Open access | Original research

BMJ Open

Cost savings of a nationwide project preventing healthcare-associated infections in adult, paediatric and neonatal critical care settings in Brazil: a micro-costing study

Lital Moro Bass,[1] Leonardo Henrique Fiuza de Meireles,[1] Edgard Joseph Kiriyama,[1] Nancy Oliveira dos Santos,[1] Ancelmo Honorato Ferraz de Sousa,[1] Karen Cristina da Conceição Dias Silva,[2] Rafaela Moraes de Moura,[3] Cristiana Martins Prandini,[4] Guilherme Cesar Silva Dias Santos,[5] Renata Gonsalez dos Santos,[6] Flavia Fernanda Franco,[1] Ademir Jose Petenate,[1,2,3,4,5,6] Cristiane Maria Reis Cristalda,[7] Claudia Garcia de Barros,[1] Sebastian Vernal [1,2,3,4,5,6]

To cite: Bass LM, de Meireles LHF, Kiriyama EJ, *et al*. Cost savings of a nationwide project preventing healthcare-associated infections in adult, paediatric and neonatal critical care settings in Brazil: a micro-costing study. *BMJ Open* 2025;**15**:e097515. doi:10.1136/bmjopen-2024-097515

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2024-097515).

Received 04 December 2024
Accepted 20 March 2025

Check for updates

For numbered affiliations see end of article.

Correspondence to
Dr Sebastian Vernal;
vernal.carranza@gmail.com

ABSTRACT

Objective To provide evidence of the cost savings of a quality improvement (QI) initiative preventing healthcare-associated infections (HAIs) in critical care settings.

Design A micro-costing study focused on financial data related to a nationwide multicentric project preventing central line-associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP) and catheter-associated urinary tract infection (CAUTI).

Setting Brazilian public healthcare system.

Participants Adult, paediatric and neonatal intensive care units (ICUs) participating in the QI initiative.

Intervention This collaborative QI project implemented a multifaceted strategy to enhance infection-control measures. Participating ICUs reported the number of patients with and without HAIs and information on each HAI's aggregate average cost (AC), which was analysed following the Brazilian Ministry of Health's micro-costing guidelines. The 1-year preintervention period evidenced an aggregated AC in adult, paediatric and neonatal ICUs, respectively, of Intl$21 763.5 (95% CI 20 683.6 to 22 843.0), Intl$34 062.4 (95% CI 25 819.6 to 42 304.9) and Intl$32 903.2 (95% CI 29 203.6 to 36 602.4) for CLABSI; Intl$25 202.5 (95% CI 24 276.6 to 26 127.8), Intl$44 753.6 and Intl$17 238.4 for VAP and Intl$19 166.3 (95% CI 17 676.2 to 20 656.1) and Intl$55 873.3 (95% CI 43 563.1 to 68 183.1) for CAUTI (not included neonatal ICUs).

Primary outcome The cost savings were estimated using the HAIs prevented—expenses avoided—during the QI intervention period from September 2021 to December 2023. The HAIs prevented were estimated using the difference between observed and predicted infections based on the aggregated preintervention baseline.

Results Of the 188 participating ICUs, 31 voluntarily completed and provided the requested financial data with 100% accuracy. Considering the prevented 7342 HAIs for adult, paediatric and neonatal ICUs, respectively: 1647, 86 and 205 CLABSI; 3775, 114 and 118 VAP; and 1377 and 20 CAUTI, we estimated a saving of Intl$175.3 million (95% CI 153.2 to 180.9 million) to the Brazilian unified health system and a resultant estimated return on investment (ROI) of 890%.

Conclusion This QI collaborative is a value-based initiative preventing HAIs in adult, paediatric and neonatal ICUs in South American settings. The substantial cost savings and a remarkable ROI underscore the economic viability of investing in comprehensive QI infection prevention strategies.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We provide a comprehensive micro-costing analysis for healthcare-associated infections in intensive care units from a middle-income country in South America.

⇒ We performed subgroup analysis: (1) adult, paediatric and neonatal; (2) with and without HAIs and (3) CLABSI, VAP and CAUTI.

⇒ Regarding the economic focus and structured financial database, some HAI-related clinical features (such as age, comorbidities and severity score) and long-term impacts (such as quality of life and years of life lost) were not assessed.

INTRODUCTION

Despite global efforts, healthcare-associated infections (HAIs) remain a severe and pervasive threat to patient safety.[1 2] HAIs not only compromise clinical outcomes but also incur substantial financial burdens, further stressing healthcare budgets worldwide.[3–6] For example, central line-associated bloodstream infections (CLABSIs), ventilator-associated

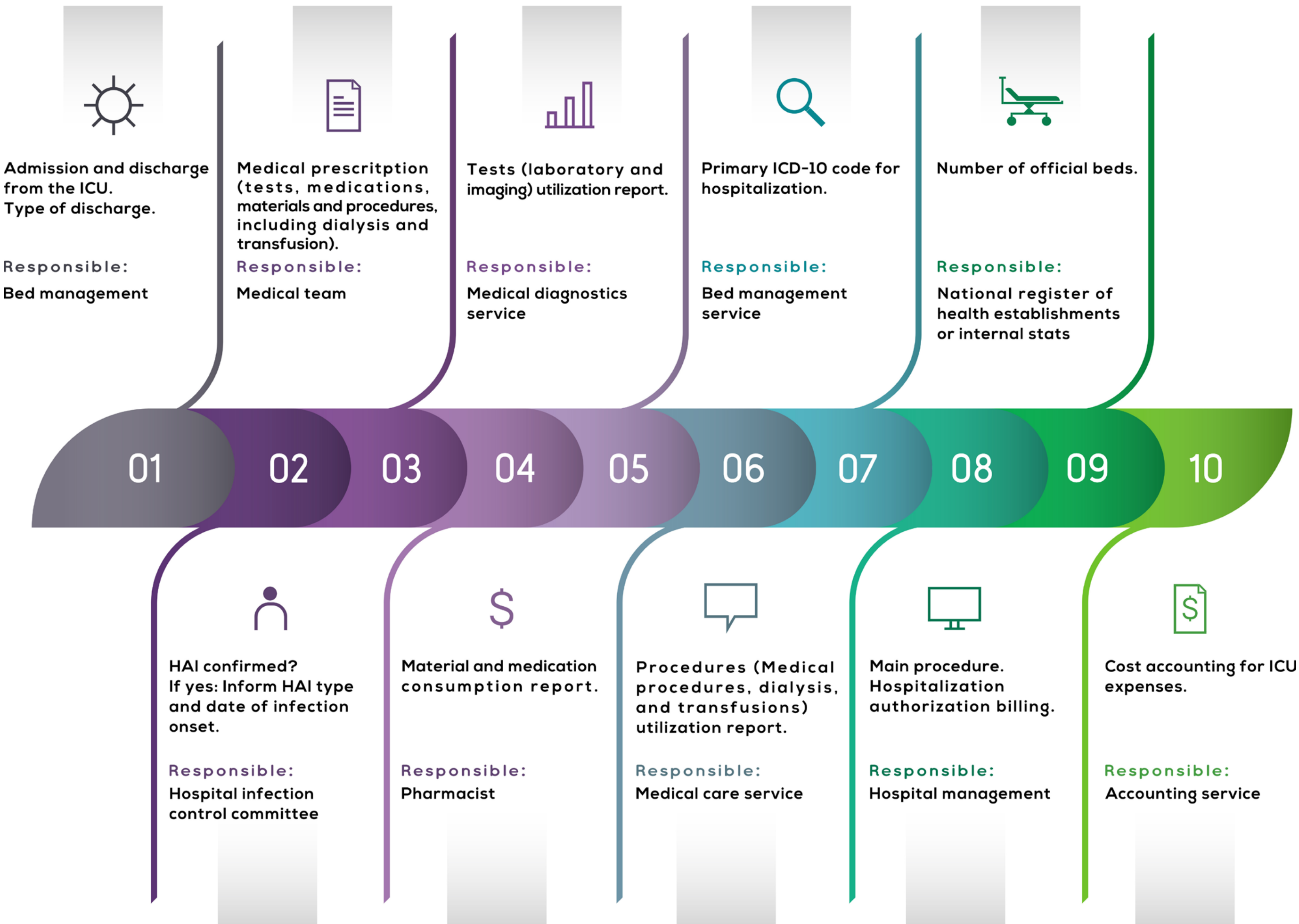

Figure 1 The 10 steps to obtain costs for each patient represent the data obtained in different areas during hospitalisation and the main costs generated. ICU, intensive care unit; HAI, healthcare-associated infection; ICD-10, International Classification of Diseases, 10th revision.

pneumonia (VAP), surgical site infections, *Clostridioides difficile* infection and catheter-associated urinary tract infections (CAUTIs), the most critical HAIs, add an estimated USD$9.8 billion annually to direct medical costs in the USA.[7] In the UK, HAIs are estimated to cost the National Health Service approximately £774 million annually, with CLABSI and VAP being the most expensive.[8] Similarly, a recent Italian study showed that HAIs increased hospitalisation costs by up to 60%, primarily because of extended hospital stays and additional treatments.[9]

This problem is particularly critical in low- and middle-income countries (LMICs), where obtaining maximum efficiency with chronically low budgets is crucial for providing reasonable monetary value in programmes to control HAIs.[10 11] An Ethiopian study found that patients with HAIs incurred an additional 8.3 days of hospitalisation on average, with direct medical costs significantly higher than those of non-infected patients.[12] In Africa, HAIs account for economic losses of approximately $13 billion per year, with an estimated 500 000 deaths, highlighting the disproportionate burden in resource-limited settings.[13]

This issue is even more concerning for patients admitted to the intensive care unit (ICU). Therapeutic indications expose critically ill patients to more invasive devices and procedures, resulting in a higher risk of infection. ICU-associated HAIs lead to higher mortality, longer length of stay (LOS) and higher financial costs.[14]

Various HAI-prevention strategies exist, including surveillance programmes, outbreak investigations, infection control measures and education of healthcare workers, patients and families. However, determining the most effective and cost-efficient approach remains challenging.[15–18]

Up to 70% of HAIs are avoidable; therefore, prevention and control programmes are recognised as cost-effective strategies.[19] In response to this multifaceted challenge, in 2018, a groundbreaking project was initiated in Brazil that focused on preventing HAIs in adult ICUs.[20] This nationwide project, called 'Saúde em Nossas Mãos' (SNM), adopted a holistic approach, leveraging a quality improvement (QI) model centred on training healthcare professionals and engaging and implementing prevention bundles.[20 21] Understanding the economic implications of this initiative is imperative, as financial resources are finite and optimal allocation is paramount.[22]

Following local Brazilian policies, the SNM was scaled up in 2021. The initiative expanded its coverage throughout the Brazilian territory, included more units and admitted paediatric and neonatal patients to ICUs. This study not only seeks to quantify the cost savings resulting from the prevention of the analysed HAIs but also aims to underscore broader implications for healthcare decision-makers. By exploring the economic viability of such comprehensive infection-prevention strategies, this study contributes to the ongoing discourse on the intersection of the quintuple aims proposed by the Institute for Healthcare Improvement.[23] This study aims to report the financial analysis and savings of the SNM's second phase (2021–2023).

METHODS

Study design

A micro-costing study following the local guidelines recommended by the Brazilian Ministry of Health (BMoH)[24] focused on financial data related to the SNM collaborative project. We followed the principles of the 'Reference Case for Estimating the Costs of Global Health Services and Interventions' proposed by the Global Health Cost Consortium,[25] described in online supplemental table S1.

Context

Brazil has adopted a comprehensive approach to enhancing the quality and safety of healthcare services by implementing pivotal health policies. Central to this endeavour are the National HAI Prevention and Control Program (*Programa Nacional de Prevenção e Controle de Infecções Relacionadas à Assistência à Saúde*)[26] and the National Patient Safety Policy (*Política Nacional de Segurança do Paciente*).[27] These policies are foundational to Brazil's overarching strategy to elevate healthcare service quality and improve patient outcomes, with the SNM being a crucial component within these frameworks. A previous publication provides detailed information on QI methodology, patient care, and relevant clinical indicators of the SNM.[20]

Furthermore, the Program for Institutional Development of the Unified Health System (*Programa de Apoio ao Desenvolvimento Institucional do Sistema Único de Saúde* (PROADI-SUS)) represents a strategic initiative that fosters collaboration between public health institutions and six private, non-profit hospitals of recognised excellence. This partnership is designed to facilitate the exchange of knowledge, technology and best practices to create a more equitable, inclusive and high-calibre public health system. Financial support for the SNM is provided through the resources allocated by PROADI-SUS, underscoring the programme's significant role in supporting Brazil's health policy infrastructure.

Location

Participating ICUs were from the five macro-regions of Brazil: North, Northeast, Midwest, Southeast and South.

Study population

An open call was made to all the participating institutions joining the SNM initiative. Participation was voluntary, and no financial incentive was provided, avoiding conflicts of interest. The data were organised into a prestructured template following a 10-step process (figure 1).

The inclusion criteria for the financial analysis module were (1) active participation in the SNM interventions, (2) having a cost and expense accounting system segregated by cost centre, (3) performing allocation of variable costs (supplies and drugs) for each patient and (4) having a database containing information about the patients treated by unit. The sole exclusion criterion was the lack of the necessary infrastructure to provide the information required by these 10 steps.

Health economic analysis plan

Participating institutions were invited to report the number of patients with and without HAIs, accompanied by information on each HAI's aggregate average cost (AC), during a 1-year preintervention period.

Perspective and time horizon

The financial saving analysis was conducted from the Unified Health System (*Sistema Único de Saúde* or SUS) perspective. The temporal framework for this evaluation was anchored to the SNM duration, spanning from September 2021 to December 2023.

Data preparation

Before further analysis, our expert team, comprising five health economic specialists, carefully evaluated the model forms sent by the participating institutions. Through a detailed internal checklist, we meticulously verified and detected conformity between the care procedures, laboratory tests, materials and medications and medical procedures directly dispensed to the patient. In cases of inconsistencies, the form was returned to the institution of origin for adjustments, and this procedure was repeated until the data were entirely consistent.

Each participant was assigned a unique code, ensuring a distinct and accurate financial record for each hospital admission, preventing duplication or double-counting costs. No case was excluded from the analysis due to missing data.

Selection of financial outcomes

On receiving completed forms containing financial data, the fixed costs (FC) and variable costs (VC) associated with the medical care provided by each participating ICU were delineated. FC are expenses that do not depend on the number of patients or care provided; they rely on hospital capacity (ie, salaries of professionals, depreciation, inputs, supplies, commonly used medications and maintenance costs of the facilities). In contrast, VC refers to expenses directly dependent on the medical care provided to each patient. The VC appropriation of materials and medicines is based on the moving average price.

Table 1 Aggregate average cost (fixed and variable cost) stratified by macro-region of Brazil

	North (n=541)	Northeast (n=2320)	Midwest (n=950)	Southeast (n=12 767)	South (n=879)	Total (n=17 457)
Fixed cost (BRL$)	58 496	83 086	56 483	84 281	147 096	85 290
Variable cost (BRL$)	25 905	42 508	33 334	54 405	115 919	54 040
Total (BRL$)	44 917 (95% CI 44 917 to 44 917)	66 179 (95% CI 45 413 to 86 945)	46 838 (95% CI 40 236 to 53 440)	71 834 (95% CI 63 753 to 79 915)	**134 106** (95% CI 126 133 to 142 079)	72 270 (95% CI 65 044 to 79 496)
Total (Intl$)	18 408 (95% CI 18 408 to 18 408)	27 122 (95% CI 18 611 to 35 633)	19 195 (95% CI 16 490 to 21 901)	29 440 (95% CI 26 128 to 32 752)	**54 961** (95% CI 51 693 to 58 229)	29 618 (95% CI 26 657 to 32 580)

Bold, highest average cost per intensive care unit bed/day.
BRL$, Real (Brazilian currency); Intl$, Purchasing Power Parity (International dollar); n, number of patients analysed.

Each patient's total cost (total cost=FC+VC) was estimated using these data.

The bed cost per day was calculated based on salaries/wages, external consultations, vacation provision, social charges, 13th salary provision, night shifts, gratuity, health insurance plan and in-house medical assistance, sick leave, food vouchers and meals, employee transportation, compensations/agreements, service time guarantee fund, health assistance for dependents, dental insurance plan, overtime, social integration programme and service time guarantee fund without vacation, 'Mais Vida' programme and pharmacy benefits. Other costs related to the bed cost per day pertained to administrative resources, electricity and water supply and general services, including nutrition, maintenance, cleaning, linen items, pharmacy management, and security.

Additionally, metrics such as the number of ICU admissions per month, incidence of patients with and without HAIs per month, and mean LOS in days were also recorded.

Based on these parameters, AC for each analysed HAI was calculated using a designated formula:

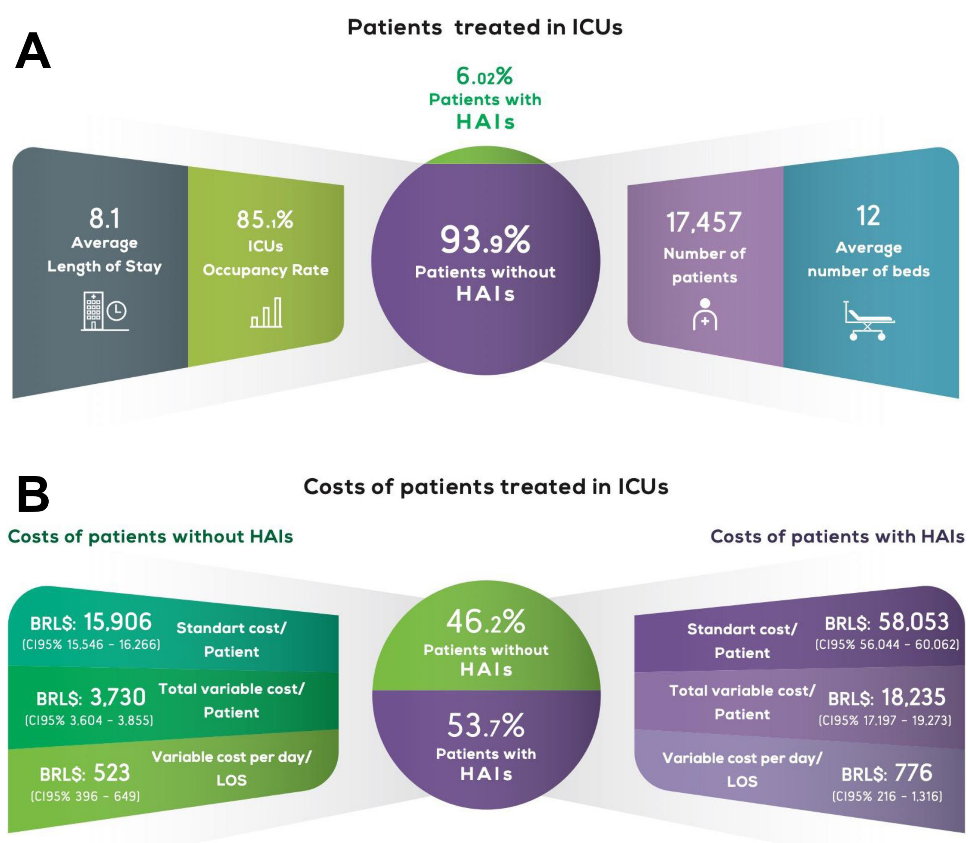

Figure 2 Overview of the clinical and financial indicators of the 'Saúde em Nossas Mãos' project. (A) Patients treated in intensive care units; (B) Cost of patients treated in intensive care units. ICUs, intensive care units; HAIs, healthcare-associated infections; BRL$, real (Brazilian currency); LOS, length of stay.

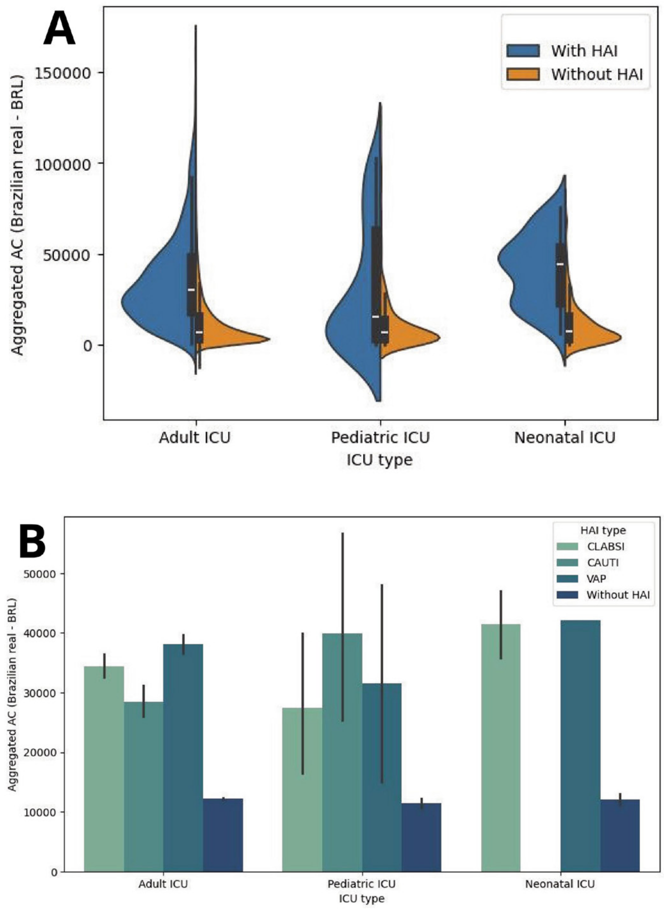

Figure 3 (A) Violin plot showing the aggregate average cost (BRL$) by intensive care unit type, with and without healthcare-associated infection. (B) Boxplot showing the aggregate average cost (BRL$) by intensive care unit type for each healthcare-associated infection analysed. AC, average cost; BRL$, real (Brazilian currency); HAI, healthcare-associated infection; ICU, intensive care unit; CLABSI, central line-associated bloodstream infection; VAP, ventilator-associated pneumonia; CAUTI, catheter-associated urinary tract infection.

$$Average\ Cost\ (HAI) = \frac{FC\ (patient\ with\ HAI) + VC\ (patient\ with\ HAI)}{Total\ ICU\ admission\ with\ HAI}$$

Measurement and valuation of resources

The collection of 31 financial spreadsheets, compiled to ascertain the aggregated AC for each HAI under analysis, served as a foundational resource for evaluating the overall savings of the SNM initiative. The potential for infection prevention attributable to the project was estimated as follows: the baseline months (m_1, m_2, … m_n), intervention months (m_{n+1}, m_{n+2}, …m_{n+m}), number of infections per month (N_I_{mi}), number of devices-day per month (N_D_{mi}) and density incidence baseline (D_{BL}):

$$D_{BL} = \frac{\sum_{m_1}^{m_n} N\_I}{\sum_{m_1}^{m_n} N\_D} \times 1000$$

If there is no intervention, the predicted density incidence in the intervention months (m_{n+1}, m_{n+2}, …m_{n+m}) would be the same as D_{BL}. The predicted value for the number of infections (N_I_P) in the intervention months (m_{n+1}, m_{n+2}, …m_{n+m}), if no changes had occurred, is

$$N\_I_P = \sum_{m_{n+1}}^{m_{m+n}} \frac{D_{BL}}{1000} \times N\_D_{iBL}$$

The number of infections observed (N_I_O) in the intervention period (m_{n+1}, m_{n+2}, …m_{n+m}) is

$$N\_I_O = \sum_{m_{n+1}}^{m_{m+n}} N\_I_i$$

Therefore, the estimated number of infections prevented (E_{IP}) is given by

$$E_{IP} = N_{I_P} - N_{I_O}$$

Consequently, synthesising aggregated AC data preintervention and quantifying HAIs averted through the project's implementation facilitated a robust assessment of the SNM initiative's economic impact.

The project investment throughout the PROADI-SUS is also presented to determine the return on investment (ROI).

Analysis

The absorption model was used following the BMoH's recommendations.[24] The results are presented in tables and figures summarising the main findings. Additionally, a violin plot offers the aggregate AC for each ICU type regarding patients with and without HAIs. The main expenses by category are presented in the tables.

A univariate sensitivity analysis was performed to evaluate the robustness of the cost estimates by varying individual cost parameters within a 95% CI range. The study considered cost parameters with and without HAIs. These variations' effect on the total was assessed to determine the most influential cost drivers. Univariate sensitivity analysis was also performed in two settings: (1) worst scenario, including the inferior limit of the prevented HAIs, and (2) best scenario, including the superior limit of the prevented HAIs. These results are illustrated using tornado diagrams.

The cost of each analysed HAI is shown using a box-plot graphic, followed by a 3-Dimension (3D) plot including ICU type and mean LOS. After parametric assumptions were tested against normal plots, groups were contrasted using the Mann-Whitney U test. Aggregate AC was correlated with the mean LOS, and Spearman's rank test was calculated. The significance level was set to ∂=5%. Graphs and statistical analysis were performed using Visual Studio Code, version 1.86.0 (USA), PowerBI, version 2.128.1177 (USA), Microsoft Excel 2024 (USA) and Python, version 3.11.7 (USA).

Currency, price date and conversion

For the purposes of this report, all values are presented in Brazilian reais (BRL$) and later adjusted for

Table 2 Aggregated average cost by expense category, without and with healthcare-associated infection.

Cost parameters	Without HAIs Mean (95% CI) in BRL$	With HAIs Mean (95% CI) in BRL$
Drugs (direct cost)	2247.02 (2198.52–2342.08)	13 160.99 (1775.29–35 476.95)
Physician labour	2966.52 (2932.61–3033.00)	9311.83 (9129.39–9669.40)
Institutional administration	2978.25 (2937.21–3058.68)	9013.39 (8775.37–9479.92)
Technical nursing labour	1737.49 (1711.60–1788.24)	5386.76 (5237.68–5678.95)
Nursing labour	1383.15 (1364.31–1420.08)	5189.05 (5045.40–5470.61)
Medical materials (indirect cost)	864.13 (849.51–892.79)	3346.91 (3223.18–3589.43)
Laboratory and exams	851.44 (837.20–879.37)	2443.48 (328.41–6589.03)
Physiotherapist labour	554.20 (546.99–568.34)	2056.67 (2007.68–2152.71)
Medical materials (direct cost)	415.09 (407.61–429.74)	1847.32 (249.45–4979.14)
Other ICU professional labour	442.02 (432.98–459.74)	1496.01 (1435.66–1614.30)
Drugs (indirect cost)	285.77 (275.74–305.44)	971.00 (896.99–1116.05)
ICU administration	476.43 (457.98–512.60)	1440.70 (191.86–3888.43)
Medical procedures	216.49 (207.37–234.38)	789.92 (722.66–921.74)
Depreciation	161.99 (158.47–168.88)	665.61 (638.61–718.54)
Inputs	179.81 (176.54–186.23)	518.81 (499.22–557.20)
Oxygen	146.69 (144.18–151.62)	436.06 (59.23–1174.66)
Total (BRL)	15 906.51	58 053.13
Total (Intl$)	6519.0	23 792.2

BRL$, real (Brazilian currency); HAIs, healthcare-associated infections; ICU, intensive care unit; Intl$, purchasing power parity (international dollar).

purchasing-power parity in 2023 (Intl$1=BRL$2.44), the latest year available from the World Bank.[28]

Ethics

Access to the SNM database was approved by the local human research ethics committees of the six PROADI-SUS institutions (*Certificado de Apresentação de Apreciação Ética* (CAAE) 66698023.7.0000.0071), with the consent of the SNM coordinator and the appropriate BMoH authorisation. The available database presented financial data alone and did not include any data referring to or mentioning the participating institutions or participants involved.

Patient and public involvement

Patients and/or the public were not involved in this research's design, conduct, reporting or dissemination plans.

RESULTS

A total of 31 institutions (16%) participated in the SNM micro-costing study, including the assessment of 17 457 patients. In the southeastern region, 12 767 patients were analysed, the largest number of participants. The average number of beds determined within the study baseline was 12 beds per ICU, at an AC ranging from BRL$1288 (Intl$527.86) to BRL$3710 (Intl$1520.49) per bed/day. The highest AC per bed/day was found in the Southern region (table 1).

In addition, the aggregated AC per care in the ICUs was BRL$18 445 (Intl$7559.4) for a duration of 8.1 days of mean LOS; therefore, the AC per patient per day in the ICUs in the preintervention period was BRL$2266 (Intl$928.6) (figure 2A).

We also analysed groups of patients with and without HAIs at the same period (figure 2B). Figure 3 shows the aggregated AC by ICU type with and without HAIs. The cost with HAIs was significantly higher than the cost without HAIs in all ICU settings (p value<0.001, p value=0.005 and p value<0.001 for adult, paediatric and neonatal ICUs, respectively).

Regarding the type of HAI, in adult ICUs, VAP was significantly higher than CLABSI (p value=0.001) and CAUTI (p value<0.001). No statistical differences were found between paediatric and neonatal ICUs when comparing each HAI (p value>0.05 for all).

Table 2 presents the aggregated AC by expense category. Most expenses are concentrated in direct costs related to used drugs and healthcare workers' labour. Figure 4 shows the sensitivity analysis for the aggregated AC by cost parameters (with and without HAIs).

In the group without HAIs, 16 405 patients (93.98%) had a mean LOS of 7.1 days, while in the group with HAIs, 1051 patients (6.02%) had a mean LOS of 23.8 days,

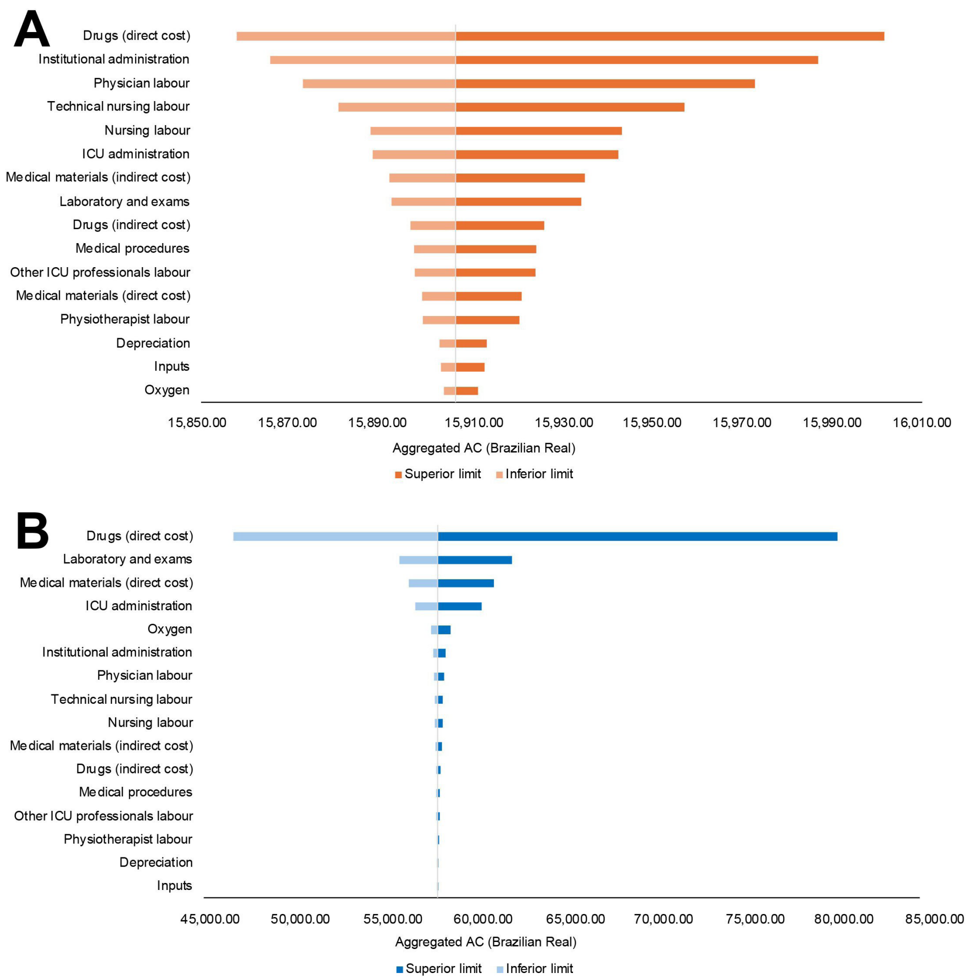

Figure 4 Sensitivity analysis. Tornado diagram detailing the aggregate average cost (BRL$) by expense categories comparing patients without (A) and with (B) healthcare-associated infections. AC, average cost; BRL$, real (Brazilian currency); ICU, intensive care unit.

representing an increase of 3.4 times. Figure 5A presents a 3D plot crossing aggregated AC, HAI type and mean LOS. Figure 5B shows the correlation between LOS and aggregated AC.

Our results also showed that the total hospitalisation cost for patients without HAIs was BRL$15 906.51 (95% CI 15 545.73 to 16 266.27) (Intl$6519.0; 95% CI 6371.20 to 6666.50), with an aggregated AC per day of BRL$2229 (95% CI 443.77 to 4014.23) (Intl$913.5; 95% CI 181.87 to 1645.17). When compared with the group of patients with HAIs, the total hospitalisation cost was BRL$58 053.13 (95% CI 56 043.59 to 60 062.41) (Intl$23 792.2; 95% CI 22 968.68 to 24 615.74), with an aggregated AC per day of BRL$2438 (95% CI 1877.37 to 2988.63) (Intl$999.18; 95% CI 769.41 to 1224.84), evidencing a 9.4% increase in patients' daily cost when HAIs occurred.

Regarding the cost of inputs for ICU patients, the average consumption value for patients without HAIs per day was BRL$523 (Intl$214.34), representing 23.45% of the total AC. However, this input representation was 31.41% for patients with HAIs, demonstrating a 7.96 percentual-point increase.

To estimate the AC of each HAI, we analysed 369, 561 and 121 patients for CLABSI, VAP and CAUTI, respectively (table 3). The financial impact resulting from the SNM implementation, based on 7342 prevented HAIs, resulted in an estimated saving of BRL$427 742 620.78 million (95% CI 373.9 to 441.4 million) (Intl$175.3 million; 95% CI 153.2 to 180.9 million) to SUS. Online supplemental figure S1 presents the sensitivity analyses for the savings by prevented infections. The PROADI-SUS investment for the SNM project was BRL$43 188 442 (Intl$17.7 million), leading to an estimated ROI of 890%.

DISCUSSION

The SNM project offers valuable lessons in the fight against HAIs, presenting a comprehensive analysis of the financial impact of HAIs in Brazilian ICUs and the effectiveness of a nationwide infection prevention initiative. Its success underscores the importance of thorough and multifaceted approaches to infection prevention, including the extensive process of QI, staff engagement, patient participation and plan-do-study-act cycles followed

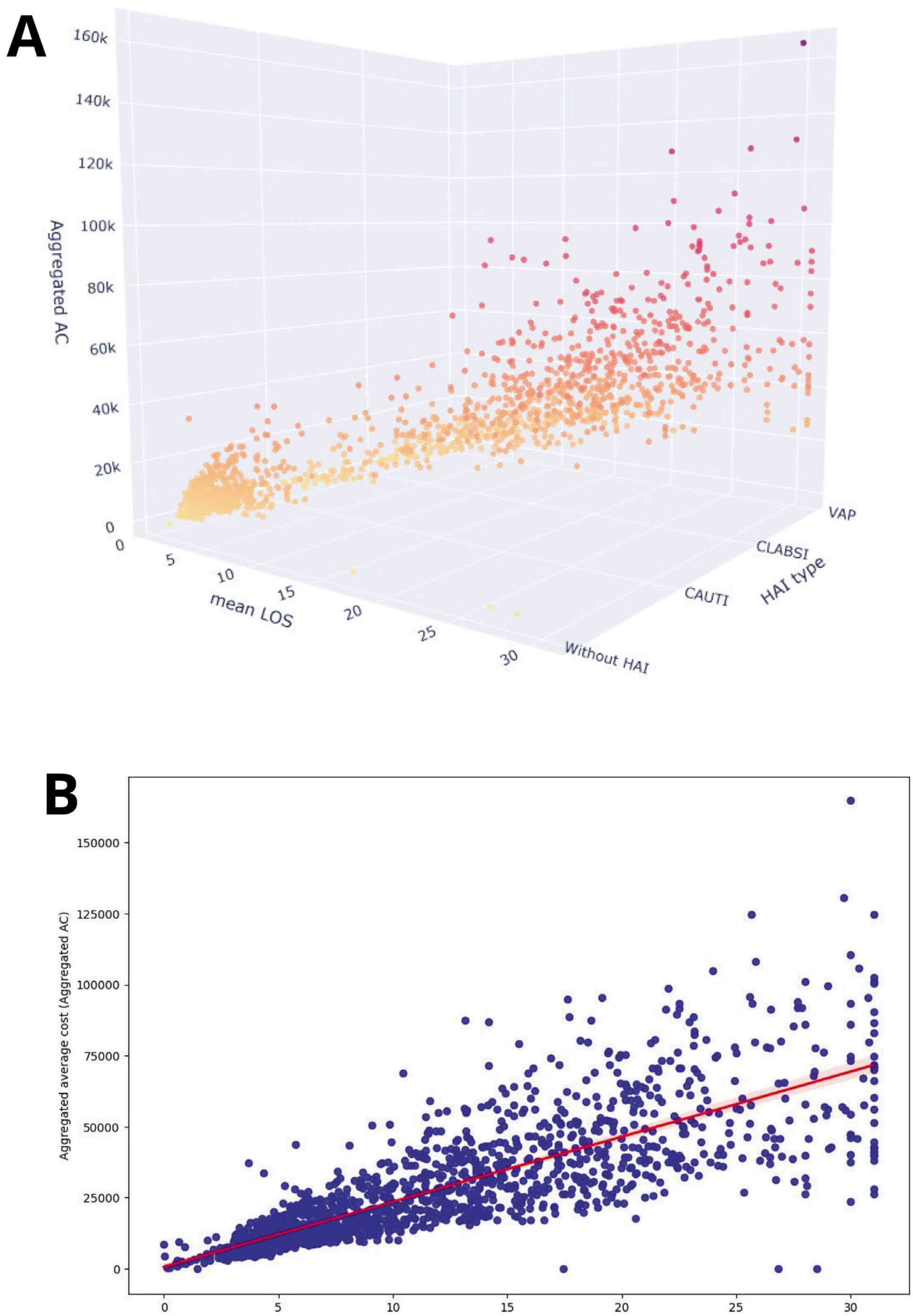

Figure 5 (A) 3D plot showing the distribution of aggregated average cost by healthcare-associated infection and the mean length of stay. (B) Overall correlation between aggregated average cost and the mean length of stay. AC, average cost; BRL$, real (Brazilian currency); HAI, healthcare-associated infection; CLABSI, central line-associated bloodstream infection; VAP, ventilator-associated pneumonia; CAUTI, catheter-associated urinary tract infection; LOS, length of stay.

by implementing evidence-based prevention bundles and safety protocols. This project's clinical and economic benefits are a compelling argument favouring continued investment and innovation in HAI-prevention strategies.

As previously discussed,[22] our costing approach presents a feasible approach to estimate the aggregated AC for each HAI analysed and the projection of savings among all participating ICUs. Therefore, we highlight two outstanding points: (i) the estimation of three different types of ICUs, where we can have a more comprehensive overview of HAIs' impact, including children and newborns, and (ii) the saving and ROI reproducibility, by establishing the full financial impact of the nationwide project from the perspective of a publicly funded health system in different units and two timelines, reinforcing that SNM is a practical, trusted

Table 3 Estimating the savings of the *Saúde em Nossas Mãos* initiative

HAI type	Profile	N	LOS	AC per bed-day (BRL$)	AC per hospitalisation in BRL$ (95% CI)	Estimation of HAIs prevented	Saving (BRL$) (95% CI)
CLABSI	Adult	340	21	2566	53 103.19 (50 468–55 737)	1647	87.4 million (83.1 to 91.7)
	Paediatric	12	30	2793	83 112.40 (63 000–103 224)	86	7.1 million (10.5 to 17.2)
	Neonatal	17	34	2344	80 283.98 (71 257–89 310)	205	16.4 million (14.6 to 18.3)
VAP	Adult	559	25	2433	61 494.22 (59 235–63 752)	3775	232.1 million (223.6 to 240.6)
	Paediatric	1	41	2642	109 198.83 (NA)	114	12.4 million (NA)
	Neonatal	1	19	2220	42 061.86 (NA)	118	4.9 million (NA)
CAUTI	Adult	117	23	2035	46 765.87 (43 130–50 401)	1377	64.3 million (59.3 to 69.4)
	Paediatric	4	39	3512	136 330.91 (106 294–166 367)	20	2.7 million (2.7 to 4.3)
Total (BRL$)							427 742 620.78 (373.9 to 441.4 million)
Total (Intl$)							175 304 352.77 (153.2 to 180.9 million)

AC, average cost; BRL$, real (Brazilian currency); CAUTI, catheter-associated urinary tract infection; CLABSI, central line-associated bloodstream infection; HAIs, healthcare-associated infections; Intl$, purchasing power parity (international dollar); LOS, mean length of stay (in days); N, number of patients analysed; NA, not applicable; VAP, ventilator-associated pneumonia.

and value-based initiative that could be reproduced in diverse settings.

Furthermore, the study's findings emphasise the substantial financial burden HAIs impose on healthcare systems, mainly due to the increased cost of care and LOS for patients with HAIs compared with those without infections. Other Brazilian costing studies have also reported these findings, evidencing a significant association between higher mortality,[29] extended hospital stays and higher hospitalisation costs.[29–31]

A simulation model performed by Osme *et al*[30] using a cohort of 949 critical patients (149 with HAIs) for epidemiologic and economic parameters and based on three Brazilian prevalence scenarios of HAIs in ICU patients (29.1%, 51.2% and 61.6%) estimated an increase of up to USD$147 million, where direct cost became significant starting at a 10% prevalence of HAIs (approximately USD$2 million added for each 1% increase in prevalence).

This financial impact related to an extended stay was also observed in other LMICs: Gidey *et al*,[12] assessing 408 adult patients (204 with HAIs and 204 without HAIs) from Ethiopia, evidenced a higher in-hospital mortality, more extended hospital stays (mean of 8.3 days longer) and higher direct medical costs for patients with HAIs compared with controls. Sodhi *et al*[32] observed that 20 children affected by HAIs from India had a median extra LOS of 7 days and a higher cost when compared with 35 controls.

Brazil's cost variation across different macro-regions reflects the country's diverse prices and healthcare landscape. The higher costs in the South could indicate more expensive healthcare infrastructure or variations in ICU management practices. Such regional disparities in healthcare costs have been observed in other countries and warrant targeted strategies for infection control tailored to regional needs.[33 34]

Our findings offer valuable insight into the costs associated with specific HAIs, each presenting unique challenges and requiring customised prevention strategies. The relatively higher cost for VAP management underscores the need for targeted interventions in ventilator care, consistent with current research emphasising the role of ventilator care bundles in reducing VAP rates.[35]

The estimated overall savings and ROI highlight the economic viability of investing in infection prevention measures. These findings support a growing body of literature advocating for increased resources for HAI prevention as a cost-effective strategy.[36] The SNM project's success suggests that similar initiatives could be effective in other settings, particularly in countries with resource constraints. Policymakers could consider adopting similar multifaceted, collaborative approaches to HAI prevention, prioritising areas with the highest rates of HAIs and most significant potential for cost savings.

Limitations

While the study provides significant insights, it also highlights areas for future research. The sample size, covering 16% of participating ICUs, raises questions about the generalisability of findings across Brazil's diverse healthcare settings. Similarly, the sample size affects the representativeness of Brazilian macro-regions and the specific features of participating ICUs. Further randomised stratified controlled studies are necessary to better assess the impact of regional and local divergences on HAIs' financial costs.

Additionally, the study's focus on the economic aspects of HAIs leaves room for further research on patient clinical outcomes (such as age, weight, comorbidities and severity score), long-term impacts (such as quality of life and years of life lost) and cost-effectiveness and cost-utility analyses from a societal perspective. Moreover, as financial indicators are closely related to clinical features and we did not assess this information, we did not perform further statistical methods (ie, multivariate analysis) to avoid misinterpretations.

The previous report[22] referred to additional limitations of our financial approach, including the absence of a control group in the cost analysis, making it difficult to compare financial impacts with usual care or other multimodal HAI-control strategies rather than single-arm interrupted time-series analysis.

Prospective

The SNM project represents a pivotal step in understanding and combating the economic impact of HAIs in ICUs. This study's findings offer compelling evidence for the effectiveness of comprehensive infection prevention strategies in improving patient outcomes and delivering substantial financial benefits. As healthcare systems worldwide continue to grapple with the challenge of HAIs, the lessons learnt from the SNM project can inform future initiatives to create more resilient healthcare environments worldwide and provide new insights into the potential cost savings due to QI initiatives.

CONCLUSION

This QI collaborative is a value-based initiative to prevent HAIs in adult, paediatric and neonatal ICUs in South American settings. Substantial cost savings, coupled with a remarkable ROI, underscore the economic viability of investing in comprehensive QI strategies for infection prevention.

Author affiliations

[1]Hospital Israelita Albert Einstein, São Paulo, Brazil
[2]Hospital Alemão Oswaldo Cruz, São Paulo, Brazil
[3]Hospital Moinhos de Vento, Porto Alegre, Brazil
[4]Hcor, São Paulo, Brazil
[5]BP - A Beneficência Portuguesa de São Paulo, São Paulo, Brazil
[6]Hospital Sírio-Libanês, São Paulo, Brazil
[7]Ministério da Saúde, Brasilia, Brazil

Acknowledgements The authors thank the PROADI-SUS technical and administrative teams and all the healthcare professionals working in the participating ICUs who supported the development of the SNM initiative.

Contributors LMB, LHFdM, EJK, NOdS and AHFdS contributed to data curation, formal analysis, investigation and methodology. LMB, LHFdM, EJK, NOdS, AHFdS, KCdCDS, RMdM, CMP, GCSDS, RGdS, FFF, AJP, CMRC, CGdB and SV contributed to validation, visualisation and writing. EJK and AJP contributed to software statistical analysis. Additionally, CMRC and CGdB also contributed to conceptualisation, project administration and supervision. LMB is the guarantor.

Funding This project was performed with public funding from the Brazilian Ministry of Health through the Support Program for Institutional Development of the Unified Health System (*Programa de Apoio ao Desenvolvimento Institucional do Sistema Único de Saúde* or PROADI-SUS).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Certificate of Presentation of Ethical Appreciation (*Certificado de Apresentação de Apreciação Ética* or CAAE): 66698023.7.0000.0071.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. All relevant data are included in the article or uploaded as supplementary information. The database supporting the findings of this study is available from the corresponding author, SV, upon reasonable request.

ORCID iD

Sebastian Vernal http://orcid.org/0000-0001-8589-0089

REFERENCES

1 Allegranzi B, Bagheri Nejad S, Combescure C, *et al*. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *Lancet* 2011;377:228–41.
2 World Health Organization. Global report on infection prevention and control, 2022. Available: https://www.who.int/publications/i/item/9789240051164
3 Rahmqvist M, Samuelsson A, Bastami S, *et al*. Direct health care costs and length of hospital stay related to health care-acquired infections in adult patients based on point prevalence measurements. *Am J Infect Control* 2016;44:500–6.
4 Guest JF, Keating T, Gould D, *et al*. Modelling the annual NHS costs and outcomes attributable to healthcare-associated infections in England. *BMJ Open* 2020;10:e033367.
5 Forrester JD, Maggio PM, Tennakoon L. Cost of Health Care-Associated Infections in the United States. *J Patient Saf* 2022;18:e477–9.
6 Liu X, Spencer A, Long Y, *et al*. A systematic review and meta-analysis of disease burden of healthcare-associated infections in China: an economic burden perspective from general hospitals. *J Hosp Infect* 2022;123:1–11.
7 Zimlichman E, Henderson D, Tamir O, *et al*. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. *JAMA Intern Med* 2013;173:2039–46.
8 Manoukian S, Stewart S, Graves N, *et al*. Bed-days and costs associated with the inpatient burden of healthcare-associated infection in the UK. *J Hosp Infect* 2021;114:43–50.
9 Orlando S, Cicala M, De Santo C, *et al*. The financial burden of healthcare-associated infections: a propensity score analysis in an Italian healthcare setting. *Infect Prev Pract* 2025;7:100406.
10 Gamalathge PU, Kularatna S, Carter HE, *et al*. Cost-effectiveness of interventions to reduce the risk of healthcare-acquired infections in middle-income countries: A systematic review. *J Infect Prev* 2019;20:266–73.
11 Singh S, Kumar RK, Sundaram KR, *et al*. Improving outcomes and reducing costs by modular training in infection control in a resource-limited setting. *Int J Qual Health Care* 2012;24:641–8.
12 Gidey K, Gidey MT, Hailu BY, *et al*. Clinical and economic burden of healthcare-associated infections: A prospective cohort study. *PLoS One* 2023;18:e0282141.
13 Hutton G, Chase C, Kennedy-Walker R, *et al*. Financial and economic costs of healthcare-associated infections in Africa. *J Hosp Infect* 2024;150:1–8.
14 Vincent J-L, Rello J, Marshall J, *et al*. International study of the prevalence and outcomes of infection in intensive care units. *JAMA* 2009;302:2323–9.

15 Bryant KA, Harris AD, Gould CV, *et al*. Necessary Infrastructure of Infection Prevention and Healthcare Epidemiology Programs: A Review. *Infect Control Hosp Epidemiol* 2016;37:371–80.
16 Stone PW. Economic burden of healthcare-associated infections: an American perspective. *Expert Rev Pharmacoecon Outcomes Res* 2009;9:417–22.
17 Rennert-May E, Conly J, Leal J, *et al*. Economic evaluations and their use in infection prevention and control: a narrative review. *Antimicrob Resist Infect Control* 2018;7:31.
18 Stone PW, Larson E, Kawar LN. A systematic audit of economic evidence linking nosocomial infections and infection control interventions: 1990-2000. *Am J Infect Control* 2002;30:145–52.
19 Umscheid CA, Mitchell MD, Doshi JA, *et al*. Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs. *Infect Control Hosp Epidemiol* 2011;32:101–14.
20 Tuma P, Vieira Junior JM, Ribas E, *et al*. A National Implementation Project to Prevent Healthcare-Associated Infections in Intensive Care Units: A Collaborative Initiative Using the Breakthrough Series Model. *Open Forum Infect Dis* 2023;10:ofad129.
21 Tuma P, Vieira Júnior JM, Ribas E, *et al*. The impact of the coronavirus disease 2019 (COVID-19) pandemic on a national project preventing healthcare-associated infections in intensive care units. *Infect Control Hosp Epidemiol* 2023;44:2071–3.
22 Oliveira RMC, de Sousa AHF, de Salvo MA, *et al*. Estimating the savings of a national project to prevent healthcare-associated infections in intensive care units. *J Hosp Infect* 2024;143:8–17.
23 Nundy S, Cooper LA, Mate KS. The Quintuple Aim for Health Care Improvement: A New Imperative to Advance Health Equity. *JAMA* 2022;327:521–2.
24 Brasil, Ministério da Saúde. Diretriz de Microcusteio para avaliações econômicas em saúde no SUS, Available: https://www.gov.br/conitec/pt-br/assuntos/noticias/2022/abril/ministerio-da-saude-publica-diretriz-de-microcusteio-para-avaliacoes-economicas-em-saude-no-sus
25 Global Health Cost Consortium. Reference Case for Estimating the Costs of Global Health Services and Interventions, 2017. Available: https://ghcosting.org/pages/standards/reference_case
26 Agência Nacional de Vigilância Sanitária – ANVISA. Programa nacional de prevenção e controle de infecções relacionadas à assistência à saúde (PNPCIRAS), 2021. Available: https://www.gov.br/anvisa/pt-br/centraisdeconteudo/publicacoes/servicosdesaude/publicacoes/pnpciras_2021_2025.pdf
27 Agência Nacional de Vigilância Sanitária – ANVISA. Documento de referência para o Programa Nacional de Segurança do Paciente, Available: https://www.gov.br/saude/pt-br/acesso-a-informacao/acoes-e-programas/pnsp/materiais-de-apoio/arquivos/documento-de-referencia-para-o-programa-nacional-de-seguranca-do-paciente
28 World Bank. PPP conversion factor, GDP (LCU per international $)—Brazil, 2020. Available: https://data.worldbank.org/indicator/PA.NUS.PPP?locations=BR
29 Leal MA, Freitas-Vilela A de. Costs of healthcare-associated infections in an Intensive Care Unit. *Rev Bras Enferm* 2021;74:S0034-71672021000100178.
30 Osme SF, Souza JM, Osme IT, *et al*. Financial impact of healthcare-associated infections on intensive care units estimated for fifty Brazilian university hospitals affiliated to the unified health system. *J Hosp Infect* 2021;117:96–102.
31 Osme SF, Almeida APS, Lemes MF, *et al*. Costs of healthcare-associated infections to the Brazilian public Unified Health System in a tertiary-care teaching hospital: a matched case-control study. *J Hosp Infect* 2020;106:303–10.
32 Sodhi J, Satpathy S, Sharma DK, *et al*. Healthcare associated infections in Paediatric Intensive Care Unit of a tertiary care hospital in India: Hospital stay & extra costs. *Indian J Med Res* 2016;143:502–6.
33 Stone PW, Dick A, Pogorzelska M, *et al*. Staffing and structure of infection prevention and control programs. *Am J Infect Control* 2009;37:351–7.
34 Rosenthal VD, Maki DG, Salomao R, *et al*. Device-associated nosocomial infections in 55 intensive care units of 8 developing countries. *Ann Intern Med* 2006;145:582–91.
35 Klompas M, Branson R, Cawcutt K, *et al*. Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 Update. *Infect Control Hosp Epidemiol* 2022;43:687–713.
36 Graves N, Harbarth S, Beyersmann J, *et al*. Estimating the cost of health care-associated infections: mind your p's and q's. *Clin Infect Dis* 2010;50:1017–21.