Throughput delays: causes, predictors, and outcomes – observational cohort in a Swiss emergency department

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Summary

BACKGROUND: Optimal throughput times in emergency departments can be adjudicated by emergency physicians. Emergency physicians can also define causes of delays during work-up, such as waiting for imaging, clinical chemistry, consultations, or exit blocks. For adequate streaming, the identification of predictors of delays is important, as the attribution of resources depends on acuity, resources, and expected throughput times.

OBJECTIVE: This observational study aimed to identify the causes, predictors, and outcomes of emergency physician-adjudicated throughput delays.

METHODS: Two prospective emergency department cohorts from January to February 2017 and from March to May 2019 around the clock in a tertiary care centre in Switzerland were investigated. All consenting patients were included. Delay was defined as the subjective adjudication of the responsible emergency physician regarding delay during emergency department work-up. Emergency physicians were interviewed for the occurrence and cause of delays. Baseline demographics, predictor values, and outcomes were recorded. The primary outcome – delay – was presented using descriptive statistics. Univariable and multivariable logistic regression analyses were performed to assess the associations between possible predictors and delays and hospitalization, intensive care, and death with delay.

RESULTS: In 3656 (37.3%) of 9818 patients, delays were adjudicated. The patients with delays were older (59 years, interquartile range [IQR]: 39–76 years vs 49 years, IQR: 33–68 years) and more likely had impaired mobility, nonspecific complaints (weakness or fatigue), and frailty than the patients without delays. The main causes of delays were resident work-up (20.4%), consultations (20.2%), and imaging (19.4%). The predictors of delays were an Emergency Severity Index of 2 or 3 at triage (odds ratio [OR]: 3.00; confidence interval [CI]: 2.21–4.16; OR: 3.25; CI: 2.40–4.48), nonspecific complaints (OR: 1.70; CI: 1.41–2.04), and consultation and imaging (OR: 2.89; CI: 2.62–3.19). The patients with delays had an increased risk for admission (OR: 1.56; CI: 1.41–1.73) but not for mortality than those without delays.

CONCLUSION: At triage, simple predictors such as age, immobility, nonspecific complaints, and frailty may help to identify patients at risk of delay, with the main reasons being resident work-up, imaging, and consultations. This hypothesis-generating observation will allow the design of studies aimed at the identification and elimination of possible throughput obstacles.

Introduction

Delays during emergency department (ED) work-ups are a major concern in many healthcare systems [1, 2]. The negative impacts on ED caregivers are apparent, as delays lead to increasing throughput times, accumulating patient numbers, crowding, and, ultimately, a near break-down of ED operations, contributing to the depletion of the ED workforce [3]. The major consequences of ED delays among patients are decreasing patient satisfaction, declining quality of care, and increasing complications and, ultimately, mortality [4, 5]. The reasons for delays typically include demographic changes, comorbidity, complexity, and increasing numbers of walk-in patients [6] as well as referred and transferred patients, particularly in tertiary or reference centres [7].

The concept of the Emergency Severity Index (ESI) stipulates that patients should be "streamed" to different locations within the ED [8]. According to the theory of queuing [9], streaming is also pivotal for the reduction of complexity to reduce throughput variance in a single stream while reducing competition between acute/non-acute and complex/non-complex cases [10].

A generic model of ED operations reduces the complexity of all processes to three: input, throughput, and output [11]. Each of these main processes may be modified or improved, but systemic elements, such as patient numbers or hospital beds, are given and render input and output that

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ABBREVIATIONS

CI	confidence interval
ED	emergency department
ESI	Emergency Severity Index
IQR	interquartile range
OR	Odds ratio
SD	standard deviation

are difficult to tweak from an ED perspective [12]. Therefore, throughput times are key ED performance indicators and a cornerstone of quality improvement initiatives.

Throughput times depend on patient factors, such as acuity, prognosis, and complexity, as well as unfavourable systemic factors, such as complex protocols, serial instead of parallel processes, and the number of "external resources" used, including clinical chemistry, imaging, or specialist consultations. The increasing public demand for specialized or holistic acute care, call for standardization, and snowballing of "maximum safety" desires will not ease the pressure on ED throughput.

Throughput can be measured as an absolute amount of time between presentation and admission/discharge. However, this interval does not contain much meaningful information on delay, as the demand of individual cases largely determines the respective optimal throughput time. As there is no framework containing all relevant factors (e.g. complaints, acuity, severity, complexity, diagnostic groups, prediction of disposition and outcome) for the determination of optimal throughput time, only expert opinions are useful for adjudication of delay.

Albeit subjective, emergency physician-adjudicated delay is a key performance indicator for ED operations [13]. In this study, we planned to assess the decisions of emergency physicians regarding delays in consecutive patients. The hypotheses of this prospective study were that the causes of delay may be broadly distributed, that vulnerable patients [14, 15] may carry a higher burden of delay, and that cases with delays may experience unfavourable outcomes.

Aim

This study aimed to identify parameters available at triage associated with delays during ED work-up, to describe emergency physician-adjudicated reasons for delay, and to assess outcomes in patients with delays.

Methods

Study design and setting

This prospective observational cohort study investigated patients presenting to the ED of the University Hospital of Basel, an academic centre in Switzerland with a census of over 50,000 visits. Patients were included by a designated study team 24 hours a day 7 days a week (from 30 January 2017 to 19 February 2017 and from 18 March 2019 to 20 May 2019). The data collection was part of a quality-control study (ClinicalTrials.gov Identifier: NCT05400707), and conducted in compliance with the WMA Declaration of Helsinki. Oral consent was obtained and documented. Patients who refused to provide research consent were excluded. The study was conducted in accordance with the STROBE [16] guidelines.

Ethics approval and consent to participate

The data collection was approved by the responsible ethics committee (EKNZ-236/13; www.eknz.ch). Oral consent was obtained and documented.

Participants

All patients presenting to the ED were eligible. Obstetric and paediatric patients were not included, as they were treated elsewhere. Patients who were unable to be screened, were directly referred to other departments, or left without being seen were also not included. Multiple visits by the same patient were allowed for inclusion.

Definitions and processes

Input was defined as the number of patients presenting to the ED, including air rescue and ambulance transport. Output was defined as the number of patients admitted (to any hospital bed) or discharged (home or back to nursing home). Throughput was defined as the number of patients undergoing an ED work-up. Throughput time was defined as the interval between presentation (generation of electronic health record [EHR] file) and admission (effective transfer out of the treatment bay) or discharge (time leaving the treatment bay). Patients whose ED work-up was completed, who could be discharged, and who were only waiting for discharge were taken to the ED waiting room. Discharge time stamps were applied when leaving the treatment bay. Delay was adjudicated by a senior physician, the emergency physician in charge. The decision was based on the subjective opinion of the physician regarding delay during ED work-up. Every patient was evaluated individually regarding delay, independently of throughput time, taking a theoretical optimal throughput into account. Emergency physicians were trained regarding the main question "was there a delay during ED work-up?", and the question was repeatedly discussed at each morning round.

The cause of delay was defined as the main reason for delay, as adjudicated by emergency physicians, and assigned to one of the following pre-defined categories: "resident work-up", "senior physician availability", "consultation", "imaging", "clinical chemistry", "exit block", or "other". A resident was defined as the junior physician responsible for the ED work-up. Resident work-up was defined as history-taking, physical examination, and other necessities for the generation of a working hypothesis.

Consultation was defined as a request of the emergency physician for a specialist consultation during ED work-up. Imaging was defined as plain radiography, computed tomography, magnetic resonance imaging, or any external ultrasound examination. Clinical chemistry was defined as any test performed by the central laboratory, excluding point-of-care testing.

Exit block was defined as the inability to transfer patients to the assigned hospital beds within an hour after completion of ED work-up, as previously suggested [17].

Acuity was measured using the Emergency Severity Index. The Emergency Severity Index is a five-level triage algorithm used to assess treatment priority based on the severity of illness or injury and expected resource consumption [18].

Impaired mobility on presentation (IMOP) was defined as the lack of a stable independent gait [19].

Reported symptoms and chief complaints were recorded using a pre-defined list of 35 symptoms [20]. Weakness and fatigue were defined as nonspecific complaints [21],

chief complaint as the main symptom and reason for visiting the ED, and chief complaint replacement as replacement of the patient-defined chief complaint by the resident (unaware of the recorded chief complaint at presentation) after history-taking [22].

Frailty was defined as a Clinical Frailty Scale (CFS [23]) score of >4.

Hospitalization was defined as admission to the hospital from the ED to any ward, including the geriatric, palliative care, or intensive care unit (ICU). Patients who were admitted to the observation unit in the ED were considered as hospitalized.

The internal factors for delay were either resident work-up or senior physician availability. The external factors were either exit block, consultation, imaging, or clinical chemistry.

Outcomes

The primary outcome was delay adjudicated by the responsible emergency physician. The secondary outcomes were the throughput time; 7-, 100-, and 365-day mortality rates; and admission to the hospital and ICU.

Data collection

At presentation, an electronic health record (ISMed® by Protec-Data, Boswil, Switzerland) containing automatically generated time stamps and baseline data was generated. Patients were triaged according to the Emergency Severity Index and impaired mobility on presentation by registered nurses or emergency physicians, and the CFS score was additionally used among patients aged 65 years and older.

Immediately after triage, the chief complaints, total number of complaints, and additional information (e.g. presentation after trauma) were recorded by a trained study team, personally interviewing patients or proxies.

Immediately after the first physician assessment, the chief complaints and total number of complaints, as documented by the residents, were recorded by the study team.

At discharge/admission, another time stamp was recorded automatically, and the responsible emergency physicians (senior physicians) were interviewed by the study team. Adjudication of delay and causes of delays were recorded according to the pre-defined categories.

Chart reviews were conducted for patients with throughput times over 30 hours and manually corrected in case of missing electronic exit time stamps.

Follow-ups at 30, 100, and 365 days were performed via standardized telephone interviews with patients, proxies, or family physicians. In case of unavailability, the electronic health record, insurance data, or registration offices of the residents were consulted for further information. Patients lost to 365-day follow-up were not excluded from the calculations.

All data were recorded on machine-readable case report forms with unique patient IDs. In a two-step process, the scanned forms were cleaned: first by the ED administrators, who checked the forms for handwriting issues and unexplainable data (e.g. blood pressure of 500 mmHg), and second by an external company (Swiss Post®), which was responsible for transferring the data to the electronic database. With the unique patient ID, all other data from the electronic health record of the patients were transferred to the database.

Statistical analyses

For descriptive statistics, categorical variables were shown as counts and frequencies and metric variables as means with standard deviations. Variable comparisons for patients with missing data on delays were tested using the Kruskal–Wallis test, the chi-square test, or Fisher's exact test as appropriate.

Univariable logistic regression analyses for the predictors of delay were performed to calculate odds ratios (ORs), 95% confidence intervals (CIs), and p-values. Multivariable logistic regression for mortality outcomes was corrected for age, sex, and acuity (Emergency Severity Index). An Emergency Severity Index of 1 and a CFS score of 1–4 were considered as references for the regression analysis – no delay was expected in this group. P-values of <0.05 were defined as significant.

The R software (version 4.2.2) was used for all analyses.

Results

Characteristics of the study participants

For inclusion, 10,557 presentations were eligible. A total of 739 presentations were excluded for missing data, denied consent, or double enrolment. The final cohort consisted of 9818 presentations (figure 1).

There were no significant differences in sex, age, and the Emergency Severity Index between the patients with missing adjudication (n = 10) and the final cohort (table S1).

The median patient age was 52 (interquartile range: 34–72) years; 4648 (47.3%) patients were women; and an Emergency Severity Index of 3 (n = 4150, 42.3%) was the most common acuity (table 1).

Main results

A total of 3658 (37.3%) patients were adjudicated with delays (table 1). The patients with delays were older (mean age: 58 vs 51 years) and more likely had an Emergency Severity Index of 2 or 3 than those without delays. The mean throughput time was 4 hours 45 minutes longer in the patients with delays than in those without delays (7 hours 57 minutes vs 3 hours 24 minutes). The patient with delays more likely had impaired mobility (37.5% vs 26.2%), nonspecific complaints (6.5% vs 4.0%), and frailty (19.4% vs 13.8%) than those without delays. Chief complaint replacement was identified more often (40.1% vs 32.0%), and imaging and consultations were more frequently requested in the patients with delays than in those without delays.

The main adjudicated causes of delay were resident work-up (20.4%), consultations (20.2%), and imaging (19.4%) (table 2).

An Emergency Severity Index of 2 and 3, impaired mobility, nonspecific complaints, and frailty were predictive of delays (table 3).

Of 3447 admitted patients, 49.5% were affected by delays. The 7-day mortality rate was higher in the patients without delays than in those with delays; meanwhile, the 100- and 365-day mortality rates were higher in the patients with delays than in those without delays (table 4).

Delay corrected for age, sex, and acuity (Emergency Severity Index) was associated with a higher likelihood of admission and a lower likelihood of intensive care (table 5). Mortality was not significantly associated with delay. The patients with a throughput time of 8–12 hours had higher odds of having 100- and 365-day mortalities (OR: 1.69, CI: 1.21–2.34; p = 0.002; OR: 1.55, CI: 1.19–2.01, p < 0.001).

Discussion

The main results of this prospective study are that the causes of ED delay were broadly distributed, that the vulnerable patient groups carried a higher risk for delay, and that the patients with delays did not experience unfavourable outcomes, apart from a higher rate of hospitalization. In detail, delays were adjudicated in 37% of all ED patients. The patients with the highest odds for delays were triaged as having an Emergency Severity Index of 2 or 3 and had imaging or consultations by specialists. Frugal predictors of delays such as older age, nonspecific complaints, frailty, and immobilization may point to a throughput problem in vulnerable populations. The reasons for this finding remain unclear, as both patient and physician factors may be involved. Certain patient factors (vulnerability) may support

the hypothesis that case complexity could be responsible for slow throughput. Meanwhile, physicians may de-prioritize older and frail patients with "difficult symptoms", such as weakness or fatigue [24, 25]. It is under debate whether such symptoms can be considered predictors of serious outcomes [24–26]. The triage literature does not offer clear statements on nonspecific complaints and the necessity to up-triage, but a recent review has suggested that nonspecific complaints are still not gaining the attention they deserve [27]. Physician factors may include "ageism" (a prejudice against older patients in the ED [28]), uncertainty about the work-up [29], or the traditional "wait-and-see" strategy for frail older patients [30].

Other factors include the number of symptoms and the phenomenon of complaint replacement. While it is understandable that patients with a high number of symptoms at triage may take more time, it is a rather new finding that the chief complaints are often replaced by treating physicians. In both cases, patients have a higher use of resources and rate of admission [20, 22]. As our study was a hypothesis-generating venture, the case complexity could only be speculated to contribute to these findings. Meanwhile, patients who experience trauma have a decreased risk of delay, as their process may be more linear, highly standardized, and handled with greater routine.

Herein, delays were associated with hospitalization, but it remains unclear whether the decision to hospitalize could be a factor of slow throughput, or whether prolonged throughput may influence emergency physicians to hospitalize patients. Mortality was not associated with emergency physician-adjudicated delays but with throughput

Figure 1: Flow chart of the study population. A total of 1875 patients were excluded, leaving a final study population of 9818 ED patients.
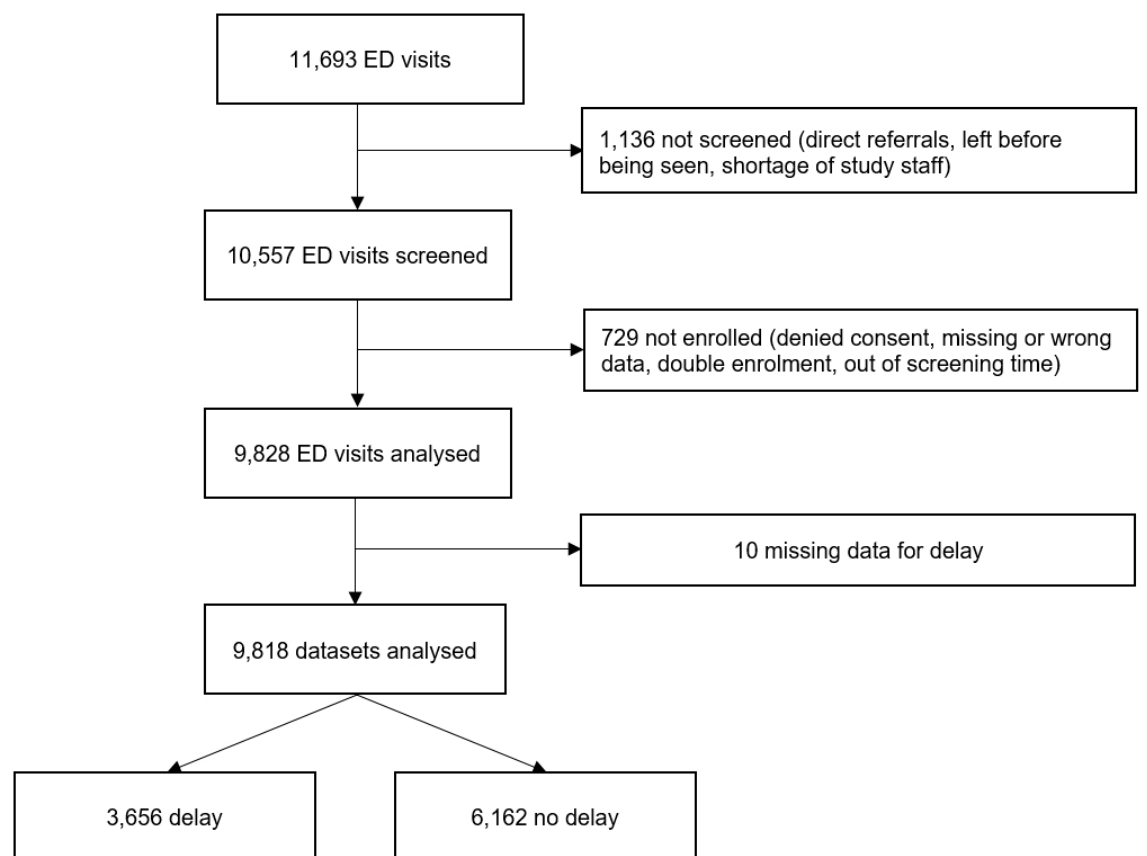
times of 8–12 hours. This association has also been previously reported [31] (see table S2).

It seems important to gather knowledge on the associations of patient-, physician-, and system-related factors with delays, as this may help to increase patient safety and improve patient experience. Older and frailer patients should not be subjected to slow work-up, as their risk of delirium may increase with every hour spent in the ED. Meanwhile, normal mobility at triage helps to identify patients with a low risk for mortality. This finding could prevent unnecessary hospitalizations and their associated complications [32].

Table 1:
Patient characteristics.

	n	All	Delay	No delay	SMD	Missing values
n (%)	9818	9818	3656 (37.3)	6162 (62.7)		
Age, mean (SD)	9818	53 (–22) y	58 (22) y	51 (21) y	0.320	–
Female sex, n (%)	9818	4648 (47.3)	1771 (48.4)	2877 (46.7)	0.035	–
ESI, n (%)	9818				0.588	–
1		246 (2.5)	52 (1.4)	194 (3.1)		
2		2534 (25.8)	1130 (30.9)	1404 (22.8)		
3		4150 (42.3)	1931 (52.8)	2219 (36.0)		
4		2693 (27.4)	536 (14.7)	2157 (35.0)		
5		195 (2.0)	7 (3.0.2)	188 (3.1)		
Throughput time, mean (SD)	9330	4 h 45 min (3 h 37 min)	7 h 57 min (3 h 59 min)	3 h 24 min (2 h 32 min)	1.059	488
Presentation, n (%)	9689				0.155	129
Walk-in patients		8709 (89.9)	3149 (86.9)	5560 (91.7)		
Ambulance referred		980 (10.1)	475 (13.1)	505 (8.3)		
Impaired mobility, n (%)	9672				0.245	146
Impaired mobility on presentation		2943 (30.4)	1356 (37.5)	1587 (26.2)		
MOP		6729 (69.6)	2256 (62.5)	4473 (73.8)		
CFS score, n (%)[a]	7186				0.152	2632
1–4		6059 (84.3)	1977 (80.6)	4082 (86.2)		
5–9		1127 (15.7)	476 (19.4)	651 (13.8)		
Trauma vs no trauma, n (%)	9738				0.058	80
Trauma		1027 (10.5)	342 (9.4)	685 (11.2)		
No trauma		8711 (89.5)	3279 (90.6)	5432 (88.8)		
Symptoms, n (%)	9608				0.116	210
Nonspecific complaints[b]		472 (4.9)	233 (6.5)	239 (4.0)		
Specific complaints		9136 (95.1)	3333 (93.5)	5803 (96.0)		
Number of symptoms, mean (SD)[a]	7298	2.1 (1.4)	2.3 (1.4)	2.0 (1.3)	0.236	2520
Chief complaint replacement, n (%)[a]	7056				0.168	2762
No		4604 (65.2)	1430 (59.9)	3174 (68.0)		
Yes		2452 (34.8)	956 (40.1)	1496 (32.0)		
Imaging, n (%)	9818	2297 (23.4)	1248 (34.1)	1049 (17.0)	0.400	–
>1 Imaging, n (%)		922 (9.4)	533 (15.1)	369 (6.0)	0.301	
Consultation, n (%)	9818	3134 (31.9)	1649 (45.1)	1485 (24.1)	0.453	–
>1 Consultation, n (%)		127 (1.3)	86 (2.4)	41 (0.7)	0.301	
Consultation and imaging, n (%)	9818	1017 (10.4)	633 (17.3)	384 (6.2)	0.349	–

Data are shown as means and SDs for continuous variables and as numbers and percentages for categorical variables. The population analyzed (n) varied owing to different availability of values.

SD: standard deviation, SMD: standard mean deviation, ESI: Emergency Severity Index, CFS: Clinical Frailty Scale

[a] Only assessed during data collection from March to May 2019

[b] Nonspecific complaints defined as weakness and fatigue

Table 2:
Causes of delay (total delays, n = 3656).

Resident work-up	745 (20.4%)
Specialist consultation	739 (20.2%)
Imaging	709 (19.4%)
Other	514 (14.0%)
Clinical chemistry	257 (7.0%)
Senior physician availability	361 (9.9%)
Exit block	310 (8.5%)
NA	21 (0.6%)

The reasons for delays may be divided into external reasons, such as imaging and consultations (40%), and internal reasons, such as time constraints of residents (20%). ED operations, transfers, or exit blocks are probably the most discussed issues [31], but exit blocks are adjudicated only in a small minority. Therefore, throughput delays for internal reasons should be paid more attention. Aggressive work-up or treatment aimed at avoiding unnecessary admission [33] may contribute to throughput delays. Early disposition decisions [30] may help to decide whether admission can realistically be avoided. If hospitalization is not preventable in older, frail, and immobile patients, the

use of external resources should be limited, as delays in throughput without change in outcome are likely.

Future research on interventions for improvement of patient flow should focus on the adequacy of external resources used and on internal processes, such as adequate staffing and flagging of patients at risk of delay.

Limitations

This study was conducted in a single academic tertiary care centre in Switzerland. Therefore, the external validity of the results may be limited. Furthermore, we focused on pa-

Table 3:

Predictors of delay: univariable logistic regression.

		Delay	
		OR	95% CI
Age, per 10 years		1.16	1.14–1.18
Female sex		1.07[*]	0.99–1.16
ESI	1	Reference	Reference
	2	3.00	2.21–4.16
	3	3.25	2.40–4.48
	4	0.93[*]	0.68–1.29
	5	0.14	0.06–0.29
Presentation, ambulance referred		1.66	1.45–1.90
Impaired mobility on presentation		1.69	1.55–1.85
CFS score[a]	1–4	Reference	Reference
	5–9	1.51	1.33–1.72
Trauma		0.83	0.72–0.95
Nonspecific complaints		1.70	1.41–2.04
Chief complaint replacement[a]		1.42	1.28–1.57
Number of symptoms[a]		1.18	1.14–1.23
Imaging		2.81	2.57–3.06
Consultation		2.59	2.37–2.83
Consultation and imaging		2.89	2.62–3.19

The table contains the results of the univariable regression for delay, including the following variables: age (per decade), sex, Emergency Severity Index, presentation, impaired mobility on presentation, CFS score, trauma, nonspecific complaints, chief complaint replacement, number of symptoms, imaging, consultation, and consultation and imaging. An Emergency Severity Index of 1 and a CFS score of 1–4 were used as the reference category – no delay was expected in this group. All ORs are adjusted for age and sex.

OR: odds ratio, CI: confidence interval, ESI: Emergency Severity Index, CFS: Clinical Frailty Scale

[a] Only assessed during data collection from March to May 2019

[*] No statistical significance

Table 4:

Outcomes of patients with delay (n = 9818).

	n	All patients	Delay	No delay
7-day mortality , n (%)	9552			
Dead		110 (1.2)	33 (0.9)	77 (1.3)
Alive		9442 (98.8)	3532 (99.1)	5910 (98.7)
100-day mortality , n (%)	9529			
Dead		376 (3.9)	159 (4.5)	217 (3.6)
Alive		9153 (96.1)	3397 (95.5)	5756 (96.4)
365-day mortality , n (%)	9514			
Dead		685 (7.2)	295 (8.3)	390 (6.5)
Alive		8829 (92.8)	3258 (91.7)	5571 (93.5)
In-hospital mortality , n (%)	9818			
Dead		123 (1.3)	44 (1.2)	79 (1.3)
Alive		9695 (98.7)	3612 (98.8)	6083 (98.7)
Admission to hospital , n (%)	9818			
Admission		3447 (35.1)	1705 (46.6)	1742 (28.3)
No admission		6371 (64.9)	1951 (53.4)	4420 (71.7)
Admission to ICU , n (%)	9818			
Admission		493 (5.0)	143 (3.9)	350 (5.7)
No admission		9325 (95.0)	3513 (96.1)	5812 (94.3)

The population analyzed (n) varied owing to different availability of values.ICU: intensive care unit. Data are shown as numbers and percentages for categorical variables.

Table 5:

Multivariable logistic regression analysis for the association of delay with admission and mortality

		Admission to hospital		Admission to ICU		In-hospital mortality		7-day mortality		100-day mortality		365-day mortality	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age		1.04	1.04–1.04	1.02	1.03–1.04	1.06	1.05–1.08	1.08	1.06–1.10	1.07	1.06–1.08	1.07	1.07–1.08
Female sex		0.89	0.81–1.0	0.57	0.46–0.70	0.47	0.30–0.65	0.80[*]	0.53–1.20	0.65	0.52–0.82	0.67	0.57–0.80
ESI	1	Ref.	–	Ref.	–	Ref.	–	Ref.	–	Ref.	–	Ref.	-
	2	0.10	0.06–0.17	0.10	0.08–0.14	0.08	0.05–0.13	0.10	0.06–0.16	0.19	0.13–0.27	0.27	0.19–0.38
	3	0.04	0.03–0.07	0.03	0.18–0.03	0.04	0.03–0.07	0.04	0.00–0.06	0.15	0.10–0.22	0.24	0.17-0.34
	4	0.01	0.00–0.01	0.0	0.00–0.01	0.00	0.00–0.02	0.00	0.00–0.02	0.04	0.02–0.07	0.09	0.06–0.14
	5	0.00	0.00–0.00	[**]	[**]	[**]	[**]	[**]	[**]	0.04	0.00–0.21	0.07	0.01–0.22
Delay		1.56	1.41–1.73	0.56	0.44–0.67	0.89[*]	0.59–1.32	0.65[*]	0.41–1.00	0.91[*]	0.73–1.14	0.89[*]	0.75–1.06

The table contains the results of the multivariable regression for admission and mortality outcomes, including the following variables: age (per year), sex, ESI, and delay. An ESI of 1 was used as the reference category – no delay was expected in this group. The ORs for the ESI and delay are adjusted for age, sex, and the ESI.

OR: odds ratio, CI: confidence interval, ESI: Emergency Severity Index[*] No statistical significance

[**] Since no event occurred, testing was not applicable.

tient factors and did not analyze physician factors such as years of experience, number of attended patients, or subjective competence, as well as availability, accessibility, and quality of primary care, which may well be among the predictors of delay. The CFS score, number of symptoms, and chief complaint replacement data were collected only in the 2019 cohort; nevertheless, this cohort comprised the vast majority of all patients included. Other possible confounders, such as comorbidity, the number of patients in the ED, occupied ED rooms, and other data to measure crowding, were not recorded owing to resource constrains. Therefore, these factors could neither be considered as potential confounders in the analysis nor used to analyze heterogeneity of the two groups. As this study was conducted before the COVID-19 pandemic, the lack of ward nursing was not an issue at the time of the study.

The Hawthorne effect, describing changes in behaviour owing to awareness of individuals being observed, could also be attributed to a possible bias. The interviews on delays and possible reasons may have reduced the availability of senior physicians and may therefore have contributed to delays. Further, delays were adjudicated by one emergency physician in charge. Therefore, no interrater reliability could be assessed.

Finally, re-presentations were not excluded. However, this concerned a small minority of all patients.

Conclusion

At triage, simple predictors such as age, immobility, nonspecific complaints, and frailty may help to identify patients at risk of delay during ED work-up. The main reasons for delays are resident work-up, imaging, and consultations. This hypothesis-generating observation will allow the design of studies aimed at the identification and elimination of possible throughput obstacles.

Availability of data and materials

Data cannot be shared without written consent of the local ethics committee. Requests for data sharing will be forwarded to the ethics committee. If the request is granted, data can be shared in fully anonymized form.

Competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. Prof. Bingisser and Prof. Nickel report being editors of medStandards.com. No other potential conflict of interest was disclosed.

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Appendix

List of packages used for the calculations

Attached base packages: stats, graphics, grDevices utils, datasets methods base

Other attached packages: lubridate_1.9.2, chron_2.3-59, pROC_1.18.0, survival_3.4-0, ranger_0.14.1, survminer_0.4.9, ggpubr_0.6.0, ggplot2_3.4.1, questionr_0.7.8, tableone_0.13.2, magrittr_2.0.3, dplyr_1.1.0

Loaded via namespace (ant not attached): Rcpp_1.0.10, lattice_0.20-45, tidyr_1.3.0, class_7.3-20, zoo_1.8-11, digest_0.6.31, utf8_1.2.3, mime_0.12, R6_2.5.1, plyr_1.8.8, backports_1.4.1, labelled_2.10.0, e1071_1.7-13, survey_4.1-1, highr_0.10, pillar_1.8.1, rlang_1.0.6, rstudioapi_0.14, data.table_1.14.8 miniUI_0.1.1.1, car_3.1-1, Matrix_1.5-1, labeling_0.4.2, splines_4.2.2, munsell_0.5.0, proxy_0.4-27, shiny_1.7.4, broom_1.0.3, compiler_4.2.2, httpuv_1.6.9, xfun_0.37, pkgconfig_2.0.3, htmltools_0.5.4, mitools_2.4, tidyselect_1.2.0, tibble_3.1.8, gridExtra_2.3, km.ci_0.5-6, fansi_1.0.4, crayon_1.5.2, withr_2.5.0, later_1.3.0, MASS_7.3-58.1, grid_4.2.2, xtable_1.8-4, gtable_0.3.1, lifecycle_1.0.3, DBI_1.1.3, KMsurv_0.1-5, scales_1.2.1, cli_3.6.0 , carData_3.0-5, farver_2.1.1, ggsignif_0.6.4, promises_1.2.0.1, ellipsis_0.3.2, survMisc_0.5.6, generics_0.1.3, vctrs_0.5.2, tools_4.2.2, forcats_1.0.0, glue_1.6.2, purrr_1.0.1, hms_1.1.2, abind_1.4-5, fastmap_1.1.1, timechange_0.2.0, colorspace_2.1-0, rstatix_0.7.2, knitr_1.42, haven_2.5.2.

Table S1:
Comparison of excluded patients because of missing information on delay with the study population.

Variable	Study population	Population with missing data on delay	p-values
n (%)	9818	10	
Age, median (IQR)	52 (34–72) y	72.5 (36–79) y	0.44
Female sex, n (%)	4648 (47.3)	4 (40)	0.76
ESI			0.46
1, n (%)	246 (2.5)	0 (0)	
2, n (%)	2534 (25.8)	5 (50.0)	
3, n (%)	4150 (42.3)	4 (40.0)	
4, n (%)	2693 (27.4)	1 (10.0)	
5, n (%)	195 (2.0)	0	

IQR: interquartile range, ESI: Emergency Severity Index

Table S2:

Comparison of patient groups according to the length of stay in the emergency department.

	n	All	LOS of <8 h	LOS of 8–12 h	LOS of >12 h	SMD	Missing values
n (%)	9330		8192	792	346		–
Age, mean (SD)	9330	54 (–22) y	52 (22) y	64 (20) y	62 (22) y	0.367	–
Female sex, n (%)	9330	4387 (47.0)	3841 (46.9)	387 (48.9)	159 (46.0)	0.039	–
Delay, n (%)	9330	3560 (38.2)	2597 (31.7)	675 (85.2)	288 (83.2)	0.857	–
ESI, n (%)	9330						–
1		205 (2.2)	182 (2.2)	16 (2.0)	7 (2.0)		
2		2465 (26.4)	2063 (25.2)	283 (35.7)	119 (34.4)		
3		4021 (43.1)	3390 (41.1)	437 (55.2)	194 (56.1)		
4		2453 (26.3)	2372 (29.0)	56 (7.1)	25 (7.2)		
5		186 (2.0)	185 (2.3)	0	1 (0.3)		
Throughput time, mean (SD)	9330	4 h 45 min (3 h 37 min)	3 h 45 min (1 h 52 min)	9 h 28 min (1 h 4 min)	17 h 35 min (5 h 15 min)	3.126	–
Presentation, n (%)	9201					0.293	129
Walk-in patients		8323 (90.5)	7383 (91.5)	680 (86.7)	260 (75.6)		
Ambulance referred		878 (9.5)	690 (8.5)	104 (13.3)	84 (24.4)		
Impaired mobility, n (%)	9184					0.383	146
Impaired mobility on presentation		2806 (30.6)	2244 (27.8)	372 (52.3)	190 (55.2)		
MOP		6378 (69.4)	5816 (72.2)	408 (47.7)	154 (44.8)		
CFS score, n (%)[a]	7170					0.270	2160
1–4		6046 (84.3)	5485 (86.1)	405 (69.6)	156 (72.2)		
5–9		1124 (15.7)	887 (13.9)	177 (30.4)	60 (27.8)		
Trauma vs no trauma, n (%)	9269					0.165	61
Trauma		984 (10.6)	929 (11.4)	39 (5.0)	16 (4.7)		
No trauma		8285 (89.4)	7218 (88.6)	744 (95.0)	323 (95.3)		
Symptoms, n (%)	9139					0.199	191
Nonspecific complaints[b]		414 (4.5)	310 (3.9)	65 (8.4)	39 (11.7)		
Specific complaints		8725 (95.5)	7725 (96.1)	706 (91.6)	294 (88.3)		
Number of symptoms, mean (SD)[a]	7279	2.1 (1.4)	2.0 (1.4)	2.4 (1.4)	2.4 (1.4)	0.193	2051
Chief complaint replacement, n (%)[a]	7040					0.098	2290
No		2449 (34.8)	2137 (34.1)	225 (39.6)	87 (41.2)		
Yes		4591 (65.2)	4124 (65.9)	343 (60.4)	124 (58.8)		
Imaging, n (%)	9330	5472 (58.6)	4540 (55.4)	662 (83.6)	270 (78.0)	0.426	–
>1 imaging, n (%)		2233 (23.9)	1714 (20.9)	363 (45.8)	156 (45.1)	0.365	
Consultation, n (%)	9330	3037 (32.6)	2406 (29.4)	43 (55.3)	193 (55.8)	0.369	–
>1 consultation, n (%)		25 (0.3)	16 (0.2)	6 (0.8)	3 (0.9)	0.062	–
Consultation and imaging, n (%)	9330	1195 (12.8)	855 (10.4)	242 (30.6)	98 (28.3)	0.343	–

Data are shown as means and SDs for continuous variables and as numbers and percentages for categorical variables. The population analyzed (n) varied owing to different availability of values.

SD: standard deviation, SMD: standard mean deviation, ESI: Emergency Severity Index, CFS: Clinical Frailty Scale, LOS: length of stayNonspecific complaints defined as weakness and fatigue Only assessed during data collection from March to May 2019 Nonspecific complaints defined as weakness and fatigue

[a] Only assessed during data collection from March to May 2019

[b] Nonspecific complaints defined as weakness and fatigue