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RESEARCH

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Clinical impact of healthcare-associated infections in Brazilian ICUs: a multicenter prospective cohort

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Abstract

Background Limited data is available to evaluate the burden of device associated healthcare infections (HAI) [central line associated bloodstream infection (CLABSI), catheter associated urinary tract infection (CAUTI), and ventilator associated pneumonia (VAP)] in low and-middle-income countries. Our aim is to investigate the population attributable mortality fraction and the absolute mortality difference of HAI in a broad population of critically ill patients from Brazil.

Methods Multicenter cohort study from September 2019 to December 2023 with prospective individual patient data collection. VAP, CLABSI, and CAUTI were diagnosed by each center in accordance with Brazilian regulatory agency guidance. If a patient fulfilled all diagnostic criteria, he was deemed to have Confirmed HAI. An adjusted disability multistate model was used to evaluate the population attributable in-hospital mortality fraction (PAF) and the absolute in-hospital mortality difference (AMD).

Results A total of 128,247 patients were included. 4066 (3.2%) distinct patients had at least one diagnosis of HAI (1493 CLABSI, 433 CAUTI, 2742 VAP, and 435 patients with more than one HAI) during the ICU stay. The PAF was 3.89% (95% CI 3.68–4.11%) for HAI, 2.16% (2.05–2.33%) for VAP, 1.2% (1.08–1.32%) for CLABSI, 0.11% (0.07–0.16%) for CAUTI, and 0.33% (0.26–0.4%) for ≥ 2 HAI. The AMD for HAI was 33.69% (95% CI 32.27–35.33%), 29.01% (27.15–30.98%) for VAP, 31.64% (29.3–34.81%) for CLABSI, 9.94% (3.88–15.54%) for CAUTI and 35.6% (28.93–42.99%) for ≥ 2 HAI.

Conclusions Device-associated HAI significantly contribute to hospital mortality and impose a high excess risk of death for critically ill patients.

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Keywords Healthcare associated infection, Intensive care unit, Ventilator-associated pneumonia, Bloodstream infection, Attributable mortality

Background

Healthcare-associated infections (HAI) are the most common adverse event in hospitalized patients worldwide [1] and are associated with increased mortality [2–4]. Although the burden of HAI in high-income countries is well-documented, limited data is available to assess the characteristics and outcomes of HAI in low and middle-income countries [1, 5, 6]. This disparity may be attributed to the complexity of diagnosing HAIs, which relies on multiple criteria that can vary between countries, a lack of research funding, and suboptimal surveillance systems in these countries [1, 7, 8]. Furthermore, the differences in the burden of HAI between high-income and low- to middle-income countries may be significantly greater for critically ill patients with device-associated infections [1, 5].

In 2019, the hospitals members of the Program to Support Institutional Development of Universal Health System (Programa de Apoio ao Desenvolvimento Institucional do Sistema Único de Saúde—PROADI-SUS), an initiative of the Brazilian Health Ministry to promote research, launched the IMPACTO-MR (Impact of Infections by Antimicrobial-Resistant Microorganisms in Patients Admitted to Adult Intensive Care Units in Brazil: Platform of Projects to Support the National Action Plan for the Prevention and Control of Antimicrobial Resistance) program, a national intensive care unit (ICU) clinical database platform [9]. This platform allows for multiple and comprehensive observational and interventional researches focused on device associated HAI in Brazilian ICUs [10].

In this study, we aimed to investigate the population attributable mortality fraction (the percentage of population mortality that could be prevented by theoretically eliminating an exposure) and the absolute mortality difference (excess risk of death attributable to an exposure) of three device associated HAI (CLABSI, CAUTI, and VAP) in critically ill patients from Brazil.

Methods

Study design and population

This was an observational prospective cohort study, nested on the IMPACTO-MR platform. Details on the IMPACTO-MR platform are provided elsewhere [9].

We included all adult patients admitted to the 60 participating ICUs from September 2019, to December 2023. Ethical approval was given by each participating institution's Ethics Committee and waiver of consent to data collection was given to all but one participating site, which collected individual consent forms for all participating patients. This report has been prepared in accordance with the STROBE statement [11].

Data collection and definitions

Main data were collected in all participating ICUs using the Epimed Monitor System® (Epimed Solutions®, Rio de Janeiro, Brazil) [12] customized for the study's objectives. At each center, a data collection team was trained by the study's coordinators and the Epimed Solutions® team. We collected data on demographics, comorbidities, admission type, admission diagnosis, Simplified Acute Physiology Score (SAPS) 3, invasive device usage (endotracheal tube, tracheostomy, urinary catheter, and intravascular devices), microbiology, antibiotic usage, infections during ICU stay, ICU and hospital length of stay, and ICU and hospital mortality.

Data on HAI (CLABSI, CAUTI, and VAP) were inserted directly in the database. In Brazil, device-associated HAI diagnosis should follow the Brazilian Health Regulatory Agency (Agência Nacional de Vigilância Sanitária—ANVISA) definitions [8]. Investigators at all sites were instructed to follow ANVISA's definitions and report HAI appropriately. Patients were deemed to have Confirmed HAI if they fulfilled all the following criteria: a HAI diagnosis was inserted in the database, plus corresponding device use within the infection window (for at least 48 h or device has been removed in the last day), plus presence of specific signs or symptoms. For CLABSI and CAUTI, diagnosis required a positive microbiological culture, while VAP diagnoses included both microbiologically confirmed and non-microbiologically confirmed cases (clinical VAP).

We also considered two additional HAI definitions for sensitivity analysis. All patients with a HAI diagnosis in the database plus device use within the infection window (including patients with Confirmed HAI diagnosis), irrespective of fulfilling all ANIVSA's criteria, were deemed to have Reported HAI. Patients with HAI diagnosis in the database plus device use within the infection window (Reported HAI) and that did not fulfill the ANVISA's criteria were deemed to have Possible HAI (S1 figure). Therefore, the set of Reported HAI is formed by the

Confirmed HAI plus Possible HAI (More details on HAI diagnosis can be found on page 4 of the supplement).

Direct data verification was unfeasible in our study; however, the data management team performed several checks to optimize data quality. Quality reports were sent to each center periodically to check for inconsistencies (for example: infections diagnosis without the device associated data). In addition, the Epimed Monitor System® has built-in data quality tools (plausible limit values, mandatory fields, and automatic data quality-report to each center). The coordinating centers were available through e-mail and telephone support to all participating sites.

Outcomes

The main outcome was hospital mortality censored at 90 days. Secondarily, we evaluated for hospital length-of-stay (LOS).

Statistical Analysis

Baseline and clinical characteristics on continuous variables were summarized using median and interquartile-range (IQR) or mean and standard deviation (SD) and compared using t-test or Wilcoxon Rank-Sum test, as appropriate. Categorical variables were expressed using absolute numbers and percentages and compared using $\chi 2$ test. We did not perform imputation for missing data and the percentages shown in tables are valid percentages (not including missing data).

For estimating the population attributable hospital mortality fraction up to day 90 (PAF) and the absolute mortality difference up to day 90 (AMD), we performed an adjusted disability multistate model to take into account competing risks (hospital death and discharge) and the time dependency exposure to an HAI at each time-point, and adjusted for baseline covariates [age, Simplified Acute Physiology Score (SAPS) 3 and admission type] [13, 14]. This continuous-time stochastic process (S2 Figure) allows for estimation of population attributable mortality fraction as a function of the transition probabilities between states, where death and discharge are absorbing states, and HAI acquisition is an intermediate state. The transition intensities between states are modeled using Cox proportional-hazard models, and then the transition probabilities are defined [13]. Finally, we were able to calculate the PAF and AMD. The PAF at a time *t*, given the covariates Z is given by:

$$PAF(t|Z) = \frac{P(D,t,Z) - P(D|\overline{HCAI},t,Z)}{P(D,t,Z)}$$

where $P(D,t,Z)$ represents the probability of death before time t given the covariates Z and $P(D|\overline{HCAI},t,Z)$ represents the conditional probability of death in patients not exposed to HAI before time t given the covariates Z and that exposure to HAI did not occur before time t.

The AMD at a time *t*, given the covariates Z is given by:

$$AMD(t|Z) = P(D|HCAI,t,Z) - P\left(D|\overline{HCAI},t,Z\right)$$

where $P(D|HCAI,t,Z)$ represents the conditional probability of death in patients exposed to HAI before time t given the covariates Z and that exposure to HAI occurred before time t, $P(D|\overline{HCAI},t,Z)$ represents the conditional probability of death in patients not exposed to HAI before time t given the covariates Z and that exposure to HAI did not occurred before time t. The 95% confidence intervals for both PAF and AMD were obtained by bootstrap analyses. Finally, PAF can be interpreted as the fraction of the population mortality that could be prevented by eliminating the exposure (HAI) up to time t, and AMD can be interpreted as a measure of the excess risk of death attributable to the exposure (HAI) up to time t for an individual patient.

Considering each specific Confirmed HAI might have distinct impact on the outcomes, we performed analyses of each HAI on the PAF and AMD. We performed the same analyses as sensitivity analyses for the Reported HAI and Possible HAI.

Exploratory analyses included a time-dependent Cox model with hospital survival to 90 days for the HAI exposure, adjusted for age, SAPS 3, and admission type. For estimating the hospital LOS (change in LOS—cLOS) we used a multistate model adjusted for age, SAPS 3, and admission type. Multistate models are useful in evaluating cLOS given their ability in dealing with time-dependent bias, especially in setting of HAI when subjects transition between states [15, 16]. We also compared the outcomes between the groups consisted of only Confirmed HAI versus patients with Possible HAI.

No adjustments for multiplicity were performed and a 2-sided P value of less than 0.05 was considered statistically significant. All statistical analyses were performed using the R software (version 3.6.3; R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/) [17].

Results

Sample characteristics

We analyzed data from 128,247 adult patients admitted to 60 participating units between September 2019 and December 2023. Most centers were public (61.7%), with a median of 1932 admissions per ICU during the study period [IQR, 970–2882]. The mean patient age

was 61.6 years (SD, 17.5); 67,667 were men (52.8%), and 54.7% of admissions were from public hospitals. Most patients were from the Southeast region of Brazil (37.9%). The majority were admitted from the emergency department (30.9%) or operating room (29.4%), with a median Charlson comorbidity index of 1 [IQR 0–2] and a median SAPS 3 score of 45 [IQR 34–57]. Data on hospital outcomes (LOS and mortality) were available for 125,995 patients (98.2%) (Table 1 and S1 table in supplement).

A total of 4066 patients (3.2%) were diagnosed with at least one Confirmed HAI during their ICU stay, with 435 having more than one. Diagnoses included 1493 CLABSIs (0.89/1,000 patient-device days), 433 CAUTIs (0.45/1000 patient-device days), and 2742 VAPs (5.04/1000 patient-device days), of which 1126 were clinical VAP. The yearly HAI density/1000 patients-device/day remained stable during the study period, including during the COVID-19 pandemic. The median time from device insertion to Confirmed HAI diagnosis was 9 days for CLABSI [IQR 5–14], 8 days for CAUTI [IQR 5–14], and 7 days for VAP [IQR 4–11] (Table 1 and S3 Figure).

Of the Confirmed VAP cases, 1514 (55.2%) were early (≤7 days from device insertion) and 1228 (44.8%) were late (>7 days). The most common microorganisms in VAP were *Klebsiella spp.*, *Acinetobacter spp.*, *Pseudomonas spp.*, and *Staphylococcus aureus* (S4 Figure). *Acinetobacter spp.* was more common in late VAP, while *Staphylococcus aureus*, *Enterobacter spp.*, and other Gram-positive bacteria were more prevalent in early VAP (S5 Figure). *Klebsiella spp.* was the most common identified microorganism in CLABSI and CAUTI (S4 Figure).

Population attributable mortality fraction

For Confirmed HAI, the PAF begins increasing by the end of the second week, stabilizing around day 60 (Fig. 1). The PAF for Confirmed HAI was 3.89% (95% CI 3.68–4.11%) (Table 2). VAP was the HAI with highest associated PAF (2.16%, 95% CI 2.05–2.33%). The PAF for CLABSI and CAUTI are shown in S6 Figure and Table 2.

Table S6 present the PAF by covariates, showing higher PAF in less severely ill patients (1st and 2nd SAPS 3 quartiles), elective surgical patients, and those older than 80 years.

Absolute mortality difference

The AMD for Confirmed HAI was 33.69% (95% CI 32.27–35.33%), with a nearly linear increase up to day 60, stabilizing afterward (Table 3; Fig. 2). The AMD for specific Confirmed HAIs was: 29.01% (95% CI 27.15–30.98%) for VAP, 31.64% (95% CI 29.3–34.81%) for CLABSI, 9.94% (95% CI 3.88–15.54%) for CAUTI, and 35.6% (95% CI 28.93–42.99%) for ≥2 HAI (Table 3 and S11 Figure). S9 Table and S16 Figure show that the excess risk of death is higher in less severely ill patients (1st and 2nd SAPS 3 quartiles), elective surgical patients, and those over 80 years. S12–15 Tables present AMD for each Confirmed HAI by covariates.

Sensitivity analyses

Data on Reported and Possible HAI are presented in S2 and S3 Tables. The PAF for Reported HAI was 6.07% (95% CI 5.77–6.33%) (S4 Table). PAF for each specific Reported HAI is shown in S7-S8 Figures and S4 Table. The PAF for Possible HAI was 2.54% (95% CI 2.35–2.71%) (S4 Table). PAF for each specific Possible HAI is shown in S9-S10 Figures and S4 Table. Tables S7-S8 present the PAF for Reported and Possible HAI by covariates.

Both Reported and Possible HAI show similar AMD to Confirmed HAI: 33.13% (95% CI 31.86–34.4%) and 33.49% (95% CI 31.08–35.48%), respectively. Results for specific Reported and Possible HAI are shown in S5 Table and S12–15 Figures. S10–11 and S16–23 Tables, and S17–18 Figures, show AMD for Reported and Possible HAI by covariates.

Secondary outcome and exploratory analyses

Patients with Confirmed HAI had higher hospital LOS [mean 43.9 days (SD 36.9) vs. mean 18.1 days (SD 26.7)] and higher mortality [57.6% vs. 24.11%] compared to those without Confirmed HAI. A multistate model indicated that Confirmed HAI is associated with increased hospital LOS [cLOS 5.01 days (95% CI 4.28–5.92), $p < 0.001$] and hospital mortality [Hazard Ratio 1.32 (95% CI 1.26–1.39), $p < 0.001$]. Similar results were observed using the Reported HAI definition (S24 Table and S19 Figure).

Compared to Possible HAI, Confirmed HAI was associated with higher hospital mortality [Hazard Ratio 1.07 (95% CI 1.002–1.15), $p = 0.045$] but not with higher hospital LOS [cLOS 0.28 (95% CI − 1.36 to 1.92), $p = 0.74$] (S25 Table).

Discussion

In this prospective cohort of 128,247 patients across 60 Brazilian ICUs, ICU-acquired HAI (CLABSI, CAUTI, and VAP) significantly contributed to hospital mortality, with a PAF of 3.89% and an AMD of 33.69%.

Both PAF and AMD increased after the second week, stabilizing around day 60, with an initial paradoxical negativity due to early deaths among patients who hadn't had time to acquire HAI. Under a more sensitive HAI definition (Reported HAI), the PAF was higher at 6.07%, reflecting the greater prevalence of HAI. This should be interpreted as the observable proportion of attributable in-hospital death cases associated with

Table 1 Characteristics of the study population

	Confirmed HAI			p-value
	No (N = 124,181)	Yes (N = 4066)	Total (N = 128,247)	
Region, n (%)				< 0.001
Southeast	47,217 (38)	1362 (33.5)	48,579 (37.9)	
South	27,991 (22.5)	1758 (43.2)	29,749 (23.2)	
Northeast	35,508 (28.6)	834 (20.5)	36,342 (28.3)	
Center-west	8291 (6.7)	55 (1.4)	8346 (6.5)	
North	5174 (4.2)	57 (1.4)	5231 (4.1)	
Hospital type, n (%)				< 0,001
Public	67,760 (54.6)	2344 (57.6)	70,104 (54.7)	
Private	56,421 (45.4)	1722 (42.4)	58,143 (45.3)	
Age, years, mean (SD)	61.7 (17.5)	59.2 (17.3)	61.6 (17.5)	< 0,001
Sex at birth, n (%)				< 0.001
Female	58,963 (47.5)	1610 (39.6)	60,573 (47.2)	
Male	65,211 (52.5)	2456 (60.4)	67,667 (52.8)	
Admission type, n (%)				< 0.001
Emergency—clinical	73,991 (62)	3087 (76)	77,078 (62.5)	
Emergency—surgical	13,063 (10.9)	670 (16.5)	13,733 (11.1)	
Elective surgery	32,270 (27)	304 (7.5)	32,574 (26.4)	
Hospital location before ICU admission, n (%)				< 0.001
Emergency department	36,702 (30.7)	1557 (38.3)	38,259 (30.9)	
Operating room	35,588 (29.7)	776 (19.1)	36,364 (29.4)	
Other Hospital	15,802 (13.2)	632 (15.6)	16,434 (13.3)	
Hospital ward	15,608 (13)	617 (15.2)	16,225 (13.1)	
Other ICU	3804 (3.2)	208 (5.1)	4012 (3.2)	
Other[a]	12,140 (10.2)	271 (6.7)	16,953 (10.1)	
Location before hospital admission, n (%)				< 0.001
Home	70,915 (61.5)	1778 (44.6)	72,693 (60.9)	
Other hospital or health services	44,434 (38.5)	2210 (55.4)	46,644 (39.1)	
Comorbidities and risk factors, n (%)				
Hypertension	45,072 (36.3)	1647 (40.5)	46,719 (36.4)	< 0,001
Diabetes	22,656 (18.2)	910 (22.4)	23,566 (18.4)	< 0,001
Alcohol abuse	4624 (3.7)	237 (5.8)	4861 (3.8)	< 0,001
Smoking	9143 (7.4)	369 (9.1)	9512 (7.4)	< 0,001
Locoregional solid tumor	8248 (6.6)	221 (5.4)	8469 (6.6)	0.003
Metastatic solid tumor	2920 (2.4)	63 (1.5)	2983 (2.3)	0.001
Charlson Comorbidity Index, median [IQR]	1 [0–2]	1 [0–2]	1 [0–2]	< 0,001
Length of hospital stay prior to ICU admission, median [IQR]	1 [0–3]	1 [0–4]	1 [0–3]	< 0,001
SAPS 3, median [IQR]	44 [34–56]	58 [47–70]	45 [34–57]	< 0,001
Infection density/1000 patients-device/day				
CLABSI			1493/1669336 (0.89)	
CAUTI			433/953008 (0.45)	
VAP			2742/543688 (5.04)	
Median time from device insertion to HAI diagnosis, days				
CLABSI		9 [5–14]		
CAUTI		8 [5–14]		
VAP		7 [4–11]		
Year of ICU admission, n (%)				< 0,001
2019	1986 (1.6)	65 (1.6)	2051 (1.6)	

Table 1 (continued)

	Confirmed HAI			p-value
	No (N = 124,181)	Yes (N = 4066)	Total (N = 128,247)	
2020	29,864 (24.05)	1080 (26.56)	30,944 (24.13)	
2021	23,186 (18.67)	1059 (26.05)	24,245 (18.9)	
2022	32,456 (26.14)	914 (22.48)	33,370 (26.02)	
2023	36,689 (29.54)	948 (23.32)	37,637 (29.35)	

SD standard deviation, *IQR* interquartile range, *SAPS 3* Simplified Acute Physiology Score 3, *CLABSI* central line associated bloodstream infection, *CAUTI* catheter associated urinary tract infection, *VAP* ventilator associated pneumonia, *HAI* healthcare-associated infection

[a] Catheterization laboratory, home, step-down unit, obstetric center, and other not specified

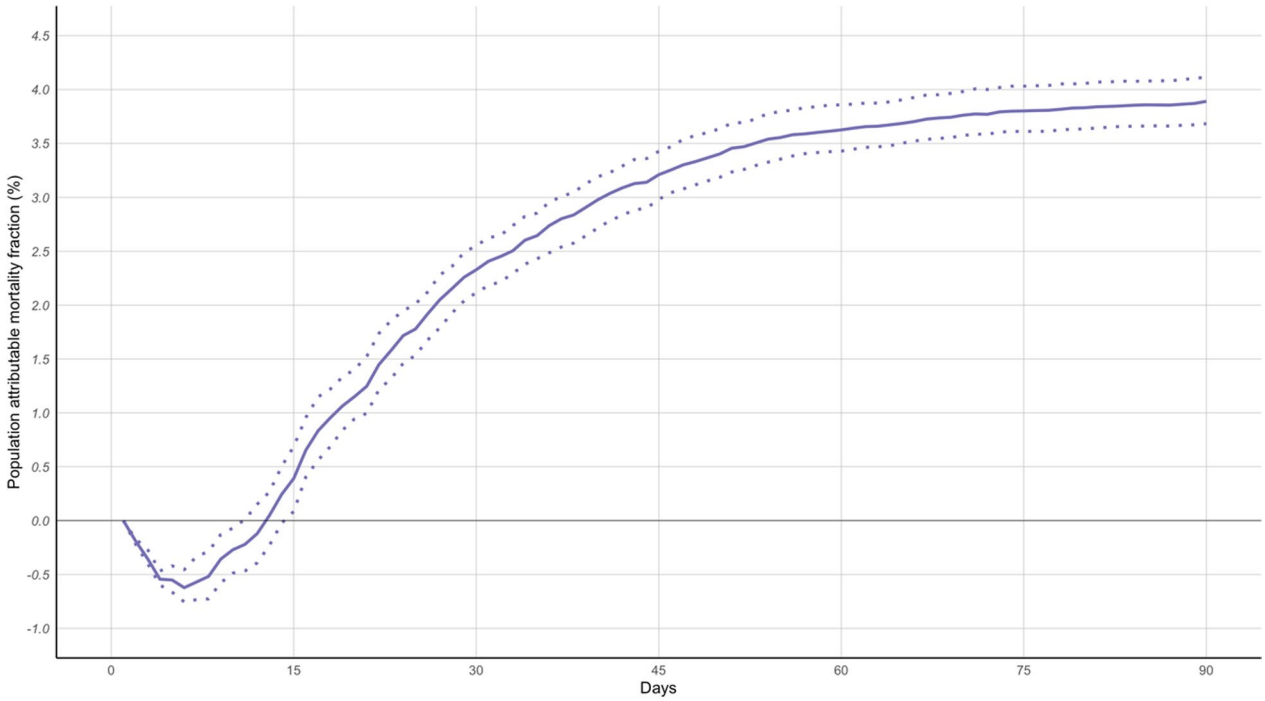

Fig. 1 Population attributable mortality fraction for confirmed HAI

Table 2 Population attributable mortality fraction

	Population attributable mortality fraction (95% CI)[a]		
	Day 30	Day 60	Day 90
Confirmed HAI			
All HAIs	2.33% (2.12–2.55%)	3.63% (3.43–3.86%)	3.89% (3.68–4.11%)
VAP	1.43% (1.27–1.63%)	2.04% (1.91–2.23%)	2.16% (2.05–2.33%)
CLABSI	0.68% (0.55–0.77%)	1.09% (0.96–1.2%)	1.2% (1.08–1.32%)
CAUTI	0.03% (−0.02–0.08%)	0.1% (0.05–0.14%)	0.11% (0.07–0.16%)
≥ 2 HAIs	0.06% (−0.03–0.11%)	0.29% (0.22–0.37%)	0.33% (0.26–0.4%)

[a] Estimated using a disability multistate model adjusted for age, SAPS 3 and admission type

the exposure (HAI) among all patients admitted to the ICU. Therefore, in our population, depending on HAI definition, between 3.89% and 6.07% of all deaths are attributable to HAI. The higher PAF with the more sensitive definition is due to additional deaths among newly diagnosed patients [18]. The AMD was consistently elevated across all HAI definitions, resulting in a more than 30% excess mortality risk attributable to HAI for individual patients. Notably, the HAI burden was higher among less severely ill patients, those undergoing elective surgeries, and older individuals, though still significant, it was relatively lower in more severely

Table 3 Absolute mortality difference

	Absolute mortality difference (95% CI)[a]		
	Day 30	**Day 60**	**Day 90**
Confirmed HAI			
All HAIs	17.34% (15.35–19.04%)	30.4% (28.97–32.35%)	33.69% (32.27–35.33%)
VAP	16.61% (14.26–18.67%)	26.66% (24.54–28.55%)	29.01% (27.15–30.98%)
CLABSI	16.54% (13.14–19.92%)	28.24% (25.28–30.78%)	31.64% (29.3–34.81%)
CAUTI	2.47% (−4.17–7.43%)	8.8% (2.78–15.33%)	9.94% (3.88–15.54%)
≥ 2 HAIs	4.11% (−0.99–11.83%)	30.51% (24.37–37.54%)	35.6% (28.93–42.99%)

[a] Estimated using a disability multistate model adjusted for age, SAPS 3 and admission type

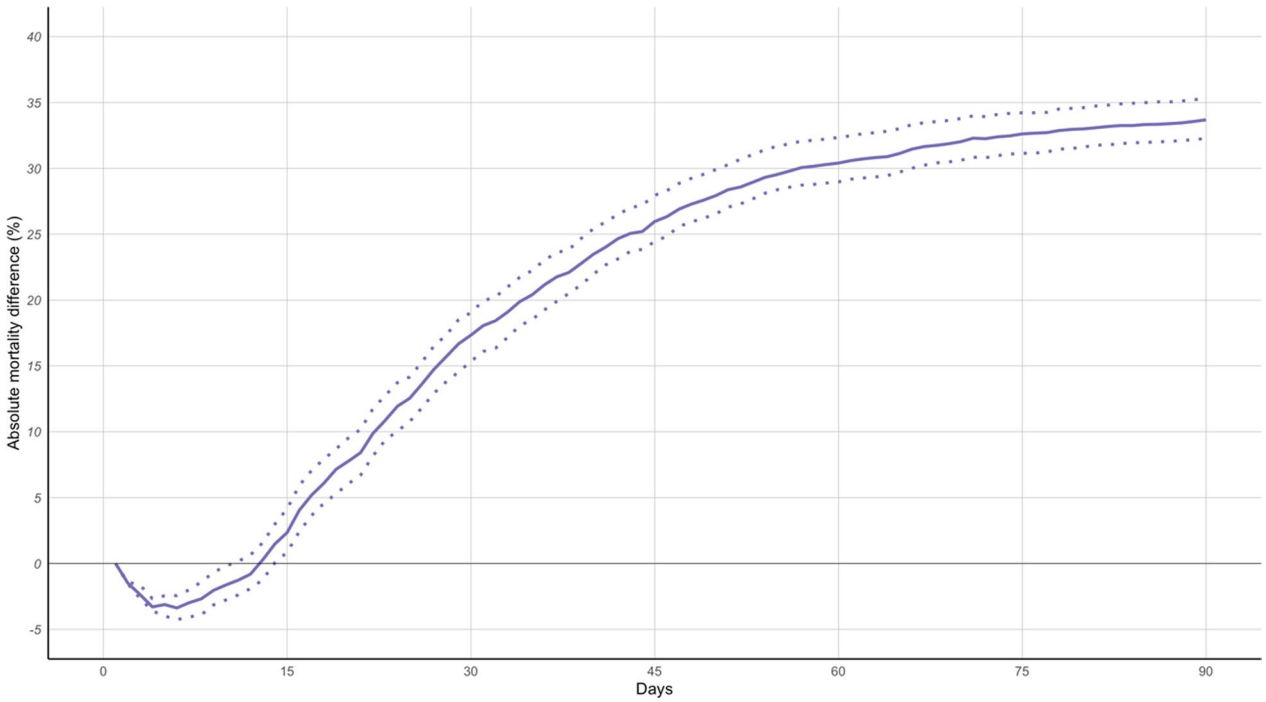

Fig. 2 Absolute mortality difference for confirmed HAI

ill patients—a pattern consistent across all HAI definitions. Both HAI definitions were also associated with longer ICU stays and higher mortality. Interestingly, when comparing mortality and hospital LOS between patients with Confirmed HAI and those with Possible HAI, there was no difference in hospital LOS, but a slight increase in mortality risk for Confirmed HAI.

Population attributable mortality fraction (PAF) is a measure used to estimate the impact of a hypothetical intervention that could eliminate the exposure of interest entirely. Importantly, it assumes exchangeability between exposure levels and is influenced by the prevalence of the exposure [19]. Therefore, it's not surprising that VAP has a higher PAF than CLABSI and CAUTI, given VAP's greater prevalence as an HAI. Additionally, the more sensitive definition of HAI yielded a higher, expected PAF, which carries important implications for interpreting these results While achieving zero events may be feasible for CLABSI [20]. this assumption does not hold for VAP or CAUTI. For example, efforts to eliminate VAP through financial incentives have been associated with gaming the definition of VAP [21] and diagnosis bias [22]. Consequently, although we observed a PAF of 2.16% for VAP, it is likely that efforts to reduce VAP—without manipulating its definition—would only achieve a portion of this potential reduction. In contrast, efforts to reduce CLABSI to zero are more likely to reach their full potential, supported by experimental evidence. Furthermore, these interventions should account for the ceiling effect of standardized care bundles in reducing each type of HAI.

These results are significant because contextualizing the burden of device-associated HAI in low- and middle-income countries is challenging due to the lack of national-level data with proper methodology for calculating PAF or AMD [1, 5]. A Brazilian study on nosocomial sepsis reported an attributable mortality fraction of 7.6% [23]. A meta-analysis of randomized trials on VAP prevention found an attributable mortality of 13% [24], while a multicenter study indicated that 60-day ICU-attributable mortality for VAP was 5.9% [25]. The median hospital LOS for patients with HAI in our study was comparable to that of the HAI subgroup in the EPIC III study [2]. However, our study's results on the impact of HAI on hospital LOS are on the conservative end of previously reported estimates [1, 26], likely due to the more rigorous methodology we employed.

Our study provides valuable insights in a field that otherwise lacks data in low- and middle-income countries and may aid in the design of future trials. Given the challenges in diagnosing HAI, especially VAP [22, 27], our findings should be viewed as a minimum estimate of HAI's population attributable mortality fraction. Additionally, our results highlight the urgent need for healthcare and government stakeholders to support further research on the prevention and management of HAI, particularly in low- and middle-income countries [6, 28]. Together with other initiatives [29], our platform is expanding the understanding of outcomes for critically ill patients in Brazil and can contribute to improving national HAI surveillance.

Despite the effort to conduct a multicenter study in a middle-income country, our work has several limitations. First, the diagnosis of HAI was not individually adjudicated by independent reviewers, which introduces a potential risk of exposure misclassification bias. However, the results were consistent across both HAI definitions, and we employed the same reporting framework across all centers to obtain valid estimates, considering the definition used, which differs from CDC definitions, for example. Second, data on the microbiological resistance of all HAI were not available for all isolates, limiting our ability to explore the issue of multidrug resistance further. However, this was not the primary objective of this analysis. Third, although we adjusted for baseline confounders and accounted for the competing risks of death and ICU discharge, we did not have data on time-dependent daily confounding variables necessary to derive a full counterfactual definition of population attributable mortality fraction [30], which would likely yield even more conservative estimates, as demonstrated by Bekaert et al. for VAP [25]. Fourth, we observed no fluctuations in HAI density during the study period, including the COVID-19 pandemic, which could suggest underreporting of HAI during this period. Fifth, the ICUs were not randomly selected to participate in the platform. Nonetheless, our goal of achieving representativeness of Brazil's geographical regions and hospital financing systems, to enhance generalizability, was accomplished. We believe our results are therefore generalizable to Brazil and other countries facing resource constraints.

Conclusion

Device-associated HAI significantly contribute to hospital mortality and impose a high excess risk of death for individual critically ill patients in a middle-income country setting. These results can aid in designing much-needed trials on the prevention and treatment of HAI, fostering high-quality research in low- and middle-income countries.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13054-024-05203-8.

Additional file 1.

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Author contributions
The primary investigators (BMT, BAMPB, VCV, ABC, APNJ, AJP) for this manuscript contributed to the conception and study design of the manuscript. BMT and RHNS conducted data analysis. BMT and ABC performed the interpretation of study results and wrote the first draft of the manuscript. All other authors participated in data acquisition, provided critical revision of the article and final approval of the version submitted for publication.

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Availability of data and materials
The datasets generated for this study are not publicly available, since individual participants did not consent for individual data availability for secondary analyses. Access to the datasets may be provided for secondary analysis upon approval of the IMPACTO-MR study steering committee and Brazilian Ministry of Health consent for further data analysis, and further ethical approval may apply.

Declarations

Ethics approval and consent to participate
All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the institutional review board of the coordinating center HCor (IRB approval number 3,025,217) and in appointed IRBs of all participating hospitals. A waiver of informed consent was obtained given the collection of routine clinical data with no intervention from study investigators and assurance of anonymization of datasets for data analysis, in accordance with Brazilian law and current regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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