Impact of age on the discriminative ability of an emergency triage system:

A cohort study

Abbreviated Title: Age affects the discriminative ability of a triage system

Authors:

Akira Kuriyama

1. Director, Emergency and Critical Care Center, Kurashiki Central Hospital
2. Researcher, Department of Health Informatics, Kyoto University Graduate School of Medicine and Public Health

Tetsunori Ikegami

Head, Emergency and Critical Care Center, Kurashiki Central Hospital

Takeo Nakayama

Professor, Department of Health Informatics, Kyoto University Graduate School of Medicine and Public Health

Corresponding author:

Akira Kuriyama, MD, MPH, FACP

Emergency and Critical Care Center, Kurashiki Central Hospital, Okayama

Department of Health Informatics, Kyoto University Graduate School of Medicine and Public Health

1-1-1 Miwa Kurashiki Okayama 710-8602 JAPAN

E: akira.kuriyama.jpn@gmail.com / kuriyama.akira.26r@kyoto-u.jp

T: +81-86-422-0210 F: +81-86-421-3424

Word count: 3033 words for text; 264 words for abstract.

Conflict of Interest: None.

Funding: None.

ABSTRACT

Background: Emergency triage systems optimize resources in emergency departments (EDs) for those who need urgent care. Five-level triage systems, such as the Canadian Triage and Acuity Scale (CTAS), have been used worldwide. We examined whether the discriminative ability of an emergency triage system varies according to age group using a patient cohort triaged with the Japan Triage and Acuity Scale (JTAS), a validated system based on the CTAS.

Methods: We conducted a cohort study of 27,120 self-presenting patients aged 16 years and older who were triaged with (JTAS) between June 2013 and May 2014 at a Japanese tertiary care hospital. Outcome measures were admission to intensive care units (ICUs) as primary and in-hospital death as secondary. We described the trends of the discriminative ability of JTAS using areas under the curve of the receiver operating characteristic (AUROC), sensitivity, specificity, positive predictive value, and negative predictive value of JTAS for seven age categories.

Results: The AUROC of JTAS for ICU admission decreased with age (maximum 0.85 to minimum 0.71), sensitivity non-significantly decreased (maximum 0.67 to minimum 0.32), and specificity declined with age (maximum 0.96 to minimum 0.88). The positive and negative predictive value increased (minimum 0.03 to maximum 0.09) and decreased (minimum 0.98 to maximum 0.99), respectively, with age. Overall misclassification increased across age groups ($p < 0.001$). This trend was mostly consistent with the analysis of in-hospital death.

Conclusion: Our study suggests that the discriminative ability of an emergency triage system decreases as patient age increases, corresponding to a decrease in specificity. Undertriage may not significantly increase, but misclassification significantly increases as patient age increases.

Keywords: triage; emergency medicine; discriminative ability; sensitivity; specificity; undertriage; observational study.

INTRODUCTION

Emergency triage systems have been developed to categorize patients according to those who do or do not need urgent care, thus optimizing resources in the emergency department (ED) for patients in need of immediate intervention.

As the general population of developed countries continues to grow steadily older, the average age of patients visiting EDs reflects this trend. Older patients account for 12–24% of all ED visits [1-4], and older patients who visit an ED with non-specific complaints are more likely to be misdiagnosed, remain untreated for an unrecognized entity, and encounter adverse events [3,5-9]. Mistriage as a downside of emergency triage systems has been emphasized less frequently in research than the accuracy of these systems, and older patients are more likely to be mistriaged [10-13]. Some studies have focused on geriatric emergency department[14] or emergency triage systems for elderly patients only[8,15-18]. In contrast, few studies have attempted to examine the discriminative ability of an emergency triage system in other age populations. To the best our knowledge, it is unknown how discriminative ability of an emergency triage varies according to wide age groups.

Five-level triage systems, such as the Canadian Triage and Acuity Scale (CTAS), are used worldwide. Many EDs in Japan use the Japan Triage and Acuity Scale

(JTAS), which was developed from the CTAS with some modifications for the local context. To examine the impact of age on the discriminative ability of an emergency triage system, we analyzed data from a large cohort of self-presenting adults, which was previously used to validate the JTAS [19].

MATERIALS AND METHODS

Japan Triage and Acuity Scale

The JTAS was developed in 2012 by the Japanese Society for Emergency Medicine, the Japanese Association for Acute Medicine, the Japanese Society for Emergency Paediatrics, and the Japanese Association for Emergency Nursing. As in the CTAS, the JTAS begins with an evaluation of 17 main complaint groups and 165 specific complaints. Primary modifiers such as vital signs, pain, and mechanism of injury help nurses to assign one triage level to a patient. Additional modifiers for certain complaints or groups of complaints occasionally help refine their prioritization. The JTAS assigns a patient to one of five levels of urgency: level 1, resuscitation; level 2, emergent; level 3, urgent; level 4, less urgent; and level 5, nonurgent. The JTAS, like the CTAS, also recommends the time to care by physicians for each level as follows: immediate (level 1); within 10 minutes (level 2); within 30 minutes (level 3); within 60 minutes (level 4);

and within 120 minutes (level 5) (**Table 1**). Since its introduction in 2012, the JTAS has been implemented in many Japanese EDs and has been validated [19].

Study Design and Setting

This was a single-centre cohort study conducted at the emergency department of Kurashiki Central Hospital in Okayama, Japan from June 1, 2013 to May 31, 2014. Kurashiki Central Hospital is an 1166-bed, tertiary care hospital located in western Japan. Nearly 70,000 patients are examined in the ED annually, including both adults and children, of which approximately 9,000 are transferred by ambulance.

Selection of Participants

Patients who met the following criteria were included in our study: 1) ≥16 years of age according to the age classification used in the JTAS; 2) self-presented to the ER and were triaged during the selected 1-year period (June 2013 through May 2014); and 3) had one disposition per ED visit (admission, death, or discharge from the ED). Patients transferred by ambulance to the ED are not triaged with JTAS in our institution, as ED physicians immediately examine these patients on arrival to the ED; thus, these patients were excluded. Patients who left the ED without being seen by physicians or being triaged by triage nurses were also excluded.

Measurements

All self-presenting patients were triaged by triage nurses using JTAS when they were registered at the entrance of the ED, except in cases when triage nurses were unavailable. The ED at Kurashiki Central Hospital uses the JTAS to triage patients and has developed its own program for training triage nurses; this program has been previously reported[19].

When a patient arrives to the ED, information to identify the patient, such as patient identification number, age, sex, and the time of the visit, are prospectively registered in the ED database. After a triage nurse assigns the patient to a triage level with the help of a computer-based software that is compliant with JTAS, the triage level is recorded in the database. ED clerks document the final disposition (death, admission, or discharge from the ED) and the time of occurrence. This constitutes the dataset collected at the ED.

For the present study, the information related to patient prognosis (in-hospital death) of admitted patients was manually confirmed by the medical charts and added to the dataset. This data was then deidentified for research purpose, and has previously been used to validate the JTAS [19].

Outcomes

Our systematic review found that overall and intensive care unit (ICU) admission are frequently used outcomes to validate 5-level triage systems [20]. We previously used both of these admission outcomes to validate the JTAS [19]; however, in Japan it is possible that there are many admissions for non-medical indications, and thus in the Japanese context overall admission may less precisely reflect patient urgency than ICU admission. However, it is possible that there were cases who were critically ill but received limited intensive treatment, e.g., elderly adults or patients with advanced care planning, who would likely have been overlooked if we had limited the outcome to only ICU admission. Therefore, we defined ICU admission as primary and in-hospital death as secondary outcome measures in this study. ICU admission included both admission to ICUs or death in the ED. We planned to set age groups by every 10 years of age. When there were a small number of patients in a single age group for ICU admission, we considered merging some categories.

Our institution has several ICUs according to diseases, and clinicians share the following principle indications for admission to ICUs: 1) altered mental status or use of sedatives that require airway protection; 2) respiratory compromise that requires mechanical ventilation; 3) circulatory compromise that requires circulatory assist device or hourly titration of fluids, vasopressors, and inotropes; 4) severe metabolic disorders, electrolytes disturbances, or acute medical diseases that require close monitoring of vital signs; and 5) emergency or elective surgeries of high-risk patients that require close monitoring of vital signs.

Statistical Analysis

We used typical 5-level triage categories to examine the discriminative ability of JTAS for ICU admission using receiver operating characteristic (ROC) curves for each age category and determined the areas under the curve of the ROC (AUROC).

The JTAS levels 1 and 2 are clinically deemed most urgent and patients assessed as such levels may potentially require ICU admission. The JTAS levels 3, 4, and 5 are considered less urgent, and patients assigned to these levels may not require ICU admission. We therefore divided the triage levels to two groups: one group of patients assigned levels 1–2, and the other group of patients assigned levels 3–5. We used the two-class triage categories to operationally determine the sensitivity, specificity, positive predictive value, and negative predictive value of JTAS for ICU admission and in-hospital death in each age category. We tested for trends of sensitivity, specificity, and positive and negative predictive values in each age category using the Cochrane-Armitage test. We conducted a further sensitivity analysis by grouping the triage levels differently (JTAS levels 1–3 and 4–5). P-values of <0.05 were considered statistically significant. We conducted all analyses using Stata (version 15.1; StataCorp, College Station, TX, USA).

The institutional review board of Kurashiki Central Hospital and Kyoto University Graduate School and Faculty of Medicine Ethics Committee approved this study. Individual written informed consent was waived as the data was originally intended for clinical use and deidentified for study purpose.

RESULTS

Characteristics of the Study Subjects

A total of 38,414 adult patients visited the ED during the 1-year study period, of which 8,753 arrived by ambulance. After excluding non-triaged patients (n = 2535) and patients who left without being seen (n = 6), a total of 27,120 triaged, self-presenting adult patients (female: 14,154 [52.2%]) were included in this study (**Figure 1**). The characteristics of the participants are shown in **Table 2**. Participant median age was 58 years. We initially categorized the patients into age groups as follows: 16–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, and 85+. Since a small number of patients aged 16–24 and 25–34 were admitted to ICUs, we merged the two age groups into 16–34, for a total of seven age groups. Dominant age categories were 16–34, 65–74, and 75–84. Triage levels 3 and 4 were the most common (36.6% and 49.3%, respectively). A total of 3,272 (12.1%) patients were admitted, of which 311 (1.1%) were admitted to the ICU and 5 (0.02%) died in the ED. Proportion of ICU admission increased with increasing patient age (p<0.001) (**Table 3**).

Main Results

The 2 × 2 table of each age category for ICU admission is shown in **Supplementary Table 1**. The AUROC of JTAS for ICU admission ranged between the highest at 0.85 among the youngest group and the lowest at 0.71 among the oldest group; the AUROC tended to decrease with patient age. The sensitivity of the JTAS for ICU admission decreased with age, although this trend was statistically non-significant (p = 0.43), ranging between 0.32–0.67 (**Table 4).** The specificity of the JTAS for ICU declined with age (p < 0.001) but remained above 0.90 except for in the age category of 85+.

The positive predictive value for ICU admission ranged between 0.03–0.09 and increased with patient age ($p = 0.013$). The negative predictive value for ICU admission ranged between 0.98–0.99 and decreased with increasing patient age ($p < 0.001$).

In each age group, the proportion of admission to general wards/discharged to home in patients assigned levels 1–2 and that of ICU admission in those assigned levels 3–5 ranged 0.04–0.11 and 0.001–0.01, respectively, and increased across age groups ($p < 0.001$, each). Consequently, overall misclassification (ICU admission in patients assigned levels 1–2 and admission to general wards/discharged to home in those assigned levels 3–5) increased across age groups ($p < 0.001$).

Secondary Outcomes

The 2 × 2 table of each age category for in-hospital death is shown in **Supplementary Table 2**. The AUROC of JTAS for in-hospital death ranged between 0.76 and 0.56, but all 95% confidence intervals overlapped across age groups (**Table 5**). As patient age increased, the sensitivity of the JTAS for in-hospital death non-significantly decreased ($p = 0.087$), and specificity significantly declined with age ($p < 0.001$). The positive predictive value for in-hospital death increased ($p < 0.001$), and negative predictive value decreased with patient age ($p < 0.001$).

The proportion of survival at discharge from ED or hospitalization in patients assigned levels 1–2 and that of in-hospital death in those assigned levels 3–5 in each age group ranged from 0.04–0.12 and 0.0003–0.01, respectively, and increased across age groups ($p < 0.001$, each). Consequently, overall misclassification increased across age groups ($p < 0.001$).

The in-hospital death of patients who were admitted to ICUs was 6.5% (9/137) for levels 1–2 and 5.5% (10/179) for levels 3-5, and there was no significant difference between these two groups ($p = 0.81$).

Sensitivity Analysis

Sensitivity analysis performed by dividing JTAS levels 1–3 and 4–5 suggested a finding similar to the primary analyses: sensitivity increased but not significantly ($p = 0.90$), specificity decreased ($p < 0.001$), positive predictive value increased ($p < 0.001$), and negative predictive value decreased ($p < 0.001$) with increasing patient age (**Supplementary Table 3**). Of note, the sensitivity in this sensitivity analysis ranged between 0.79–0.96, which was higher than the primary analysis finding, while the specificity ranged between 0.39–0.71, which was lower.

DISCUSSION

We found that the discriminative ability of the JTAS, as shown in the AUROC, varied among age groups, with a general decreasing trend corresponding to increasing patient age. The sensitivity of JTAS did not significantly vary with age, but the positive predictive value increased and the specificity and negative predictive value of the JTAS decreased. This trend was also observed in the analysis examining in-hospital death, with the exception of AUROC, thereby confirming the robustness of our findings. Misclassification tended to increase with age for both outcomes of ICU admission and in-hospital death.

Vital signs constitute a critical part of assessment in the JTAS, but responses change with age [13,21-23]. Generally, clinicians observe normal vital signs in older patients even under severe conditions; for example, heart rate [24,25], blood pressure [22,23], and body temperature [26] tend to remain within the normal range of values. We thus guessed that the discriminative ability of JTAS might decline as the age of triaged patients increased. We previously reported that the AUROC of the JTAS was 0.792 among all age categories when the outcome was ICU admission [19]. In the present study, we found that the AUROC varied among different age groups, with a general decreasing trend according to age. Since patients who were not admitted to ICUs outnumbered ICU admissions in our study, we speculated that the decreased specificity corresponding with increased age outweighed the sensitivity, resulting in a decreased AUROC with aging. A similar phenomenon was noted in studies of the Emergency Severity Index (ESI). Grossman et al. conducted a single-centre prospective study using the German version of the ESI [8,27] and indicated a slight decline in the AUROC when the analysis was restricted to the older population (an AUROC of 0.856 for ICU admission in unselected patients [27] and 0.749 for patients aged ≥65 years [8]). To the best of our knowledge, the present study is the first to demonstrate a gradual decline in the accuracy of an emergency triage system with aging.

In the primary outcome analysis, the sensitivity of an emergency triage system indicates the proportion of patients rated as emergent among all that need critical care, and undertriage represents the remaining patients (1-sensitivity). In contrast, specificity refers to the proportion of patients assessed as non-urgent among all that do not need critical care, and overtriage represents all others (1-specificity). Our study suggests that the sensitivity of JTAS did not significantly vary, but specificity decreased with increasing patient age. This decreasing trend in specificity could be due in part to a spectrum effect of the patient age groups [28]. Correctly triaging patients at risk for ICU admission among older adults might be more difficult than among younger patients because the difference between those who truly need ICU admission and those who not is occasionally subtle. The proportion of overall misclassification (undertriage and overtriage) tended to increase across age groups as well. The analysis of the secondary outcome, in-hospital death, showed almost the same tendency as mentioned above. Clinicians should be aware that overtriage and misclassification in older patients may increase with the real use of JTAS.

In our study, for both outcomes, the positive predictive value and negative predictive value of the JTAS increased and decreased, respectively, as patient age increased. Since older patients are known to have multiple comorbidities and a higher risk of hospital admission and mortality [1,3,5,29-32], it is expected that the prevalence of severe patients who might need ICU admission may increase with aging. This might have led to increased admission to ICUs in older patients rated as true urgent (positive predictive value) or non-urgent (1-negative predictive value). Thus, the present findings are plausible. The results of our analysis of in-hospital death as secondary outcome were almost compatible with these findings.

Overall, our study suggests that the discriminative ability of JTAS decreased corresponding to decreasing specificity with patient age, with respect to the need of critical care or in-hospital death. No significant change of sensitivity suggests that it is unlikely that clinicians using JTAS undertriage patients, but the decrease of specificity indicates that clinicians are likely to overtriage patients leading to an excess use of medical resources in older patients. These potentially highlight the necessity of setting different cutoffs of vital signs in JTAS for older patients.

The results of the sensitivity analysis were consistent with the primary analysis, thereby confirming the robustness of our findings. Meanwhile, the sensitivity analysis found that lowering the threshold for immediate care (considering Level 3 as urgent) largely decreased the specificity and subsequently increased overtriage, which suggests that overly permitting overtriage might lead to an excess use of medical resources. Although it is hard to find the sweet spot in this trade-off, clinicians should acknowledge that JTAS tends to lead to overtriage in older patients.

Our study has some limitations. First, we assessed the discriminative ability of JTAS using surrogate markers of severity instead of patient acuity. We used ICU admission as the primary outcome, which includes elements of both urgency and severity, rather than using overall admission in which severity and other non-medical factors might be more weighted. However, patient acuity and severity are not identical, which is a limitation commonly shared by studies of emergency triage systems. Second, ICU admission might have been underestimated in very old patients, as patients and clinicians may opt for non-invasive treatment in consideration of life expectancy. This might have underestimated sensitivity and potential discriminative ability, as shown in the AUROC, among particularly old patients. By examining in-hospital death as the secondary outcome, however, the current findings concerning the performance of the JTAS could be robust, regardless of possible critical cases with treatment limitations. Third, the present study was conducted using the JTAS at a large but single hospital. Further studies are needed to confirm reproducibility in other emergency triage systems or in other populations using the JTAS. These findings would underscore the importance of focusing on age when revising existing emergency triage systems.

In conclusion, our study suggests that the discriminative ability of an emergency triage system decreases with patient age, corresponding to a decrease in specificity. Undertriage may not significantly increase, but increase in misclassification is significant as patient age increases.

Acknowledgement

None.

References

1. Niska R, Bhuiya F, Xu J. National Hospital Ambulatory Medical Care Survey: 2007 emergency department summary. National health statistics reports 2010: 1-31.

2. Salvi F, Morichi V, Grilli A, Giorgi R, De Tommaso G, Dessi-Fulgheri P. The elderly in the emergency department: a critical review of problems and solutions. Internal and emergency medicine 2007; 2: 292-301.

3. Gruneir A, Silver MJ, Rochon PA. Emergency department use by older adults: a literature review on trends, appropriateness, and consequences of unmet health care needs. Medical care research and review : MCRR 2011; 68: 131-55.

4. Hu SC, Yen D, Yu YC, Kao WF, Wang LM. Elderly use of the ED in an Asian metropolis. The American journal of emergency medicine 1999; 17: 95-9.

5. Samaras N, Chevalley T, Samaras D, Gold G. Older patients in the emergency department: a review. Annals of emergency medicine 2010; 56: 261-9.

6. Djarv T, Castren M, Martenson L, Kurland L. Decreased general condition in the emergency department: high in-hospital mortality and a broad range of discharge diagnoses. European journal of emergency medicine : official journal of the European Society for Emergency Medicine 2015; 22: 241-6.

7. Wachelder JJH, Stassen PM, Hubens L, Brouns SHA, Lambooij SLE, Dieleman JP, Haak HR. Elderly emergency patients presenting with non-specific complaints: Characteristics and outcomes. PloS one 2017; 12: e0188954.

8. Grossmann FF, Zumbrunn T, Frauchiger A, Delport K, Bingisser R, Nickel CH. At risk of undertriage? Testing the performance and accuracy of the emergency severity index in older emergency department patients. Annals of emergency medicine 2012; 60: 317-25 e3.

9. Platts-Mills TF, Travers D, Biese K, McCall B, Kizer S, LaMantia M, Busby-Whitehead J, Cairns CB. Accuracy of the Emergency Severity Index triage instrument for identifying elder emergency department patients receiving an immediate life-saving intervention. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine 2010; 17: 238-43.

10. Gasperini B, Cherubini A, Fazi A, Maracchini G, Prospero E. Older adults in Emergency Departments: the challenge of undertriage. Internal and emergency medicine 2016; 11: 1145-47.

11. Kodadek LM, Selvarajah S, Velopulos CG, Haut ER, Haider AH. Undertriage of older trauma patients: is this a national phenomenon? The Journal of surgical research 2015; 199: 220-9.

12. van der Wulp I, van Baar ME, Schrijvers AJ. Reliability and validity of the

Manchester Triage System in a general emergency department patient population in the Netherlands: results of a simulation study. Emergency medicine journal : EMJ 2008; 25: 431-4.

13. Lamantia MA, Stewart PW, Platts-Mills TF, Biese KJ, Forbach C, Zamora E, McCall BK, Shofer FS, Cairns CB, Busby-Whitehead J, Kizer JS. Predictive value of initial triage vital signs for critically ill older adults. The western journal of emergency medicine 2013; 14: 453-60.

14. Keyes DC, Singal B, Kropf CW, Fisk A. Impact of a new senior emergency department on emergency department recidivism, rate of hospital admission, and hospital length of stay. Annals of emergency medicine 2014; 63: 517-24.

15. Baumann MR, Strout TD. Triage of geriatric patients in the emergency department: validity and survival with the Emergency Severity Index. Annals of emergency medicine 2007; 49: 234-40.

16. Ichwan B, Darbha S, Shah MN, Thompson L, Evans DC, Boulger CT, Caterino JM. Geriatric-specific triage criteria are more sensitive than standard adult criteria in identifying need for trauma center care in injured older adults. Annals of emergency medicine 2015; 65: 92-100 e3.

17. Galvin R, Gilleit Y, Wallace E, Cousins G, Bolmer M, Rainer T, Smith SM, Fahey T. Adverse outcomes in older adults attending emergency departments: a systematic review and meta-analysis of the Identification of Seniors At Risk (ISAR) screening tool. Age and ageing 2017; 46: 179-86.

18. Tavares JPA, Sa-Couto P, Boltz M, Capezuti E. Identification of Seniors at Risk (ISAR) in the emergency room: A prospective study. International emergency nursing 2017; 35: 19-24.

19. Kuriyama A, Ikegami T, Kaihara T, Fukuoka T, Nakayama T. Validity of the Japan Acuity and Triage Scale in adults: a cohort study. Emergency medicine journal : EMJ 2018; 35: 384-88.

20. Kuriyama A, Urushidani S, Nakayama T. Five-level emergency triage systems: variation in assessment of validity. Emergency medicine journal : EMJ 2017; 34: 703-10.

21. Lucke JA, de Gelder J, Clarijs F, Heringhaus C, de Craen AJM, Fogteloo AJ, Blauw GJ, Groot B, Mooijaart SP. Early prediction of hospital admission for emergency department patients: a comparison between patients younger or older than 70 years. Emergency medicine journal : EMJ 2018; 35: 18-27.

22. Brown JB, Gestring ML, Forsythe RM, Stassen NA, Billiar TR, Peitzman AB, Sperry JL. Systolic blood pressure criteria in the National Trauma Triage Protocol for geriatric trauma: 110 is the new 90. The journal of trauma and acute care surgery 2015; 78:

352-9.
23. Heffernan DS, Thakkar RK, Monaghan SF, Ravindran R, Adams CA, Jr., Kozloff MS, Gregg SC, Connolly MD, Machan JT, Cioffi WG. Normal presenting vital signs are unreliable in geriatric blunt trauma victims. The Journal of trauma 2010; 69: 813-20.
24. Green JE, Ariathianto Y, Wong SM, Aboltins C, Lim K. Clinical and inflammatory response to bloodstream infections in octogenarians. BMC geriatrics 2014; 14: 55.
25. Christou DD, Seals DR. Decreased maximal heart rate with aging is related to reduced {beta}-adrenergic responsiveness but is largely explained by a reduction in intrinsic heart rate. Journal of applied physiology (Bethesda, Md : 1985) 2008; 105: 24-9.
26. Bellmann-Weiler R, Weiss G. Pitfalls in the diagnosis and therapy of infections in elderly patients--a mini-review. Gerontology 2009; 55: 241-9.
27. Grossmann FF, Nickel CH, Christ M, Schneider K, Spirig R, Bingisser R. Transporting clinical tools to new settings: cultural adaptation and validation of the Emergency Severity Index in German. Annals of emergency medicine 2011; 57: 257-64.
28. Mulherin SA, Miller WC. Spectrum bias or spectrum effect? Subgroup variation in diagnostic test evaluation. Annals of internal medicine 2002; 137: 598-602.
29. Fortin M, Soubhi H, Hudon C, Bayliss EA, van den Akker M. Multimorbidity's many challenges. BMJ (Clinical research ed) 2007; 334: 1016-7.
30. Marengoni A, Angleman S, Melis R, Mangialasche F, Karp A, Garmen A, Meinow B, Fratiglioni L. Aging with multimorbidity: a systematic review of the literature. Ageing research reviews 2011; 10: 430-9.
31. Menotti A, Mulder I, Nissinen A, Giampaoli S, Feskens EJ, Kromhout D. Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause mortality: The FINE study (Finland, Italy, Netherlands, Elderly). Journal of clinical epidemiology 2001; 54: 680-6.
32. Vogeli C, Shields AE, Lee TA, Gibson TB, Marder WD, Weiss KB, Blumenthal D. Multiple chronic conditions: prevalence, health consequences, and implications for quality, care management, and costs. Journal of general internal medicine 2007; 22 Suppl 3: 391-5.

Figure Legend

Figure 1. Selection of study participants

Table 1. Summary of the Japan Triage and Acuity Scale.

Triage Level	Examples of dieases	Recommended Time to Care
Level 1 (Resuscitation)	Cardiac arrest, severe trauma, epilepsy, severe altered mental status, severe respiratory compromise.	See patient immediately
Level 2 (Emergent)	Cardiogenic chest pain, severe headaches or abdominal pain, moderate altered mental status, depression, self-injury, depressive state.	Within 15 minutes
Level 3 (Urgent)	Asymptomatic hypertension, status post epilepsy, deformed limbs, moderate headache or abdominal pain, intrapartum period on arrival.	Within 30 minutes
Level 4 (Less Urgent)	Urinary tract infection, wounds requiring closure, delirium.	Within 60 minutes
Level 5 (Non-urgent)	Mild anaphylaxis, wounds that do not require close, request for prescriptions or examinations.	Within 120 minutes

Note: refer to the Canadian Emergency Department Triage and Acuity Scale Implementation Guidelines for the cutoffs of vital signs used in the Japan Triage and Acuity Scale.

Table 2. Baseline characteristics of the participants.

Characteristics		
No. of participants		27120
Median age, years (first, third quartile)		58 (35, 73)
Age category, n (%)		
	16- 34	6756 (24.9 %)
	35- 44	3429 (12.6 %)
	45- 54	2505 (9.2 %)
	55- 64	3343 (12.3 %)
	65- 74	4884 (18.0 %)
	75- 84	4417 (16.3 %)
	85+	1786 (6.7 %)
Female, n (%)		14154 (52.2 %)
Shift of arrival, n (%)		
	Day (8:30 AM- 4:30 PM)	11307 (41.7 %)
	Evening (4:30 PM- 0:30 AM)	11757 (43.3 %)
	Night (0:30 AM- 8:30 AM)	4056 (15.0 %)
Day of week		
	Weekdays	16640 (61.4 %)
	Weekends/ Holidays	10480 (38.6 %)
Triage level, n (%)		
	1	106 (0.4 %)
	2	1807 (6.7 %)
	3	9921 (36.6 %)
	4	13388 (49.3 %)
	5	1898 (7.0 %)
Median ED length of stay, minutes		128 (77, 203)
	(first, third quartile)	
Final disposition at the ED, n (%)		
	Admission to ICUs	311 (1.1 %)
	Admission to general wards	2961 (10.9 %)
	Death	5 (0.02 %)
	Discharged	23843 (87.9 %)

Abbreviations; ED, emergency department.

Table 3. Patient outcomes according to age category

Age category	ICU admission/ Deaths in ED	In-hospital death / Death in ED
16- 34	15 (0.5 %)	2 (0.03 %)
35- 44	19 (0.6 %)	5 (0.15 %)
45- 54	28 (1.1 %)	6 (0.24 %)
55- 64	47 (1.4 %)	13 (0.39 %)
65- 74	83 (1.7 %)	44 (0.90 %)
75- 84	93 (2.1 %)	42 (0.95 %)
85-	31 (1.7 %)	25 (1.40 %)

Abbreviation: ICU, intensive care unit; ED, emergency department.

Percentages in the brackets indicate the proportion of admission in each age category.

Table 4. Sensitivity, specificity, positive predictive value, and negative predictive value for intensive care unit admission by age category.

Age category	AUROC	Sensitivity	Specificity	PPV	NPV	GW admission or discharge home in levels 1-2 in age group	ICU admission in levels 3-5 in age group	Overall misclassification in age group
16- 34	0.851 (0.728- 0.973)	0.67 (0.38- 0.80)	0.96 (0.96- 0.97)	0.04 (0.02- 0.07)	0.999 (0.998- 1.000)	0.036 (0.032- 0.041)	0.001 (0.0002- 0.002)	0.037 (0.033- 0.042)
35- 44	0.763 (0.662- 0.866)	0.32 (0.13- 0.57)	0.95 (0.94- 0.96)	0.03 (0.01- 0.07)	0.996 (0.993- 0.998)	0.05 (0.04- 0.06)	0.004 (0.002- 0.006)	0.05 (0.04- 0.06)
45- 54	0.826 (0.777- 0.875)	0.32 (0.16- 0.52)	0.94 (0.93- 0.95)	0.06 (0.03- 0.11)	0.992 (0.987- 0.995)	0.06 (0.05- 0.07)	0.008 (0.005- 0.012)	0.06 (0.05- 0.07)
55- 64	0.823 (0.766- 0.880)	0.55 (0.40- 0.69)	0.92 (0.91- 0.93)	0.09 (0.06- 0.13)	0.993 (0.989- 0.996)	0.08 (0.07- 0.09)	0.006 (0.004- 0.096)	0.09 (0.08- 0.10)
65- 74	0.766 (0.714- 0.817)	0.45 (0.34- 0.56)	0.92 (0.91- 0.93)	0.09 (0.06- 0.13)	0.990 (0.986- 0.993)	0.08 (0.07- 0.09)	0.009 (0.007- 0.013)	0.087 (0.078- 0.095)
75- 84	0.737 (0.690- 0.783)	0.38 (0.28- 0.48)	0.91 (0.90- 0.92)	0.09 (0.06- 0.12)	0.986 (0.981- 0.989)	0.08 (0.07- 0.09)	0.013 (0.010- 0.017)	0.10 (0.09- 0.11)
85-	0.711 (0.617- 0.805)	0.45 (0.27- 0.64)	0.88 (0.87- 0.90)	0.06 (0.04- 0.11)	0.989 (0.983- 0.994)	0.11 (0.10- 0.13)	0.010 (0.006- 0.02)	0.12 (0.11- 0.14)
p-value for trend	Not estimable	0.43	< 0.001	0.013	< 0.001	< 0.001	< 0.001	< 0.001

Abbreviation: AUROC, area under receiver operational characteristic curve; PPV, positive predictive value; NPV, negative predictive value; GW, general ward.

Table 5. Sensitivity, specificity, positive predictive value, and negative predictive value for in-hospital mortality by age category.

Age category	AUROC	Sensitivity	Specificity	PPV	NPV	Survival in levels 1-2 in age group	In-hospital mortality in levels 3-5 in age group	Overall misclassification in age group
16- 34	0.611 (0.179- 1.000)	0 (0- 0.84)	0.96 (0.95- 0.97)	0 (0- 0.01)	0.9996 (0.9988- 0.9999)	0.038 (0.033- 0.043)	0.0003 (0.00004- 0.001)	0.038 (0.033- 0.043)
35- 44	0.711 (0.540- 0.881)	0 (0- 0.52)	0.95 (0.94- 0.96)	0 (0- 0.02)	0.998 (0.996- 0.999)	0.05 (0.04- 0.06)	0.001 (0.0004- 0.003)	0.05 (0.04- 0.06)
45- 54	0.561 (0.373- 0.749)	0 (0- 0.46)	0.80 (0.78- 0.81)	0 (0- 0.02)	0.997 (0.994- 0.999)	0.06 (0.05- 0.07)	0.002 (0.0009- 0.005)	0.06 (0.05- 0.07)
55- 64	0.755 (0.706- 0.804)	0.15 (0.02- 0.45)	0.91 (0.90- 0.92)	0.01 (0.001- 0.02)	0.996 (0.993- 0.998)	0.09 (0.08- 0.10)	0.003 (0.002- 0.006)	0.09 (0.08- 0.10)
65- 74	0.735 (0.668- 0.801)	0.32 (0.19- 0.48)	0.91 (0.90- 0.92)	0.03 (0.02- 0.06)	0.993 (0.990- 0.995)	0.08 (0.07- 0.09)	0.006 (0.004- 0.009)	0.09 (0.08- 0.10)
75- 84	0.693 (0.626- 0.761)	0.24 (0.12- 0.39)	0.91 (0.90- 0.92)	0.02 (0.01- 0.04)	0.992 (0.989- 0.995)	0.09 (0.08- 0.10)	0.007 (0.005- 0.01)	0.10 (0.09- 0.11)
85-	0.657 (0.561- 0.755)	0.28 (0.12- 0.49)	0.88 (0.86- 0.89)	0.03 (0.01- 0.07)	0.989 (0.982- 0.993)	0.12 (0.10- 0.13)	0.01 (0.006- 0.02)	0.13 (0.11- 0.14)
p-value for trend	Not estimable	0.087	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Abbreviation: AUROC, area under receiver operational characteristic curve; PPV, positive predictive value; NPV, negative predictive value.

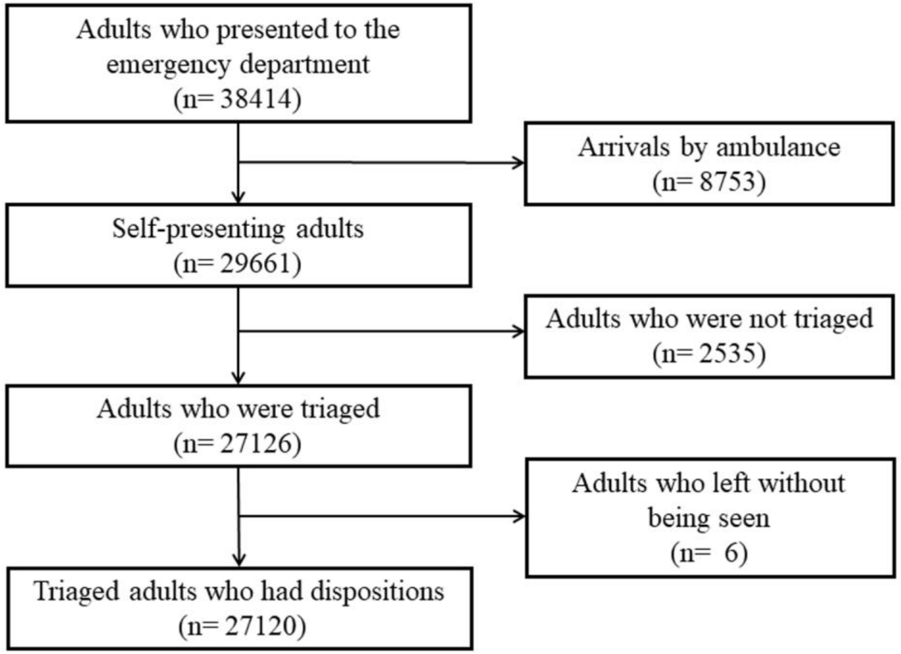
Adults who presented to the emergency department (n= 38414)
Arrivals by ambulance (n= 8753)
Self-presenting adults (n= 29661)
Adults who were not triaged (n= 2535)
Adults who were triaged (n= 27126)
Adults who left without being seen (n= 6)
Triaged adults who had dispositions (n= 27120)

Figure 1

Supplementary Table 1. 2 x 2 Tables by Emergency Triage Levels and ICU Admission/ Death in the ED.

Age 16- 34

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	10	246
	3- 5	5	6495

Sensitivity	0.67 (95% CI, 0.38- 0.80)
Specificity	0.96 (95% CI, 0.96- 0.97)
Positive predictive value	0.04 (95% CI, 0.02- 0.07)
Negative predictive value	0.999 (95% CI, 0.998- 1.000)

Age 35- 44

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	6	166
	3- 5	13	3244

Sensitivity	0.32 (95% CI, 0.13- 0.57)
Specificity	0.95 (95% CI, 0.94- 0.96)
Positive predictive value	0.03 (95% CI, 0.01- 0.07)
Negative predictive value	0.996 (95% CI, 0.993- 0.998)

Age 45- 54

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	9	141
	3- 5	19	2336

Sensitivity	0.32 (95% CI, 0.16- 0.52)
Specificity	0.94 (95% CI, 0.93- 0.95)
Positive predictive value	0.06 (95% CI, 0.03- 0.11)
Negative predictive value	0.992 (95% CI, 0.987- 0.995)

Age 55- 64

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	26	268
	3- 5	21	3028

Sensitivity	0.55 (95% CI, 0.40- 0.69)
Specificity	0.92 (95% CI, 0.91- 0.93)
Positive predictive value	0.09 (95% CI, 0.06- 0.13)
Negative predictive value	0.993 (95% CI, 0.989- 0.996)

Age 65- 74

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	37	377
	3- 5	46	4424

Sensitivity	0.45 (95% CI, 0.34- 0.56)
Specificity	0.92 (95% CI, 0.91- 0.93)
Positive predictive value	0.09 (95% CI, 0.06- 0.12)
Negative predictive value	0.990 (95% CI, 0.986- 0.993)

Age 75- 84

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	35	374
	3- 5	58	3950

Sensitivity	0.38 (95% CI, 0.28- 0.48)
Specificity	0.91 (95% CI, 0.90- 0.92)
Positive predictive value	0.09 (95% CI, 0.06- 0.12)
Negative predictive value	0.986 (95% CI, 0.981- 0.989)

Age 85+

		Patient Outcomes	
		ICU Admission/ Death in the ED	The others
Emergency Triage Levels	1- 2	14	204
	3- 5	17	1551

Sensitivity	0.45 (95% CI, 0.27- 0.64)
Specificity	0.88 (95% CI, 0.87- 0.90)
Positive predictive value	0.06 (95% CI, 0.04- 0.11)
Negative predictive value	0.989 (95% CI, 0.983- 0.994)

Supplementary Table 2. 2 x 2 Tables by Emergency Triage Levels and In-hospital Death.

Age 16- 34

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	0	256
	3- 5	2	6498

Sensitivity	0 (95% CI, 0- 0.84)
Specificity	0.96 (95% CI, 0.95- 0.97)
Positive predictive value	0 (95% CI, 0- 0.01)
Negative predictive value	0.9996 (95% CI, 0.9988- 0.9999)

Age 35- 44

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	0	172
	3- 5	5	3252

Sensitivity	0 (95% CI, 0- 0.52)
Specificity	0.95 (95% CI, 0.94- 0.96)
Positive predictive value	0 (95% CI, 0- 0.02)
Negative predictive value	0.998 (95% CI, 0.996- 0.999)

Age 45- 54

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	0	150
	3- 5	6	2349

Sensitivity	0 (95% CI, 0- 0.46)
Specificity	0.80 (95% CI, 0.78- 0.81)
Positive predictive value	0 (95% CI, 0- 0.02)
Negative predictive value	0.997 (95% CI, 0.994- 0.999)

Age 55- 64

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	2	292
	3- 5	11	3038

Sensitivity	0.15 (95% CI, 0.02- 0.45)
Specificity	0.91 (95% CI, 0.90- 0.92)
Positive predictive value	0.01 (95% CI, 0.001- 0.02)
Negative predictive value	0.996 (95% CI, 0.993- 0.998)

Age 65- 74

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	14	400
	3- 5	30	4440

Sensitivity	0.32 (95% CI, 0.19- 0.48)
Specificity	0.91 (95% CI, 0.90- 0.92)
Positive predictive value	0.03 (95% CI, 0.02- 0.06)
Negative predictive value	0.993 (95% CI, 0.990- 0.995)

Age 75- 84

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	10	399
	3- 5	32	3976

Sensitivity	0.24 (95% CI, 0.12- 0.39)
Specificity	0.91 (95% CI, 0.90- 0.92)
Positive predictive value	0.09 (95% CI, 0.01- 0.07)
Negative predictive value	0.992 (95% CI, 0.989- 0.995)

Age 85+

		Patient Outcomes	
		In-hospital death/ Death in the ED	The Others
Emergency Triage Levels	1- 2	7	211
	3- 5	18	1550

Sensitivity	0.28 (95% CI, 0.12- 0.49)
Specificity	0.88 (95% CI, 0.86- 0.89)
Positive predictive value	0.03 (95% CI, 0.03- 0.07)
Negative predictive value	0.989 (95% CI, 0.982- 0.993)

Supplementary Table 3. Sensitivity, specificity, positive predictive value, and negative predictive value for intensive care unit admission by age category in the sensitivity analysis.

Age category	Sensitivity	Specificity	PPV	NPV
16- 34	0.80 (0.52- 0.96)	0.71 (0.69- 0.72)	0.006 (0.003- 0.010)	0.999 (0.998- 1.000)
35- 44	0.79 (0.54- 0.94)	0.65 (0.63- 0.67)	0.012 (0.007- 0.020)	0.998 (0.995- 1.000)
45- 54	0.96 (0.82- 1.00)	0.62 (0.60- 0.64)	0.027 (0.018- 0.040)	0.999 (0.996- 1.000)
55- 64	0.91 (0.80- 0.98)	0.53 (0.51- 0.55)	0.027 (0.020- 0.036)	0.998 (0.994- 0.999)
65- 74	0.88 (0.79- 0.94)	0.49 (0.48- 0.50)	0.029 (0.023- 0.036)	0.996 (0.992- 0.998)
75- 84	0.88 (0.80- 0.94)	0.46 (0.44- 0.47)	0.034 (0.027- 0.042)	0.994 (0.990- 0.997)
85-	0.84 (0.66- 0.95)	0.39 (0.37- 0.41)	0.024 (0.016- 0.035)	0.993 (0.983- 0.998)

Abbreviation: PPV, positive predictive value; NPV, negative predictive value.