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Resource Utilization and Reported Economic Components Among Adult Intensive Care Patients with Healthcare-Associated Infections in Managua, Nicaragua, October 2023–October 2024

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Abstract:

- ***Background:***
  Healthcare-associated infections (HAIs) pose challenges to patient safety and resource allocation in intensive care.

- ***Objective:***
  To describe the characteristics of patients with HAIs, the microbiological profile, and reported economic components in an adult intensive care service in Nicaragua.

- ***Methods:***
  Retrospective analysis of records included in an institutional thesis describing a sample of 324 adult patients with HAIs selected through simple random sampling. Frequencies, distributions, and recorded costs of medications, antimicrobials, devices, and diagnostic tests were extracted. Results are presented descriptively; no attributable incremental cost was calculated because a comparable group without HAIs was unavailable.

- ***Results:***
  Urban residence was reported for 312 patients (96.3%). The thesis reported 55% men and 45% women, with mean ages of 80 and 65 years, respectively. Escherichia coli accounted for 60 isolates in 2023 and 68 in 2024. Costs recorded for ten antimicrobials show inconsistencies between the sums of individual items and the published totals and therefore require reconciliation. Listed device costs totaled C$15,800.

- ***Conclusions:***
  The document identifies components of resource consumption and the need for economic monitoring.

Keywords: *Healthcare-Associated Infections; Intensive Care; Hospital Costs; Antimicrobials; Resource Utilization.*

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I. INTRODUCTION

HAIs are important patient safety events, particularly in intensive care units, where clinical complexity, exposure to invasive devices, and the need for antimicrobial treatment may increase resource utilization. The World Health Organization has emphasized the importance of strengthening infection prevention and control programs and surveillance [1,2].

The economic burden of HAIs encompasses hospital stays, testing, medications, procedures, and healthcare resources. However, expenditures recorded for infected patients are not equivalent to costs attributable to infection: the latter require a valid comparison, adjustment for confounding factors, and consideration of the timing of infection onset [3,4].

In Nicaragua, describing documented economic components in intensive care can support management decisions, provided that measured values are distinguished from causal estimates. The objective was to describe the characteristics of patients with HAIs, identified microorganisms, and resources and costs recorded in the institutional thesis covering October 2023–October 2024.

II. MATERIALS AND METHODS

Study design and setting. A descriptive review and synthesis of aggregate data from a thesis were performed. The thesis describes an observational, retrospective cohort study conducted in an intensive care service in Managua, Nicaragua, comprising three units and a sample of 324 patients. According to the reported protocol, adults older than 18 years admitted during the study period with an HAI and a complete medical record were included; patients without HAIs and stays shorter than 48 hours were excluded.

Data sources and variables. Aggregate results originally obtained from medical records, the Fleming system, and Avicena management records were reviewed. Frequencies and monetary amounts were transcribed as presented in the tables. Arithmetic totals and denominator consistency were checked. No hypothesis tests, confidence intervals, or multivariable adjustments were performed because individual-level data were unavailable. Monetary values are retained in Nicaraguan córdobas (C$). Ethics: the article states that the study was reviewed and authorized by the relevant committee and that the data were anonymized.

III. RESULTS

The reported sample comprised 324 patients. Urban residence was reported for 312 (96.30%) and rural residence for 12 (3.70%). The thesis reports 55% men and 45% women, with mean ages of 80 and 65 years, respectively. Another table presenting sex distributions for 2023 and 2024 contains percentages that exceed 100% within each year; therefore, those values were not used to estimate annual proportions.

Table 1 Reported Demographic Characteristics and Selected Comorbidities.

Indicator	Reported Result
Sample	324 patients
Urban residence	312 (96,30 %)
Rural residence	12 (3,70 %)
Men / women	55 % / 45 %
Mean age, men / women	80 / 65 years
Chronic kidney disease	45 % (2023); 35 % (2024)
Type 2 diabetes mellitus	22 % (2023); 10 % (2024)

Among the microbiological records, Escherichia coli was the most frequently reported isolate in both years (60 and 68). Staphylococcus aureus (48 and 44), Pseudomonas aeruginosa (30 and 40), and Staphylococcus hominis (34 and 40) were also recorded. These figures refer to microorganism records and do not necessarily represent unique patients or independent episodes.

Table 2 Microorganisms Recorded by Year, 2023–2024.

Microorganism	2023 (n)	2024 (n)
Escherichia coli	60	68
Pseudomonas aeruginosa	30	40
Burkholderia cepacia	25	10
Acinetobacter baumannii	25	20
Klebsiella pneumoniae	33	28
Staphylococcus epidermidis	30	33
Staphylococcus hominis	34	40
Candida tropicalis	33	13
Staphylococcus aureus	48	44
Staphylococcus haemolyticus	26	19

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Reported antimicrobial amounts included meropenem, piperacillin, cefepime, tigecycline, linezolid, and five other agents. The sum of the ten individual rows was C$2,512,678.20 for 2023 and C$1,325,200.72 for 2024, whereas the article reports annual totals of C$2,147,433.20 and C$1,326,098.73.

Table 3 Antimicrobial Costs Recorded in the Source Document, in Nicaraguan Córdobas.

Antimicrobial	2023 (C$)	2024 (C$)
Piperacillin	491,215.15	154,263.95
Meropenem	622,356.85	490,102.23
Cefepima	432,403.86	98,110.76
Tigeciclina	308,250.00	188,894.53
Linezolid	191,309.41	131,104.97
Ertapenem	163,264.13	80,957.20
Cefazolin	93,807.43	73,381.04
Moxifloxacin	79,434.06	39,927.54
Vancomycin	65,694.01	59,911.17
Metronidazole	64,943.30	8,547.33
Annual total	2,147,433.20	1,326,098.73

Within a subset of five medications, albumin and vecuronium each accounted for 25% of recorded costs. Norepinephrine accounted for 15% of costs and 5% of administration frequency. These shares do not represent overall pharmaceutical expenditures. Across ten antimicrobial categories, values totaled C$2,300,000 in series A and C$1,360,000 in series B. The original chart's time labels contradict the study period; therefore, neither series is assigned a year and no temporal trend is asserted.

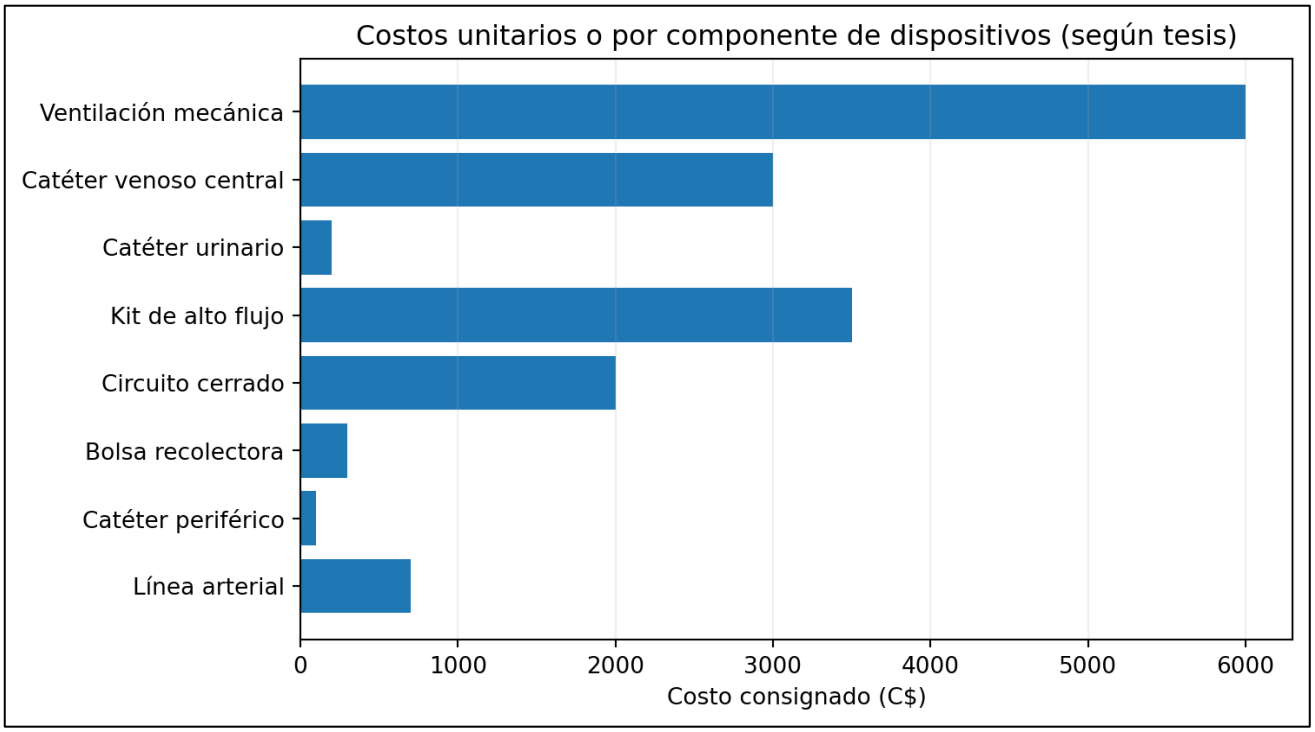


Fig 1 Reported Amounts for Invasive Devices, Labeled as Costs Attributable to HAIs in the Source.

Table 4 Comorbidity Index Associated with HAIs in the Adult ICU.

Comorbidity	2023 (%)	2024 (%)
Type 2 diabetes mellitus	22.00	10.00
Chronic kidney disease	45.00	35.00
Septic shock	30.00	15.00
Aortic valve replacement	15.00	10.00
Ischemic cerebrovascular event	20.00	15.00
Postoperative exploratory laparotomy	15.00	10.00
Postoperative cesarean section	20.00	15.00

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Table 5 Most Frequently Reported Pathogenic Microorganisms in HAIs, 2023–2024.

Pathogenic Microorganism	2023 (n)	2024 (n)
Escherichia coli	60	68
Pseudomonas aeruginosa	30	40
Burkholderia cepacia	25	10
Acinetobacter baumannii	25	20
Klebsiella pneumoniae	33	28
Staphylococcus epidermidis	30	33
Staphylococcus hominis	34	40
Candida tropicalis	33	13
Staphylococcus aureus	48	44
Staphylococcus haemolyticus	26	19

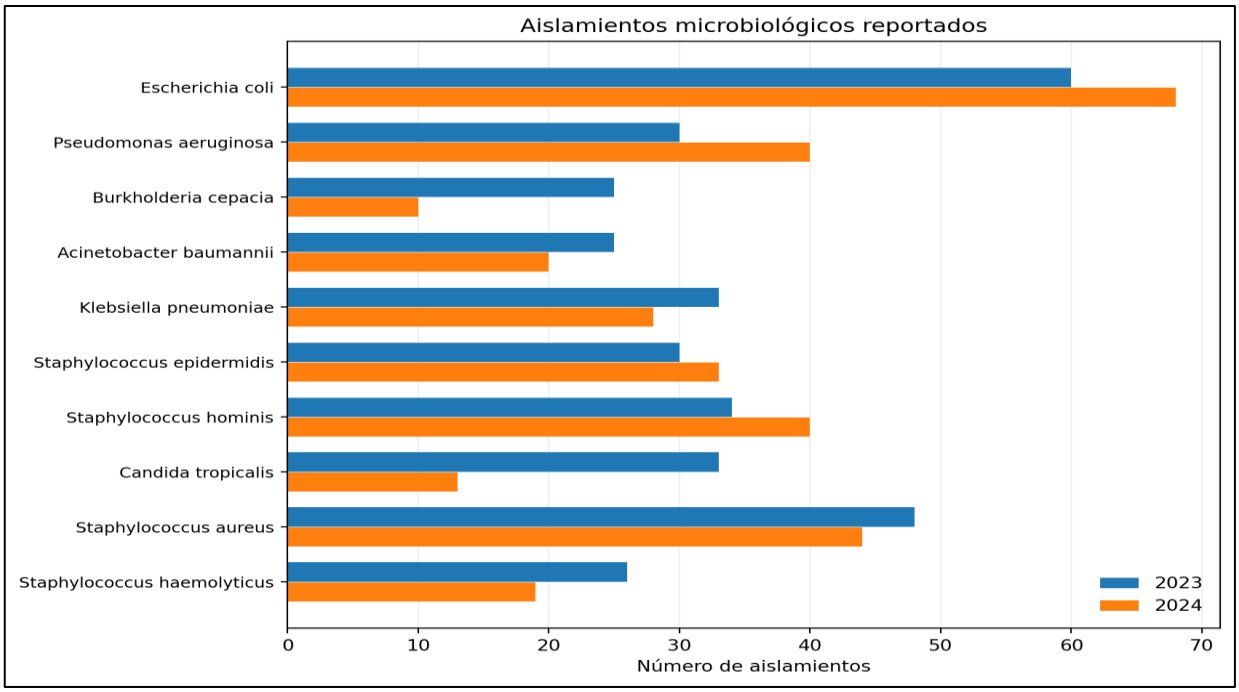


Fig 2 Most Frequently Reported Pathogenic Microorganisms in HAIs, 2023–2024.

Among adults with infection-associated increases in intensive care costs, Escherichia coli was the most frequently reported microorganism in both study years, with 60 records in 2023 and 68 in 2024, indicating an increase in frequency. Staphylococcus aureus followed, with 48 records in 2023 and 44 in 2024, remaining among the principal organisms associated with HAIs. Staphylococcus hominis increased from 34 records in 2023 to 40 in 2024, while Pseudomonas aeruginosa increased from 30 to 40 over the same period. In contrast, Candida tropicalis declined from 33 records in 2023 to 13 in 2024. Overall, Escherichia coli, Staphylococcus aureus, Staphylococcus hominis, and Pseudomonas aeruginosa were the most frequently recorded microorganisms during 2023–2024 and were described in the source as principal agents related to increased costs among adult ICU patients.

Frequency of use and economic burden: vecuronium accounts for 25% of costs with only 15% of administrations. Estimation method: Cmed = Σ (Qi × CUi), quantity administered multiplied by unit cost.

Table 6 Supplementary Table: Supportive Care and Sedation Medications.

Medication	Frequency (n)	Total Cost (C$)	Percentage (%)
Albumin	9	8,000	23
Epinephrine	11	10,000	28
Norepinephrine	2	12,000	5
Propofol	3	14,000	8
Midazolam	9	16,000	23
Vecuronium	6	20,000	15
Total	40	80,000	100

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Table 7 Total Costs of Broad-Spectrum Antibiotics in Intensive Care, 2023–2024.

Antibiotic	2023 (C$)	2024 (C$)
Piperacillin	491,215.15	154,263.95
Meropenem	622,356.85	490,102.23
Cefepima	432,403.86	98,110.76
Tigeciclina	308,250.00	188,894.53
Linezolid	191,309.41	131,104.97
Ertapenem	163,264.13	80,957.20
Cefazolin	93,807.43	73,381.04
Moxifloxacin	79,434.06	39,927.54
Vancomycin	65,694.01	59,911.17
Metronidazole	64,943.30	8,547.33
Annual total	2,147,433.20	1,326,098.73

From an economic perspective, the reported total expenditure for the ten antibiotics decreased from C$2,147,433.20 in 2023 to C$1,326,098.73 in 2024, an absolute reduction of C$821,334.47. Piperacillin and cefepime jointly accounted for an important share of this decrease. Changes in broad-spectrum antimicrobial expenditures should be interpreted alongside HAI indicators, length of stay, antimicrobial treatment intensity, and patients' clinical complexity. Changes in expenditure alone cannot establish costs causally attributable to HAIs; nevertheless, they provide a useful economic indicator for subsequent estimation of attributable costs by identifying treatments administered to individual patients with HAIs.

Table 8 Total Costs of Invasive Devices in Intensive Care.

Invasive Device	Total Cost (C$)
Mechanical ventilation	6,000.00
Central venous catheter	3,000.00
Urinary catheter	200.00
High-flow kit	3,500.00
Closed circuit	2,000.00
Collection bag	300.00*
Peripheral catheter	100.00*
Arterial line	700.00*
Total	15,800.00

37% + 28% = 65% → C$10,270.00. Mechanical ventilation and high-flow kits account for almost two-thirds of net costs and are priority items for supply expenditure control. Distribution of device and supply costs in intensive care. Total net cost: C$15,800.00. Mechanical ventilation and high-flow kits account for 65% of net ICU material costs.

Table 9 Indirect Costs of Diagnostic Studies Performed in Intensive Care Patients.

Diagnostic Study	2023 (C$)	2024 (C$)
Specialized studies (EXTRS)	573	326
Biopsy	409	143
Monitoring	390	313
Ultrasound scans	351	106
Blood cultures	313	87
Laboratory tests	286	159
Angiography	257	231
Computed tomography	185	6
X-rays	157	2
Total	2,921	1,373

IV. DISCUSSION

The principal scientific contribution of this article is an economic analysis concerning costs attributed to increases in reported percentage values for both sexes between 2023 and 2024. Among women, the indicator increased by 15 percentage points, from 60% to 75%, while among men it increased by 5 percentage points, from 75% to 80%. These findings indicate differences in the distribution of the analyzed indicator by sex. From an economic perspective, the results suggest that resource utilization is not uniform.

The monthly pattern showed greater concentration of the indicator during certain periods of the year. The monthly average increased from 7.63% in 2023 to 9.50% in 2024, an increase of 1.87 percentage points and a relative change of

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24.5%. February had the highest value in both years, rising from 9.53% in 2023 to 12.25% in 2024, an increase of 2.72 percentage points.

Chronic kidney disease was the most frequently reported comorbidity in both periods, although its reported proportion decreased by 10 percentage points, from 45% in 2023 to 35% in 2024. This finding is relevant to economic analysis because kidney disease may increase the complexity of critical care and require closer clinical, laboratory, and pharmacological monitoring. Septic shock also decreased from 30% to 15%, a reduction of 15 percentage points. These findings are consistent with international literature indicating that increasing antimicrobial resistance can require rescue therapies and newer antimicrobials, substantially increasing healthcare costs. Systematic reviews have documented significantly higher costs for infections caused by resistant organisms than for those caused by susceptible strains, especially in intensive care settings (Zhen et al., 2019; Wozniak et al., 2019).

The observed decrease in comorbidities does not necessarily imply a proportional decrease in costs, because resource consumption may be determined by other factors, including length of stay, antimicrobial treatment, invasive procedures, and illness severity.

Microbiological findings indicate changes in the profile of identified microorganisms between the two periods. Escherichia coli remained the most frequent, increasing from 60 to 68 isolates. Pseudomonas aeruginosa increased from 30 to 40 records (33.3%), while Staphylococcus hominis increased from 34 to 40. These changes are economically relevant because treatment difficulty and antimicrobial resistance may increase antimicrobial use, diagnostic testing, and duration of care. WHO notes that HAIs place a greater burden on health systems and that antimicrobial resistance can increase hospital stays, intensive care needs, and use of second-line antibiotics (Global Report on Infection Prevention and Control 2024). Scientific evidence suggests that infections caused by these organisms may increase hospitalization costs through more complex treatments, longer stays, and additional diagnostic and therapeutic procedures (Zhen et al., 2019; Naylor et al., 2023).

Analysis of pharmaceutical resource use shows a difference between administration frequency and economic share. Epinephrine had the highest administration frequency (28%) but represented only 12.5% of costs. In contrast, vecuronium accounted for 25% of costs with 15% of administrations, while norepinephrine accounted for 15% of costs despite representing only 5% of administrations. This pattern illustrates why medication expenditure management must consider frequency, quantity administered, and unit cost together, since less frequently administered medications can account for a disproportionately high economic burden. Thus, the high expenditure observed in this study may reflect not only supply consumption but also the clinical complexity of affected patients and the relationship between device use and HAIs in intensive care. The source text contains an incomplete reference to a systematic review. Broad-spectrum antimicrobial expenditure was also described as increasing substantially between 2023 and 2024: according to the values shown in that analysis, accumulated cost rose from approximately C$1.36 million to C$2.30 million, an increase of 69.1%. Piperacillin and cefepime together accounted for approximately 70.2% of that reported increase. This finding is important because antimicrobial use is one of the economic components potentially related to caring for patients with HAIs. Antimicrobial resistance is a major global health threat; bacterial antimicrobial resistance was estimated to be associated with more than 4.7 million deaths worldwide in 2021 (1).

Respiratory support devices accounted for the largest share of the analyzed costs. Mechanical ventilation represented 37%, while the high-flow kit accounted for 28%, together comprising 65% of total device costs. This finding is relevant to ICU financial management because these devices are essential for critically ill patients but also require strict infection prevention and control measures.

Indirect costs associated with diagnostic studies decreased from C$2,921 in 2023 to C$1,373 in 2024, a reduction of C$1,548 (53.0%). The largest reductions were observed for X-rays and computed tomography, decreasing by 98.7% and 96.8%, respectively. However, this reduction should not automatically be interpreted as a decrease in severity or HAIs, because it may reflect changes in patient numbers, clinical indications, test availability, diagnostic protocols, or patient characteristics. The source describes an integrated assessment of costs associated with these infections among critically ill ICU patients rather than merely quantifying HAI frequency.

Unlike studies that assess only pharmaceutical costs or prolonged hospital stays, this research included direct costs associated with medications, broad-spectrum antibiotics, and invasive devices, as well as indirect costs associated with diagnostic procedures, clinical monitoring, and supplementary tests. This multidimensional approach is presented as allowing a more comprehensive assessment of the economic burden attributed to HAIs and as being consistent with international methodological recommendations for evaluating the economic impact of antimicrobial resistance and nosocomial infections (Wozniak et al., 2019; Naylor et al., 2018).

Another relevant finding was the contribution of indirect costs from diagnostic procedures and monitoring activities. These components are traditionally underestimated in hospital economic evaluations; however, the present study describes them as a substantial share of total expenditures. Recent literature suggests that HAI cost estimates should include not only pharmaceutical and therapeutic expenses but also diagnostic testing, microbiological surveillance, continuous monitoring, and human resources, which more fully reflect the economic burden of disease (Wozniak et al., 2019; The Economics of Antibiotic Resistance, 2025).

Finally, these findings are particularly relevant in the current context of antimicrobial resistance, which the World

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Health Organization considers a major health threat. Accordingly, the study presents local evidence on the economic impact of HAIs in critically ill patients and information that may inform hospital management, resource optimization, antimicrobial stewardship programs, and strengthened infection prevention and control strategies. This profile is consistent with recent Latin American studies identifying exposure to mechanical ventilation, central venous catheters, and urinary catheters as major risk factors for HAIs among critically ill patients (1,2).

V. CONCLUSIONS

- Population characteristics showed that men accounted for the largest proportion of cases associated with increased infection-related costs in the ICU during 2023–2024. However, women showed the greatest relative increase in admissions between the two years. Urban residence predominated, representing more than 96% of analyzed cases. Patients were mainly older adults, with reported mean ages of 80 years for men and 65 years for women. The source interprets advanced age as relevant to infection occurrence and increased care costs among critically ill patients.
- Monthly HAI incidence was described as following a similar pattern in both study years, with February having the highest case frequency, followed by other months in the first half of the year. A subsequent downward trend was reported. Chronic kidney disease was the most frequent comorbidity among patients with HAIs, followed by septic shock, ischemic cerebrovascular events, and postoperative conditions. These findings suggest that chronic diseases and complex clinical conditions increase critically ill patients' vulnerability to infection and contribute to hospital expenditures.
- Escherichia coli was identified as the most prevalent microorganism during 2023–2024, followed by Staphylococcus aureus, Staphylococcus hominis, and Pseudomonas aeruginosa. The frequency of some of these pathogens increased between years, reflecting the persistence of microorganisms capable of causing infections in critically ill patients. Their high reported frequency underscores the importance of strengthening prevention, epidemiological surveillance, and rational antimicrobial use to reduce HAI incidence and clinical and economic impact.
- Estimated costs associated with HAIs varied between 2023 and 2024. Broad-spectrum medications were among the main expenditure components, while advanced respiratory support devices, particularly mechanical ventilation and high-flow systems, accounted for a substantial share of direct costs. Among costs associated with diagnostic studies, specialized tests, monitoring, and biopsies were prominent. Overall, the source concludes that HAIs impose a considerable financial burden on intensive care units and supports strengthening prevention, infection control, and optimization of healthcare resources.

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