Research Square

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Impact of system shocks on pediatric prehospital time performance: a nationwide EMS registry study from South Korea

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Research Article

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Abstract

Background

Health system crises, such as pandemics and workforce disruptions, can compromise emergency medical services capacity and time performance, and pediatric patients may be particularly vulnerable to these system-level disruptions. We assessed how the COVID-19 pandemic and the 2024 workforce crisis were associated with pediatric prehospital time performance and whether crisis-related changes differed between pediatric and adult transports.

Methods

We conducted a retrospective observational study using nationwide ambulance transport records from South Korea's National Fire Agency (2019–2024). Pediatric patients (< 18 years) transported between March and December of each year were included; adult transports (≥ 18 years) served as a comparator. Prespecified exposure periods were the COVID-19 pandemic (March 2020–April 2023) and the workforce crisis (March–December 2024). Outcomes were response, scene, transport, and total prehospital time intervals. We performed descriptive comparisons, interrupted time-series regression of monthly mean scene time to estimate level and trend changes at crisis onset, and difference-in-differences models to compare pediatric versus adult changes with covariate adjustment.

Results

A total of 636,495 pediatric transports were analyzed. After COVID-19 onset, all prehospital time intervals increased, peaked in 2021–2022, and improved in 2023. During the 2024 workforce crisis, total prehospital time increased again, driven predominantly by a subsequent increase in scene time, while other components showed less consistent worsening. This scene-time–dominant pattern was consistent across major pediatric chief complaint categories. In interrupted time-series analysis, COVID-19 onset was associated with an immediate increase in monthly mean scene time (1.88 minutes; 95% confidence interval 0.57–3.18), with no significant slope change thereafter. At the onset of the workforce crisis, no significant level or slope change in scene time was detected. In difference-in-differences analyses, scene time prolongation during both crises was similar in pediatric and adult transports.

Conclusions

Both crises were associated with prolonged pediatric prehospital times, largely driven by increased scene time. Similar pediatric–adult changes suggest system-wide strain affecting the interface between ambulance services and receiving hospitals, supporting crisis-responsive planning and routine monitoring of pediatric prehospital time performance.

Trial registration:

Not applicable.

Background

Emergency medical services (EMS) time performance is a core indicator of prehospital care quality and a pragmatic marker of system resilience. Large-scale health system shocks can compromise EMS capacity and time performance by altering care-seeking behavior, field workflow, and destination availability, producing measurable changes in response, scene, transport, and total prehospital time intervals. During the COVID-19 pandemic, multiple EMS systems reported changes in transport volume, prolongation of prehospital time intervals, and increased non-transport or difficulty in hospital acceptance, collectively indicating operational strain under crisis conditions [1–4].

Pediatric prehospital emergency care warrants specific attention because children have distinct physiology and a narrower clinical reserve than adults, making timely recognition, stabilization, and access to definitive care particularly important [5–7]. Evidence from pediatric time-sensitive emergencies, including out-of-hospital cardiac arrest, suggests that prehospital time intervals—especially scene time—are associated with survival and neurologic outcomes, implying that crisis-related deterioration in time performance may have clinically meaningful consequences for pediatric patients [8–10].

In Korea and other Asian settings, nationwide studies have described pediatric EMS utilization patterns, and standardized reporting frameworks such as the Utstein templates underscore the importance of consistent definitions for prehospital time intervals in resuscitation research [11–13]. However, it remains unclear how distinct crisis mechanisms—such as an infectious disease emergency versus a workforce-related

disruption—translate into changes in pediatric prehospital time performance within the same national EMS system. Moreover, few studies have directly tested whether crisis-associated changes in key time intervals differ between pediatric and adult transports, limiting inference about pediatric-specific vulnerability versus system-wide strain.

South Korea experienced two temporally distinct disruptions that plausibly threatened EMS time performance: the COVID-19 pandemic and a workforce-related crisis in 2024. Workforce disruptions have been associated with impaired hospital performance and may constrain emergency department capacity and acceptance, potentially affecting EMS destination decision-making and prehospital time intervals [14–15]. Therefore, we evaluated the association of these two crises with pediatric prehospital time intervals using nationwide ambulance transport data and assessed whether crisis-related changes differed between pediatric and adult transports using a Difference-in-Differences framework.

Methods

Aim and study design

We conducted a retrospective observational study to evaluate how two distinct health system crises (the COVID-19 pandemic and a workforce-related crisis in 2024) were associated with pediatric prehospital time performance in a national emergency medical services (EMS) system and whether crisis-related changes differed between pediatric and adult transports.

Data source, setting, and ethics

This study used the nationwide 119 EMS registry operated by the National Fire Agency (NFA) in South Korea. South Korea's 119 EMS is a single, publicly operated national EMS system. The registry contains patient demographics, EMS-recorded field triage category and chief complaint, and electronically captured timestamps for key phases of prehospital care[3].

The protocol was approved by the Institutional Review Board of CHA Bundang Medical Center (CHAMC 2025-05-018). Informed consent was waived because de-identified secondary data were used. The NFA authorized use of the registry for research.

Participants and study period

We included pediatric patients (< 18 years) transported to hospital by ambulance between March 1 and December 31 of each year from 2019 through 2024 to ensure seasonal comparability. Non-transport encounters were excluded. Records with missing timestamps required to calculate prehospital time intervals were excluded. For comparative analyses, adult transported encounters (≥ 18 years) from the same calendar windows were included as a comparator group.

Exposure periods and comparisons

We prespecified two crisis exposure periods: the COVID-19 period (March 1, 2020–April 30, 2023) and the workforce crisis period (March 1–December 31, 2024). For Difference-in-Differences (DID) analyses, pre–post comparisons were defined as March–December 2019 versus March 2020–April 2023 for the pandemic, and May–December 2023 versus March–December 2024 for the workforce crisis.

Variables

Patient-level variables included age and sex. Operational timing variables included weekday/weekend and daytime (09:00–18:00) versus nighttime (18:00–09:00). Clinical and field variables included EMS-recorded reason for transport (disease vs non-disease), field triage category, and chief complaint. Metropolitan region was coded as a binary variable.

Outcomes (prehospital time intervals)

Primary outcomes were prehospital time intervals derived from EMS timestamps: response time interval (RTI; call receipt to scene arrival), scene time interval (STI; scene arrival to scene departure), transport time interval (TTI; scene departure to hospital arrival), and total prehospital time interval (PTI; RTI + STI + TTI) [3].

Statistical analysis

Categorical variables were summarized as counts and percentages and compared using the chi-square test. Continuous variables were summarized as means with standard deviations and compared using the t-test (two groups) or analysis of variance (multiple groups), as appropriate.

To evaluate temporal changes associated with each crisis, we performed interrupted time-series regression of monthly mean STI, estimating level and slope changes at each crisis onset and accounting for autocorrelation using an AR(1) error structure.

For DID analyses, STI at the individual transport level was modeled with terms for period (pre vs post), age group (pediatric vs adult), and their interaction, with adjustment for prespecified covariates (age, sex, weekday/weekend, daytime/nighttime, and metropolitan region). Robust (sandwich) standard errors were used for inference. Two-sided P values < 0.05 were considered statistically significant.

Because all eligible encounters within the study windows were included, no a priori sample size or power calculation was performed. Analyses were conducted using SAS Studio (SAS Institute Inc., Cary, NC, USA). Reporting followed the STROBE guidelines.

Role of funding

No external funding was received. No sponsor had any role in study design, analysis, interpretation, or reporting.

Results

From March 1 to December 31 of each year (2019–2024), 14,103,606 EMS activations were recorded nationwide, of which 9,457,764 (67.1%) resulted in patient transport. Among transported encounters, 636,495 (6.7%) involved pediatric patients (<18 years). Pediatric transport volume decreased in 2020, recovered through 2023, and decreased again in 2024. Cohort derivation is shown in **Figure 1**.

Baseline characteristics across study periods are summarized in **Table 1**. Compared with the pre–COVID-19 period, the pediatric age distribution shifted toward older age groups during the early pandemic and the workforce crisis, and field triage patterns differed across periods, with fewer encounters categorized as “emergency” during the workforce crisis (**Table 1**).

Prehospital time intervals by period are presented in **Table 2**, and temporal trends are illustrated in **Figure 2**. Following the onset of COVID-19, RTI, STI, TTI, and PTI increased, peaking during 2021–2022 and improving in 2023. During the workforce crisis, STI increased again, with a corresponding increase in PTI (**Table 2**; **Figure 2**). Time intervals stratified by major pediatric chief complaints are provided in **Supplementary Table S1**(Additional file 1); the temporal pattern of STI was consistent across complaint categories (**Supplementary Table S1**(Additional file 1)).

Interrupted time-series analysis demonstrated changes in STI associated with crisis onset (**Table 3**). At the start of the COVID-19 pandemic, there was a significant immediate increase in monthly mean STI (1.88 minutes; 95% CI 0.57–3.18; p = 0.007), with no significant slope change during the pandemic period (p = 0.788). At the onset of the workforce crisis, the immediate STI change was not significant (0.52 minutes; 95% CI −0.84 to 1.88; p = 0.460), and the subsequent slope change was also not significant (p = 0.201).

Difference-in-differences estimates for STI are summarized in **Table 4**. The pediatric–adult difference in STI change was not significant during either crisis (COVID-19: DID 0.01 minutes, p = 0.85; workforce crisis: DID 0.00 minutes, p = 0.96). Models were adjusted for prespecified covariates available in the registry (age, sex, day of week, time of day, and metropolitan region; Table 4). A parallel visual comparison is shown in **Supplementary Figure S1**(Additional file 2).

Discussion

Prehospital EMS time performance is a sensitive indicator of system resilience because it integrates demand, field workflow, and access to receiving facilities under time pressure. During the COVID-19 pandemic, multiple EMS systems reported changes in transport volume, prolonged prehospital time intervals, and increased non-transport or difficulty in hospital acceptance, collectively suggesting operational strain during infectious disease emergencies [1–4, 17]. Similarly, workforce-related disruptions—including physician strikes—have been associated with adverse effects on hospital performance and emergency care delivery, supporting the premise that workforce shocks can destabilize acute care pathways [15]. Building on this literature, our nationwide analysis suggests that distinct crisis mechanisms can be associated with measurable changes in pediatric prehospital time performance within a single national EMS system.

A key finding was that prehospital time intervals worsened after COVID-19 onset, peaked in 2021–2022, and improved in 2023, followed by a subsequent increase in total prehospital time during the 2024 workforce crisis that was driven predominantly by scene time. ITS models were consistent with an abrupt disruption at the onset of the COVID-19 pandemic, whereas we did not detect a statistically significant step or slope change at the prespecified onset of the 2024 workforce crisis. This discrepancy should be interpreted in light of how “onset” was operationalized. Unlike the pandemic, which had a clearer system-wide inflection early in 2020, workforce-related disruptions may evolve over weeks to months, vary by region and facility, and manifest as cumulative operational friction rather than an immediate, discrete shift. Accordingly, a period-level increase in scene time can coexist with an ITS model that does not identify a sharp discontinuity at a single start date, underscoring the importance of considering gradual or staggered disruption patterns when interpreting time-series signals.

Our Difference-in-Differences analyses provide additional context: crisis-associated scene time prolongation was similar in pediatric and adult transports in both crises, suggesting system-wide strain rather than a pediatric-specific operational effect. This finding supports the interpretation that delays during health system disruptions may concentrate at the EMS–hospital interface—where destination selection, acceptance, and handover constraints can prolong the scene phase and propagate into total prehospital time—rather than arising primarily from pediatric care processes alone[18]. Consistent patterns across major pediatric chief complaint categories further reinforce a broadly shared operational mechanism rather than diagnosis-specific delays.

Although pediatric-specific operational effects were not evident in the DID comparisons, pediatric patients may be particularly vulnerable to the clinical consequences of delay. Prior pediatric out-of-hospital cardiac arrest studies have linked scene time and other prehospital intervals with survival and neurologic outcomes, suggesting that both very short and prolonged on-scene times may be harmful and that the therapeutic window for scene management may be narrower in children [8–10]. In addition, pediatric trauma studies have reported systematic differences in prehospital scene and transport times between pediatric and adult patients [16]. Therefore, even when absolute delays are comparable across age groups, system-wide deterioration in time performance may carry disproportionate risk for pediatric patients depending on case mix and acuity distribution.

Several practical implications follow. First, preparedness planning should prioritize scene-phase processes that tend to expand under system strain, including operationally feasible pediatric assessment and stabilization pathways and clear guidance for destination decision-making when hospital acceptance is constrained[18]. Second, routine performance surveillance that includes pediatric scene time and total prehospital time may enable earlier detection of emerging system stress, irrespective of whether the trigger is an infectious disease emergency or a workforce disruption. Third, strengthening coordination mechanisms between EMS and receiving hospitals—particularly around acceptance, diversion, and handover—may reduce the likelihood that downstream constraints translate into prolonged scene time and increased total prehospital time during future crises[18].

Limitations

Several limitations warrant consideration. First, we analyzed transported encounters only; non-transport activations and repeat contacts were not captured, which may underestimate crisis-related changes in overall pediatric EMS demand and utilization patterns [17]. Second, time intervals were derived from routine EMS timestamps and the registry lacked granular measures of EMS–hospital interface processes (e.g., receiving-hospital acceptance delay, diversion/refusal events, and handover duration), limiting mechanistic attribution of scene-time prolongation [18]. Third, causal inference is limited by the observational design and unverifiable ITS/DID assumptions (including parallel trends), and gradual or heterogeneous workforce disruption may not be well represented by a single onset date. Finally, findings from a single national EMS system may not generalize to settings with different dispatch, staffing, or hospital access pathways.

Conclusion

In this national EMS system, both the COVID-19 pandemic and the 2024 workforce-related crisis were associated with worsening pediatric prehospital time performance, driven primarily by increased scene time and reflected in longer total prehospital time. These findings suggest system-wide strain at the EMS–hospital interface and support crisis-responsive strategies that routinely monitor pediatric time metrics, minimize avoidable on-scene delays when hospital capacity is constrained, and link EMS-to-hospital data to quantify clinical impact and identify modifiable targets for resilience.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of CHA Bundang Medical Center (CHAMC 2025-05-018), and the requirement for informed consent was waived due to the retrospective use of de-identified data. All methods were carried out in accordance with the Declaration of Helsinki and relevant guidelines and regulations. Data access and use were authorized by the National Fire Agency (NFA) of South Korea.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study were obtained from the National Fire Agency (NFA) of South Korea under permission for research use. The data are not publicly available due to data governance restrictions. Access may be considered by the NFA upon reasonable

request and with appropriate approvals.

Competing interests

The authors declare that they have no competing interests.

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This research did not receive external funding.

Authors' contributions

MJK and HSM contributed equally to this work and share first authorship. MJK, HSM, and SHP contributed to the study conception and design. MJK and HSM contributed to data acquisition and interpretation. MJK performed the statistical analyses and drafted the initial manuscript. HSM and SHP critically reviewed and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Tables

Table 1. Baseline characteristics across study periods (Panel A: demographics; Panel B: EMS and clinical)

	Pre COVID-19	**COVID-19 pandemic**				**Before resignation**	**After resignation**	**P-value**
	2019	**2020**	**2021**	**2022**	**2023**	**2023**	**2024**	
	Mar-Dec	**Mar-Dec**	**Mar-Dec**	**Mar-Dec**	**Mar–Apr**	**May–Dec**	**Mar-Dec**	
	112,527	**72,637**	**93,087**	**125,180**	**27,134**	**107,328**	**98,602**	
Age,years,median (IQR)	4(2-5)	4(3-5)	4(2-5)	4(2-5)	3(2-5)	2(2-3)	4(2-5)	<0.01
Age group								<0.01
Infant	6,665(5.9)	5,204(7.2)	6,469(7.0)	11,592(9.3)	2,210(8.1)	8,727(8.1)	6,871(7.0)	
Toddler	28,052(24.9)	12,706(17.5)	17,943(19.3)	27,953(22.3)	7,559(27.9)	22,383(20.9)	18,597(18.9)	
Preschool	18,548(16.5)	10,210(14.1)	13,034(14.0)	19,293(15.4)	4,806(17.7)	19,215(18.0)	12,222(12.4)	
School-age	26,897(23.9)	18,266(25.2)	24,045(25.8)	30,052(24.0)	5,509(20.3)	25,507(23.8)	25,588(26.0)	
Adolescent	32,365(28.8)	26,251(36.1)	31,596(33.9)	36,290(29.0)	7,050(26.0)	31,496(29.4)	35,324(35.8)	
Female	45,516(40.5)	29,559(40.7)	38,621(41.5)	51,113(40.8)	11,393(42.0)	44,258(41.2)	38,826(39.4)	<0.01
Daytime	61,876(55.0)	41,827(57.6)	53,733(57.7)	66,704(53.3)	14,002(51.6)	57,374(53.5)	54,607(55.4)	<0.01
Weekdays	79,584(70.7)	52,416(72.2)	66,390(71.3)	88,089(70.4)	18,723(69.0)	75,747(70.6)	68,919(70.0)	<0.01

Values are presented as n (%) unless otherwise specified. Age is presented as median (IQR).

Pandemic period: March 2020–April 2023; Resignation period: March 2024–December 2024.

Table 1. Baseline characteristics across study periods (Panel A: demographics; Panel B: EMS and clinical)

	Pre COVID-19	COVID-19 pandemic				Before resignation	After resignation	P-value
2019	**2020**	**2021**	**2022**	**2023**	**2023**	**2024**		
Mar-Dec	**Mar-Dec**	**Mar-Dec**	**Mar-Dec**	**Mar–Apr**	**May–Dec**	**Mar-Dec**		
112,527	**72,637**	**93,087**	**125,180**	**27,134**	**107,328**	**98,602**		
Disease	59,311(52.7)	34,497(47.5)	51,227(55.0)	77,854(62.2)	17,777(65.5)	68,178(63.5)	52,767(53.5)	<0.01
Field Triage								<0.01
Emergency	27,071(24.1)	14,866(20.5)	17,851(19.2)	26,717(21.3)	6,385(23.5)	25,718(24.0)	10,111(10.3)	
Sub-emergency	35,353(31.4)	22,337(30.8)	27,821(29.9)	40,653(32.5)	9,091(33.5)	36,308(33.8)	23,122(23.5)	
Non-emergency (Latency-emergency)	48,831(43.4)	33,729(46.4)	42,789(46.0)	56,617(45.2)	11,493(42.4)	44,562(41.5)	64,893(65.8)	
Death	47(0.0)	40(0.1)	33(0.0)	40(0.0)	5(0.0)	42(0.0)	31(0.0)	
Others	1,225(1.1)	1,665(2.3)	4,593(4.9)	1,153(0.9)	160(0.6)	698(0.7)	445(0.5)	

Values are presented as n (%)

Pandemic period: March 2020–April 2023; Resignation period: March 2024–December 2024.

Table 2. Prehospital time intervals among transported pediatric patients, 2019–2024

Time intervals, min	Pre COVID-19	COVID-19 pandemic				Before resignation	After resignation
	2019 Mar-Dec	**2020 Mar-Dec**	**2021 Mar-Dec**	**2022 Mar-Dec**	**2023 Mar–Apr**	**2023 May-Dec**	**2024 Mar-Dec**
RTI	8.23±6.77	10.38±9.78	14.35±19.27	10.49±7.17	9.31±6.11	9.45±6.08	9.45±6.40
STI	5.78±6.12	7.56±7.67	8.22±8.24	9.80±9.62	8.40±7.06	8.07±7.01	10.30±9.26
TTI	12.58±10.18	14.48±13.41	18.72±19.03	16.64±14.61	15.40±12.45	15.18±12.50	15.52±13.97
PTI	26.55±14.58	32.73±20.00	41.17±33.18	36.89±20.75	33.09±16.63	32.66±16.67	35.23±19.26

Values are presented as mean ± standard deviation (minutes).

RTI = response time interval; STI = scene time interval; TTI = transport time interval; PTI = total prehospital time interval.

Table 3. Interrupted time-series regression of monthly mean scene time interval (STI), 2019–2024

Variable	Estimate	95% CI (Lower-Upper)	p-value
Intercept	5.61	4.45 - 6.78	<0.0001
Time (months)	0.04	-0.10 - 0.18	0.574
COVID-19 step	1.88	0.57 - 3.18	0.007
COVID-19 slope	-0.02	-0.16 - 0.12	0.788
Resignation step	0.52	-0.84 - 1.88	0.460
Resignation slope	0.15	-0.08 - 0.38	0.201

Model accounted for autocorrelation using an AR(1) error structure. Dependent variable was monthly mean STI (minutes). CI = confidence interval.

Table 4. Summary of Difference-in-Differences (DID) analysis for scene time interval (STI) (pediatric vs adult)

Comparison Group	Mean Before (min)	Mean After (min)	Change (min)	DID Effect (Pediatric vs Adult)
Pre–COVID-19 vs COVID-19 period , Adult	11.34	13.10	+1.76	-
Pre–COVID-19 vs COVID-19 period , Pediatric	11.85	13.63	+1.78	+0.01(P = 0.850)
Before resignation vs resignation , Adult	10.13	12.23	+2.10	-
Before resignation vs resignation , Pediatric	9.99	12.09	+2.10	0.00(P = 0.960)

Values are presented as mean STI (minutes). Pre and post periods were defined as follows: COVID-19 (pre: Mar–Dec 2019; post: Mar 2020–Apr 2023) and resignation (pre: May–Dec 2023; post: Mar–Dec 2024). DID models were adjusted for age, sex, weekday/weekend, daytime/nighttime, and metropolitan region (binary). DID = Difference-in-Differences; STI = scene time interval.

Figures

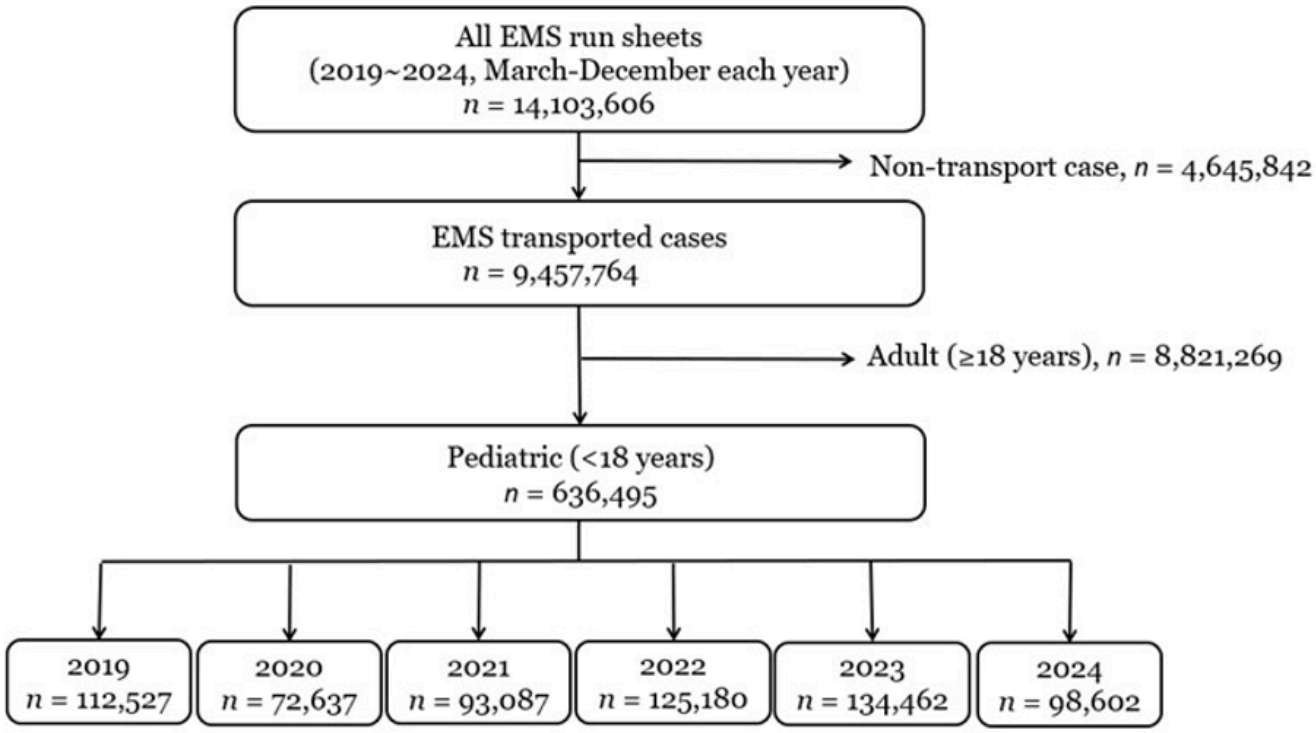


Figure 1

Flow diagram of the study cohort of pediatric EMS transports between 2019 and 2024.

The figure shows all 119 EMS incidents recorded in the national registry, the subset resulting in transport, exclusion of non-transport encounters and records with missing timestamps required to compute prehospital intervals, and the final pediatric cohort (<18 years).

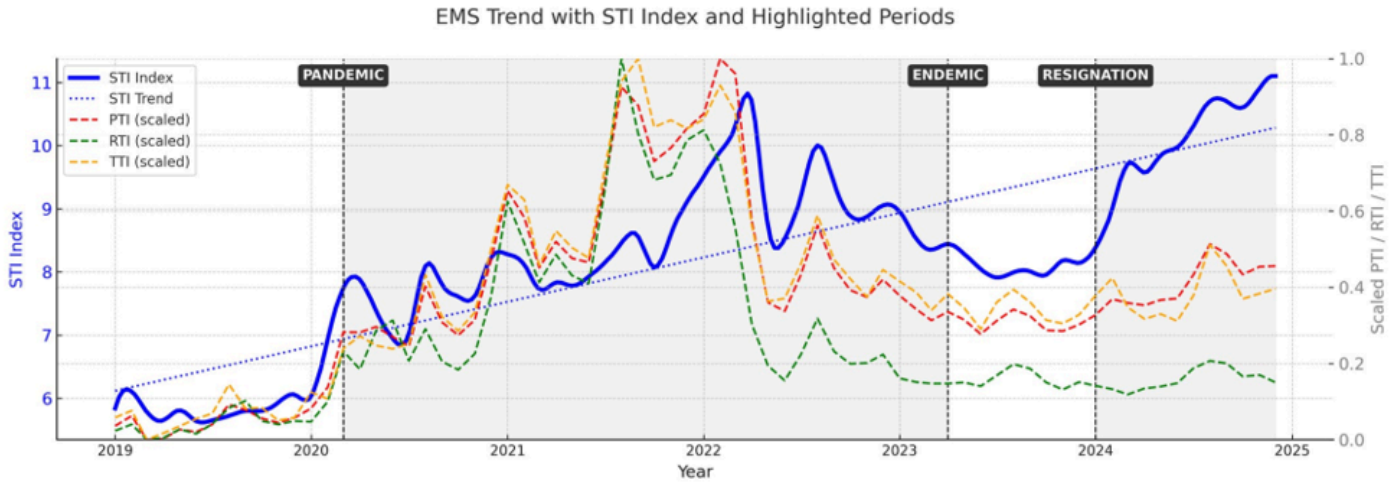


Figure 2

Annual trends in pediatric prehospital time intervals from 2019 to 2024.

Lines show yearly mean values for response time interval (RTI), scene time interval (STI), transport time interval (TTI), and total prehospital time interval (PTI) among pediatric transports.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1TableS1.docx
- Additionalfile2FigureS1.tif