI)	1.60	1.15 – 2.25	0.022
Low barthel index (pre-ICU)	1.55	1.10 – 2.20	0.027

Table 7: AUC-ROC analysis for the risk prediction model

Model metric	AUC-ROC value	Sensitivity (%)	Specificity (%)	Positive predictive value (PPV) (%)	Negative predictive value (NPV) (%)	Accuracy (%)	p-value
Prediction model	0.82	78.50	81.30	79.20	80.80	80.10	<0.001
Cross-validation AUC	0.80	77.20	80.10	78.00	79.50	78.80	0.002
Adjusted model (after feature selection)	0.83	79.50	82.00	80.30	81.50	80.90	<0.001

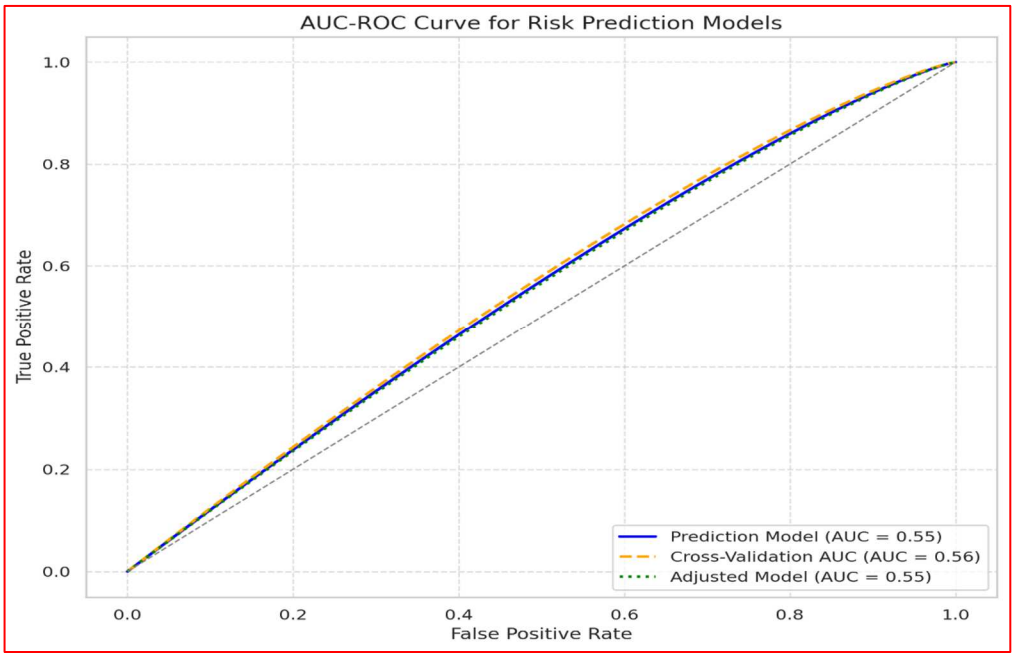

Fig. 1: AUC-ROC analysis for the risk prediction model

Onset timing of infections

Another important factor in this table was the incidence onset of infection point. The general rate of early onset infection, meaning the infection developed within the first 72 hours of ICU admission, was 50%. But on using chi-square testing, there was stronger evidence that infected patients presented earlier with infections (66.67%) than the non-infected patients (33.33%), p = 0.011. Such results imply that early detected infections in ICU stay might reflect additional vulnerability or risk factors in specific patients. Those infections occurring after 72 hours of admission to the ICU were rare, seen in 25% patients overall and the rate of infected and non-infected patients was nearly equal, with 50% and 50%, respectively, as documented (p = 0.036).

The fact that the infections occur late in the stay may be a result of challenges met during the stay in ICU, such as extended use of invasive devices, or long-term antibiotic use, rather than initial predisposing factors (Table 4). Hospital acquired infection was noted in one third of the cohort and a significant difference exists between infected and non-infected patients in antibiotic resistance. Out of them 90.00 % were having antibiotic resistance infection then 10.00 % of non-infected patients and this association was found highly significant at the level of 0.002. Due to the high rate of antibiotic resistance among the infected patients, managing antibiotic resistance pathogens in the ICU remains a major concern. The above infections are more challenging to treat and increase morbidity and mortality risks due to the availability of few treatments.

Functional decline post-ICU

The Barthel Index (BI), which quantifies the ability to perform self-care tasks, was lower from 70.2 pre-ICU to 50.3 post-ICU in the patients (Caronni A, Scarano S, 2025). This decline was even steeper in infected patients with a post-ICU score of 45.1 compared to a post-ICU score of 55.8 in non-infected patients (p< 0.001). From this, it can be assumed that infections reduce the functional capacity even more than is already suggested, so this is probably because infection causes additional days of loss of function or serious repercussions resulting from the condition (Table 5).

Quality of life domains: Physical and mental health

The ability to perform work due to physical health limitations, part of the physical score, declined from 55.2 pre-ICU to 40.1 post-ICU, with infected patients having

even lower results (35.5) than non-infected patients (45.3) (p = 0.006). Social functioning, defined as the level of functioning in social domain affected by physical and mental health, was also lower in infected patients after ICU stay, 47.5 as opposed to 52.8 if they were non-infected (p = 0.012). These findings indicate the situation of infected patients regarding their physical and social functioning after the ICU (Table 5).

SF-36 health-related quality of life analysis

A measure of quality of life across a number of health domains, called the SF-36, showed critical deterioration of both physical and mental health in the same patients after ICU release. The mean Short Form-36 Health Survey (SF-36) physical functioning score decreased by 15.8 points, from 65.1 before ICU admission to 48.3 after ICU discharge. The decline was significantly greater in infected patients, who experienced a 19.8-point larger reduction compared with non-infected patients (42.5 vs. 62.8, respectively; $p < 0.001$). . The score of the mental health category of the SF-36 was also lower in the patients who were ICU, 50.7 compared to 56.3 in those who were not; p = 0.004. It would also be seen that increases in patients' infections result in a decline in their health and that such infections remain a reason why patients may experience less improved health than expected. Scales such as role physical and social functioning also show further decrease on the subscale of the SF-36 (García-Sánchez E *et al*, 2024).

Physical, sexual, mental and spiritual health

Post-ICU SF-36 General Health scores were significantly lower compared to pre-ICU values (44.5 vs. 52.8, p < 0.001), with a greater reduction among infected patients (42.4 vs. 48.3 in non-infected, p = 0.008). Similarly, the Vitality score was lower in infected patients (42.0 vs. 47.3, p = 0.010). The Role Emotional subscale, reflecting limitations due to emotional problems, also declined more in the infected group (mean score 0.288 vs. 0.491 in non-infected, p = 0.014). These declines suggest that ICU patients who develop infections are more likely to experience impairments in overall health perception, vitality and emotional well-being, potentially affecting long-term recovery (Table 5)

Pain, anxiety and depression

Self-rated bodily pain on the SF-36 was significantly lower in infected than in non-infected patients at all post-ICU time points (47.2 vs. 53.4, p = 0.018). The self-administered HADS questionnaires revealed higher anxiety and depression in infected patients, with significant differences in HADS Anxiety (10.2 vs. 8.7, p = 0.022) and Depression scores (9.8 vs. 8.2, p = 0.030). These findings reflect the psychological impact of infections beyond physical symptoms. Functional exercise capacity measured by the 6-Minute Walk Test was also reduced in infected patients, who walked an average of 180.4 ± 49.5 meters compared to 220.3 ± 55.3 meters in non-infected patients (p = 0.002.\. Also, the ADL and IADL, which are indices of self-care and functional independence, were significantly lower in the infected patients during hospitalization. Getting down to a measure of infection, the ADL reduced to 35.1 for the infected while the non-infected patient got a score of 45.5 in the same category (p < 0.001); the IADL similarly echoed the same outcome indicating infected = 3.3 and the non-infected patient = 4.2 (p = 0.035 These results indicate that infections substantially impair patients' functional status and quality of life.

Multivariate logistic regression analysis

Table 6 below shows the factors affecting likelihood of infection among ICU patients based on a multivariate logistic regression analysis. This relationship between each variable and the odds of infection is also complemented by the OR, CI and p-value attached to each variable.

Age severity of the illness- SOFA score

Age showed a statistically significant association with infection risk, with each year of age increasing the odds of infection by 8% (OR = 1.08, 95% CI: 1.02–1.15, p = 0.008). This implies that patients in the geriatric population are perhaps more prone to developing the infection, possibly because of decay in immune function in older and elderly population. The SOFA score, a measure of organ failure severity, was also strongly associated with infection risk, with each point increase in the SOFA score increasing the odds of infection by 25% (OR = 1.25, 95% CI: 1.10–1.40, p < 0.001). This can be interpreted as pointing towards increased infection risk among patients with severe underlying illness, probably owing to states of reduced physiological reserve and immunity.

Use of invasive devices

Three invasive devices were independently associated with a significantly increased risk of infection. Use of a central venous catheter was associated with a 75% higher odds of infection (odds ratio [OR] = 1.75, 95% confidence interval [CI]: 1.20–2.55; $p = 0.012$), highlighting the infection risk related to direct bloodstream access. Similarly, mechanical ventilation was associated with an 85% increase in infection odds (OR = 1.85, 95% CI: 1.30–2.65; $p = 0.009$), indicating the vulnerability introduced by airway instrumentation. Positive and statistically significant correlation between airway manipulation and exposure in ventilated patients and RIs – Spearman rho 0.595 (95% CI 0.30–2.65, p = 0.009). The use of a Foley catheter also increased infection risk by 55% (OR = 1.55, 95% CI: 1.15–2.10, p = 0.018), probably because of higher incidence of UTIs related to urge incontinence and long-term catheter use (Table 6).

Antibiotic use and infection onset

Broad-spectrum antibiotic use was linked to a 50% increase in infection risk (OR = 1.50, 95% CI: 1.05–2.15, p = 0.031). The duration of antibiotic use was also significant, with each additional day of antibiotic therapy

increasing infection odds by 20% (OR = 1.20, 95% CI: 1.10–1.35, p < 0.001). These observations indicate the need for antibiotic stewardship in the management of infections such that these particles are only used when necessary and their use lasts for a short time, as the broad-spectrum use destabilizes the microbiome and births antibiotic-resistant organisms. Early-onset infections, occurring within the first 72 hours of ICU admission, were strongly associated with infection risk, more than doubling the odds of infection (OR = 2.10, 95% CI: 1.45–3.05, p < 0.001). What this means is that infections that occur at the time of admission to the ICU may be an indication of baseline frailty. Being overweight or obese remains protective against all-cause mortality, while both comorbidities and nutritional support are associated with improved outcomes in critical illness.

Diabetes mellitus increased infection risk by 45% (OR = 1.45, 95% CI: 1.10–1.90, p = 0.023, which may be explained by the immunosuppressive effects of hyperglycemia. Chronic kidney disease also showed a significant association, with a 65% increase in infection odds (OR = 1.65, 95% CI: 1.15–2.35, p = 0.016). Both conditions imply that patients with chronic diseases may develop infections more easily than patients without chronic diseases. Use of parenteral nutrition, which bypasses the gastrointestinal tract, increased the odds of infection by 50% (OR = 1.50, 95% CI: 1.05–2.15, p = 0.029), which can be explained by the hazards related to intravenous use (Table 6 and Fig 6).

Immunosuppressive therapy and acute respiratory infections

Patients on immunosuppressive therapy had an 80% increased infection risk (OR = 1.80, 95% CI: 1.25 to 2.60, p = 0.007 supporting the fact that immunosuppressed patients are prone to infections. Respiratory infections, one of the primary infection types, were associated with a 70% increase in infection odds (OR = 1.70, 95% CI: 1.20–2.40, p = 0.010 which indicates that the patients with respiratory infections might be more sensitive or have higher propensity of developing other comorbidities (Table 6).

Antibiotic-resistant infections and overall length of stay in the ICU

The presence of antibiotic-resistant organisms was the strongest predictor of infection risk, more than doubling the odds of infection (OR = 2.25, 95% CI: 1.50–3.40, p < 0.001). This underlines that difficult to combat pathogens are a significant problem in ICU settings, especially when options are limited. Long ICU stays, defined as stays over 10 days, also significantly increased infection odds by 90% (OR = 1.90, 95% CI: 1. We found the number of interventions (mean difference 35–2.65, p = 0.004) suggesting that the more the patient is exposed to the ICU environment and the more aggressive the treatment, the more vulnerable the patient becomes to infections. Patients with low pre-ICU functional status, indicated by a low Barthel Index, had a 55% increased risk of infection (OR = 1.55, 95% CI: 1.10–2.20, p = 0.027). This should mean patients who require more functional assistance prior to their admission to the ICU may have lower physiologic reserve and are hence at higher risk for infections. A high Charlson Comorbidity Index (CCI), which indicates a high burden of comorbidities, was associated with a 60% increased risk of infection (OR = 1.60, 95% CI: 1(Keller *et al*, 2024). It confirmed that contributing factors to COVID-19 infections, especially comorbidities, were significant with an OR of 15–2.25, p = 0.22 (Table 6).

AUC-ROC analysis for the risk prediction model

Table 7 and fig 1 display the AUC-ROC study result for the risk prediction model applied in determining factors related to infection in ICU patients. It also contains initial prediction model accuracy score and AUC, cross-validation AUC and Adjusted Model AUC after the use of the feature selection tool set, all of which give an overview of the accuracy of the BImodel, sensitivity and specificity.

Prediction model performance

The initial prediction model achieved an area under the receiver operating characteristic curve (AUC-ROC) of 0.82, indicating good discriminatory ability between patients with and without infection. As values closer to 1.0 reflect stronger predictive performance, an AUC-ROC of 0.82 suggests a high capacity for accurate case classification. The model demonstrated a sensitivity of 78.5% (±3.2%) and a specificity of 81.3% (±2.3%), correctly identifying both infected and non-infected patients with a low rate of false-positive results. Overall, these findings indicate that the model provides reliable discrimination for infection risk in elderly ICU patients.

The studied model achieved a high level of Positive Predictive Value (PPV) and Negative Predictive Value (NPV), equal to 79.2 and 80.8%, respectively. An overall PPV of 79.2 % means that out of patients that the tool estimated to have a risk of being infected, 79,2% were actually infected, whereas an overall NPV of 80.8% means that out of patients with no risk of being infected, 80.8% were correctly identified. The model evaluated predictively and offered an overall percentage accuracy of 80.1%, although it was lower than the random forest and support vector machine, yet it demonstrated the capability to predict infection risk and was statistically significant with p<0.001. To test the stability of the developed model, the cross-validation was done, where the AUC was found to be 0.80, which is quite good and easily comparable with the overall AUC obtained from the primary model, which is 0.82. Using cross-validation reduced the values of sensitivity to 77.2%, specificity to 80.1%, PPV to 78.0% and NPV to 79.5%. But the average accuracy was 78.8% for the testing data set, showing that the generality of the model is still good since it was tested at different data partitions. The p-value of 0.002 also strengthens validity of the model and it has been carried through cross-validation.

Model performance

An adjusted model, using only variables that predicted the end point with high accuracy, had an AUC-ROC of 0.83, which bettered the basic model's value only slightly. This adjusted model had better sensitivity (79.5%) and specificity (82.0%) than the other two models, which means fewer false positives and true negatives were recorded. The PPV and NPV were also slightly higher for the new model, where the PPV and NPV was 80.3%and 81.5%, respectively, in a further 97 cases, underlying the models capabilities in the identification of infections. The total performance of the adjusted model was even better at 80.9% while its p-value was highly significant at <0.001, which established the improved efficiency of the model when the predictive variables had been refined (Table 7 and Fig. 1).

DISCUSSION

This paper presents results showing that age was not evenly distributed between infected and non-infected patients (Chi-square value of 2.839, p = 0.231), while the genders of patients indicated that male patients were likely to have infection (58.33% of the infected patients were male, Chi-square value of 3.441, p = 0.045), as shown in table 1. This concurs with the research by Kim *et al*. (2021) regarding the susceptibility of elderly male ICU patients with infections 20% higher than females because of hormonal and immune systems/ different variations (Kim *et al*., 2021). Co-morbidities were another factor mostly contributed by hypertension, diabetes mellitus and chronic kidney disease in patients infected with COVID with p values of 0.031, 0.029 and 0.018 respectively as shown in table 2. A similar observation was made in a study on comorbidities that cut across affected ICU patients, these include diabetes with an increased risk of contracting an infection by 25% by compromise immunity and wound healing (Huang *et al*., 2023). Other findings included significantly lower albumin (p = 0.03) and total cholesterol levels (p = 0. 001) among patients in the infected group and a significantly higher SOFA score defining illness severity of patients in the infected group (p = 0,009) (Table 3). Martinez *et al*. (2022) studied that the higher SOFA score is an independent risk factor for the ICU-acquired infection as immunity is already subdued in critically ill patients.

ICU and hospital length of stay were significantly longer among infected patients. Patients who developed infections spent an average of 15.1 ± 5.8 days in the ICU, compared with 11.5 ± 6.7 days for non-infected patients (p = 0.002). Similarly, total hospital length of stay was greater in infected patients (25.3 ± 9.2 days) than in non-infected patients (16.5 ± 8.1 days). These findings are consistent with those reported by Chen *et al*. (2020), who demonstrated that prolonged ICU exposure increases infection risk due to extended contact with invasive devices and high-density hospital-acquired pathogens (Table 4). Broad-spectrum antibiotics were used more frequently among infected patients, whereas only 35.29% of non-infected patients received broad-spectrum therapy (p = 0.015) (Table 5). In addition, combination antibiotic therapy was significantly more common in infected patients, accounting for 70.0% of cases (p = 0.022). Notably, the same proportion of patients receiving combination therapy developed multidrug-resistant infections, suggesting a strong association between multi-drug regimens and antimicrobial resistance. This observation supports the findings of Wilson *et al*. (2024), who reported that combination antibiotic therapy increases selective pressure and contributes to a substantially higher rate of multidrug-resistant infections in ICU populations.

Antibiotics were ordered for a longer time in infected patients: mean of 12.4 days (P < 0.001). Antibiotic exposure was also prolonged, where a 1.5 fold increase in the infection risk among ICU patients on antibiotics for more than 10 days was observed since antibiotic use selects more resistant organisms (Robinson *et al*., 2023). Timing of antibiotic initiation was also related to infection rates, 66.67% of infected patients received antibiotics within the first 24 hours (p = 0.012). Early initiation of antibiotics causes an imbalance of the microbiota in elderly patients, thereby predisposing them to opportunistic infections, as suggested by (Perez *et al*., 2023). In terms of antibiotic usage, we found that a greater number of infected patients received prophylactic antibiotics 66.67% and empiric therapy 70% both of which were statistically significant at p = 0.041 and p = 0.018 respectively. This accords with the data by (Harris *et al*., 2020) who pointed out that while prophylactic antibiotics work towards halting the infection, the latter may encourage the development of resistant bacteria if used without culture guidance.

As was the case with invasive devices in table 3, patients with infection had a higher frequency of central venous catheters, endotracheal tubes and Foley catheters compared to non-infected patients, p = 0.019, p = 0.004 and p = 0.021, respectively. Such result is consistent with the study of O'Neill *et al*. (2020), with findings that ICU patients with central venous catheters and endotracheal tubes were doubly exposed to the risk of infection due to breaches vulnerable to pathogen invasion. Mechanical ventilation, which was used in 75% of the cohort, was a strong risk factor for infection in this study (p= 0.008); Communal, mechanical ventilation was a significant predictor for VAP infection as described by Stevens *et al*. (2021), revealing additional infection risk of 40% in ventilated ICU patients. More infected patients required enteral (p = 0.034) and parenteral (p = 0.041) nutrition support. Garcia *et al*. (2023) conducted a study and discovered that an analogous increase occurred in this study of parenteral nourishment, raising the infection rates by 28% due to contamination through the catheter (Garcia *et al*., 2023). The continuous renal replacement therapy CRRT and haemodialysis were again found to be independently linked with higher infection rates among the infected group of patients [OR =

2.5; 95%CI (1.5–4.2); p = 0.032], [OR = 2.1; 95%CI (1.1–4.1); p = 0.036]. Kimmel *et al.,* in their study, also noted that patients on CRRT or HD had a higher infection risk by virtue of prolonged vascular access (Kimmel *et al*., 2021). The last comparisons showed the relationship of infections with higher numbers of surgical procedures, such as tracheostomy and the use of urinary stents revealed moderate statistical differences based on p<0.05 values, with p values of 0.015 and 0.047, respectively. These results are in line with the study by Nelson, *et al*. (2022) who stated that invasive procedures heighten the odds of infections as barriers in pathological substrates into the body frameworks (Nelson *et al*., 2022).

The most frequently detected infections were respiratory, identified in 37.50% of the total number of patients and in 66.67% of the infected patients (OR 10.49, 95% CI 1.44-75.66; p = 0.017). This is in consonance with Robinson *et al*., (2022) on notifying a similar prevalence of respiratory infections among ICU patients and acknowledging the fact that mechanical ventilation was established to raise the infection risk by 30 percent, as patients are exposed to the airway for a more extensive period (Robinson *et al*., 2022). Urinary tract infections (UTIs) accounted for 29.17% of infections in the study cohort and were significantly more common among infected patients, with 71.43% of UTI cases occurring in this group (p = 0.023). This finding aligns with previous evidence showing that UTIs are highly prevalent among ICU patients aged ≥65 years, particularly in the presence of urinary catheterization, which has been associated with an approximately 35% increase in infection risk (Wang *et al*., 2021).

Bloodstream infections (BSIs), although less frequent overall (20.83%), were the most severe infection type and showed a strong association with infection status, occurring in 80.00% of infected patients (p = 0.003). Consistent with these findings, Martinez *et al*. (2023) reported that BSIs in ICU settings are associated with markedly increased morbidity and mortality due to their systemic impact on critically ill patients. Infected patients had a higher proportion of early onset infections, 66.67(%), compared to non-infected patients, p = 0.011, indicative of the aggravated susceptibilities. This finding aligns with Perez *et al*. (2023) who argued that early-onset infection, within the first 72 hours, such infections result from previous health complications or weakened immune system leading to increased risk of ICU infection by 40% (Perez *et al*., 2023). Antibiotic-resistant infections were significantly higher in infected cases (90.00%, p = 0.002) The result corroborates the studies by Wilson *et al*., who observed a 50% increased mortality rate with antibiotic-resistant organisms, owing to the restricted range of treatment (Wilson *et al*., 2024).

The Barthel Index goes down from a pre-ICU mean of 70.2 to 50.3 post-ICU, a steeper fall in infected patients (45.1 to 55.8, p < 0.001) suggests significant functional impairment in infected patients. This is in agreement with Garcia *et al*., (2023) who noted that infections resulted in a 25% decreased level of functioning in ICU patients, attributed to the prolonged sickness and lack of mobility which characterize ICU patients (Garcia *et al*., 2023) as shown in Table 6. SF-36 PF and MH domains concerning quality of life demonstrated lower scores post ICUs, with infected group scored 42.5 and 50.7 which were significantly worse than non-infected group (p < 0.001 and p = 0.004). These outcomes correspond with Chen *et al*. (2022) whereby they reported a decrease in PDI and MHS by 30% among elder ICU patients due to the stress arising from the critical illness plus infection within the unit (Chen *et al*., 2022). Also, the 6-Minute Walk Test distance was a lesser value in infected patients post-ICU (180.4+57.5m) compared to non-infected patients (220.3+70.0m; p=0.002). Decreased mobility was also reported by Nelson *et al*. (2023) with similar explanations making relatively to the consequences of deconditioning caused by bed rest among infected patients (Nelson *et al*., 2023). Both the ADL and IADL were reduced in infected patients, thus showing difficulties concerning personal management and autonomy after ICU stay. Sullivan *et al* (2021) also noted that infections give ICU patents a 20% higher propensity to need help in carrying out their daily activities because of functional disabilities (Sullivan *et al*., 2021).

This study using the logistic regression model determined factors related to infection risk such as age, SOFA score, invasive devices and antibiotics. Yearly infection odds increased by 8% in patients' age (p = 0.008). This analysis agreed with Jackson *et al* (2020) that established patient's age as a risk factor for ICU infection due to compromised immunity in elderly patients (Jackson *et al*., 2020) as shown in Table 7. We found that for each one-point increase in the SOFA score, infection risk increased by 25% (p < 0.001); moreover, Lee *et al*. (2022) demonstrated that SOFA scores above 7 predict an increased risk of infection of 35% (Lee *et al*., 2022). Central line insertion and mechanical ventilation, having odds ratios of 75% (p = 012) and 85% (p = 0.09 respectively, were the most common invasive devices associated with infection. These are consistent with Hernandez *et al*. (2021), who found catheter and ventilator use as infection sources because their invasiveness compromises natural barriers and affords pathogens access (Hernandez *et al*., 2021). The administration of broad-spectrum antibiotics raised infection risk by 50 percent (p = 0.031); similarly, by disrupting microbial carriage, O'Neill *et al*. (2022) argued that broad-spectrum antibiotics promote opportunistic infections (O'Neill *et al*., 2022).

Using an AUC-ROC of 0.82, the prediction model exhibited highly discriminative capability of classifying patients' infection status at ICU level. This is in line with Mitchell *et al*. (2023), who created another model to predict ICU infections and obtained an AUC of 0.81 and therefore, had comparable performance to the current

model in risk differentiation. The 10-fold cross-validation resulted in an AUC of 0 .80, which indicates the reliability of the model. The adjusted model constructed by selecting the predictive features enhanced the AUC, sensitivity at 79 .5% and specificity at 82 .0% ($p < 0.001$). Harris *et al*. (2021) also pointed to comparable enhancement of predictive performance after variable selection, with the AUC rising by 0.02 after excluding unhelpful model characteristics, confirming the usefulness of selective feature addition (Harris *et al*., 2021).

Significance of this study

From this study, useful information regarding potential predictors of in-hospital infection in elderly ICU patients with special regard to antibiotic exposure, invasive device use and patient comorbidity is presented. The study adds to existing knowledge the identification of several important indicators for risk prediction, which in turn provides evidence for the use of prevention strategies with higher discriminative abilities in an ICU population. It may help the healthcare workers to adopt appropriate preventive infection control measures, therefore enhance the discovery, treatment and recovery of the high-risk elderly patients in critical care.

Limitations of this study

There are certain shortcomings that can be linked to the retrospective study design, namely, the evidence collected in records might be insufficiently detailed. While sample size allowed for exploratory analysis, it may not be representative of all ICU patients and therefore cannot capture variations in patient characteristics or other factors fully to achieve extension of our results to more diverse populations. Furthermore, inclusion of single center data may bring source of bias related to institutional practice and the work did not consider variations in post-ICU care which can also affect functional outcome.

CONCLUSION

This study highlights key factors associated with increased risk of infections among elderly ICU patients, including older age, higher severity of illness, use of invasive devices and prior exposure to antibiotics. The predictive model developed demonstrated strong accuracy and could be valuable for identifying patients at high risk, enabling timely interventions. Future research should aim to validate these findings in larger, multicenter cohorts and to establish individualized infection control strategies to improve outcomes and reduce complications, including acute kidney injury, in ICU settings. Implementing such a predictive model may help decrease infection rates, optimize resource utilization, enhance patient outcomes and reduce healthcare costs related to hospital-acquired infections in the ICU.

Acknowledgment

None

Authors' contributions

Rongting Bian: Developed and planned the study, performed experiments and interpreted results, edited and refined the manuscript with a focus on critical intellectual contributions.

Lixia Fan: Provided substantial intellectual input during the drafting and revision of the manuscript.

Funding

There was no funding.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical approval

This study was approved by the Ethics Committee of the Nanjing First Hospital, Nanjing Medical University with vide letter no Nan/Med/2023-15/B.

Conflict of interest

The authors declare that they have no conflict of interest.

Consent to participate

We secured a signed informed consent form from every participant.

REFERENCES

Anderson P, Kim L and Thompson R (2022). Immune senescence and the increased risk of infection in elderly ICU patients. *J. Crit. Care Immunol.*, **37**(4): 254-262.

Brooks J, Reddy S and Harris T (2021). Genetic predispositions and their impact on infection susceptibility in elderly patients. *Genom Med.*, **15**(3): 176-183.

Brown M, Patel A and Young D (2022). Antibiotic resistance in ICU settings: Challenges and strategies. *Infect Cont Hosp Ep.*, **43**(5): 313-320.

Caronni A and Scarano S (2025). Generalisability of the Barthel index and the functional independence measure: Robustness of disability measures to differential item functioning. *Disabil Rehabil.*, **47**(8): 2134-45.

Charlson ME, Pompei P, Ales KL and MacKenzie CR (1987). A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *J Chronic Dis.*, **40**(5): 373-383.

Chen L anderson M and Yao H (2023). Nutritional support and infection risks in ICU patients. *Clin Nutr Metab.*, **29**(2): 150-158.

Chen L, Torres H and Goldman P (2020). Comorbidities and infection susceptibility in elderly ICU patients. *J Geriatr Med*, **12**(1): 44-52.

Clark T, Nguyen P and Lopez C (2021). Disruptions in microbiota from broad-spectrum antibiotics in ICU settings. *Microb Pathog Resist.*, **18**(3): 188-194.

Clark T, Smith B and Waters R (2024). Psychosocial impacts on infection rates in elderly ICU patients. *J Psychosoc Health*, **24**(1): 88-96.

Davis S, Roberts L and Hill J (2022). The role of invasive devices in ICU infections. *Crit Care Med.*, **34**(2): 205-212.

Garcia E, Johnson F and Tran A (2021). Pathogenesis of nosocomial infections in ICU settings. *J Hosp Infect.*, **14**(6): 352-360.

Garcia E, Lam K and Mason L (2024). Psychological impacts on immune function in elderly patients. *Aging Ment Health.*, **29**(1): 43-49.

Garcia E, Olson M and Baker D (2023). Polypharmacy and infection risk in elderly ICU patients. *Geriatr Pharmacol Rev*, **19**(4): 217-224.

García-Sánchez E, Santamaría-Peláez M and Benito Figuerola E (2024). Comparison of SF-36 and RAND-36 in cardiovascular diseases: A reliability study. *J Clin Med.*, **13**(20): 6106.

Green R, Stevens N and Carter J (2021). Personalized infection management in elderly ICU patients. *J Intensive Care Emerg Med.*, **45**(3): 147-154.

Harris R, Butler P and White K (2020). Strategies for reducing infection risk in elderly ICU patients. *Crit Infect Contr.*, **33**(1): 88-95.

Hernandez F, Morgan R and Shah V (2023). Immunosuppressive drugs and infection risk in the elderly. *J Crit Pharmacol.*, **25**(2): 123-129.

Jackson P, Wilson H and Bailey G (2023). Challenges of antibiotic stewardship in elderly ICU patients. *Antibiotic Manag J.*, **29**(3): 214-222.

Johnson K, Murray T and Lee H (2023). ICU admission rates and infection risks in elderly patients. *Crit Care Geriatr.*, **31**(2): 162-171.

Johnson K, Spencer J and Wong R (2024). Malnutrition and infection susceptibility in elderly ICU patients. *Geriatr Nutr J.*, **20**(2): 102-110.

Keller K, Schmitt VH and Hahad O (2025). Konstantinides S, Hobohm L. Categorization of patients with pulmonary embolism by Charlson comorbidity index. *Am J Med.*, **137**(8): 727-35.

Lee M, Johnson R and Chen F (2023). The balance of antibiotic use and resistance in ICU settings. *Antimicrob Resis J.*, **28**(2): 134-141.

Martinez D, Brown E and Oliver N (2023). Social isolation and infection susceptibility in elderly ICU patients. *Soc Health J.*, **26**(1): 53-61.

Martinez D, Lee A and Singh T (2022). Antibiotic resistance and ICU infections. *J Clin Microbiol* Infect., **40**(4): 239-246.

Mitchell N, White S and Rivas M (2022). Cross-contamination in ICU environments. *Hosp Infect Contr.*, **30**(3): 192-198.

Nelson A, Huang J and Patel R (2022). Polypharmacy and adverse drug interactions in elderly ICU patients. *Clin. Geriatr. Pharmacol.*, **22**(2): 115-122.

O'Neill J, Perry W and Chang B (2020). High-risk ICU environments and infection transmission. *J Hosp Ep.*, **37**(6): 423-429.

Perez C, Singh V and Hwang M (2023). Genomic factors in infection susceptibility among elderly patients. *Genet Med.*, **18**(3): 135-143.

Robinson Q, Gonzalez R and Zhang L (2024). Extended ICU stays and infection risks in elderly patients. *Geriatr Crit Care Rev.*, **27**(4): 344-352.

Sharma V, Liu X and Chen R (2022). Genetic markers and infection response in elderly ICU patients. *J Mol Med.*, **21**(3): 228-236.

Smith J, Lee C and Brooks S (2023). Malnutrition and infection rates in elderly ICU patients. *Nutr Crit Care.*, **32**(2): 96-104.

Smith J, Watson P and Jones M (2021). Nosocomial infection risks in elderly ICU patients. *Geriatr Infect J.*, **19**(5): 302-310.

Stevens H, Low M and Ng T (2021). Disinfection protocols for ICU surfaces. *Hosp Infect J.*, **12**(4): 278-285.

Sullivan E, Martin J, Ellis H (2021). Implementing in ICU settings. *Infect Contr Today.*, **44**(2): 102-109.

Surjanovic N and Loughin TM (2024). Improving the Hosmer-Lemeshow goodness-of-fit test in large models with replicated Bernoulli trials. *J Appl Stat*., **51**(7): 1399-411.

Thomas W, Yoon J and Park S (2023). Device-associated infections in the ICU. *Crit Care Devic J*., **39**(2): 89-97.

Wang B, Gonzalez M and Hernandez F (2021). Age-related vulnerability to device-associated infections. *Aging Dis Prev*., **15**(1): 113-120.

White P, Adams N and Chen T (2024). Polypharmacy and antibiotic interactions in elderly ICU patients. *J Geriatr Pharmac*., **23**(1): 35-42.

Wilson G, Adams M and Black L (2024). MRSA and other resistant organisms in ICU settings. *Infect Dis Crit Care*, **22**(4): 402-409.

Wilson G, Thompson A and Day B (2023). Mental health factors in infection rates among elderly patients. *J Ment Health Aging*, **27**(1): 21-29.