International Journal of Emergency Medicine

RESEARCH Open Access

Critical revisits after discharge from the emergency department

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Abstract

Aims Emergency department (ED) revisits within 72 h is a standard quality measure for emergency care but most revisits are managed and discharged. However, a sub-group of revisits are due to clinical deterioration resulting in admissions to higher acuity care or even mortality. We aimed to identify these critical revisits and their associated risk factors. Identification of these factors would allow development of strategies to reduce incidence of post discharge deterioration.

Methods A retrospective cohort study was conducted on all patients who had a revisit within 72 h of discharge from the ED of a tertiary hospital in Singapore from 2008 to 2020. Deidentified data were extracted from the electronic health records (EHR). We identified critical revisits, defined as a revisit that resulted in death or admission to Intensive Care Unit or High Dependency. These patients were compared to patients who had a revisit that resulted in discharge or admission to general ward. The main outcome was the rate of critical revisit. We also determined the commonest index and critical revisit ED diagnosis as well as factors associated with critical revisits.

Results Out of 1,057,533 discharges from the ED over the study period, 44,506 (4.2%) had a revisit within 72 h, of which 1321 (0.12%) were critical revisits. Adjusted odds ratios from multivariable logistic regression analysis indicated that higher heart rate, higher mean arterial pressure, and several lab abnormalities were associated with critical revisits. Diagnosis categories at the initial visit with the highest contribution to the likelihood of a critical revisit included "acute cerebrovascular disease" (OR: 38.00, 95%CI: 27.04–53.39), "other gastrointestinal disorders" (OR: 3.10, 95%CI: 2.41–3.99) and "residual codes; unclassified" (OR: 2.69, 95%CI: 2.01–3.60).

Conclusion Critical revisits after discharge were rare in our study population, most prevalent amongst the elderly with multiple comorbidities. Future research should focus on diagnoses at higher risk of a critical revisit to develop practical approaches to follow up these patients.

Keywords Revisits, Triage, Patient safety, Ed administration

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Introduction

Emergency department (ED) revisits within 72 h of discharge is a standard quality measure for emergency care [1–3]. The rate of ED revisits varies between hospital systems but has been described in the literature to range from 0.99-6.7% [4–13]. While ED revisits have not been definitively linked to poorer outcomes [14], various studies have identified associations of revisits with medical errors in prognosis, treatment, follow-up care and information during the initial visit [2, 4, 5, 15].

While most ED revisits are managed and discharged, roughly 5-46% of revisits require admission to the inpatient ward [2, 4, 5, 15–18], and a further subgroup of patients present with major clinical deterioration. These cases are typically defined by the need for ICU (Intensive Care Unit) admission, HD (High Dependency) admission or death during the revisit episode, and is reported at between 0.1 and 6.1% of revisits within 72 h [4, 5, 15, 19].

While preventing revisits is important to reduce ED overcrowding, patients who present critically ill are of clinical concern due to the morbidity and mortality involved. For these patients, it is unclear if there are features in their initial visit that could predict their subsequent deterioration, and early identification of these predictors in the initial visit will serve as an opportunity for clinical teams to consider a different disposition or monitoring options for these patients.

Objectives

We aimed to identify critical revisits within 72 h of discharge and their associated risk factors. Identification of these factors would allow development of strategies to reduce the incidence of post discharge deterioration.

Methods

Study design and setting

This was a retrospective cohort study of patients who attended the Singapore General Hospital (SGH) Emergency Department (ED) between January 2008 and December 2020. Singapore, a city-state in Southeast Asia, has seen rising ED attendances over the years and a rapidly ageing population [20]. Singapore's healthcare system consists of mainly government-run, publicly funded universal healthcare, as well as a private sector. While many private hospitals have 24- hour clinics and urgent care centers, the national ambulance system only conveys patients to public hospitals based on proximity. ED visits are universally subsidized for citizens and permanent residents, with a standard charge of roughly 100USD (including basic blood tests and radiographs). Citizens and permanent residents are enrolled in the national healthcare insurance program and are also obliged to contribute to a mandatory medical savings account called Medisave [21].

SGH is the largest public hospital in Singapore with close to 2000 inpatient beds. The ED sees about 350 patients daily- with about 70% being discharged [22], and the 72 h revisit rate is roughly 3%[10]. Collaborating with many specialty clinics and general clinics, the ED generally does not have planned revisits, with all patients requiring a second visit (e.g. rabies vaccination, follow up for abscesses) being referred to another provider. As such, revisits are generally unplanned.

Electronic Health Record (EHR) data for this study were obtained from Singapore Health Services. Our data set contained a pseudonymized version of all ED visits to SGH ED occurring between January 2008 to December 2020, including patient demographics, comorbidities, diagnosis, vital signs, lab results and treatment. As each unique patient in the dataset had a unique study number, repeat visits by the same patient could be identified.

Reporting of this study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline.

Study population

ED admissions during the study period that resulted in a discharge, termed "index visits", were included, while patients who were admitted to the ward or the ED observation unit were excluded. Non- resident foreign citizens were excluded, as they may not have a complete medical history recorded in the EHR, and their reattendance might be registered under a non-linkable ID. Patients who left without being seen (i.e. no disposition diagnosis) were excluded, while patients who left against medical advice (AMA) were included if they had a disposition diagnosis. In our institution, if a patient has been seen by a medical provider and leaves subsequently before complete assessment, they will be given a diagnosis code indicating abscondment- these cases were included and analyzed as abscondment as the diagnosis.

Outcomes and measures

The primary outcome was a critical revisit, defined as an ED revisit within 72 h of the index visit (time of discharge) that resulted in death, ICU admission or admission to HD. High dependency is a care setting where patients who are not intubated, and not on high-dose inotropes, but who require closer monitoring or certain interventions are admitted to. For example, glyceryl trinitrate infusions, thrombolysis, high flow nasal cannula, or non-invasive ventilation are performed in the HD. We measured the outcomes and variables of interest for all discharges, non-critical revisits, and critical revisits.

We compared index visit characteristics of discharges that resulted in a critical revisit with those that did not result in a critical revisit (no revisit at all and non-critical revisit). The index visits characteristics studied included

patient demographics, vital signs, lab tests, comorbidities as per the Charlson Comorbidity Index (CCI), as well as diagnosis codes. We decided on these measures based on expert input as well as availability of data.

We also determined the most common diagnoses associated with critical revisits, and their corresponding index visits.

Statistical analysis

Patients characteristics for the overall cohort, critical ED revisits and specific outcomes (HD or ICU admissions, and deaths) were reported. Vital signs and lab tests were categorized as high, normal or low based on the ED's thresholds for abnormal values and the hospital's laboratory reference ranges. To determine whether there were statistically significant differences in the distribution of demographics, vital signs, lab tests and CCI between the 'No Critical ED Revisit' group and the 'Critical ED Revisit' group, chi-square tests were performed.

A multivariable logistic regression model was employed to evaluate the association between baseline variables and the likelihood of critical ED revisits. Due to the rare event outcome, Firth's bias-reduced logistic regression method was applied to account for potential bias. Backward variable selection method was conducted by iteratively removing variables with an overall p-value threshold of ≥ 0.2. Adjusted odds ratios (aOR) with 95% confidence intervals (CI) and p-values from the final multivariable logistic regression model were reported. The goodness of fit for the logistic regression model was assessed using the Hosmer-Lemeshow statistic evaluating how well the predicted probabilities aligned with the observed data. The model's discriminatory ability was quantified using the c-statistic.

Missing values were handled using complete-case analysis, excluding cases with missing data for each variable in the univariate analysis and for the variables included in the multivariable logistic regression model.

The most common diagnosis categories for index visits that resulted in critical revisits were identified. After 2014, the ED discharge diagnosis was in SNOMED format- these codes were converted to ICD codes for analysis. Discharge diagnosis before 2014 was in ICD 9 format. The ICD codes were then categorized into clinically meaningful groups using the Clinical Classifications Software (CCS) to facilitate presentation and analysis; these are referred to as diagnosis categories [23].

For the top ten index visit diagnosis categories that resulted in a critical revisit, ORs and 95% CIs were calculated to assess the association with critical revisits. These ORs represent the odds of a critical revisit occurring for patients within each diagnosis category compared to those with all other diagnosis categories.

All statistical assessments were two-sided and evaluated at the 0.05 level of significance. Data analysis was conducted using R software (R Core Team (2024); R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org).

Results

Characteristics of study population

This study cohort comprised 1,057,533 discharges from the ED over a 13-year period. Only 10 missing values were present in the dataset, all related to age, gender, and race. Among these, 44,506 discharges (4.2%) resulted in revisits, with 1,321 (0.12% of all discharges, 3% of revisits) classified as critical revisits (Fig. 1). Table 1 shows the characteristics of our cohort- among critical revisits, there were 68 deaths, 214 ICU admissions, and 1,039 admissions to HD. The average age of all ED discharges was 48 years, with an average CCI of 0.396. Patients with critical revisits had an average age of 56 years and an average CCI of 1.59 (Tables 2 and 3).

Risk factors for a critical ED revisit: demographics, vitals, lab tests and comorbidities

Univariate analysis using chi-square tests comparing demographics and vital signs between patients with and without critical revisits is presented in Table 2, while Table 3 shows the results comparing the CCI and its components. Additionally, Supplement 1 compares laboratory test results between the two groups. Table 4 presents the adjusted odds ratios of the final model derived from the backward variable selection in the multivariable logistic regression model. The results indicate that the following demographic factors were associated with higher odds of a critical revisit: age > 65 (aOR: 1.68, 95% CI: 1.48–1.91, p-value < 0.0001), male gender (aOR: 1.30, 95% CI: 1.16–1.47, p-value < 0.0001). Regarding race, Chinese individuals were used as the reference group. Indian (aOR: 0.65, 95% CI: 0.55–0.78, p-value < 0.0001), Malay (aOR: 0.77, 95% CI: 0.64–0.93, p-value = 0.0065), and other races (aOR: 0.64, 95% CI: 0.51–0.93, p-value < 0.0001) were associated with lower odds of a critical revisit compared to the Chinese race. Shift timing was not selected in the final model. A triage class of P2 was associated with higher odds of a critical ED revisit (aOR: 1.35, 95% CI: 1.05–1.74, p-value = 0.0178), while a triage class of P3 was associated with lower odds of a critical revisit (aOR: 0.76, 95% CI: 0.59–0.99, p-value = 0.0417) (Table 4).

For vital signs, multivariable analysis showed that having a high heart rate (aOR: 1.52, 95% CI: 1.30–1.79, p-value < 0.0001) and higher mean arterial pressure (aOR: 1.31, 95% CI: 1.16–1.46, p-value < 0.0001) were significantly associated with higher odds of a critical revisit.

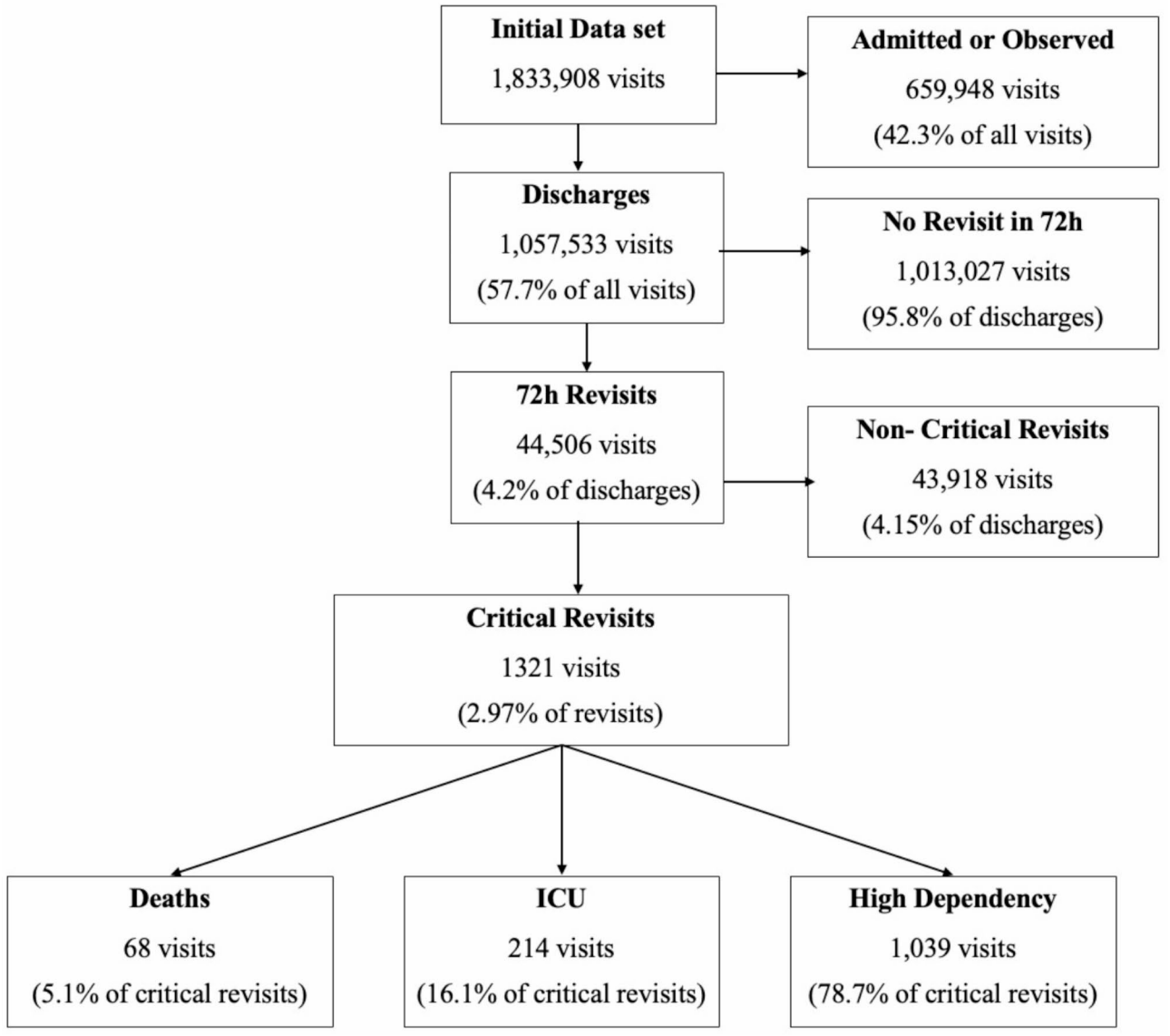

Fig. 1 Study flowchart

With regards to lab testing, a low bicarbonate, (aOR: 1.57, 95% CI: 1.22–2.11, p-value = 0.0005), low chloride (aOR: 2.11, 95% CI: 1.79–2.49, p-value < 0.0001), low platelet (aOR: 1.49, 95% CI: 1.11-2.00, p-value = 0.0085), abnormal troponin (aOR: 1.36, 95% CI: 1.22–1.53, p-value < 0.0001), high urea (aOR: 1.23, 95% CI: 1.02–1.46, p-value = 0.0283), low urea (aOR: 1.38, 95% CI: 1.02–1.86, p-value = 0.0363), and high white cell count (aOR: 2.25, 95% CI: 1.96–2.58, p-value < 0.0001) being significantly associated with higher odds of a critical revisit.

In terms of CCI, a higher CCI was associated with higher rates of critical revisits. Patients with CCI scores of 1, 2, and >2 had aORs of 2.58 (95% CI: 2.13–3.12, p-value < 0.0001), 2.51 (95% CI: 2.05–3.07, p-value < 0.0001), and 3.02 (95% CI: 2.46-3/71, p-value < 0.0001), respectively. Furthermore, the presence of the following comorbidities was associated with an increased likelihood of critical revisits: Peripheral Vascular Disease (PVD) (aOR: 1.53, 95% CI: 1.19–1.97, p-value = 0.0010), stroke (aOR: 1.77, 95% CI: 1.45–2.16, p-value < 0.0001), and renal disease (aOR: 1.60, 95% CI: 1.31–1.97, p-value < 0.0001). In contrast, dementia (aOR: 0.48, 95% CI: 0.25–0.92, p-value = 0.0261) and pulmonary disease (aOR: 0.53, 95% CI: 0.42–0.68, p-value < 0.0001) were associated with a lower likelihood of critical revisits.

The most common diagnosis categories at critical ED revisits

The most common diagnosis category at critical ED revisit were acute cerebrovascular disease (204, 15.4% of all critical revisits), septicemia (76, 5.8%) and biliary tract

Table 1 Patients' characteristics of the cohort

	ED Discharges (*N* = 1057533)	Critical ED Revisit (*N* = 1321)	HD (*N* = 1039)	ICU (*N* = 214)	Death (*N* = 68)
Gender					
Female	489,614 (46.3%)	538 (40.7%)	437 (42.1%)	80 (37.4%)	21 (30.9%)
Male	567,918 (53.7%)	783 (59.3%)	602 (57.9%)	134 (62.6%)	47 (69.1%)
Missing	1	0	0	0	0
Age, year					
18–65	890,530 (84.2%)	810 (61.3%)	654 (62.9%)	125 (58.4%)	31 (45.6%)
> 65	166,999 (15.8%)	511 (38.7%)	385 (37.1%)	89 (41.6%)	37 (54.4%)
Missing	4	0	0	0	0
Race					
Chinese	642,734 (60.8%)	965 (73.1%)	755 (72.7%)	157 (73.4%)	53 (77.9%)
Indian	156,551 (14.8%)	138 (10.4%)	107 (10.3%)	26 (12.1%)	5 (7.4%)
Malay	123,786 (11.7%)	130 (9.8%)	106 (10.2%)	18 (8.4%)	6 (8.8%)
Others	134,456 (12.7%)	88 (6.7%)	71 (6.8%)	13 (6.1%)	4 (5.9%)
Missing	6	0	0	0	0

ED: Emergency Department, HD: High Dependency, ICU: Intensive Care Unit; Percentages are computed using complete cases

disease (53, 4.0%) (Table 5). Among the top 10 diagnosis categories for critical revisits, 4 were abdominal in nature (183, 13.8%).

The most common diagnosis categories at index ED visits

The most common diagnosis categories at index ED visit prior to a critical revisit included spondylosis; intervertebral disc disorders; other back problems (88, 6.7% of all critical revisits) and gastritis and duodenitis (66, 5%) (Table 5). Of the top diagnosis CCS categories for index visits, 4 were abdominal in nature (232, 17.6%).

The OR of a critical ED revisit was greater than 1.0 for seven index visit diagnosis categories. These categories include acute cerebrovascular disease (OR 38.00, 95% CI: 27.40-53.39), other gastrointestinal disorders (OR 3.10, 95% CI: 2.41–3.99), residual codes; unclassified (OR 2.69, 95% CI: 2.01–3.60), genitourinary symptoms and ill-defined conditions (OR 2.34, 95% CI: 1.71–3.19), gastritis and duodenitis (OR 1.8, 95% CI: 1.41–2.31), conditions associated with dizziness or vertigo (OR 1.5, 95% CI: 1.15–1.95), and abdominal pain (OR1.41, 95% CI: 1.07–1.85).

Discussion

Critical revisits after ED discharge were rare in our study population, with only 0.12% of more than a million studied discharges having a critical revisit. Elderly patients with preexisting comorbidities were more likely to have a critical revisit, particularly those with 2 or more comorbidities. The commonest critical revisits were associated with diseases of the neurological and abdominal systems.

Our study builds on previous studies looking at unscheduled revisits. While most studies focus on revisits in general, most revisits are low risk and do not require changes in initial care. Our study focuses only on critical reattendances, which is the outcome that most medical professionals would be most concerned about. Our large dataset allowed us to analyze a comparatively large number of revisits and the pseudonymized nature of the dataset allowed us to link index and revisit diagnosis categories. Also, by using CCS diagnosis categories to classify different codes, we can better understand the reasons for revisits while accounting for different practices in coding.

Strokes and transient ischemic attacks (TIA) accounted for many critical revisits, with the most common critical revisit diagnosis category being acute cerebrovascular incident and transient ischemic attack being the 6th. Combined, this formed roughly 20% of all critical revisits, a much higher rate compared to other studies. Hutchinson et al. [18] studied critical revisits within 28 days of discharge across 3 EDs, and TIA/ Stroke did not account for any of the 71 critical revisits reported. Tsai et al. [14] reported 3.8% of revisits (critical and non-critical) being due to stroke. Notably, our institution admits all suspected transient ischemic attacks (TIA) and strokes to the stroke unit, which is considered a high dependency ward in our dataset. This is done prior to a review by the neurology team in the stroke unit, where patients can be rapidly transferred out of the stroke unit if further assessment deems their symptoms to be not due to a stroke. This contrasts with other HDs or ICUs in our institution, where the inpatient doctor is required to review the patient in the ED prior to admission to the HD or ICU. We are thus unable to be determine retrospectively if the severity of these TIAs and Strokes can be considered critical and equivalent to other HD admissions. In other institutions, TIAs might be admitted to observation units, general wards or not at all [24]. Also, stroke units might not always be classified as a high dependency or ICU depending on each institution's treatment of the

Table 2 Demographics and vital signs at index visit: no critical ED revisit vs. critical ED revisit

	No Critical ED Revisit (*N* = 1056212)	Critical ED Revisit (*N* = 1321)	*P*-Value
Gender			< 0.001
Female	489,076 (46.3%)	538 (40.7%)	
Male	567,135 (53.7%)	783 (59.3%)	
Missing	1	0	
Age, year			< 0.001
18–65	889,720 (84.2%)	810 (61.3%)	
> 65	166,488 (15.8%)	511 (38.7%)	
Missing	4	0	
Race			< 0.001
Indian	156,413 (14.8%)	138 (10.4%)	
Chinese	641,769 (60.8%)	965 (73.1%)	
Malay	123,656 (11.7%)	130 (9.84%)	
Others	134,368 (12.7%)	88 (6.66%)	
Missing	6	0	
Shift Time			0.385
08:00 to 16:00	510,196 (48.3%)	663 (50.2%)	
16:00 to 24:00	393,427 (37.2%)	472 (35.7%)	
24:00 to 8:00	152,589 (14.4%)	186 (14.1%)	
Triage Class[1]			< 0.001
P1	41,441 (3.92%)	69 (5.22%)	
P2	314,536 (29.8%)	671 (50.8%)	
P3	700,235 (66.3%)	581 (44.0%)	
Mean Arterial Pressure (Normal 70–100)			< 0.001
High	271,545 (25.7%)	463 (35.0%)	
Low	29,456 (2.79%)	46 (3.48%)	
Normal	755,211 (71.5%)	812 (61.5%)	
Heart Rate (Normal 60–100)			< 0.001
High	99,571 (9.43%)	181 (13.7%)	
Low	48,264 (4.57%)	65 (4.92%)	
Normal	908,377 (86.0%)	1075 (81.4%)	
Respiration (Normal 12–18)			0.017
High	103,291 (9.78%)	156 (11.8%)	
Low	1652 (0.16%)	0 (0.00%)	
Normal	951,269 (90.1%)	1165 (88.2%)	
Oxygen Saturation (Normal 95–100)			0.014
Low	5609 (0.53%)	14 (1.06%)	
Normal	1,050,603 (99.5%)	1307 (98.9%)	

[1] PACS Acuity Scale: **P1**: Patients with immediate life-threatening conditions who require immediate medical attention. **P2**: Patients with major emergencies who require surgical or medical intervention within 2–4 h. **P3**: Patients with minor emergencies who can safely wait for treatment beyond 4 h; Percentages are computed using complete cases; ED: emergency department

Table 3 Distribution of Charlson comorbidity index: no critical ED revisit vs. critical ED revisit

Variable	No Critical ED Revisit (*N* = 1056212)	Critical ED Revisit (*N* = 1321)	*P*-Value
CCI:			< 0.001
0	894,166 (84.7%)	699 (52.9%)	
1	66,905 (6.33%)	153 (11.6%)	
2	38,793 (3.67%)	126 (9.54%)	
>2	56,348 (5.33%)	343 (26.0%)	
Myocardial Infarction	11,871 (1.12%)	74 (5.60%)	< 0.001
CHF	17,699 (1.68%)	105 (7.95%)	< 0.001
PVD	7953 (0.75%)	74 (5.60%)	< 0.001
Stroke	25,067 (2.37%)	172 (13.0%)	< 0.001
Dementia	2945 (0.28%)	9 (0.68%)	0.013
Pulmonary	44,502 (4.21%)	78 (5.90%)	0.003
Rheumatic	3590 (0.34%)	13 (0.98%)	0.001
PUD	8340 (0.79%)	38 (2.88%)	< 0.001
Paralysis	8820 (0.84%)	52 (3.94%)	< 0.001
Renal	27,652 (2.62%)	226 (17.1%)	< 0.001
HIV	487 (0.05%)	0 (0.00%)	1.000

CCI: Charleston comorbidity index, CHF: congestive heart failure, PVD: peripheral Vascular Disease, PUD: peptic ulcer disease, HIV: human immunodeficiency virus, ED: emergency department

data. These differences in institutional practices might account for the difference in findings.

Out of the top 10 index visit diagnosis categories, four were abdominal in nature (gastritis and duodenitis, other gastrointestinal disorders, abdominal pain, intestinal infection), forming 17.6% of the index visit diagnosis categories. Abdominal system related categories also accounted for four of the top 10 critical revisit diagnosis categories (biliary tract disease, abdominal pain, intestinal obstruction without hernia, gastrointestinal hemorrhage, combined 13.9%). Notably, for many of the critical revisits associated with abdominal system related diagnosis categories, the most common index visit diagnosis category was also abdominal in nature (Supplement 2). These further adds to the evidence that abdominal symptoms of uncertain cause should be treated with caution, especially in the elderly [25–27].

Apart from abdominal symptoms, another group that had a higher risk of a revisit are those diagnosed at the index visit as "residual codes, unclassified". These patients had an odds ratio of 2.69 compared to other diagnosis categories. A further look at the individual codes included in this category shows that most were under general symptoms (20/47, 42.5%) and abscondment (11/47, 23.4%). A code of general symptoms could represent diagnostic uncertainty. Notably, other studies have not found the risk of mortality and readmission to be higher amongst patients discharged with nonspecific diagnosis [28, 29]. These differing findings might be due to the approach to data analysis- our use of the CCS means that nonspecific symptoms specific to an organ system would not be classified under residual codes. The higher risk of patients who abscond, on the other hand, adds to the existing literature that abscondment is not

Table 4 Adjusted odds ratios for factors associated with critical ED revisits, calculated using a multivariable logistic regression model

	OR	95% CI	Pairwise *P*-value	Overall *P*-value
Male Gender	1.30	(1.16, 1.47)	< 0.0001	< 0.0001
Age, **year**				< 0.0001
> 65 vs. 18–65	1.68	(1.48, 1.91)	< 0.0001	
Race				< 0.0001
Chinese	Ref.			
Indian	0.65	(0.55, 0.78)	< 0.0001	
Malay	0.77	(0.64, 0.93)	0.0065	
Others	0.64	(0.51, 0.93)	< 0.0001	
Triage class				< 0.0001
P2 vs. P1	1.35	(1.05, 1.74)	0.0178	
P3 vs. P1	0.76	(0.59, 0.99)	0.0417	
Heart Rate				< 0.0001
High vs. Normal	1.52	(1.30, 1.79)	< 0.0001	
Low vs. Normal	0.86	(0.67, 1.10)	0.2302	
Mean Arterial Pressure				< 0.0001
High vs. Normal	1.31	(1.16, 1.46)	< 0.0001	
Low vs. Normal	1.19	(0.88, 1.60)	0.2664	
CCI				< 0.0001
0	Ref.			
1	2.58	(2.13, 3.12)	< 0.0001	
2	2.51	(2.05, 3.07)	< 0.0001	
> 2	3.02	(2.46, 3.71)	< 0.0001	
PVD	1.53	(1.19, 1.97)	0.0010	0.0010
Stroke	1.77	(1.45, 2.16)	< 0.0001	< 0.0001
Dementia	0.48	(0.25, 0.92)	0.0261	0.0261
Pulmonary	0.53	(0.42, 0.68)	< 0.0001	< 0.0001
Renal	1.60	(1.31, 1.97)	< 0.0001	< 0.0001
Bicarbonate (Normal:19–29)				0.0013
High vs. Normal	1.26	(0.85, 1.88)	0.2527	
Low vs. Normal	1.57	(1.22, 2.11)	0.0005	
Chloride (Normal:100–107)				< 0.0001
High vs. Normal	0.97	(0.73, 1.29)	0.8257	
Low vs. Normal	2.11	(1.79, 2.49)	< 0.0001	
Platelet (Normal:140–440)				0.0311
High vs. Normal	0.99	(0.66, 1.49)	0.9613	
Low vs. Normal	1.49	(1.11, 2.00)	0.0085	
Troponin T (Normal < 30)				< 0.0001
Abnormal vs. Normal	1.36	(1.22, 1.53)	< 0.0001	
Urea (Normal:2.7–6.9)				0.0150
High vs. Normal	1.23	(1.02, 1.46)	0.0283	
Low vs. Normal	1.38	(1.02, 1.86)	0.0363	
White Blood Cell Count (Normal:4–10)				< 0.0001
High vs. Normal	2.25	(1.96, 2.58)	< 0.0001	
Low vs. Normal	0.70	(0.39, 1.27)	0.2435	

CCI: Charleston comorbidity index, PVD: peripheral vascular disease, OR: odds ratio, CI: confidence interval

Table 5 Most common diagnosis categories at index and critical revisit

Most Common Index Visit Diagnosis Categories Resulting in Critical Revisits		
	Diagnosis Category	**Number (%)**
1	Spondylosis; intervertebral disc disorders; other back problems	88 (6.66)
2	Gastritis and duodenitis	66 (5)
3	Other gastrointestinal disorders	64 (4.84)
4	Conditions associated with dizziness or vertigo	58 (4.39)
5	Abdominal pain	53 (4.01)
6	Intestinal infection	49 (3.71)
7	Residual codes; unclassified	47 (3.56)
8	Genitourinary symptoms and ill-defined conditions	41 (3.1)
9	Viral infection	38 (2.88)
10	Acute cerebrovascular disease	36 (2.73)
Most Common Critical Revisit Diagnosis Categories		
	Diagnosis Category	**Number (%)**
1	Acute cerebrovascular disease	204 (15.44)
2	Septicemia (except in labor)	76 (5.75)
3	Biliary tract disease	53 (4.01)
4	Abdominal pain	51 (3.86)
5	Intestinal obstruction without hernia	48 (3.63)
6	Transient cerebral ischemia	48 (3.63)
7	Spondylosis; intervertebral disc disorders; other back problems	42 (3.18)
8	Fluid and electrolyte disorders	38 (2.88)
9	Skin and subcutaneous tissue infections	33 (2.5)
10	Gastrointestinal hemorrhage	31 (2.35)
Index Visit Diagnosis Categories with Highest Odds Ratios of Critical Revisit		
	Diagnosis Category	**OR (95%CI)**
1	Acute cerebrovascular disease	38.00 (27.04, 53.39)
2	Other gastrointestinal disorders	3.10 (2.41, 3.99)
3	Residual codes; unclassified	2.69 (2.01, 3.60)
4	Genitourinary symptoms and ill-defined conditions	2.34 (1.71, 3.19)
5	Gastritis and duodenitis	1.80 (1.41, 2.31)
6	Conditions associated with dizziness or vertigo	1.50 (1.15, 1.95)
7	Abdominal pain	1.41 (1.07, 1.85)
8	Viral infection	1.28 (0.93, 1.77)
9	Spondylosis; intervertebral disc disorders; other back problems	1.22 (0.98, 1.52)
10	Intestinal infection	1.09 (0.82, 1.46)

OR: odds ratio, CI: confidence interval

only a risk factor for unscheduled revisits [30], but also for a critical revisit.

Our study also identified index visit vital signs and lab tests associated with a critical revisit. It is not surprising that abnormal vital signs and lab results indicate a patient at higher risk. However, these results should be interpreted with caution, as we were unable to elucidate

if these abnormal vitals/ results were intervened on and resolved, or if the patient opted to discharge against advice. Without patient level analysis, it would be difficult to draw further conclusions.

In terms of comorbidities, while it is not surprising that having more comorbidities increased the odds of a critical revisit, of interest is the finding that that having dementia or pulmonary diseases seems to confer a preventive effect on a critical revisit. We postulate that this might be due to two reasons. Firstly, for patients with existing dementia there is a very low threshold to opt for admission. As such, it is likely that those that are discharged are very well. Secondly, for pulmonary diseases, this forms the most common comorbid in our population (44580 patients). Possibly, a large percentage of this could be due to asthma or COPD, both of which have robust evidence and guidelines on risk stratification, allowing for safer discharge should they present with these diseases. However, these are purely postulations and will require further investigation.

In conclusion, our study identified groups at risk of critical revisits, including the elderly, those with a CCI of 2 or more, and those presenting with abdominal related complaints. Further research should investigate risk mitigation approaches in these groups of patients. While it would not be possible to admit all at-risk patients for monitoring, there is opportunity for using other approaches to monitor these patients closely, including hospital at home programs [31], telehealth [32, 33], or phone follow up [34].

Limitations

Firstly, while we utilized a large dataset, this was a single center dataset from a tertiary hospital with a high proportion of patients with multiple comorbidities. This limits the generalizability of our findings. Secondly, due to the nature of the dataset, we were unable to elicit if there were revisits, critical or not, in another institution. Thus, our numbers are likely an underestimation of the true number of critical revisits.

Conclusion

Critical visits were rare in our institution but more likely amongst the elderly and those with multiple comorbidities. Clinicians should have a high index of suspicion for these patients as well as those who present with abdominal symptoms. Further studies should focus on these patients to understand if there were modifiable factors at the index visit, and if there are ways to enable earlier identification of worsening illness after discharge.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12245-025-00847-x.

Supplementary Material 1

Acknowledgements
Nil.

Author contributions
Study concept and design: ZL, SES, WLTC, MN, MEHO. Acquisition of data: FJS, MEHO. Analysis and interpretation of the data: ZL, RM, SES, FJS. Drafting of the manuscript: ZL, RM, WLTC, MEHO. Critical revision of the manuscript for important intellectual content: All. Statistical expertise: RM, SES. Acquisition of funding: ZL, SES, WLTC, MN.

Funding
This study was funded by the Singhealth Duke-NUS Academic Medicine Research Grant. The funders of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report. Study authors had access to the data. All authors took the decision to submit for publication.

Data availability
The datasets generated and/or analysed during the current study are not publicly available due to institutional policies but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by Singapore Health Services' Centralized Institutional Review Board (CIRB 2021/2122) with a waiver of consent granted for collection of EHR data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 11 November 2024 / Accepted: 25 February 2025
Published online: 03 March 2025

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