GeroScience
https://doi.org/10.1007/s11357-026-02228-5

ORIGINAL ARTICLE

What emergency department length of stay reveals about aging-related vulnerability and declining resilience

Szabolcs Gaal-Marschal · Dora Melicher · Kornel Adam · Dora Gaal · Bence Sipos · Brigitta Szilagyi · Csaba Varga

Received: 27 January 2026 / Accepted: 16 March 2026

Abstract Emergency department (ED) length of stay (LOS) is associated with adverse outcomes and increases with age, but the extent to which this reflects differences beyond triage acuity is unclear. Emergency department (ED) length of stay (LOS) is associated with adverse outcomes and increases with age, but the extent to which this reflects differences beyond triage acuity is unclear.We conducted a retrospective cohort study of adult ED visits at a tertiary hospital in Hungary between 2016 and 2023 ($n = 188{,}082$). Triage data have been available from 2019 onward. LOS was modelled using gamma regression, adjusting for age, triage category, sex, season, and an age–triage interaction, with sensitivity analyses incorporating additional operational covariates. Admission and ED mortality were analysed using multivariable logistic regression. ED LOS increased progressively with advancing age across all triage categories. Mean LOS rose from 5.9 h in patients <65 years to 9.7 h in those ≥85 years (+64%). Age remained independently associated with longer LOS after adjustment (rate ratio per year 1.005, 95% CI 1.004–1.006), with a significant age–triage

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11357-026-02228-5.

S. Gaal-Marschal · D. Melicher · K. Adam · D. Gaal · C. Varga
Department of Emergency Medicine, Semmelweis University, Üllői út 26, H-1085, Budapest, Hungary

D. Melicher
e-mail: melicher.dora@semmelweis.hu

K. Adam
e-mail: adam.kornel@semmelweis.hu

D. Gaal
e-mail: dorkagaal6@gmail.com

C. Varga
e-mail: varga.csaba2@semmelweis.hu

S. Gaal-Marschal (✉)
Department of Emergency Medicine, North-Buda St. John Central Hospital, Diós árok 1–3, H-1125, Budapes, Hungary
e-mail: gaal.szabolcs@semmelweis.hu

B. Sipos · B. Szilagyi
Budapest University of Technology and Economics, Budapest, Hungary, Műegyetem rkp. 3., H-1111, Budapest, Hungary
e-mail: bence.sipos.sb@gmail.com

B. Szilagyi
e-mail: szilagyibr@gmail.com

B. Szilagyi
Corvinus University of Budapest, Hungary, Budapest, Hungary, Fővám tér 8., H-1093

C. Varga
Somogy County Kaposi Mór Teaching Hospital, Kaposvár, Hungary, Tallián Gyula u 20-32, H-7400

interaction ($p < 0.001$). Higher-acuity triage assignments were more frequent with age, yet age-related LOS differences persisted within each triage category. ED mortality increased markedly with advancing age. These patterns were consistent across sensitivity analyses. Advancing age was associated with longer ED LOS across all triage categories, independent of triage acuity, indicating that age-related differences in emergency care trajectories extend beyond differences in initial acuity. The persistence of LOS prolongation across triage strata suggests that standard acuity-based assessment does not fully capture aging-related vulnerability. From a geroscience perspective, ED LOS may reflect as a routinely available, system-level signal of aging-related vulnerability beyond triage acuity, with direct relevance for early risk identification, geriatric care pathways, delirium prevention, and health system planning.

Keywords Aging · Frailty · Emergency-service · Length-of-stay

Introduction

Aging is increasingly understood as a progressive decline in physiological resilience and stress tolerance across multiple organ systems. From a geroscience perspective, vulnerability emerges when aging-related reductions in homeostatic reserve limit the ability to maintain function under acute stress, leading to disproportionate adverse outcomes following otherwise routine insults [1]. Acute illness and emergency care encounters, therefore, provide a unique window into biological aging, as they expose latent deficits in resilience that may remain clinically silent under baseline conditions. In this context, the emergency department (ED) is a critical setting in which such stress responses unfold at scale.

ED crowding has become a persistent global challenge, reflecting the inability of health systems to match rising demand for unscheduled acute care with inpatient capacity and to manage patient flow efficiently. Systematic reviews consistently demonstrate that prolonged ED length of stay (LOS) is not merely an operational inconvenience but is associated with measurable harms, including delays in diagnostics and treatment, increased adverse events, and higher in-hospital mortality [2–4]. These associations persist across healthcare systems and study designs, suggesting that crowding reflects a fundamental mismatch between patient needs and system capacity rather than isolated local failures. Notably, the adverse effects of crowding appear to be amplified in vulnerable populations, particularly older adults and individuals living with frailty, for whom prolonged exposure to the ED environment may exacerbate physiological stress, functional decline, and risk of harm [5]

Population aging is profoundly changing emergency department (ED) demand, with older adults accounting for an increasing share of visits, admissions, and resource utilization, and contributing to longer ED length of stay even under routine operating conditions [6]. However, these population-level trends mask substantial heterogeneity in how older individuals tolerate acute illness. Chronological age alone does not adequately explain individual vulnerability to adverse outcomes, which reflects fundamental differences in biological aging trajectories. Frailty represents a clinically recognizable manifestation of this heterogeneity, capturing reduced physiological, cognitive, and functional reserve and independently predicting short-term mortality, hospitalization, and intensive care admission in the ED, even after adjustment for age and presenting condition [7, 8]. Conventional ED triage systems prioritize acute physiological instability but are less sensitive to aging-related vulnerability, such that older adults with similar triage acuity may follow markedly different clinical trajectories, a limitation that is rarely apparent at the point of initial assessment [9, 10].

Emergency department length of stay (LOS) is most often treated as an operational or quality metric; however, it may also be conceptualized as a system-level manifestation of aging-related vulnerability. In older adults, prolonged LOS reflects the cumulative consequences of reduced physiological and cognitive reserve, diagnostic complexity, and impaired capacity to stabilize and recover under acute stress. From this perspective, LOS functions as an integrative, system-visible signal of declining resilience, emerging at the intersection of biological aging, clinical complexity, and healthcare delivery processes, and consistently associated with adverse short-term outcomes, including in-hospital mortality [11]. Despite this, LOS is rarely conceptualized or examined as a vulnerability marker across older age strata.

Although the influence of aging, frailty, and system-level pressures on emergency care outcomes is increasingly acknowledged, vulnerability remains poorly operationalized in routinely available ED datasets. Existing studies have examined crowding, triage acuity, or LOS in isolation, often treating older adults as a homogeneous group defined solely by chronological age. As a result, little is known about how different older age strata experience emergency care processes, how vulnerability manifests beyond initial triage categorization, or whether routinely collected metrics such as LOS capture aging-related differences in risk. In particular, the interaction between age and triage acuity in shaping ED LOS and its implications for identifying vulnerable older patients under real-world conditions remain insufficiently characterized.

Methods

We conducted a retrospective cohort study using de-identified ED data from a large tertiary hospital in Hungary, covering the period from June 2016 through August 2023.

Analysis samples and variable availability

ED visit data were available for the whole study period (June 13, 2016–August 31, 2023). The triage category was systematically recorded from January 1, 2019 onwards.

Analyses were therefore conducted on the largest applicable sample for each research question. Descriptive analyses of visit volume and overall LOS trends were performed using the full cohort. Analyses requiring stratification or adjustment by triage category were restricted to the 2019–2023 subcohort with complete triage data.

Triage information was included only when conceptually necessary for comparison or interpretation; it was not introduced into analyses where it was not required, to preserve statistical power and avoid unnecessary sample restriction.

Population and variables

All adult ED visits (age $\geq$ 18) were included; visits missing age data were excluded. Encounters with a documented COVID-19 diagnosis (ICD-10 codes U07.10, U07.20 or B34.20) were excluded from the analysis.

Age was examined as a continuous variable for length-of-stay (LOS) analyses and categorized into four groups (< 65, 65–74, 75–84, and $\geq$ 85 years) for admission and mortality models. Covariates included sex, triage category (Hungarian Triage System I–V; lower categories indicating higher acuity), and season of presentation (spring, summer, autumn, and winter).

Outcomes

Three outcomes were examined: ED LOS (in hours), hospital admission (transfer to an inpatient ward), and ED mortality (death during the ED encounter).

ED length of stay was calculated as the time interval between recorded ED arrival and discharge timestamps. Hospital admission was defined administratively as transfer from the ED to any inpatient ward, and ED mortality was defined as death occurring during the ED encounter.

Time-to-event modeling was not pursued because hospital admission in the ED context represents a discrete disposition decision rather than a censored longitudinal outcome. However, we acknowledge that alternative modeling strategies may capture different aspects of patient flow.

Pandemic definitions

Although ED encounters with COVID-19 diagnoses were excluded, calendar-based pandemic periods were defined to account for broader system-level effects on emergency care unrelated to individual SARS-CoV-2 infection. The pandemic period was defined as from March 4, 2020 (the first confirmed case in Hungary) to March 7, 2022 (the end of the "national emergency period"). Periods of strict lockdown (March 28–May 18, 2020; November 11, 2020–May 23, 2021) were examined separately in sensitivity analyses by including a lockdown indicator variable in the models. Inclusion of this variable did not materially alter the estimated age- or triage-related associations.

Statistical analysis

LOS values ≤ 0 were set to missing; values > 72 h or above the 99th percentile were excluded in sensitivity analyses. LOS was modeled using a generalized linear model (GLM) with a gamma distribution and log link, including age, triage category, sex, season, and an age–triage interaction term. The significance of the interaction was assessed using a joint Wald test.

In a sensitivity analysis, gamma and multivariable logistic regression models were extended by including four additional covariates available in the dataset (time of day of arrival (day/evening/night), weekend vs. weekday presentation, number of recorded ICD-10 diagnoses, and daily ED census) to assess the robustness of age effects to potential confounders.

Hospital admission and mortality were analyzed using multivariable logistic regression models adjusting for age group, triage category, and sex. Descriptive comparisons between groups were performed using the chi-square test and the Mann–Whitney *U* test.

To assess the potential influence of competing risk from ED mortality on hospital admission estimates, we conducted a sensitivity analysis excluding all encounters with ED death.

All analyses were conducted using Python (pandas, NumPy, SciPy, and statsmodels). Statistical tests were two-sided, with p-values < 0.05 considered statistically significant.

Results

Study population

Between June 13, 2016, and August 31, 2023, a total of 188,082 ED visits were recorded at the Emergency Department of Semmelweis University, Budapest, Hungary. Triage-level data were available from January 1, 2019, covering 150,347 cases (Figure S1). Patients were stratified into four age categories: < 65 years, 65–74 years, 75–84 years, and ≥ 85 years. A detailed overview of baseline demographic characteristics is provided in Table 1. The use of different analysis samples reflects differences in variable availability over time and was handled a priori to ensure internal consistency within each analytic comparison.

Temporal trends

The number of monthly ED presentations increased steadily from fewer than 500 in 2016 to more than 3000 by the end of the study period. A regression model incorporating calendar year showed a significant upward trend (+ 14.9 visits/day/year, $p < 0.001$), which was consistent across all age categories (Fig. 1). The relative proportion of older adults displayed mild seasonal fluctuation, with higher representation during colder months (Fig. 2). Monthly distributions of ED presentations by sex, age group, and triage category are summarized in Tables S3a and b. Consistent with Fig. 2, older adults accounted for a larger share of presentations in colder months, while younger adults were relatively more represented during summer.

Significant seasonal variation was observed in both age distribution (χ^2 $p < 0.001$) and triage category distribution (χ^2 $p < 0.001$) (Figs. 2 and 3). Older adults represented a higher proportion of ED presentations during colder months (Fig. 2). Age-related differences

Table 1 Baseline characteristics of emergency department visits. Percentages may not sum to 100 due to rounding

Category	Variable	Male	Female	Total
Demographics	Age, years (mean ± SD)	54.0 ± 19.4	56.1 ± 21.8	55.1 ± 20.7
	Age group < 65 years, n (%)	57,062 (64.7)	57,739 (57.9)	114,859 (61.1)
	Age group 65–74 years, n (%)	16,430 (18.6)	16,482 (16.5)	32,918 (17.5)
	Age group 75–84 years, n (%)	10,715 (12.2)	16,054 (16.1)	26,771 (14.2)
	Age group ≥ 85 years, n (%)	4,000 (4.5)	9,533 (9.6)	13,534 (7.2)
Visit characteristics	Total ED visits, n	88,207	99,808	188,082
	Daily visit count, median (IQR)	33 (19–47)	38 (22–53)	71 (42–101)
	Winter, *n* (%)	21,255 (24.1)	24,240 (24.3)	45,509 (24.2)
	Spring, *n* (%)	23,884 (27.1)	26,771 (26.8)	50,673 (26.9)
	Summer, *n* (%)	23,192 (26.3)	26,278 (26.3)	49,486 (26.3)
	Fall, *n* (%)	19,876 (22.5)	22,519 (22.6)	42,414 (22.6)

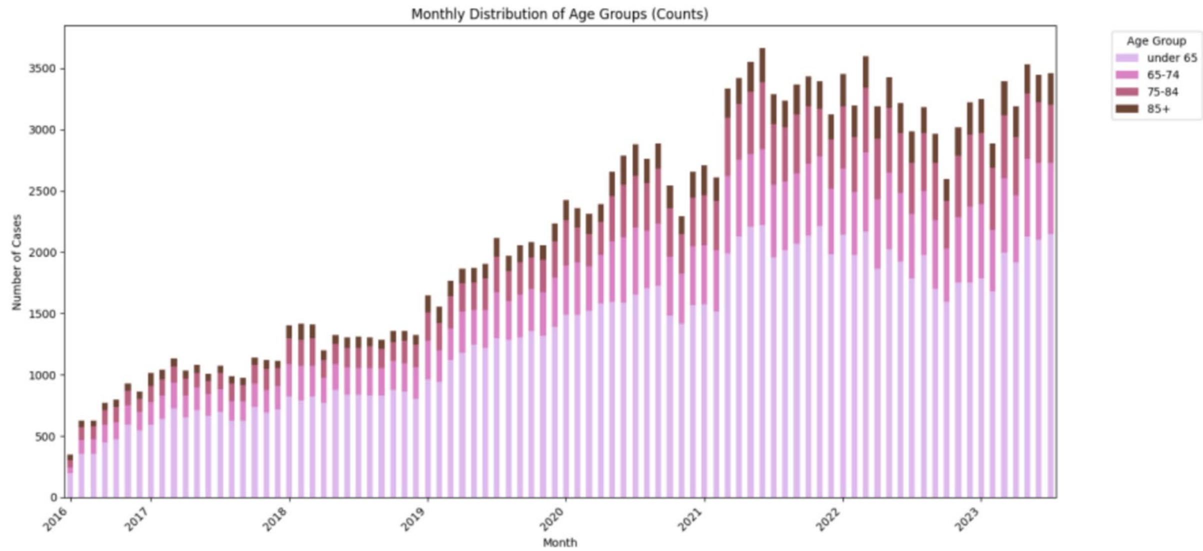

Fig. 1 Temporal trends in emergency department visits and age composition (2016–2023). Monthly ED visit counts between June 2016 and August 2023, stratified by age group (< 65, 65–74, 75–84, and ≥ 85 years). Total ED volume increased steadily over the study period, with a parallel rise in the absolute number and relative proportion of older adults. The increase was consistent across all age categories, indicating both system-level growth and demographic aging of the ED population

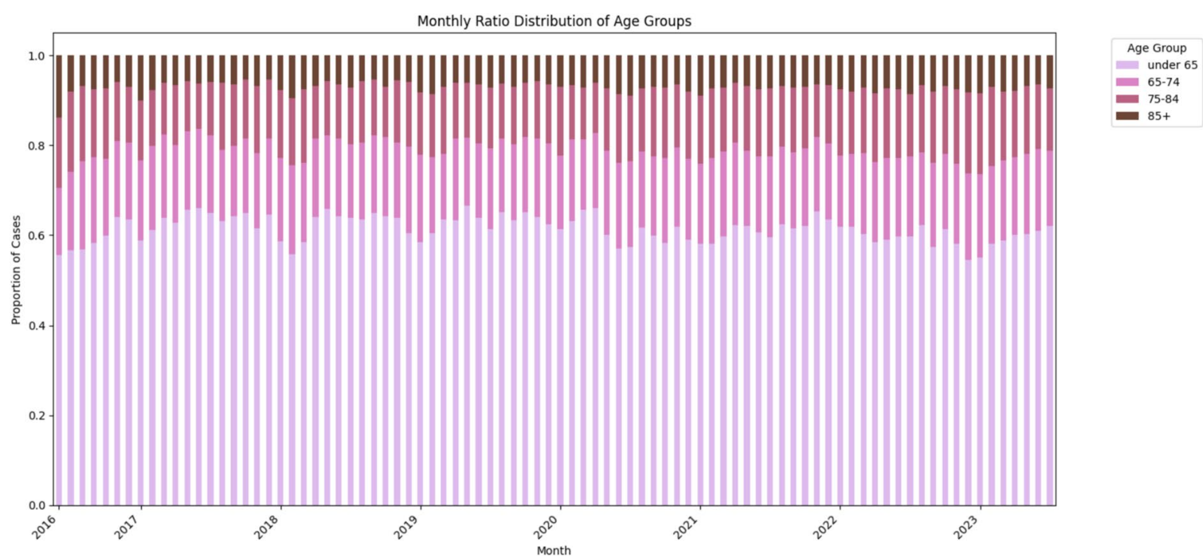

Fig. 2 Seasonal variation in the age distribution of emergency department visits. Seasonal distribution of ED visits by age group. Older adults (≥ 65 years) accounted for a higher proportion of visits during colder months, whereas younger adults (< 65 years) were relatively more represented during summer. Seasonal differences in age composition were statistically significant (χ^2 test), indicating systematic temporal variation in the demographic structure of ED presentations

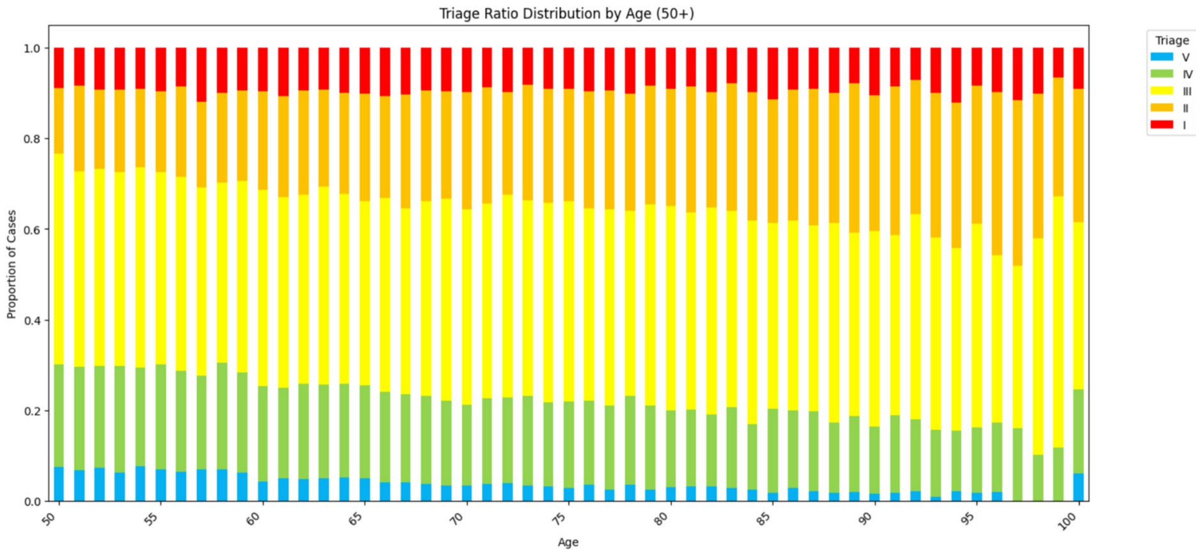

Fig. 3 Distribution of triage categories by age. Distribution of triage categories (I–V, with I indicating the highest acuity) across age groups. With advancing age, the proportion of high-acuity presentations (Triage I–II) increased, while the proportion of low-acuity presentations (Triage IV–V) declined. This shift toward higher clinical urgency was continuous across the adult age spectrum and most pronounced in the oldest age group (≥ 85 years)

in triage acuity and LOS persisted after adjustment for season (Table S7).

Triage distribution by age

Across all age groups, Triage III was the most frequent urgency category (Fig. 3). The distribution of triage categories varied systematically with age: the proportion of high-acuity visits (Triage II) increased progressively with age, while the proportion of low-acuity visits (Triage IV–V) declined. This trend continued from age 50 onwards, as shown in Fig. 3. In the oldest age category (≥ 85 years), the combined proportion of Triage I–II visits exceeded that observed in the 50–60-year range, whereas the share of Triage IV–V presentations was notably reduced. Detailed percentages by age group are provided in Table 2.

The distribution of triage categories showed a strong, progressive shift toward higher acuity with advancing age. High-acuity presentations (Category I–II) accounted for 20.8% of all visits among patients < 65 years, increasing to 34.1% in the 65–74-year group, 35.6% in those aged 75–84 years, and 39.8% in patients ≥ 85 years.

Compared with adults < 65 years, the odds of presenting in high-acuity triage were 1.86 (95% CI 1.80–1.91) for patients aged 65–74 years, 2.00 (95% CI 1.94–2.07) for those aged 75–84 years, and 2.34 (95% CI 2.25–2.44) in the ≥ 85-year group. Conversely, the odds of low-acuity triage (Category IV–V) decreased with age to 0.56 (95% CI 0.54–0.58) in the 65–74-year group, 0.50 (95% CI 0.49–0.52) in patients aged 75–84 years, and 0.43 (95% CI 0.41–0.45) among those ≥ 85 years (Table S4).

Length of stay and age–triage relationship

The unadjusted ED LOS stratified by age group, triage category, and sex is presented in Table 3. The mean ED LOS was 6.91 ± 5.54 h. Across all triage categories, LOS increased progressively with advancing age (Figs. 4 and 5). Mean LOS rose from 5.90 h in patients < 65 years to 8.00 h in the 65–74-year group (+ 36%), 8.73 h in those aged 75–84 years (+ 48%), and 9.66 h in patients ≥ 85 years (+ 64%).

Importantly, this age-related prolongation was observed across all triage categories. Among Triage III patients, mean LOS increased from 6.36 h (< 65 years) to 8.65 h (65–74 years), 9.55 h (75–84 years), and 10.81 h (≥ 85 years), corresponding to a relative increase of approximately 70% between the youngest

Table 2 Distribution of emergency department triage categories by age group and sex. Percentages are calculated within each triage category and sex. Percentages may not sum to 100 due to rounding

Triage category	Variable	Male	Female	Total
Category I	Total visits, *n*	6121	5616	11,741
	Age < 65 years, *n* (%)	3482 (56.9)	2698 (48.0)	6181 (52.6)
	Age 65–74 years, *n* (%)	1423 (23.2)	1102 (19.6)	2528 (21.5)
	Age 75–84 years, *n* (%)	891 (14.6)	1099 (19.6)	1990 (16.9)
	Age ≥ 85 years, *n* (%)	325 (5.3)	717 (12.8)	1042 (8.9)
Category II	Total visits, *n*	13,850	14,345	28,199
	Age < 65 years, *n* (%)	7297 (52.7)	5614 (39.1)	12,913 (45.8)
	Age 65–74 years, *n* (%)	3252 (23.5)	3114 (21.7)	6367 (22.6)
	Age 75–84 years, *n* (%)	2353 (17.0)	3299 (23.0)	5652 (20.0)
	Age ≥ 85 years, *n* (%)	948 (6.8)	2318 (16.2)	3267 (11.6)
Category III	Total visits, *n*	29,238	35,971	65,240
	Age < 65 years, *n* (%)	18,986 (64.9)	21,109 (58.7)	40,124 (61.5)
	Age 65–74 years, *n* (%)	5,399 (18.5)	5,812 (16.2)	11,212 (17.2)
	Age 75–84 years, *n* (%)	3,582 (12.3)	5,786 (16.1)	9,369 (14.4)
	Age ≥ 85 years, *n* (%)	1,271 (4.3)	3,264 (9.1)	4,535 (7.0)
Category IV	Total visits, *n*	16,000	18,392	34,406
	Age < 65 years, *n* (%)	11,473 (71.7)	12,322 (67.0)	23,807 (69.2)
	Age 65–74 years, *n* (%)	2433 (15.2)	2575 (14.0)	5009 (14.6)
	Age 75–84 years, *n* (%)	1542 (9.6)	2272 (12.4)	3815 (11.1)
	Age ≥ 85 years, *n* (%)	552 (3.5)	1223 (6.6)	1775 (5.2)
Category V	Total visits, *n*	5400	5352	10,761
	Age < 65 years, *n* (%)	4,497 (83.3)	4,401 (82.2)	8,907 (82.8)
	Age 65–74 years, *n* (%)	523 (9.7)	470 (8.8)	993 (9.2)
	Age 75–84 years, *n* (%)	304 (5.6)	342 (6.4)	646 (6.0)
	Age ≥ 85 years, *n* (%)	76 (1.4)	139 (2.6)	215 (2.0)

and oldest age groups. Similar patterns were observed in Triage I, II, IV, and V (Table S5).

In multivariable gamma regression analysis adjusting for triage category, sex, and season, age remained an independent predictor of LOS (RR 1.005 per year, 95% CI 1.004–1.006; Table S7). In a sensitivity analysis extending the model to include time of day, weekend/weekday presentation, number of diagnoses, and daily ED census ($n = 150{,}102$), the age effect on LOS remained significant, with minimal change in estimate (extended RR 1.001 per year, 95% CI 1.001–1.002; change − 0.38%). The age–triage interaction remained highly significant (Wald $p = 6.0 \times 10^{-95}$). Among the additional covariates, the number of diagnoses (RR 1.43, $p < 0.001$) and higher daily census (RR 1.005 per additional patient, $p < 0.001$) were independently associated with longer LOS. Evening arrival was associated with a slightly longer LOS (RR 1.03), and weekend presentation with a slightly shorter LOS (RR 0.98).

Markers of clinical complexity increased with advancing age. The mean number of recorded ICD-10 diagnoses rose from 1.96 in patients < 65 years to 2.49 in those aged ≥ 85 years. Repeat ED visits were also more frequent in older age groups, with mean visit counts of 1.62–1.64 in patients aged 65–84 years compared with 1.47 among patients < 65 years. These findings are consistent with increasing multimorbidity and recurrent care needs with age.

Model-based estimates illustrating relative LOS by triage category and the corresponding annual age-related increase are summarized in Table 4. Male sex was associated with slightly longer LOS, while LOS was shorter during summer and winter compared with the reference season. The right-skewed distribution of LOS across age groups and triage categories was consistent with the gamma regression model's assumptions.

We additionally examined whether observation time varied by disposition and age group. Mean LOS

Table 3 Emergency department length of stay (hours) by age group, triage category, and sex. LOS is expressed in hours as mean ± standard deviation

Category	Variable	Male	Female	Total
Overall	Mean LOS ± SD	6.91 ± 5.54	6.98 ± 5.30	6.95 ± 5.41
	Age < 65 years	6.08 ± 5.04	5.72 ± 4.21	5.90 ± 4.65
	Age 65–74 years	8.07 ± 5.91	7.93 ± 5.59	8.00 ± 5.75
	Age 75–84 years	8.66 ± 6.08	8.78 ± 6.12	8.73 ± 6.10
	Age ≥ 85 years	9.28 ± 6.49	9.82 ± 6.63	9.66 ± 6.59
Triage I	Mean LOS ± SD	8.28 ± 6.57	8.08 ± 6.33	8.18 ± 6.45
	Age < 65 years	7.81 ± 6.22	7.33 ± 5.46	7.60 ± 5.91
	Age 65–74 years	8.92 ± 7.05	8.84 ± 7.28	8.88 ± 7.15
	Age 75–84 years	8.84 ± 6.73	8.42 ± 6.53	8.61 ± 6.62
	Age ≥ 85 years	9.07 ± 7.09	9.19 ± 7.08	9.15 ± 7.08
Triage II	Mean LOS ± SD	7.69 ± 5.53	7.97 ± 5.67	7.83 ± 5.60
	Age < 65 years	6.81 ± 5.00	6.46 ± 4.86	6.66 ± 4.95
	Age 65–74 years	8.25 ± 5.72	8.23 ± 5.58	8.24 ± 5.65
	Age 75–84 years	8.95 ± 6.06	9.00 ± 5.90	8.98 ± 5.97
	Age ≥ 85 years	9.38 ± 6.14	9.79 ± 6.30	9.67 ± 6.25
Triage III	Mean LOS ± SD	7.46 ± 5.19	7.58 ± 5.22	7.52 ± 5.20
	Age < 65 years	6.52 ± 4.43	6.23 ± 3.96	6.36 ± 4.19
	Age 65–74 years	8.77 ± 5.79	8.54 ± 5.47	8.65 ± 5.63
	Age 75–84 years	9.42 ± 5.96	9.63 ± 6.18	9.55 ± 6.10
	Age ≥ 85 years	10.39 ± 6.59	10.97 ± 6.73	10.81 ± 6.69
Triage IV	Mean LOS ± SD	6.58 ± 4.95	6.53 ± 4.90	6.55 ± 4.92
	Age < 65 years	5.75 ± 4.12	5.42 ± 3.81	5.58 ± 3.97
	Age 65–74 years	8.30 ± 6.03	7.72 ± 5.30	8.00 ± 5.67
	Age 75–84 years	8.83 ± 5.89	8.97 ± 5.94	8.91 ± 5.92
	Age ≥ 85 years	10.00 ± 6.78	10.60 ± 6.82	10.42 ± 6.81
Triage V	Mean LOS ± SD	3.82 ± 4.22	3.65 ± 4.23	3.74 ± 4.23
	Age < 65 years	3.45 ± 3.81	3.15 ± 3.59	3.31 ± 3.72
	Age 65–74 years	5.30 ± 5.13	5.67 ± 5.17	5.47 ± 5.15
	Age 75–84 years	6.11 ± 6.00	5.88 ± 6.56	5.99 ± 6.30
	Age ≥ 85 years	5.71 ± 5.52	6.47 ± 6.39	6.20 ± 6.10

among discharged patients increased markedly with age (6.1 h for < 65 years to 11.9 h for ≥ 85 years), whereas LOS among admitted patients showed a more modest increase (5.8 to 6.4 h).

Patient outcomes

Hospital admission rates declined modestly with age, from 73.4% among patients < 65 years to 58.6%, 57.0%, and 56.6% in the 65–74, 75–84, and ≥ 85-year groups, respectively (Table S6). In multivariable logistic regression, adjusting for triage category and sex, age remained an independent predictor of hospital admission (Table S8). Compared with patients aged 65–74 years (reference group), patients younger than 65 years had a higher adjusted likelihood of hospital admission (OR 1.92, 95% CI 1.86–1.99), whereas the estimate for patients aged ≥ 85 years did not reach statistical significance (OR 0.96, 95% CI 0.91–1.01).

In sensitivity analyses that extended the logistic models to include additional covariates (arrival time, weekend/weekday, number of diagnoses, and daily ED census), the age group effects remained largely stable relative to the primary models (Table S9). This pattern likely reflects a combination of treatment limitation decisions, alternative care pathways, and threshold effects in admission decision-making among the oldest patients, rather than lower clinical severity.

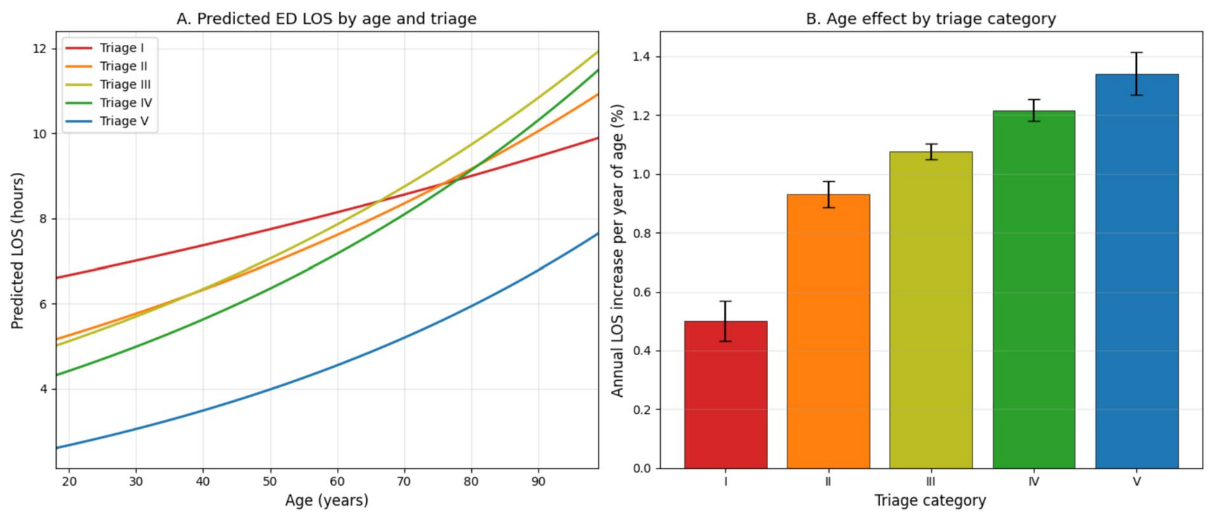

Fig. 4 Predicted emergency department length of stay and age effects by triage category. **A** Model-predicted ED length of stay (LOS) across age by triage category, derived from the multivariable gamma regression model. LOS increased with advancing age across all triage categories, with increasingly divergent trajectories at older ages. **B** Estimated annual percentage increase in LOS per additional year of age within each triage category with 95% confidence intervals. The magnitude of the age effect increased monotonically from Triage I to Triage V, illustrating the significant age × triage interaction and steeper age-associated LOS increases in lower acuity presentations

By contrast, ED mortality progressively increased with age. Mortality was 0.20% in patients < 65 years, 0.79% in those aged 65–74 years, 1.02% in the 75–84-year group, and 1.57% among patients ≥ 85 years. Relative to younger adults, the odds of ED death were 4.02 (95% CI 3.36–4.80) in the 65–74-year group, 5.16 (95% CI 4.33–6.16) in the 75–84-year group, and 8.00 (95% CI 6.63–9.65) among those ≥ 85 years.

To assess whether the competing risk of death influenced admission estimates, we conducted a sensitivity analysis excluding 808 patients who died during the ED encounter. The admission ORs were virtually unchanged (Table S10), suggesting minimal bias from mortality.

Crude distributions of admissions, discharges, and ED mortality, stratified by age group, sex, and triage category, are provided in Table 5 and Supplementary Tables S1a and b.

Data completeness

The proportion of missing triage data after the start of electronic triage category recording, which started in January 2019, declined markedly over time, from approximately 8–10% in 2019 to 1–3% from 2020 onward, with consistently higher missingness among older patients (Table S2). For LOS analyses, encounters with implausible values were excluded, and 11,286 encounters with missing LOS values were omitted from LOS modeling.

All datetime components had high completeness: admission date and time were available for 100% of visits, and discharge date/time for 94.0%.

Together, these findings indicate that advancing age independently shapes ED acuity, resource utilization, and short-term outcomes, beyond differences captured by triage severity alone.

Discussion

From a geroscience perspective, the ED represents a setting in which aging-related declines in physiological and cognitive resilience are exposed under acute stress. In this large retrospective cohort, we demonstrate that emergency department LOS increases continuously with advancing age, independent of triage acuity, sex, and season. Our sensitivity analyses adjusting for additional operational and visit-level factors confirmed that the associations between age and prolonged LOS, as well as age group effects on admission and mortality outcomes, were robust to the

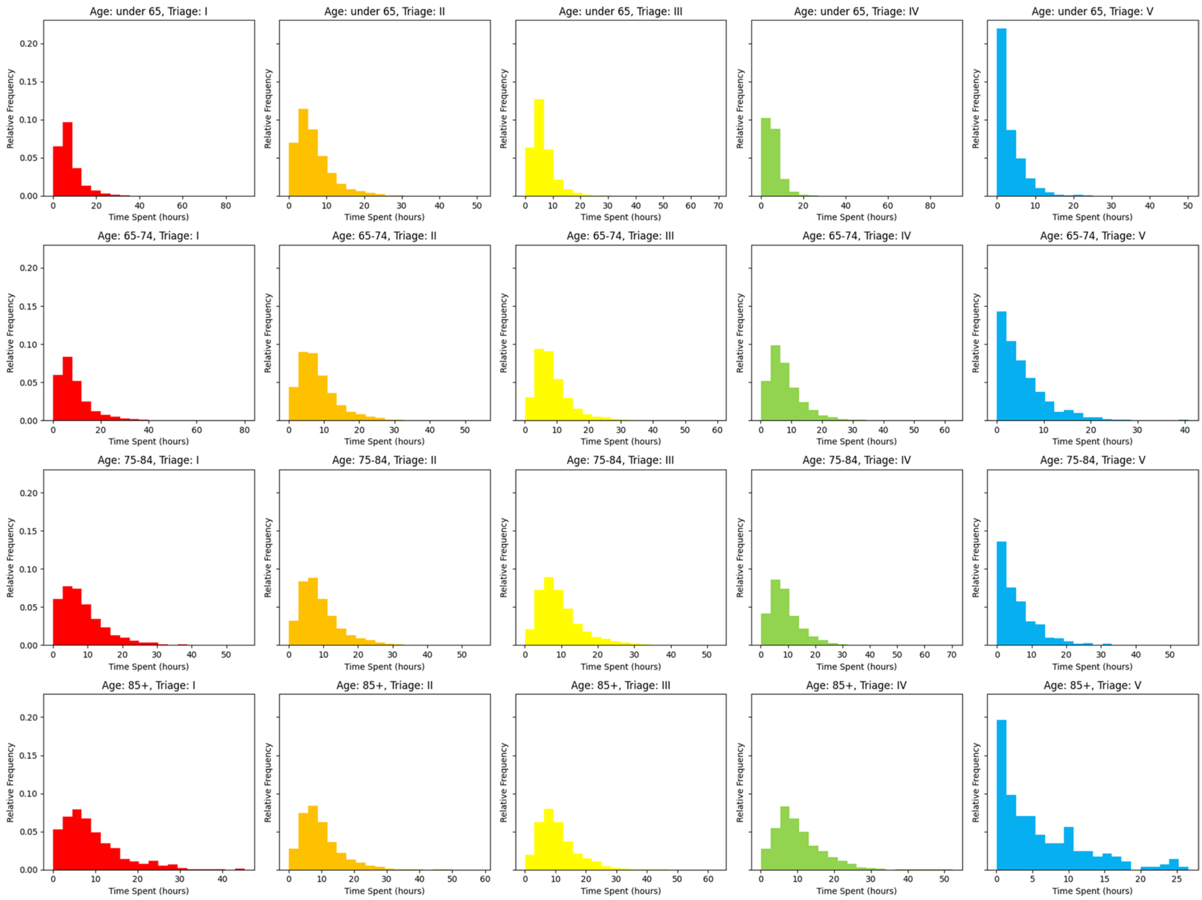

Fig. 5 Model-based age-related increase in emergency department length of stay by triage category**.** The figure displays adjusted estimates of the *relative annual percentage increase* in ED length of stay (LOS) per additional year of age within each triage category, derived from a multivariable gamma regression model with log link. Slopes represent age-related rate ratios, adjusted for sex and season. The figure illustrates a significant age–triage interaction, with progressively steeper increases in the LOS with age in lower acuity triage categories

Table 4 Model-based relative emergency department length of stay by triage category and age. Relative LOS estimates are derived from a multivariable gamma regression model with log link, using Triage I as the reference category. Annual change represents the percentage increase in LOS per additional year of age within each triage category

Triage category	Relative LOS vs. Triage I (reference)	Annual change in LOS per year of age
I (reference)	1.00	+ 0.50% (95% CI + 0.43 to + 0.57)
II	0.72 (95% CI 0.69–0.76)	+ 0.93% (95% CI + 0.89 to + 0.97)
III	0.68 (95% CI 0.65–0.72)	+ 1.08% (95% CI + 1.05 to + 1.10)
IV	0.57 (95% CI 0.55–0.60)	+ 1.22% (95% CI + 1.18 to + 1.25)
V	0.34 (95% CI 0.32–0.36)	+ 1.34% (95% CI + 1.27 to + 1.41)

inclusion of these potential confounders. Our competing-risk sensitivity analysis excluding ED deaths showed virtually unchanged hospital admission odds ratios compared with the full sample. It indicates that mortality during the ED encounter did not meaningfully bias the admission estimates. This further supports the robustness of our findings regarding age group effects on admission.

Table 5 ED disposition and mortality by age group and sex. Percentages are calculated within each subgroup (overall or each age group). ED death refers to death occurring during the ED encounter. Percentages may not sum to 100 due to rounding

Category	Subgroup	Outcome	Male, *n* (%)	Female, *n* (%)	Total, *n* (%)
Overall	All patients	Admission	57,761 (65.5)	68,734 (68.9)	126,547 (67.3)
		Discharge	21,599 (24.5)	21,310 (21.4)	42,921 (22.8)
		ED death	456 (0.5)	517 (0.5)	973 (0.5)
Age group	< 65 years	Admission	40,440 (70.9)	43,857 (76.0)	84,346 (73.4)
		Discharge	10,849 (19.0)	8,098 (14.0)	18,953 (16.5)
		ED death	140 (0.2)	88 (0.2)	228 (0.2)
	65–74 years	Admission	9216 (56.1)	10,064 (61.1)	19,281 (58.6)
		Discharge	5574 (33.9)	4816 (29.2)	10,395 (31.6)
		ED death	141 (0.9)	120 (0.7)	261 (0.8)
	75–84 years	Admission	5940 (55.4)	9322 (58.1)	15,264 (57.0)
		Discharge	3740 (34.9)	5268 (32.8)	9008 (33.6)
		ED death	113 (1.1)	159 (1.0)	272 (1.0)
	≥ 85 years	Admission	2165 (54.1)	5491 (57.6)	7656 (56.6)
		Discharge	1436 (35.9)	3128 (32.8)	4565 (33.7)
		ED death	62 (1.6)	150 (1.6)	212 (1.6)

Importantly, the age-related prolongation was observed across all triage categories. This indicates that conventional acuity-based assessment does not fully capture aging-related vulnerability. The magnitude of this age effect varied systematically by triage acuity: the annual increase in ED LOS per year of age ranged from +0.50% in the highest acuity presentations (Triage I) to +1.34% in the lowest acuity category (Triage V). This inverse gradient suggests that aging-related vulnerability exerts a proportionally greater influence on care trajectories when immediate physiological instability is absent. In contrast, in high-acuity presentations, LOS is largely driven by protocolized emergency interventions. These findings position LOS as a potential system-level marker of declining resilience, reflecting how biological aging shapes clinical trajectories beyond immediate physiological instability.

A central and novel insight of this study is the persistence of age-related prolongation of LOS within fixed triage categories, including the highest acuity presentations. If ED crowding or case mix were the primary drivers of prolonged LOS, the age effect would be expected to attenuate after stratification by acuity. Instead, the consistent age gradient observed within each triage category suggests the presence of patient-intrinsic factors that influence stabilization, diagnostic processes, and disposition decisions. This pattern is consistent with and may reflect aging-related reductions in reserve and stress tolerance. In addition, our analysis showed that mean LOS increased much more with age among discharged patients than among those admitted. This indicates systematic variation in observation time across the outcome and age groups.

Frailty provides a clinically recognizable framework for understanding these findings, as a manifestation of diminished physiological and cognitive reserve that modifies how individuals respond to acute stress rather than determining the severity of initial presentation alone. [12] Frailty has been shown to modify how patients interact with emergency care systems by increasing diagnostic uncertainty, consultation requirements, and care coordination demands, independently of crowding conditions [8, 13].

ED workflows are largely optimized for rapid throughput and single-problem care, creating a structural mismatch for older adults living with frailty, who inherently require more time for person-centered assessment, goal clarification, and interdisciplinary decision-making [13, 14]. In this context, prolonged LOS can be understood not as inefficiency but as an operational manifestation of vulnerability. At the same time, our extended models identified a modifiable system-level contribution: a higher daily ED census was independently associated with longer LOS, suggesting that aging-related vulnerability may interact with operational pressure rather than acting in isolation. Older patients may be disproportionately affected by these pressures, as bottlenecks in specialist consultation, diagnostic pathways, and inpatient bed availability are more likely to delay disposition in patients with greater clinical complexity and care coordination needs.

The continuous, year-by-year increase in LOS across all triage categories further supports this interpretation. Triage systems are designed to identify immediate physiological instability, yet vulnerability-driven complexity often manifests later through prolonged observation, iterative diagnostics, and delayed disposition rather than through overt instability at presentation [10, 15]. Prolonged ED LOS has consistently been associated with lower quality of care and adverse clinical outcomes, particularly among older adults [6, 11]. Prior studies demonstrate that diagnostic testing, consultations, and observation decisions contribute disproportionately to LOS, particularly in older patients, even when initial acuity is comparable [16]. Together, these findings support the interpretation of LOS as a population-level, system-visible marker of declining resilience associated with aging. From a geriatric perspective, ED LOS may thus reflect not only acute care complexity but also erosion of healthspan, capturing how aging-related declines in physiological and cognitive resilience translate into prolonged recovery and delayed stabilization under acute stress.

However, as outlined above, acuity-based triage primarily captures immediate physiological instability and does not fully reflect baseline aging-related vulnerability and reduced reserve. With advancing age, patients were increasingly assigned to higher acuity triage categories, while low-acuity classifications became progressively less common. This monotonic shift toward higher triage severity indicates that triage systems do recognize the increased urgency and complexity of older patients at presentation. This pattern reinforces the limitations of acuity-based stratification. Our findings, therefore, support a nuanced interpretation: triage identifies part of the vulnerability signal in older adults, but substantial complexity remains unmeasured and emerges later in the care trajectory.

Seasonal variation in patient volume and age composition further contextualizes these findings. Older adults accounted for a higher proportion of ED presentations during colder months, consistent with known seasonal vulnerabilities related to cardiovascular and respiratory conditions. Population aging has been identified as a key amplifier of temperature-related morbidity and mortality, increasing susceptibility to both cold- and heat-related stressors [17]. Although our data do not allow causal attribution to climate change, these predictable seasonal patterns underscore the importance of anticipating how demographic aging may interact with environmental stressors to intensify future emergency care demand. System resilience must therefore adapt not only to long-term demographic shifts but also to recurrent seasonal pressures that disproportionately affect older adults [18, 19].

An important clinical implication of prolonged ED LOS in older adults is the increased risk of delirium. Delirium represents a prototypical manifestation of reduced brain resilience, in which diminished cognitive reserve renders patients disproportionately sensitive to environmental and physiological stressors [12, 20]. Prolonged ED stays expose older adults to multiple delirium precipitants, including environmental disorientation, sleep disruption, immobilization, sensory overload, and polypharmacy. Delirium has been associated with prolonged ED LOS and may impair communication, attention, and engagement with diagnostic and disposition processes [21, 22] Beyond short-term morbidity, even short-term delirium has been associated with accelerated functional decline, institutionalization, and increased mortality, positioning it as a key mediator linking acute care processes to long-term aging outcomes [23, 24]. Preexisting cognitive vulnerability may prolong ED trajectories through increased monitoring and care complexity, while prolonged ED exposure itself may precipitate delirium in susceptible patients. In this context, delirium could be best viewed not as a single causal pathway but as part of a bidirectional process linking vulnerability and extended length of stay.

Taken together, these findings portray an emergency care system increasingly shaped by the biological and functional consequences of aging. Quantifying age-related prolongation of ED LOS provides a measurable index of how aging affects not only individual patients but also the operational performance of acute care systems. LOS may therefore serve as an integrative marker for unmeasured geriatric syndromes such as frailty and delirium, which are incompletely captured by standard triage systems but exert substantial influence on care trajectories.

Within aging trajectories, ED length of stay is best interpreted as a system-level risk marker rather than a surrogate outcome. Prolonged LOS reflects how age-related vulnerability and declining resilience become operationally visible during acute care, shaped by the interplay of patient complexity and organizational constraints. Importantly, this vulnerability is not fully captured by initial triage acuity but emerges dynamically over the course of emergency care, particularly in lower acuity presentations where diagnostic uncertainty and disposition complexity dominate.

Clinical implications

Integrating brief frailty or vulnerability screening at triage may help identify older patients at risk of prolonged ED trajectories, even when initial acuity appears low, thereby supporting earlier geriatric consultation, targeted diagnostic pathways, and proactive delirium prevention strategies.

Second, our results suggest that ED length of stay should be reframed as a system operational marker of vulnerability rather than interpreted solely as an efficiency or throughput metric. Prolonged LOS in older adults reflects not only workflow inefficiencies but also the cumulative burden of biological aging, multimorbidity, cognitive vulnerability, and care coordination needs. At the system level, age-stratified LOS patterns provide a measurable signal of how vulnerability loads the emergency department and interacts with operational pressures such as crowding and diagnostic capacity, with potential relevance for surge planning, workforce allocation, and quality improvement. In this context, disproportionate LOS prolongation among older adults within comparable triage categories may signal structural mismatches between patient needs and existing diagnostic, consultation, or disposition workflows, rather than inefficiency alone.

Limitations

Nevertheless, alternative analytic strategies, including competing-risk or time-dependent models, might yield complementary insights in settings with different data structures. Although we conducted sensitivity analyses excluding ED deaths to address potential competing-risk effects, residual bias related to disposition processes cannot be fully excluded.

In addition, several operational and clinical factors were only partially captured or unavailable in the dataset. Measures of laboratory, imaging, and consultation intensity; time-varying clinical instability; and dynamic decision-making processes during the ED encounter were not explicitly modeled and may contribute to prolonged LOS, particularly in older adults. While we adjusted for multiple operational covariates in sensitivity analyses, including time of day, weekday versus weekend presentation, number of diagnoses, and daily ED census, unmeasured time-varying confounders related to disease severity and care processes may remain.

Although diagnosis counts and repeat ED visits were available, these variables were not intended as validated proxy measures of frailty or biological aging and were therefore not used to construct composite vulnerability indices.

Although diagnosis counts and repeat ED visits were available, these variables were not intended as validated proxies for frailty or biological aging and were therefore not used to construct composite vulnerability indices.

As a single-center study conducted within a specific healthcare system, the magnitude of observed effects may vary across EDs with different case mixes, organizational structures, and access to inpatient resources. However, the large sample size, long observation period, and consistency of age-related LOS effects across triage categories and analytic approaches strengthen the robustness of our findings. The persistence of age-related LOS prolongation within fixed triage strata suggests that unmeasured vulnerability, rather than residual confounding alone, is a plausible underlying driver of the observed associations.

Further directions

Building on these findings, we plan a prospective study that incorporates standardized frailty and delirium screening in older ED patients. By directly measuring baseline vulnerability and cognitive status, such a design will allow examination of whether frailty mediates the observed age-related prolongation of LOS and whether LOS independently predicts incident delirium. Linking operational metrics to real-time measurements of geriatric syndromes may clarify causal pathways between biological aging, emergency care processes, and short-term cognitive outcomes. International consensus now supports early identification of frailty in emergency care and emphasizes the need to act on frailty findings during the index visit [20].

Conclusion

In this large retrospective cohort of more than 188,000 emergency department encounters, ED length of stay increased progressively with advancing age and remained independently associated with age after accounting for triage acuity, sex, and season. Although triage severity shifted toward higher acuity among older patients, the persistence of age-related LOS prolongation across all triage categories indicates that acuity-based assessment does not fully capture aging-related vulnerability or the downstream complexity of emergency care trajectories.

From a geroscience perspective, these findings are consistent with aging-related declines in physiological and cognitive resilience and suggest that ED length of stay may reflect a routinely observable, system-level signal of vulnerability beyond triage alone. In this sense, emergency care trajectories may function as real-world stress tests of biological resilience, revealing how aging-related reductions in reserve manifest during acute health stressors. Recognizing ED LOS as a vulnerability-sensitive operational metric may therefore help align emergency care evaluation with the realities of population aging and support earlier identification of patients who may benefit from targeted geriatric assessment and care pathways.

Prospective studies incorporating direct measures of frailty, cognitive vulnerability, and functional reserve are needed to clarify the mechanisms underlying age-related LOS prolongation and to determine how emergency care systems can better adapt to the growing burden of aging-related vulnerability. Comparative analyses across healthcare systems may further help determine whether populations experiencing accelerated or unhealthy aging exhibit steeper age-related gradients in ED LOS or earlier divergence within triage categories.

Author contribution SG contributed to the conception of the study, acquisition and interpretation of data, and drafted the manuscript. DM contributed to the conception of the study, the interpretation of results, and the critical revision of the manuscript. KÁ contributed to the interpretation of results and the critical revision of the manuscript. DG was involved in data acquisition and contributed to manuscript revision. BSi contributed to data acquisition, statistical analysis, and interpretation of results. BSz contributed to study conception, data acquisition, analysis, interpretation, and manuscript revision. CV contributed to the conception of the study and critically revised the manuscript. All authors have read and approved the final version of the manuscript. They agree to be personally accountable for their own contributions and to ensure that any questions regarding the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding This work has been implemented by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014) project within the framework of Hungary's National Recovery and Resilience Plan supported by the Recovery and Resilience Facility of the European Union. Szabolcs Gaal-Marschal reports that financial support was provided by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014). Csaba Varga, MD, PhD, reports that financial support was provided by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014). Brigitta Szilagyi reports that financial support was provided by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014). Dora Melicher reports that financial support was provided by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014). Bence Sipos reports that financial support was provided by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014).

Data availability The datasets generated and/or analysed during the current study are not publicly available due to institutional and data protection regulations. Still, they are available from the corresponding author on reasonable request. The availability is subject to approval by the relevant institutional authorities.

Declarations

Conflict of interest The authors declare no competing interests.

Ethics approval This study was conducted in accordance with the ethical standards of the Declaration of Helsinki. It was approved by the Scientific and Research Ethics Committee of Semmelweis University (SE RKEB) under approval number 198-1/2021. As this was a retrospective analysis of anonymized patient data collected for routine clinical purposes, informed consent was not required according to national regulations and institutional guidelines. All data were de-identified prior to analysis to ensure patient confidentiality. This manuscript adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational research.

References

1. Colon-Emeric C, Schmader K, Cohen HJ, Morey M, Whitson H. Ageing and physical resilience after health stressors. Stress Health. 2023. https://doi.org/10.1002/smi.3241.
2. do Nascimento Rocha HM, da Costa Farre AGM, de Santana Filho VJ, Blackwell Publishing Ltd. Adverse events in emergency department boarding: a systematic review. J Nurs Scholarsh. 2021;53:458–67. https://doi.org/10.1111/jnu.12653.
3. Burgess L, Ray-Barruel G, Kynoch K. Association between emergency department length of stay and patient outcomes: a systematic review. Res Nurs Health. 2022;45(1):59–93. https://doi.org/10.1002/NUR.22201.
4. Boudi Z, Lauque D, Alsabri M, Östlundh L, Oneyji C, Khalemsky A, et al. Association between boarding in the emergency department and in-hospital mortality: a systematic review. PLoS ONE. 2020;15:e0231253. https://doi.org/10.1371/journal.pone.0231253.
5. Iozzo P, Spina N, Cannizzaro G, Gambino V, Patinella A, Bambi S, et al. Association between boarding of frail individuals in the emergency department and mortality: a systematic review. J Clin Med. 2024;13:1269. https://doi.org/10.3390/jcm13051269.
6. Alnahari A, A'aqoulah A. Influence of demographic factors on prolonged length of stay in an emergency department. PLoS One. 2024;19:e0298598. https://doi.org/10.1371/journal.pone.0298598.
7. Takeda C, Angioni D, Setphan E, Macaron T, De Souto Barreto P, Sourdet S, et al. Age-related frailty: a clinical model for geroscience? J Nutr Health Aging. 2020;24:1140–3. https://doi.org/10.1007/s12603-020-1491-4.
8. Kaeppeli T, Rueegg M, Dreher-Hummel T, Brabrand M, Kabell-Nissen S, Carpenter CR, et al. Validation of the clinical frailty scale for prediction of thirty-day mortality in the emergency department. Ann Emerg Med. 2020;76:291–300. https://doi.org/10.1016/j.annemergmed.2020.03.028.
9. Lucke JA, Mooijaart SP, Heeren P, Singler K, McNamara R, Gilbert T, et al. Providing care for older adults in the emergency department: expert clinical recommendations from the European Task Force on Geriatric Emergency Medicine. Eur Geriatr Med. 2021;13(2):309–17. https://doi.org/10.1007/s41999-021-00578-1.
10. Ku N-W, Hsu Y-C, Mudhur J, Li J, Jebanesan N, Abrahamyan L, et al. The prognostic accuracy of frailty and vulnerability screening for older adults in the emergency department: a systematic review and meta-analysis. Ann Emerg Med. 2025;86:496–510. https://doi.org/10.1016/j.annemergmed.2025.05.018.
11. Wu L, Chen X, Khalemsky A, Li D, Zoubeidi T, Lauque D, et al. The association between emergency department length of stay and in-hospital mortality in older patients using machine learning: an observational cohort study. J Clin Med. 2023. https://doi.org/10.3390/jcm12144750.
12. Romero-Ortuno R, Wallis S, Biram R, Keevil V. Clinical frailty adds to acute illness severity in predicting mortality in hospitalized older adults: an observational study. Eur J Intern Med. 2016;35:24–34. https://doi.org/10.1016/j.ejim.2016.08.033.
13. van Oppen JD, Mooijaart S, Nickel CH, Conroy S. Considering frailty and meaningful outcomes in geriatric emergency care. Intern Emerg Med. 2025;20(6):1973–5. https://doi.org/10.1007/s11739-025-03940-4.
14. van Oppen JD, Coats TJ, Conroy SP, Lalseta J, Phelps K, Regen E, et al. What matters most in acute care: an interview study with older people living with frailty. BMC Geriatr. 2022;22(1):156. https://doi.org/10.1186/s12877-022-02798-x.
15. Elliott A, Taub N, Banerjee J, Aijaz F, Jones W, Teece L, et al. Does the clinical frailty scale at triage predict outcomes from emergency care for older people? Ann Emerg Med. 2021;77(6):620–7. https://doi.org/10.1016/j.annemergmed.2020.09.006.
16. Chaou C-H, Chen H-H, Chang S-H, Tang P, Pan S-L, Ming-Fang Yen A, et al. Predicting length of stay among patients discharged from the emergency departmentusing an accelerated failure time model. PLoS One. 2017. https://doi.org/10.1371/journal.pone.0165756.
17. Gamble JL, Hurley BJ, Schultz PA, Jaglom WS, Krishnan N, Harris M. Climate change and older Americans: state of the science. Environ Health Perspect. 2013. https://doi.org/10.1289/ehp.1205223.
18. Chen K, de Schrijver E, Sivaraj S, Sera F, Scovronick N, Jiang L, et al. Impact of population aging on future temperature-related mortality at different global warming levels. Nat Commun. 2024. https://doi.org/10.1038/s41467-024-45901-z.
19. Montoro-Ramírez ME, Parra-Anguita L, Álvarez-Nieto C, Parra G, López-Medina MI. Climate change effects in older people's health: a scoping review. J Adv Nurs. 2024. https://doi.org/10.1111/jan.16270.
20. van Oppen JD, Mason S. Frailty screening in the emergency department: why does it matter? Age Ageing. 2024. https://doi.org/10.1093/ageing/afae056.
21. Oliveira J. e Silva L, Stanich JA, Jeffery MM, Lindroth HL, Miller DM, Campbell RL, et al. Association between emergency department modifiable risk factors and subsequent delirium among hospitalized older adults. Am J Emerg Med. 2022;53:201–7. https://doi.org/10.1016/J.AJEM.2021.12.032.
22. Oliveira J. e Silva L, Berning MJ, Stanich JA, Gerberi DJ, Murad MH, Han JH, et al. Risk factors for delirium in older adults in the emergency department: a systematic review and meta-analysis. Ann Emerg Med. 2021;78:549–65. https://doi.org/10.1016/j.annemergmed.2021.03.005.

23. Giroux M, Émond M, Nadeau A, Boucher V, Carmichael P-H, Voyer P, et al. Functional and cognitive decline in older delirious adults after an emergency department visit. Age Ageing. 2021;50(1):135–40. https://doi.org/10.1093/ageing/afaa128.
24. Pérez-Ros P, Plaza-Ortega N, Francisco |, Martínez-Arnau M. Worldviews on evidence-based nursing mortality risk following delirium in older inpatients: a systematic review and meta-analysis. Worldviews Evid Based Nurs [Internet]. 2025 [cited 2026 Jan 11];22:70027. https://doi.org/10.1111/wvn.70027

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.