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Severe Bacterial Infections and Sepsis Among Hospitalized Older Adults in São Paulo State, Brazil, 2015-2025: A Population-Based Study With a Descriptive Time-Series Component

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Abstract

Objective

The objective of this study was to describe temporal trends, hospitalization rates, clinical profile, and factors associated with in-hospital mortality among older adults (⩾60 years) hospitalized for severe bacterial infections and sepsis in São Paulo State, Brazil, 2015-2025, and to characterize the subgroup with sepsis in the strict sense.

Methods

Population-based observational study using Brazilian Hospital Information System (SIH/SUS) records, including 1,310,296 hospitalizations. Hospitalization rates per 100,000 inhabitants used population estimates from the Brazilian Institute of Geography and Statistics. The annual temporal trend was modeled with quasi-Poisson regression, including a population offset and correcting for overdispersion; pre-pandemic (2015-2019) and post-pandemic recovery (2022-2025) subperiods were modeled separately given the nonlinear pattern of the series. Factors associated with in-hospital mortality were assessed with multivariable logistic regression (age band, sex, ICU admission, and comorbidity), with a sensitivity analysis excluding ICU admission.

Results

Mean age was 76.2 years (SD 9.6). After adjusting for population growth and overdispersion, the overall hospitalization rate showed no statistically significant linear trend from 2015 to 2025 (incidence rate ratio (IRR) 1.005 per year, 95% CI 0.983-1.028); the series was nonlinear, with a stable pre-pandemic rate (IRR 0.996/year, 95% CI 0.988-1.003), a marked nadir in 2020-2021, and a statistically significant recovery-period increase of approximately 5.6% per year from 2022 to 2025 (IRR 1.056/year, 95% CI 1.030-1.082). In-hospital mortality was 424,156 (32.37%), rising from 105,790 (28.06%) at 60-69 years to 48,731 (40.66%) at ⩾90 years ($p < 0.001$), while ICU admission fell from 87,467 (23.2%) to 8,270 (6.9%) across the same range. Patients aged ⩾90 years had higher adjusted odds of death (OR 2.56; 95% CI 2.52-2.60), an association that persisted, though attenuated (OR 1.91; 95% CI 1.88-1.93), in a sensitivity analysis excluding ICU admission; male sex carried a small but significant increase in odds (OR 1.08; 95% CI 1.07-1.09). Sepsis in the strict sense accounted for 248,525 (19.0%) of hospitalizations, with 159,503 (64.18%) in-hospital lethality, roughly twice that of the broad cohort.

Conclusions

The overall hospitalization rate for severe bacterial infections and sepsis among older adults in São Paulo showed no statistically significant linear trend once adjusted for population growth, but the series was markedly nonlinear: a stable pre-pandemic rate was followed by a pandemic-related nadir and a statistically significant post-pandemic recovery-period increase exceeding pre-pandemic levels. Mortality rose sharply with age as intensive care access fell, and sepsis in the strict sense formed a markedly more lethal core within this broader burden, underscoring the need for early recognition, vaccination, and adapted geriatric and intensive care capacity.

Categories: Geriatrics, Public Health, Infectious Disease
Keywords: aged, bacterial infections, hospitalization, retrospective studies, sepsis, time factors

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Introduction

Sepsis and severe bacterial infections remain leading causes of hospitalization and death worldwide. The 2021 Global Burden of Disease study estimated approximately 166 million sepsis cases and 21.4 million related deaths globally, with incidence rising during the COVID-19 pandemic and older age groups disproportionately represented among the most severe outcomes [1]. Sepsis is now widely recognized as a global health priority, and early recognition and timely treatment are considered central to reducing its high mortality [2-4]. In Brazil, accelerated population aging occurs alongside a high frequency of severe bacterial infections among older adults and a rising burden of hospital admissions in this age group [5-8], in which sepsis remains frequently underdiagnosed [9,10].

Sepsis in older adults differs substantially from sepsis in younger adults. Immunosenescence reduces the efficiency of innate and adaptive immune responses, favoring progression to organ dysfunction [11]. Classic signs such as fever and leukocytosis are frequently absent; delirium, functional decline, and altered mental status are often the first clinical clues, delaying recognition [12]. Frailty, multimorbidity, and institutionalization, together with the predominance of respiratory and urinary infectious foci, contribute to the higher risk of hospitalization, intensive care need, and death observed among older patients [13,14].

Administrative databases provide a practical means of estimating the hospital burden of severe bacterial infections and sepsis at scale. In Brazil, the Hospital Information System of the Unified Health System (SIH/SUS) captures both hospitalizations coded as septicemia and admissions for severe bacterial infections that frequently progress to sepsis. Distinguishing a broad cohort of severe bacterial infections from a narrower subgroup restricted to explicit sepsis codes allows comparison of frequency, clinical profile, and lethality between definitions in a setting where sepsis is known to be under-coded [9,10,15].

Although Brazilian studies have described epidemiological aspects of sepsis, population-based analyses using SIH/SUS data focusing specifically on older adults, and integrating temporal trends, clinical profile, and prognostic factors, remain scarce. This study examines a state-wide cohort of more than 1.3 million hospitalizations over an 11-year period spanning the pre-, intra-, and post-COVID-19 pandemic phases, comparing a broad cohort of severe bacterial infections with a subgroup restricted to sepsis in the strict sense, clarifying how population aging relates to the hospital burden of these conditions and informing strategies for vaccination, early recognition, and geriatric and intensive care planning.

The objective of this study was to describe temporal trends, hospitalization rates, clinical profile, and factors associated with in-hospital mortality among older adults (aged ⩾60 years) hospitalized for severe bacterial infections and sepsis in the state of São Paulo, Brazil, between 2015 and 2025, and to characterize the subgroup of patients with sepsis in the strict sense.

Materials And Methods

Study design

This population-based observational study had two components: a descriptive analysis of the temporal trend in annual hospitalization counts and rates, and a pooled, hospitalization-level multivariable analysis of factors associated with in-hospital mortality across the full 11-year period; the latter uses individual records as the unit of observation and is not itself a time-series or ecological analysis. Because the data derive from a routinely collected administrative surveillance system, reporting follows the STROBE statement together with the RECORD extension for routinely collected health data [16,17].

Study setting and period

We included hospitalizations of individuals aged ⩾60 years, of both sexes, resident in the state of São Paulo, Brazil, recorded between January 2015 and December 2025 (11 complete calendar years), spanning the pre-, intra-, and post-COVID-19 pandemic periods.

Data sources

Hospitalization data were obtained from the Hospital Information System of the Brazilian Unified Health System (SIH/SUS), available through the Department of Informatics of the SUS (DATASUS), using monthly microdata files of Hospital Admission Authorizations (Autorização de Internação Hospitalar, AIH) extracted with the R package microdatasus [18]. Denominator population estimates by age band and year were obtained from Brazilian Institute of Geography and Statistics (IBGE) population projections (2024 revision) [19]. The investigators had full access to the complete SIH/SUS hospitalization records for the state of São Paulo meeting the study's inclusion criteria for the entire study period.

Case definition and study population

The study population comprised hospitalizations with a code for severe bacterial infection or sepsis recorded in the primary diagnosis field or in any of the nine secondary diagnosis fields of the AIH. The broad cohort included septicemia codes (A40, A41, A02.1, A22.7, A26.7, A28.2, B37.7) and codes for severe bacterial

infections common in this age group: bacterial pneumonia (J13-J15, J18), bacterial meningitis (G00, G03), UTI (N39.0), skin and soft-tissue infection (L08.0, L08.8), pyogenic arthritis and osteomyelitis (M00, M86), and peritonitis (K65). This broad case definition follows the general approach of established administrative-data case-finding algorithms for sepsis and severe infection, such as the implicit approach described by Angus et al. [20] and the United States Centers for Disease Control and Prevention Adult Sepsis Event surveillance definition [21], both of which combine infection codes of varying etiological and anatomical specificity rather than restricting ascertainment to a small set of fully specified codes; organism identification and precise anatomical localization are infrequently recorded in Brazilian administrative hospitalization data, and requiring such specificity would systematically under-ascertain true cases. The septicemia code set includes B37.7 (candidal septicemia), a fungal rather than bacterial diagnosis, retained consistent with administrative sepsis-surveillance definitions that group septicemia of any documented organism under a single systemic-infection case-finding definition; we acknowledge this as an imprecision in the cohort's bacterial terminology (see Limitations). A subgroup restricted to sepsis in the strict sense was defined as septicemia codes (A40, A41, and related codes) recorded specifically in the primary diagnosis field. Population selection, including data-cleaning steps such as exclusion of records lacking a valid age or admission date, is summarized in the study flow diagram (Figure *1*). No a priori sample-size calculation was performed; the study included the complete administrative population of hospitalizations meeting the case definition during the study period. The cohort was also classified by the full ICD-10 chapter of the primary admission diagnosis (all Chapter I, A00-B99, diagnoses, not restricted to septicemia codes); the strict-sepsis subgroup analyzed elsewhere in the manuscript is a clinically narrower, non-equivalent subset of Chapter I.

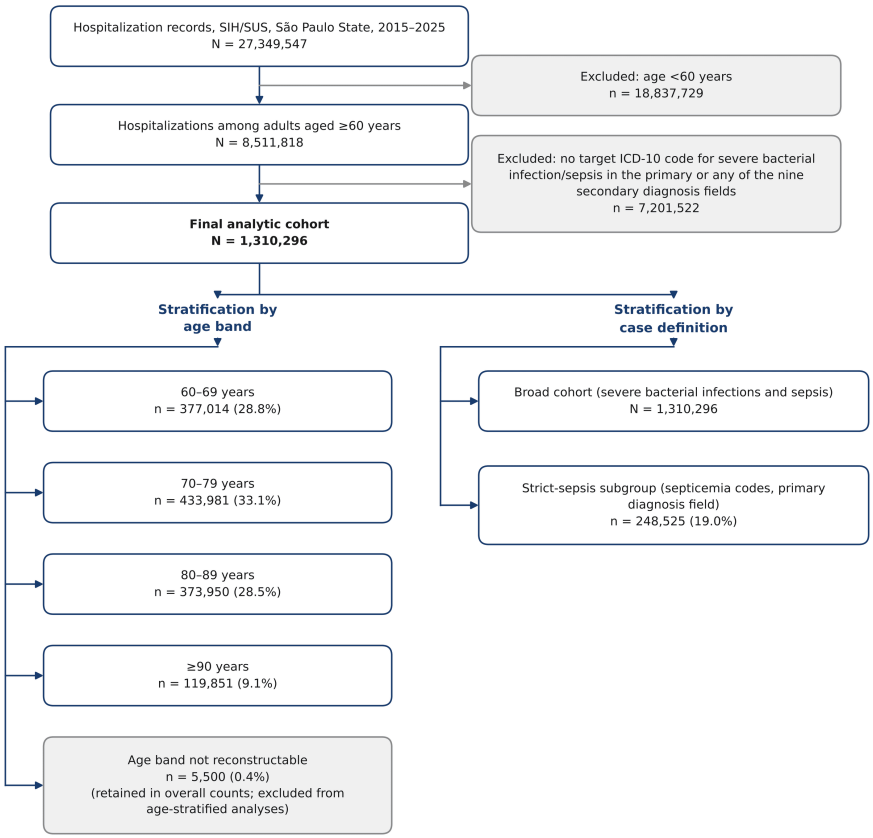


FIGURE 1: Flow diagram of population selection, SIH/SUS hospital admission records, São Paulo State, 2015-2025.

Of 27,349,547 hospitalization records among residents of all ages, 18,837,729 were excluded for being under 60 years of age, yielding 8,511,818 records among adults aged ≥60 years. Of these, 7,201,522 were excluded for not carrying a target ICD-10 code (severe bacterial infection/sepsis) in the primary or any of the nine secondary diagnosis fields, yielding the final analytic cohort (N = 1,310,296). Two independent stratifications of this final cohort are then shown: by age-band reconstruction (used for age-stratified analyses) and by case definition (broad cohort vs. strict-sepsis subgroup).

Variables

Patients were stratified into four age bands: 60-69, 70-79, 80-89, and ⩾90 years. Hospitalizations without a

reconstructable age band (n = 5,500; 0.4%) were retained in overall counts but excluded from age-stratified analyses. Baseline comorbidities were identified from secondary diagnosis fields and grouped into 10 categories: diabetes mellitus, hypertension, heart failure, chronic obstructive pulmonary disease, chronic kidney disease, neoplasms, dementia, cerebrovascular disease, liver disease, and malnutrition. Comorbidity-specific frequency and lethality were reported by category descriptively; for the mortality model, comorbidity was modeled as a single binary covariate (any of the 10 vs. none), given the low prevalence of most individual categories. In-hospital death, length of stay, total AIH cost, and ICU admission (ICU days >0) were extracted as outcomes/covariates. Under-registration of secondary diagnoses in administrative records, particularly among the oldest patients, was anticipated a priori as a potential source of information bias affecting the completeness of the comorbidity profile.

Statistical analysis

Categorical variables were described as frequencies and compared using Pearson's chi-square test; non-normally distributed continuous variables were described as median and interquartile range and compared using the Kruskal-Wallis test. Hospitalization rates per 100,000 inhabitants were calculated by year and age band using IBGE estimates as the denominator. Annual, rather than monthly, aggregation was used for the trend model. The temporal trend in annual hospitalization counts (11 data points) was modeled with quasi-Poisson regression, including a log-population (⩾60 years, IBGE projections) offset and a dispersion parameter to correct for overdispersion, for the full 2015-2025 period. Because the full-period model showed substantial residual overdispersion, consistent with the explicitly nonlinear, pandemic-disrupted pattern of the series, separate offset-adjusted quasi-Poisson models were additionally fitted to the pre-pandemic (2015-2019) and post-pandemic recovery (2022-2025) subperiods. Factors associated with in-hospital mortality were assessed using multivariable logistic regression (adjusted ORs, 95% CI), with the 60-69-year band as reference and age band, sex, ICU admission, and comorbidity as covariates; because ICU admission is a downstream, severity-dependent variable rather than a baseline patient characteristic, a sensitivity analysis re-fitting the same model without ICU admission was also performed. Given the small number of annual observations (n = 11, or fewer within each subperiod), formal autocorrelation testing was not performed, a constraint acknowledged as a limitation. Significance was set at $p < 0.05$ (two-sided); analyses were conducted in R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria).

Ethics approval

Because this study used only secondary, publicly available, de-identified administrative data, it was exempt from review by a Research Ethics Committee under Resolution No. 510/2016 of the Brazilian National Health Council, which governs research using data in the public domain or databases with no possibility of participant identification.

Results

Between 2015 and 2025, 1,310,296 hospitalizations for severe bacterial infections and sepsis among adults aged ⩾60 years were identified in the state of São Paulo. The mean age was 76.2 years (SD 9.6). The age distribution was 377,014 (28.8%) in the 60-69-year band, 433,981 (33.1%) in the 70-79-year band, 373,950 (28.5%) in the 80-89-year band, and 119,851 (9.1%) among those aged ⩾90 years; 5,500 hospitalizations (0.4%) lacked a reconstructable age band and were excluded from age-stratified analyses. The male predominance observed in younger bands (209,243 (55.5%) at 60-69 years) reversed progressively with age (43,506 (36.3%) at ⩾90 years), consistent with greater female longevity (Table *1*).

Age band	n	Male sex, N (%)	LOS (median, days)	In-hospital lethality, N (%)	ICU admission, N (%)	Any comorbidity, N (%)
60-69 years	377,014	209,243 (55.5)	7	105,790 (28.06)	87,467 (23.2)	132,709 (35.2)
70-79 years	433,981	227,406 (52.4)	6	136,053 (31.35)	83,758 (19.3)	146,686 (33.8)
80-89 years	373,950	167,530 (44.8)	6	131,032 (35.04)	48,240 (12.9)	108,445 (29.0)
≥90 years	119,851	43,506 (36.3)	5	48,731 (40.66)	8,270 (6.9)	28,525 (23.8)
Not informed	5,500	1,540 (28.0)	5	2,531 (46.02)	209 (3.8)	1,072 (19.5)

TABLE 1: Characteristics of hospitalizations for severe bacterial infections and sepsis among older adults, by age band, São Paulo, 2015-2025.

The “Not informed” row comprises 5,500 hospitalizations (0.4%) without a reconstructable age band; excluded from age-stratified analyses.

LOS, length of stay

The number of hospitalizations increased over the study period, from 102,957 in 2015 to a pandemic-period nadir of 91,706 in 2021, followed by marked recovery to 157,539 in 2025. The raw count-based incidence rate ratio (IRR) was 1.039 per year (95% CI 1.039-1.040; $p < 0.001$), corresponding to an apparent average annual growth of approximately 3.9%; however, this estimate did not account for growth of the underlying elderly population. After incorporating a log-population offset and correcting for overdispersion (quasi-Poisson regression), the adjusted IRR for the full 2015-2025 period was 1.005 per year (95% CI 0.983-1.028), which was not statistically significant, and the model showed substantial residual overdispersion (dispersion factor ≈ 1,715), indicating that a single log-linear coefficient does not adequately summarize this nonlinear series. Fitting separate offset-adjusted models to the pre-pandemic (2015-2019) and post-pandemic recovery (2022-2025) subperiods showed a stable pre-pandemic rate (IRR 0.996/year, 95% CI 0.988-1.003; not statistically significant) and a statistically significant recovery-period increase of approximately 5.6% per year (IRR 1.056/year, 95% CI 1.030-1.082), exceeding the pre-pandemic rate. Hospitalization rates per 100,000 inhabitants showed a steep and consistent age gradient across the study period: the ⩾90-year band had a mean rate of 8,056.8 per 100,000, approximately ninefold that of the 60-69-year band (873.9) and approximately double that of the 80-89-year band (4,117.6). The overall rate declined from 1,771.5 per 100,000 in 2015 to a nadir of 1,271.6 in 2021, before rising to 1,926.5 in 2025 (Figure *2*).

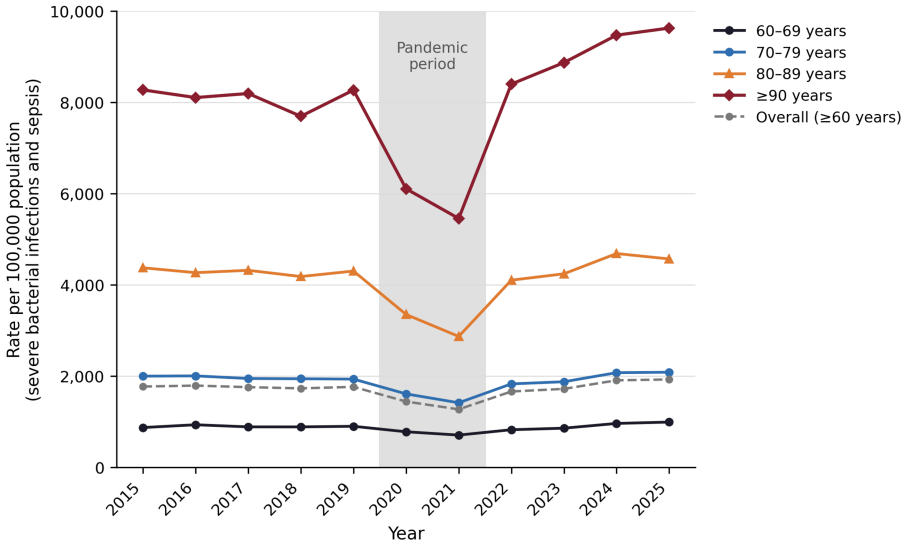


FIGURE 2: Annual hospitalization rate per 100,000 population for severe bacterial infections and sepsis among older adults, by age band, São Paulo State, 2015-2025.

Rates were calculated using annual population estimates from the Brazilian Institute of Geography and Statistics (IBGE) as the denominator. The shaded area indicates the pandemic period (2020-2021).

Overall in-hospital mortality was 424,156 (32.37%) and increased monotonically with age: 105,790 (28.06%) at 60-69 years, 136,053 (31.35%) at 70-79 years, 131,032 (35.04%) at 80-89 years, and 48,731 (40.66%) at ⩾90 years (χ^2=8,389.1; df=3; p < 0.001). ICU admission, conversely, decreased with age, from 87,467 (23.2%) at 60-69 years to 8,270 (6.9%) at ⩾90 years, despite rising mortality (Table *1*). In the multivariable model, the odds of death increased progressively with age relative to the 60-69-year reference, reaching an adjusted OR of 2.56 (95% CI 2.52-2.60) at ⩾90 years. Male sex was associated with a small but statistically significant increase in the odds of death (OR 1.08; 95% CI 1.07-1.09), and the presence of any comorbidity increased the odds by approximately 50% (OR 1.49; 95% CI 1.48-1.50). ICU admission carried the largest adjusted OR (4.30; 95% CI 4.26-4.34), consistent with its role as a marker of clinical severity rather than a modifiable causal factor (Table *2*). Because ICU admission occurs during hospitalization and is influenced by illness severity and care decisions rather than being a baseline patient characteristic, a sensitivity analysis re-fitting the mortality model without ICU admission was performed: the age gradient persisted but was attenuated (OR at ⩾90 years 1.91, 95% CI 1.88-1.93, vs. 2.56 with ICU admission included), while the comorbidity OR increased slightly (OR 1.63, 95% CI 1.62-1.65, vs. 1.49) (Table *2*). Notably, the proportion of hospitalizations with any recorded comorbidity decreased with age, from 132,709 (35.2%) at 60-69 years to 28,525 (23.8%) at ⩾90 years, a pattern opposite to the clinically expected accumulation of comorbidity with age, and one more plausibly explained by under-registration of secondary diagnoses in the oldest patients than by a true decline in comorbidity burden; because this apparent under-registration is age-dependent, the comorbidity variable is likely differentially misclassified by age band, and the reported comorbidity OR should be interpreted as a lower-bound approximation rather than an unbiased estimate.

Variable	Adjusted OR (95% CI)	Adjusted OR without ICU (95% CI)
Age band 60-69 years	1 (reference)	1 (reference)
Age band 70-79 years	1.29 (1.27-1.30)	1.19 (1.17-1.20)
Age band 80-89 years	1.76 (1.74-1.78)	1.45 (1.43-1.46)
Age band ≥90 years	2.56 (2.52-2.60)	1.91 (1.88-1.93)
Male sex	1.08 (1.07-1.09)	1.10 (1.09-1.10)
ICU admission	4.30 (4.26-4.34)	- (excluded)
Presence of comorbidity	1.49 (1.48-1.50)	1.63 (1.62-1.65)

TABLE 2: Factors associated with in-hospital mortality (multivariable logistic regression), São Paulo, 2015-2025.

Adjusted for age band, sex, ICU admission, and comorbidity. ICU admission represents a severity marker, not a modifiable causal factor. A sensitivity analysis excluding ICU admission (given its status as a downstream, severity-dependent covariate rather than a baseline characteristic) is shown in the adjacent column; excluding ICU admission attenuates but does not reverse the age-mortality gradient and slightly increases the comorbidity OR.

The respiratory system chapter was the most frequent primary admission diagnosis (598,681 hospitalizations, 45.7%; lethality 148,533 (24.81%)), followed by ICD-10 Chapter I, other infectious and parasitic diseases (282,287 hospitalizations, 21.5%), which, despite being less frequent, showed the highest lethality of the cohort (175,949 (62.33%)), together with substantially longer stays and higher costs than other admission chapters. This chapter-level count reports all Chapter I primary diagnoses and is not restricted to septicemia codes; the strict-sepsis subgroup analyzed below (A40/A41) accounts for 248,525 (88.0%) of these hospitalizations, with the remainder corresponding predominantly to other infectious and parasitic diagnoses such as unspecified viral and bacterial infections, erysipelas, mycobacterial disease, and dengue fever. Genitourinary causes, with lower lethality (28,889 (12.16%)), were the third most frequent group (Table *3*). Among secondary diagnoses, pneumonia, UTI, unspecified septicemia, hypertension, and heart failure predominated, reflecting both infectious foci and the baseline comorbidity profile typical of this age group. Comorbidity-specific lethality was highest for liver disease (5,128/9,022 (56.84%)), malnutrition (2,205/4,354 (50.64%)), neoplasms (39,619/80,968 (48.93%)), and cerebrovascular disease (28,322/60,422 (46.87%)).

ICD-10 chapter	n	Lethality, N (%)	LOS (days)	Mean cost (R$)	Mean cost (US$)
Respiratory system	598,681	148,533 (24.81)	7.9	1,446.21	322.81
I. Other infectious and parasitic diseases (ICD-10 Chapter I, all primary diagnoses)	282,287	175,949 (62.33)	11.7	4,114.90	918.5
Genitourinary system	237,571	28,889 (12.16)	7.2	846.42	188.93
Circulatory system	70,101	25,608 (36.53)	13.4	3,857.45	861.04
Neoplasms	30,558	15,707 (51.4)	10.2	2,827.41	631.12
Digestive system	29,848	12,542 (42.02)	9.3	3,938.23	879.07
Musculoskeletal system	15,146	928 (6.13)	9.4	1,452.37	324.19
Injury and external causes	9,161	4,270 (46.61)	16	5,308.39	1,184.91
Endocrine/metabolic	8,323	2,238 (26.89)	9	1,482.37	330.89
Skin and subcutaneous tissue	8,127	1,858 (22.86)	10.6	1,806.46	403.23

TABLE 3: Composition of the cohort by ICD-10 chapter of the primary admission diagnosis, with lethality, LOS, and cost, São Paulo, 2015-2025.

The 10 most frequent chapters are shown. LOS and cost are expressed as means. Costs are also expressed in US dollars using the average official USD/BRL exchange rate for the 2015-2025 study period (R$4.48 = US$1.00; simple average of the 11 annual period-average rates, World Bank Official Exchange Rate data, series PA.NUS.FCRF). Because costs were pooled across the full study period without adjustment for inflation or the specific exchange-rate year of each hospitalization, this conversion is an approximation for reference and not a year-specific or inflation-adjusted estimate. The “I. Other infectious and parasitic diseases” row reports all ICD-10 Chapter I (A00-B99) primary diagnoses; it is a chapter-level count and not restricted to septicemia codes. The strict-sepsis subgroup analyzed in the Results and Table 2 (A40/A41 codes) accounts for 248,525 (88.0%) of these hospitalizations; the remainder corresponds predominantly to other infectious and parasitic diagnoses outside the septicemia code set (e.g., unspecified viral and bacterial infections, erysipelas, mycobacterial disease, dengue fever).

LOS, length of stay

The subgroup restricted to sepsis codes in the primary diagnosis comprised 248,525 hospitalizations, 19.0% of the cohort, with an in-hospital lethality of 159,503 (64.18%), approximately twice that of the broad cohort (424,156 (32.37%)). Lethality in this subgroup also rose monotonically with age, from 43,964/77,162 (56.98%) at 60-69 years to 53,370/84,457 (63.19%) at 70-79 years, 46,264/66,329 (69.75%) at 80-89 years, and 15,207/19,744 (77.02%) at ⩾90 years. Consistent with the broad cohort, ICU admission in this subgroup decreased with age, from 32,924/77,162 (42.7%) at 60-69 years to 2,711/19,744 (13.7%) at ⩾90 years, despite rising lethality.

Discussion

This population-based study of 1,310,296 hospitalizations for severe bacterial infections and sepsis among older adults in São Paulo found a markedly nonlinear pattern in hospitalization incidence over an 11-year period. Once adjusted for population growth and overdispersion, the overall trend across 2015-2025 was not statistically significant (IRR 1.005/year, 95% CI 0.983-1.028); the raw, unadjusted count-based estimate previously reported (IRR 1.039/year) reflected growth of the underlying elderly population rather than an independent increase in incidence. Separating the series into a pre-pandemic period (2015-2019), essentially stable (IRR 0.996/year, 95% CI 0.988-1.003), a pandemic-related nadir in 2020-2021, and a post-pandemic recovery period (2022-2025) revealed a statistically significant increase of approximately 5.6% per year during the recovery period (IRR 1.056/year, 95% CI 1.030-1.082), exceeding the pre-pandemic rate. Mortality increased monotonically with age, while ICU admission declined, and sepsis in the strict sense, 248,525 (19.0%) of the cohort, carried roughly twice the lethality of the broader cohort, reaching more than three-quarters of cases at ⩾90 years.

The statistically significant increase in hospitalization rate observed specifically during the 2022-2025 recovery period, exceeding the pre-pandemic rate, is a novel finding that these administrative data cannot mechanistically explain. Plausible contributors include a rebound in care-seeking and hospital capacity following the pandemic-related disruption of health services well documented internationally [22], and an accumulated backlog of presentations delayed during 2020-2021, consistent with the disruption and subsequent rebound in acute health care use reported elsewhere during the same period [23]. Post-COVID-19 sequelae and a broader post-pandemic shift in the epidemiology of infectious disease in this population, described in pediatric populations as an "immune debt" following reduced pathogen exposure during periods of social distancing [24], remain speculative, age-group-specific hypotheses that these administrative data, drawn from an older-adult population, cannot test directly. We report this pattern descriptively and without attributing it to any single mechanism, consistent with our approach to the ICU-admission findings discussed below.

The co-occurrence of rising mortality and declining ICU admission with age has been described elsewhere. In the ELDICUS study, across 11 European ICUs, 28-day mortality rose from 11% (18-44 years) to 48% (>84 years), while ICU refusal rose in parallel, from 11% to 36% [25]. In the VIP1 study of patients aged ≥80 years admitted to 309 European ICUs, withholding or withdrawal of life-sustaining therapy occurred in 27.2% of cases and was independently associated with advancing age, frailty, and severity of illness [26]. The rising lethality with age is mechanistically consistent with immunosenescence and reduced cardiovascular, renal, and respiratory reserve [11]. The lower rate of ICU admission at older ages should not be read as lower severity; it more plausibly reflects complex care decisions, including assessment of frailty and treatment proportionality, though these observational data cannot establish a causal link between age, treatment-limitation decisions, and outcome, and unmeasured factors such as implicit age-related bias in triage may also contribute. These findings support reviewing ICU admission criteria to ensure that chronological age alone is not used as an exclusion criterion and strengthening the integration of intensive care, palliative care, and advance directive planning.

The predominance of the respiratory chapter among admissions is consistent with pneumonia being a leading infectious focus and a common precursor of sepsis in older adults, a pattern also reported internationally [13,14]. That systemic infections, although less frequent, concentrated the highest lethality, longest stays, and highest costs is compatible with the septicemia code selecting patients who already present organ dysfunction or shock, not with respiratory infection being inherently less severe; frequency in an administrative dataset should not be read as a proxy for clinical severity. The comorbidities most strongly associated with lethality (liver disease, malnutrition, neoplasms, and cerebrovascular disease) reflect the multimorbidity typical of aging. These results reinforce the clinical relevance of respiratory vaccination and early management of pulmonary infection in older adults, while underscoring that the hierarchy of infectious foci observed here reflects administrative coding conventions rather than clinical severity alone.

The odds of in-hospital death increased progressively with age and were higher among men and among patients with any comorbidity, while ICU admission, as expected of a severity marker rather than an independent risk factor, carried the largest adjusted OR. The association with male sex was small (OR 1.08) but, given cohort size, remained statistically significant; smaller cohorts have reported comparable or larger estimates for sex without reaching significance, more likely reflecting statistical power than a true absence of association [9]. Multimorbidity may also delay recognition of sepsis in older adults, whose presentation is frequently atypical (confusion, hypothermia, falls, absence of overt fever) and can be masked by pre-existing chronic disease, a plausible though untestable mechanism for the comorbidity-outcome association.

The decline in ICU admission with advancing age, despite rising mortality, cannot be explained by this administrative dataset; plausible contributors include greater frailty, higher baseline illness severity, treatment preferences, clinical eligibility, resource availability, and other unmeasured factors, and we interpret the association without attributing it to any single mechanism. This interpretation is reinforced by the sensitivity analysis excluding ICU admission from the mortality model (Table *2*): the age-mortality gradient persisted, though attenuated, and the comorbidity OR increased slightly. This pattern is consistent with ICU admission acting as a downstream mediator rather than a baseline confounder: because older patients in this cohort were less likely to receive ICU care despite higher mortality, conditioning on ICU admission captures part of the age-associated risk that would otherwise be absorbed into unmeasured severity, and the model excluding ICU admission more closely reflects the total, policy-relevant excess mortality risk associated with age in this population.

Restricting the definition to septicemia codes in the primary diagnosis selected a smaller but markedly more lethal subgroup, consistent with evidence that narrower, code-based sepsis definitions capture fewer but more severe cases than broader definitions, which tend to inflate incidence while diluting apparent mortality [15]. In a validation exercise cited by the United States Centers for Disease Control and Prevention, the lethality of a narrowly defined Bacteremia/Fungemia Shock Event was approximately 2.3 times that of the broader Adult Sepsis Event definition (35.4% vs. 15%) [21], comparable to the near two-fold contrast observed here (64.18% vs. 32.37%). Lethality exceeding three-quarters of cases among the oldest strict-sepsis patients is considerably higher than the maximum mortality reported among patients aged ≥80 years in the ICON audit (49.3%) [27], most plausibly because ICON enrolled only patients already in intensive care, whereas the present cohort captures the whole hospitalized population, including patients markedly less

likely to be admitted to intensive care as age advanced. Coding practice and regional variation may also contribute, but the present design cannot distinguish among them. Studies of sepsis should explicitly declare the case definition used, since broad and strict definitions in administrative data describe populations with materially different frequency and lethality.

These findings derive from a single Brazilian state and reflect the coding practices and organization of the SIH/SUS system; the magnitude of the temporal trend and of specific point estimates may not be directly transferable to other Brazilian states or health systems with different case-mix, diagnostic coding, or access to intensive care. The qualitative pattern observed here, rising mortality with declining ICU admission at older ages and higher lethality under a stricter sepsis definition, is nonetheless consistent with findings from other middle- and high-income settings discussed above, supporting its plausibility beyond the present cohort, even where the precise magnitude may not generalize.

This study has limitations inherent to hospital administrative data. The SIH/SUS depends on the completeness of AIH documentation and codes diagnoses by ICD-10 without applying clinical organ-dysfunction criteria (e.g., SOFA ⩾2), so that "sepsis" here represents an administrative record rather than the Sepsis-3 clinical definition; ICD-based sepsis definitions have highly variable sensitivity (5.9%-82.3%) and a median positive predictive value near 50% [28]. The broad cohort's case definition includes low-specificity codes (unspecified-organism pneumonia, unspecified-site UTI) and one fungal code (B37.7, candidal septicemia) alongside bacterial septicemia codes; this may dilute the clinical homogeneity of the broad cohort, and findings from the strict-sepsis subgroup should be weighted more heavily when a more homogeneous, higher-severity population is of interest. In older adults, atypical presentation may further amplify under-diagnosis and under-coding; under-registration of secondary diagnoses, evident in the declining recorded comorbidity prevalence with age, likely limits the completeness of the comorbidity profile. Because comorbidity ascertainment appears to become less complete with advancing age, the "any vs. none" comorbidity variable used in the mortality model is likely differentially misclassified by age band; such differential misclassification could bias the adjusted OR for comorbidity, and potentially the age-specific ORs as well, in a direction that cannot be determined from the available data, so the comorbidity effect estimate reported here should be interpreted as a lower-bound approximation of a more complex, age-varying relationship rather than an unbiased estimate. Similarly, this administrative dataset can describe, but not explain, the observed age gradient in ICU admission; we report the association without attributing it to a specific mechanism. The retrospective, hospitalization-level design does not permit individual-level causal inference, and readmissions may be double-counted, potentially overestimating incidence. Only annual aggregates were analyzed; possible seasonal variation, plausible given that respiratory causes accounted for 598,681 (45.7%) of admissions, could not be assessed. Coding transitions and pandemic-related reorganization of hospital services may have introduced additional discontinuities, and the small number of annual observations within each subperiod (five and four years, respectively) limits the precision of the pre-pandemic and recovery-period trend estimates. Despite these limitations, strengths include the population-based sample of 1,310,296 hospitalizations, statistical power rarely achieved by chart-review studies, the explicit broad-cohort/strict-sepsis distinction, sensitivity analyses addressing the population offset, overdispersion, and ICU admission as a downstream covariate, an 11-year window spanning the pre-, intra-, and post-pandemic periods, and full documentation of the analytical pipeline. Administrative data remain essential for large-scale epidemiological surveillance where integrated electronic health records are unavailable.

Conclusions

Severe bacterial infections and sepsis represent a substantial and already highly lethal hospital burden among older adults in São Paulo. The overall hospitalization incidence showed no statistically significant linear trend from 2015 to 2025 once adjusted for population growth, but the underlying pattern was markedly nonlinear: a stable pre-pandemic rate was followed by a pandemic-related nadir and a statistically significant post-pandemic recovery-period increase that exceeded pre-pandemic levels. Mortality rose progressively with age, in apparent contrast with declining access to intensive care in the oldest patients, underscoring the need to revisit ICU admission criteria and strengthen discussion of treatment proportionality and advance directives. Sepsis in the strict sense constituted a markedly more lethal core within this broader burden. Early recognition of atypical presentations, strengthened respiratory vaccination, and adapted geriatric hospital capacity emerge as priorities warranted by these findings.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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References

1. Global, regional, and national sepsis incidence and mortality, 1990-2021: a systematic analysis . Lancet Glob Health. 2025, 13:e2013-26. 10.1016/S2214-109X(25)00356-0
2. Cecconi M, Evans L, Levy M, Rhodes A: Sepsis and septic shock. Lancet. 2018, 392:75-87. 10.1016/S0140-6736(18)30696-2
3. Jabaley CS, Blum JM, Groff RF, O'Reilly-Shah VN: Global trends in the awareness of sepsis: insights from search engine data between 2012 and 2017. Crit Care. 2018, 22:7. 10.1186/s13054-017-1914-8
4. Evans L, Rhodes A, Alhazzani W, et al.: Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021. Crit Care Med. 2021, 49:e1063-143. 10.1097/CCM.0000000000005337
5. Dias RD, Barros JV: Burden of hospitalisation among older people in the Brazilian public health system: a big data analysis from 2009 to 2015. J Epidemiol Community Health. 2019, 73:537-43. 10.1136/jech-2018-210783
6. Berezin EN, de Moraes JC, Hong T, Todd M, Seljan MP: Pneumonia hospitalization in Brazil from 2003 to 2007. Int J Infect Dis. 2012, 16:e583-90. 10.1016/j.ijid.2012.02.018
7. Buzzo AR, Roberts C, Mollinedo LG, Quevedo JM, Casas GL, Soldevilla JM: Morbidity and mortality of pneumonia in adults in six Latin American countries. Int J Infect Dis. 2013, 17:e673-7. 10.1016/j.ijid.2013.02.006
8. Pires MV de A, Araújo JE: Epidemiological characteristic of cystitis in the elderly population in the unified health system [Article in Portuguese]. Braz J Health Rev. 2021, 4:25688-99. 10.34119/bjhrv4n6-168
9. Mellhammar L, Wollter E, Dahlberg J, et al.: Estimating sepsis incidence using administrative data and clinical medical record review. JAMA Netw Open. 2023, 6:e2331168. 10.1001/jamanetworkopen.2023.31168
10. Kumar A, Hammond N, Grattan S, Finfer S, Delaney A: Accuracy of International Classification of Disease coding methods to estimate sepsis epidemiology: a scoping review. J Intensive Care Med. 2024, 39:3-11. 10.1177/08850666231192371
11. Martín S, Pérez A, Aldecoa C: Sepsis and immunosenescence in the elderly patient: a review . Front Med (Lausanne). 2017, 4:20. 10.3389/fmed.2017.00020
12. Nasa P, Juneja D, Singh O: Severe sepsis and septic shock in the elderly: an overview . World J Crit Care Med. 2012, 1:23-30. 10.5492/wjccm.v1.i1.23
13. Cillóniz C, Dominedò C, Ielpo A, et al.: Risk and prognostic factors in very old patients with sepsis secondary to community-acquired pneumonia. J Clin Med. 2019, 8:961. 10.3390/jcm8070961
14. Vaughn VM, Dickson RP, Horowitz JK, Flanders SA: Community-acquired pneumonia: a review . JAMA. 2024, 332:1282-95. 10.1001/jama.2024.14796
15. Shappell CN, Klompas M, Rhee C: Surveillance strategies for tracking sepsis incidence and outcomes . J Infect Dis. 2020, 222:S74-83. 10.1093/infdis/jiaa102
16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP: The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007, 370:1453-7. 10.1016/S0140-6736(07)61602-X
17. Benchimol EI, Smeeth L, Guttmann A, et al.: The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLoS Med. 2015, 12:e1001885. 10.1371/journal.pmed.1001885

18. Saldanha RF, Bastos RR, Barcellos C: Microdatasus: a package for downloading and preprocessing microdata from Brazilian Health Informatics Department (DATASUS) [Article in Portuguese]. Cad Saude Publica. 2019, 35:e00032419. 10.1590/0102-311X00032419
19. Population Projections [in Portuguese]. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro, Brazil; 2024.
20. Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR: Epidemiology of severe sepsis in the United States: analysis of incidence, outcome, and associated costs of care. Crit Care Med. 2001, 29:1303-10. 10.1097/00003246-200107000-00002
21. Hospital Toolkit for Adult Sepsis Surveillance. CDC, Atlanta, GA; 2018.
22. Moynihan R, Sanders S, Michaleff ZA, et al.: Impact of COVID-19 pandemic on utilisation of healthcare services: a systematic review. BMJ Open. 2021, 11:e045343. 10.1136/bmjopen-2020-045343
23. Iskander C, Stukel TA, Diong C, et al.: Acute health care use among children during the first 2.5 years of the COVID-19 pandemic in Ontario, Canada: a population-based repeated cross-sectional study. CMAJ. 2024, 196:E1-E13. 10.1503/cmaj.221726
24. Lenglart L, Titomanlio L, Bognar Z, et al.: Surge of pediatric respiratory tract infections after the COVID-19 pandemic and the concept of "immune debt". J Pediatr. 2025, 284:114420. 10.1016/j.jpeds.2024.114420
25. Sprung CL, Artigas A, Kesecioglu J, et al.: The Eldicus prospective, observational study of triage decision making in European intensive care units. Part II: intensive care benefit for the elderly. Crit Care Med. 2012, 40:132-8. 10.1097/CCM.0b013e318232d6b0
26. Guidet B, Flaatten H, Boumendil A, et al.: Withholding or withdrawing of life-sustaining therapy in older adults (≥ 80 years) admitted to the intensive care unit. Intensive Care Med. 2018, 44:1027-38. 10.1007/s00134-018-5196-7
27. Kotfis K, Wittebole X, Jaschinski U, et al.: A worldwide perspective of sepsis epidemiology and survival according to age: observational data from the ICON audit. J Crit Care. 2019, 51:122-32. 10.1016/j.jcrc.2019.02.015
28. Jolley RJ, Sawka KJ, Yergens DW, Quan H, Jetté N, Doig CJ: Validity of administrative data in recording sepsis: a systematic review. Crit Care. 2015, 19:139. 10.1186/s13054-015-0847-3