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Prediction of patient disposition by Emergency Severity Index

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Key words: Emergency severity index, resource allocation, priority of care, triage.

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Abstract

Objective: Early patient disposition is crucial to prevent crowding in emergency departments (ED). Our study aimed to characterize the need of in-house resources for patients treated in the ED according to the Emergency Severity Index (ESI) at the time point of triage.

Methods: We retrospectively analysed data of all patients who presented to the interdisciplinary ED of a tertiary care hospital in Munich, Germany, from 2014 to 2017 (n=113.693).

Results: Patient disposition varied according to ESI scores in combination with the chief complaint. Patients with low ESI scores were more likely to be admitted after treatment at the ED than patients with high ESI scores. Highly prioritized patients (ESI 1) mainly required admission to an intensive care unit (ICU, 27%), intermediate care unit (IMC, 37%) or immediate intervention (11%). In this critical patient group, 30% of patients with neurological or medical symptoms required immediate intensive care whereas only 17% of patients with surgical problems were admitted to an ICU. In general, patients with high ESI scores hardly ever needed intensive care or immediate intervention, but some patients with neurological or medical problems still required ICU or IMC treatment in this group.

Conclusions: Overall, ESI seems to be a useful tool to anticipate the need for specialized in-hospital resources upon arrival. Patients with symptoms pointing at neurological or medical problems need particular attention as ESI may fail to sufficiently predict the care facility level for this patient group.

Key words: Emergency severity index, resource allocation, priority of care, triage.

Strengths and limitations of this study:

- Real-world data on a large number of emergency patients
- Clinical impact with suggestion of ESI triage as a promising tool to improve coordination of care by predicting type and amount of hospital beds required for specific ED patient groups
- Further evaluation of our single-centre analysis is needed

Introduction

Keeping the patient flow in emergency departments (EDs) going is important to prevent (over)crowding. One of the crucial processes is to determine the most probable patient disposition as early as possible. This allows staff on the wards to get prepared even though patients still receive diagnostics before admission. Furthermore, in situations when patients in the ED with a high probability of admission to specific wards (such as general ward, intermediate care, intensive care) outnumber open beds, reallocation or early discharge of in-house patients could help to create resources long before the ED patient is ready to be admitted. Patients arriving at the ED usually undergo triage using standardized scores. These scores are designed to rapidly assess the acuteness of disease in emergency patients (1) and allow to allocate treatment priorities, which is especially important when demand for medical care exceeds disposable resources such as staff, space or medical equipment. The main goal of triage scores is to avoid waiting time that endangers patients with potential life-threatening diseases. In general, triage scores with five levels are considered to have a superior validity and reliability compared to those with three levels (2). Commonly used triage systems in EDs are the Manchester Triage System (MTS), the Australasian Triage Scale (ATS) and the Emergency Severity Index (ESI). ESI is a five-level triage algorithm that is frequently used in many European countries (3). Treatment priority according to ESI depends on severity of the disease and expected need of resources. Inter-observer reliability of ESI is considered high, reflected by the fact that there are no significant differences in triage by nurses and physicians (4, 5). Reliability may be moderate in some subgroups like in geriatric or paediatric patients (6-9), but overall, ESI is considered to be a valuable tool to assign acceptable maximum waiting times and to protect critical patients from being overlooked in overcrowded EDs. Here, we aimed to characterize the in-house resources needed for ED patients according to ESI scores at triage and the most likely medical discipline that is needed for the patient according to the chief complaint.

Methods

A single centre retrospective analysis was conducted. Data of all patients who presented to the interdisciplinary ED of a tertiary care hospital in Munich, Germany, within three years was analysed (11/2014 until 10/2017). All patients initially underwent a triage process by an experienced and specifically trained nurse supervised by an attending emergency physician. ESI was used for triage of all patients as suggested by the published algorithm (3). Simultaneously, the main complaint was identified for each patient. At discharge from the ED, the discharge destination was documented.

Data of all patients was extracted according to ESI score (levels ESI 1, ESI 2, ESI 3, ESI 4 and ESI 5), the manner in which the patient reached the ED and discharge destination from the ED. Patient flow was analysed for admissions to ICU, IMC, standard wards, monitoring at the ED admission unit, discharge, transfer to other hospitals, patient denial of admission, lost to follow up (patients who left the ED without reporting to medical staff) and death in the ED. Subgroup analysis was performed for symptoms that prompted a health problem most likely related to one of nine specialities (internal medicine, trauma surgery, neurology, general surgery, otorhinolaryngology, urology, orthopaedics, gynaecology and neurosurgery).

Data is illustrated in numbers (n) and/or percentages. For statistical analysis, chi-square test of independence was used (SigmaPlot) and $p<0.05$ was considered significant. Bonferroni alpha correction was used for multiple comparisons. The study was approved by the Ethics Committee of the University of Munich (project number 18-409).

Patient and public involvement

Patients and the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

ESI levels and most frequent triage symptoms

During the study period n=113.693 patients presented to the interdisciplinary ED. All patients underwent an initial assessment including ESI triage and identification of a main presenting symptom (Appendix A). Three percent of all patients (n=3050) were triaged with ESI 1, implying that they suffered from an immediate life-threatening health problem. Five percent were scored ESI 2 (n=5221), 42% (n=47484) were assigned to ESI 3, another 42% (n=47697) to ESI 4 and 9% (n=9843) to ESI 5. Overall, the most frequent chief complaints on presentation were abdominal pain (8%), limb injury (6%), and chest pain (5%) (Table 1).

Means of transport to the ED

The manner in which patients reached the ED were via emergency service (30%), self-referral (61%), referral of a practitioner at an ambulatory care office (5%) and others (e.g. via police or referral from abroad) (4%). Patients with a high treatment priority according to ESI were more likely to present via the emergency service: 89% of ESI 1 patients and 68% of ESI 2 patients were taken to hospital by the emergency services compared to 15% for ESI 4 and 6% for ESI 5 (Figure 1A). Patients with a low treatment priority according to ESI, however, mainly presented on their own. Self-referrals were 86% for ESI 5 patients and 76% for ESI 4 patients compared to 50% for ESI 3, 22% for ESI 2 and 2% for ESI 1 (Figure 1A).

Hospital admissions

The general admission rate was 39% (see Table 2 for admission rates according to specialty). High triage priority reflected by a low ESI level was associated with high probability of admission (Figure 1B). Admission rates were 96% for ESI 1, 80% for ESI 2, 53% for ESI 3, 22% for ESI 4, and 11% for ESI 5 patients (Figure 1B).

Required care facility levels of admitted patients

Patients with ESI 1 and ESI 2 frequently required ICU or IMC (Figure 2). ESI 1 patients had the highest admission rates to ICU (27%), interventions (11%) or IMC (37%, including stroke unit, chest pain unit and emergency ward admission unit). Most patients assigned to ESI 4 and ESI 5 were discharged after treatment in the ED (76% and 86%) and only infrequently required ICU (ESI 4 0.1%, ESI 5 0.1%) or IMC (ESI 4 3.7%, ESI 5 1.3%). In numbers, nine patients triaged as ESI 5 and 59 patients triaged as ESI 4 needed intensive care. The patients who required intensive care despite initial triage of ESI 5 had presented with dehydration, headache, a common cold, suspected shunt infection (n=2) or problems not further specified at triage (n=4). Similarly, patients who were triaged ESI 4 and required intensive care mainly suffered from a symptom indicating an internal medical (n=33) or a neurological/neurosurgical problem (n=10). Typical triage symptoms in this subgroup were for example abdominal pain (n=8), reduced general condition (n=6), headache (n=4), chest pain (n=2), nausea/vomiting (n=2), dehydration (n=2) or airway problems (n=2).

Mortality in the ED

Patients assessed to ESI 1 were at highest risk of death in the ED: 4% of all ESI 1 patients died in the ED. Four patients with ESI 4 deceased in the ED, all of them were suffering from medical problems such as heart failure (n=2), sepsis or hypovolemic shock. None of the patients appointed to ESI 5 died.

Analysis of medical subgroups

Disciplines involved in the treatment according to the chief complaint were internal medicine, trauma surgery, neurology, general surgery, otorhinolaryngology, urology, orthopaedics, gynaecology and neurosurgery (Figure 1C). Patients assigned to the main conservative disciplines (internal medicine and neurology) were more likely to present via the emergency service (37%)

than patients of the main surgical disciplines (trauma surgery and general surgery, 26%, p<0.001). For conservative disciplines, referrals via practitioners were more common than for surgical disciplines (7% versus 3%, p<0.001).

All in all, ESI triage scores were associated with admission rates (Table 2) as patients with numerically low ESI scores had higher admission rates and contrariwise (p<0.01). This held true for all ESI subgroups of patients with symptoms assigned to internal medicine, trauma surgery, neurology, otorhinolaryngology and general surgery (p<0.001). In urology, orthopaedics, gynaecology and neurosurgery, admission rates did not differ between ESI 1 and ESI 2, but the absolute numbers of patients were low in these groups. In these disciplines differences in admission rates between patients triaged ESI 2 and ESI 3 could also not be found. Furthermore, there were no significant differences between ESI 1 and ESI 3 in orthopaedics and gynaecology, between ESI 1 and ESI 4 in orthopaedics and between ESI 4 and ESI 5 in neurosurgery.

Subgroup analysis showed, that the required in-house resources according to ESI differed between the medical specialties (Figure 2). ESI 1 patients with surgical problems (trauma surgery and general surgery) less often (17%) required immediate intensive care capacities than patients of conservative disciplines (internal medicine and neurology; 30%) (p<0.001). In turns, 19% of surgical ESI 1 patients required immediate interventions such as surgery compared to 6% in the conservative group (p<0.001).

Patients with neurological symptoms

In neurology and neurosurgery, admission rates were above the average admission rate of 39%: 46% of neurological and 69% of neurosurgical patients needed admission. Of interest, neurological and neurosurgical patients with low treatment priorities according to ESI still had high admission rates (Table 2). Most important, admission rates for ESI 3, ESI 4 and ESI 5 patients to ICU and

IMC were above average. Remarkably, five of the nine ESI 5 patients who required ICU presented with a symptom that was suspicious for a neurological or neurosurgical problem.

Discussion

The main findings of our study were: (i) Low ESI scores were associated with a relatively high need for intermediate care or intensive care. (ii) This was especially the case in patients with symptoms assigned to neurology or internal medicine. (iii) Overall, patients with high ESI scores (ESI 4 or 5) could be discharged in the majority of cases and hardly ever required intensive or intermediate care (iv) with the exception of single patients with neurological symptoms who required ICU or IMC treatment despite high ESI scores at admission.

The distribution of ESI levels in our study cohort is comparable to those previously described (3, 5). Prioritized patients with numerically low ESI scores mainly presented via the emergency service and patients with high ESI scores more often on their own. This high ambulance use in prioritized patients goes along with the expected acuteness of the disease and the urgency of treatment. Our data is supported by previous studies, showing that ambulance use is related to severity of injury or illness and hospital admission (10, 11). However, ambulance use in low-acuity ED patients assessed by ESI can still be found. One reason for this might be that patients already improved by the time of arrival at the ED (12). Also, as a limitation of our study, association of ambulance use with pre-existing morbidity or age of patients cannot be excluded.

According to our results, low ESI scores were associated with mortality in the ED, admission rate and the necessity of ICU or IMC for most medical specialties. This reflects the acuteness of the diseases in prioritised patients. There are only few other studies on the prediction of hospital admission and mortality using ESI triage. One retrospective observation with fairly large numbers of patients of four EDs (37.974 patients triaged with ESI and 34.258 patients triaged with MTS)

found that both ESI and MTS predicted necessity of hospital admission and that mortality was associated with urgency categories of both triage systems (13). However, in the cited study, differentiation for medical subgroups was not performed, triage results were missing in many patients and the study period only involved a few weeks.

One important finding of our subgroup analysis is the limited association of ESI triage with the required level of in-hospital care in neurological and neurosurgical patients. In these subgroups, admission rates were above average (especially for ESI 3, 4, and 5) and five out of nine ESI 5 patients, who required ICU, had neurological or neurosurgical problems, however, three of them had already been stabilised at other hospitals and were primarily referred for consultation, explaining their low triage priority at arrival. One important reason for these high admission rates might be the limited emergency workup capacities of many neurological diseases which usually lead to hospital admission for more elaborate investigations. Also, selection bias is likely as a large number of neurological patients with medium or low priority ESI scores was referred to our ED by practitioners (9% of ESI 3, 10% of ESI 4 and 8% of ESI 5 in neurological patients compared to 6% of ESI 3, 5% of ESI 4 and 2% of ESI 5 in general). The relatively high rate of admissions to IMC is in part a result of the need of stroke unit care in many of these patients. Likewise, patients with onset of neurological symptoms >24h ago may often be assigned to ESI scores with low priority but they can turn out to suffer from subacute stroke for example and require further treatment at a stroke unit (IMC). The fact that these patients required IMC does, however, not necessarily mean that the high triage scores (and longer waiting time) were associated with a medical risk to the patient.

Recent studies showed that neurological aspects are underrepresented in the ESI triage system. For some diseases like in sepsis, ESI is known to have a low validity and combination with shock index or quick sepsis-related organ failure assessment (qSOFA) might improve validity and even

mortality (14, 15). Whether ESI triage for neurological patients might be improved by adding neurological scores, e.g. Glasgow Coma Scale (GCS) or the face arm speech test (FAST), still needs to be evaluated. One triage system recently designed for patients with neurological complaints is the Heidelberg Neurological Triage System (HEINTS) (16). The intention of this score was to identify neurological patients with urgent need for medical treatment, thereby reducing resource utilization and duration of treatment (16, 17). Interestingly, this very neuro-specific triage system has already been evaluated not only in a highly specialized neurological ED but also in an interdisciplinary emergency setting, showing promising results. However, study periods were short and the number of patients limited. Also, HEINTS consists of four levels, which might affect its applicability in large EDs that are usually using 5-level triage scores as standard (2). The authors made a great effort to integrate the score into ESI but this still needs evaluation (16).

Although we were able to assess a high number of patients, data were acquired from a single centre ED. As a tertiary care university hospital located at the outer belt of the city with a large transplant centre, selection bias might have influenced the patient mix as a significant proportion of patients reports to the ED to seek specialized advice according to long-term treatment at the hospital. In turns, the setup allows specialized consultations, diagnostics and treatment for basically any specialty at the ED at any time. As a consequence of the extended workup in the ED, admission rates might be lower than in other hospitals.

Conclusion

There are various approaches that aim to improve coordination of ED care by reducing time for triage, treatment and transfer of patients (18-21). Our work suggests that ESI might be a promising tool to improve coordination of care by predicting type and amount of hospital beds required for specific ED patient groups. Patients with symptoms pointing at neurological problems need particular attention as ESI failed to sufficiently predict the care facility level needed in this patient

group. Further studies are needed to evaluate whether ESI helps to coordinate ICU capacities or paramedic networks concerning treatment time, patient satisfaction or outcome.

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Figure 1: Analysis of the study population for manner of arrival (A), admission rate (B) and specialty according to the chief complaint (C). Data of all patients (n=113.693) was analysed for triage results according to the Emergency Severity Index (ESI) and is illustrated for ESI 1, ESI 2, ESI 3, ESI 4 and ESI 5. Possible manners of arrival (A) were via the emergency service, by self-referral, via a practitioner and others (e.g. police). After treatment in the ED, patients were either admitted or discharged (B). For further analysis, patients were grouped to medical specialties according to their chief complaint (C): internal medicine, trauma surgery, neurology, otorhinolaryngology, urology, orthopaedics, gynaecology or neurosurgery.

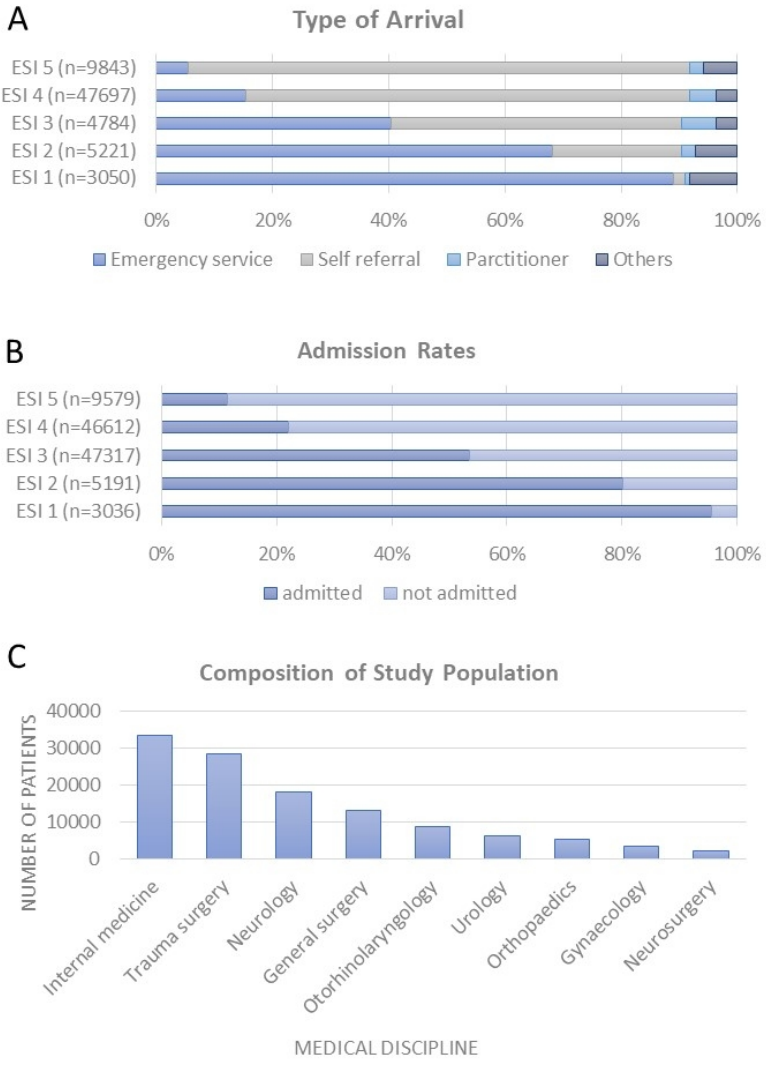
Figure 2: Patient disposition in general and according to treating medical specialties. Patient disposition according to ESI for all patients (A) and for patients with chief complaints pointing at problems related to internal medicine (B), neurology (C), trauma surgery (D) or general surgery (E).

Table 1 Percentages of the ten most frequent leading symptoms in general, for admitted patients and for discharged patients.

Frequency of symptom	All patients	Admitted patients	Discharged patients
1	Abdominal pain (8%)	Abdominal pain (9%)	Abdominal pain (8%)
2	Limb injury (6%)	Chest pain (6%)	Limb injury (7%)
3	Chest pain (5%)	Reduced general condition (6%)	Work accident (6%)
4	Work accident (4%)	Airway problem (5%)	Headache (4%)
5	Fall with injury (4%)	Craniocerebral injury (4%)	Fall with injury (4%)
6	Airway problem (4%)	Fall with injury (4%)	Chest pain (4%)
7	Headache (4%)	Other complaints (4%)	Joint pain (3%)
8	Craniocerebral injury (3%)	Limb injury (3%)	Vertigo (3%)
9	Vertigo (3%)	Hemiparesis (3%)	Craniocerebral injury (3%)
10	Reduced general condition (3%)	Fever (3%)	Micturition problems (3%)

Table 2 Admission rates and numbers of admitted patients analysed for medical specialty and Emergency Severity Index (ESI).

Discipline	Admissions				
	ESI 1 96% (n=2898)	**ESI 2 80% (n=4162)**	**ESI 3 54% (n=25333)**	**ESI 4 22% (n=10321)**	**ESI 5 11% (n=1096)**
Internal medicine	99% (n=777)	72% (n=260)	62% (n=13062)	35% (n=3016)	21% (n=208)
Trauma surgery	96% (n=874)	72% (n=260)	45% (n=3457)	13% (n=2054)	7% (n=260)
Neurology	93% (n=725)	86% (n=1844)	46% (n=3662)	28% (n=1588)	20% (n=139)
General surgery	93% (n=214)	78% (n=226)	57% (n=2690)	24% (n=1379)	11% (n=190)
Otorhinolaryngology	100% (n=13)	60% (n=70)	45% (n=822)	18% (n=970)	10% (n=151)
Urology	90% (n=9)	48% (n=45)	40% (n=872)	20% (n=714)	14% (n=75)
Orthopaedics	50% (n=2)	53% (n=10)	41% (n=329)	16% (n=546)	11% (n=113)
Gynaecology	100% (n=5)	58% (n=14)	29% (n=285)	16% (n=275)	6% (n=19)
Neurosurgery	95% (n=410)	84% (n=96)	68% (n=657)	54% (n=398)	54% (n=51)



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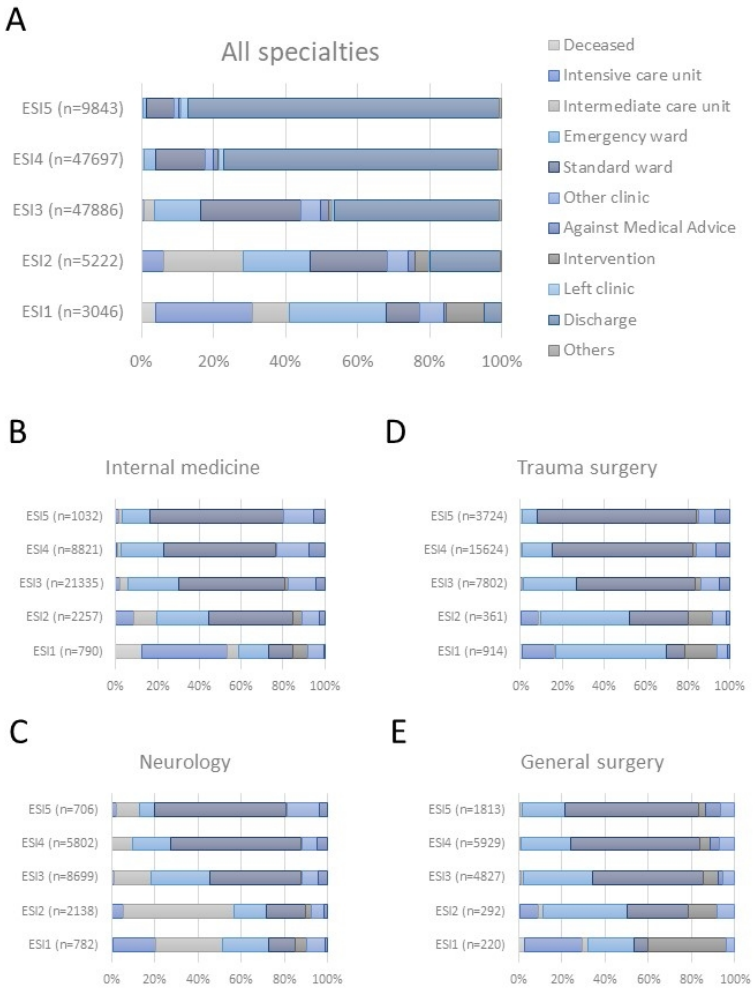

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Appendix A List of all symptoms available at triage for different specialties.

Discipline	Triage symptoms
Internal medicine	abdominal pain, airway problem, allergy and anaphylaxis, ascites and oedema, blood glucose derailment, cardiac arrhythmia, chest pain, coma, common cold, diarrhoea, dehydration, electrical accident, fever, flank pain, foreign material, gastrointestinal bleeding, hypertension, impaired consciousness, intoxication, jaundice, micturition problems, nausea and vomiting, other problems, problem of care, reduced general condition, resuscitation, skin and mucosal disease, swollen leg, syncope
Trauma surgery	accident at work, back pain with radicular symptoms, back pain without radicular symptoms, craniocerebral injury, fall with injury, hand injury, joint problems, limb injury, muscle problem, needlestick injury, other problems, polytrauma, spinal injury, wound control
Neurology	coma, double vision, facial palsy, gait disturbance, headache, hemiparesis, impaired consciousness, impaired vision, other problems, paraesthesia, paresis, problem of care, seizure, speech disorder, vertigo
General surgery	acute abdominal pain, catheter and drainage complications, chest injury, flank pain, circulatory disturbance, craniocerebral injury, polytrauma, postoperative problems and controls, rectal and stoma problems, skin and soft tissue injuries, skin and soft tissue problems, transfer from other hospital
Otorhinolaryngology	bleeding, common cold, epistaxis, ear noise, ear pain, foreign material, hearing loss, nose injury, other problems, skin and mucosal disease, sore throat, vertigo
Urology	catheter exchange, flank pain, foreign material, micturition problem, other problems, scrotal pain, skin and mucosal disease, urological bleeding
Orthopaedics	accident at work, back pain with radicular symptoms, back pain without radicular symptoms, craniocerebral injury, fall with injury, hand injury, joint problems, limb injury, muscle problem, needlestick injury, other problems, polytrauma, spinal injury, wound control
Gynaecology	abdominal pain, ascites and oedema, foreign material, gynaecological bleeding, morning-after pill, micturition problem, other gynaecological problems, pregnancy complications, rape, reduced general condition, skin and mucosal disease
Neurosurgery	back pain, headache, impaired consciousness, other problems, reduced general condition, seizure, shunt-dysfunction, wound healing disorder

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	OK
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	OK
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	OK
Objectives	3	State specific objectives, including any prespecified hypotheses	OK
Methods			
Study design	4	Present key elements of study design early in the paper	OK
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	OK
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	OK
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	OK
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*OK*
Bias	9	Describe any efforts to address potential sources of bias	OK
Study size	10	Explain how the study size was arrived at	OK
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	OK
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	OK
		(*b*) Describe any methods used to examine subgroups and interactions	OK
		(*c*) Explain how missing data were addressed	OK
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	OK
		(*e*) Describe any sensitivity analyses	OK

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	OK
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	OK
		(b) Indicate number of participants with missing data for each variable of interest	OK
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	OK
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*OK*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*OK*
		Cross-sectional study—Report numbers of outcome events or summary measures	*OK*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	OK
		(*b*) Report category boundaries when continuous variables were categorized	OK
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	OK
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	OK
Discussion			
Key results	18	Summarise key results with reference to study objectives	OK
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	OK
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	OK
Generalisability	21	Discuss the generalisability (external validity) of the study results	OK
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	OK

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Patient disposition using the Emergency Severity Index: a retrospective observational study at an interdisciplinary emergency department

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ABSTRACT

Objectives: Early patient disposition is crucial to prevent crowding in emergency departments (ED). Our study aimed to characterize the need of in-house resources for patients treated in the ED according to the Emergency Severity Index (ESI) and the presenting complaint at the time point of triage.

Design: A retrospective single centre study was conducted.

Setting: Data of all patients who presented to the interdisciplinary ED of a tertiary care hospital in Munich, Germany, from 2014 to 2017 was analysed.

Participants: n=113.694 patients were included.

Measures: ESI score, medical specialty according to the chief complaint, mode of arrival, admission rates and discharge destination from the ED were evaluated.

Results: Patient disposition varied according to ESI scores in combination with the chief complaint. Patients with low ESI scores were more likely to be admitted after treatment in the ED than patients with high ESI scores. Highly prioritized patients (ESI 1) mainly required admission to an intensive care unit (ICU, 27%), intermediate care unit (IMC, 37%) or immediate intervention (11%). In this critical patient group, 30% of patients with neurological or medical symptoms required immediate intensive care whereas only 17% of patients with surgical problems were admitted to an ICU. A significant number of patients (particularly with neurological or medical problems) required hospital (and in some cases even ICU or IMC) admission despite high ESI scores.

Conclusions: Overall, ESI seems to be a useful tool to anticipate the need for specialized in-hospital resources upon arrival. Patients with symptoms pointing at neurological or medical problems need particular attention as ESI may fail to sufficiently predict the care facility level for this patient group.

Key words: Emergency severity index, resource allocation, priority of care, triage.

Strengths and limitations of this study:

- This is a single centre study on a large number of emergency patients (n=113.694).
- ESI in combination with the medical specialty of the chief complaint was assessed for the prediction of type and amount of required hospital beds.
- Data is limited on ESI and required in-house resources; other triage scales or resource consumption within the emergency department were not assessed.

INTRODUCTION

Keeping the patient flow in emergency departments (EDs) going is important to prevent (over)crowding. One of the crucial processes is to determine the most probable patient disposition as early as possible. This allows staff on the wards to get prepared even though patients still receive diagnostics before admission. Furthermore, in situations when patients in the ED with a high probability of admission to specific wards (such as general ward, intermediate care, intensive care) outnumber available beds, reallocation or early discharge of in-house patients could help to create resources long before the ED patient is ready to be admitted. Patients arriving at the ED usually undergo triage using standardized scores. These scores are designed to rapidly assess the acuteness of the disease and allow to allocate treatment priorities, which is especially important when demand for medical care exceeds disposable resources such as staff, space or medical equipment.[1] The main purpose of triage scores is to avoid waiting time that endangers patients with potential life-threatening diseases. In general, triage scores with five levels are considered to have a superior validity and reliability compared to those with three levels.[2] Commonly used five-level triage systems in EDs are the Australasian Triage Scale (ATS), the Manchester Triage System (MTS), the Canadian Triage and Acuity Scale (CTAS) and the Emergency Severity Index (ESI). Initially, the development of the ATS in Australia was the basis for the MTS used in Great Britain and for the CTAS in Canada.[3-5] ESI is also a five-level triage algorithm which was developed in the late 1990s and is nowadays frequently

used in many European countries.[6 7] Treatment priority according to ESI depends on severity of the disease and expected need of resources. Inter-observer reliability of ESI is considered high, reflected by the fact that there are no significant differences in triage by nurses and physicians.[8 9] Reliability may be moderate in some subgroups like in geriatric or paediatric patients,[10-13] but overall, ESI is considered to be a valuable tool to assign acceptable maximum waiting times and to protect critical patients from being overlooked in overcrowded EDs. Here, we aimed to characterize the in-house resources needed for ED patients according to ESI scores at triage and the most likely medical discipline that is needed for the patient according to the chief complaint.

METHODS

A single centre retrospective analysis was conducted. Data of all patients who presented to the interdisciplinary ED of a tertiary care hospital in Munich, Germany, within three years was analysed (11/2014 until 10/2017). All patients initially underwent a triage process by an experienced and specifically trained nurse supervised by an attending emergency physician. ESI was used for triage of all patients as suggested by the published algorithm.[6] Simultaneously, the main complaint was identified for each patient. At discharge from the ED, the discharge destination was documented.

Data of all patients was extracted according to ESI score (levels ESI 1, ESI 2, ESI 3, ESI 4 and ESI 5), the manner in which the patient reached the ED and discharge destination from the ED. Patient flow was analysed for admissions to ICU, IMC, standard wards, monitoring at the emergency ward, intervention, transfer to other hospitals, discharge, discharge against medical advice, lost to follow up (patients who left the ED without reporting to medical staff), and death in the ED. Subgroup analysis was performed for symptoms that prompted a health problem most likely related to one of nine specialities

(internal medicine, trauma surgery, neurology, general surgery, otorhinolaryngology, urology, orthopaedics, gynaecology and neurosurgery).

Data is illustrated in numbers (n) and/or percentages. For statistical analysis, chi-square test of independence was used (SigmaPlot) and $p<0.05$ was considered significant. Bonferroni alpha correction was applied for multiple comparisons (statistics on admissions according to ESI, p-values <0.005 were considered significant). All data was anonymised before the authors accessed them. The study was approved by the Ethics Committee of the University of Munich (project number 18-409).

Patient and public involvement

Patients and the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

ESI levels and most frequent triage symptoms

During the study period n=113.694 patients presented to the interdisciplinary ED. All patients underwent an initial assessment including ESI triage and identification of a main presenting symptom (supplemental material). Three percent of all patients (n=3046) were triaged with ESI 1, implying that they suffered from an immediate life-threatening health problem. Five percent were scored ESI 2 (n=5222), 42% (n=47886) were assigned to ESI 3, another 42% (n=47697) to ESI 4 and 7% (n=9843) to ESI 5. Overall, the most frequent chief complaints on presentation were abdominal pain (8%), limb injury (6%), and chest pain (5%) (Table 1).

Table 1 Percentages of the ten most frequent chief complaints.

Rank of symptom frequency	All patients	Admitted patients	Discharged patients
1	Abdominal pain (8%)	Abdominal pain (9%)	Abdominal pain (8%)
2	Limb injury (6%)	Chest pain (6%)	Limb injury (7%)
3	Chest pain (5%)	Reduced general condition (6%)	Work accident (6%)
4	Work accident (4%)	Airway problem (5%)	Headache (4%)
5	Fall with injury (4%)	Craniocerebral injury (4%)	Fall with injury (4%)
6	Airway problem (4%)	Fall with injury (4%)	Chest pain (4%)
7	Headache (4%)	Other complaints (4%)	Joint pain (3%)
8	Craniocerebral injury (3%)	Limb injury (3%)	Vertigo (3%)
9	Vertigo (3%)	Hemiparesis (3%)	Craniocerebral injury (3%)
10	Reduced general condition (3%)	Fever (3%)	Micturition problems (3%)

Means of transport to the ED

The manner in which patients reached the ED were via emergency service (30%), self-referral (61%), referral of a practitioner at an ambulatory care office (5%) and others (e.g. via police or referral from abroad) (4%). Patients with a high treatment priority according to ESI were more likely to present via the emergency service: 89% of ESI 1 patients and 68% of ESI 2 patients were taken to hospital by the emergency services compared to 15% for ESI 4 and 6% for ESI 5 (Figure 1A). Patients with a low treatment priority according to ESI, however, mainly presented on their own. Self-referrals were 86% for ESI 5 patients and 76% for ESI 4 patients compared to 50% for ESI 3, 22% for ESI 2 and 2% for ESI 1 (Figure 1A).

Hospital admissions

The general admission rate was 39%, but differed in a subgroup analysis according to the responsible specialty group of the presenting complaint (Table 2). High triage priority reflected by a low ESI level was associated with high probability of admission (Figure 1B). Admission rates were 96% for ESI 1, 80% for ESI 2, 54% for ESI 3, 22% for ESI 4, and 11% for ESI 5 patients (Figure 1B).

Table 2 Admission rates (%) and total numbers of admitted patients (n) analysed for specialty groups and Emergency Severity Index (ESI).

Specialty	Admission ESI 1	Admission ESI 2	Admission ESI 3	Admission ESI 4	Admission ESI 5
All specialties	96% (n=2898)	80% (n=4162)	54% (n=25333)	22% (n=10321)	11% (n=1096)
Internal medicine	99% (n=777)	80% (n=1791)	62% (n=13062)	35% (n=3016)	21% (n=208)
Trauma surgery	96% (n=874)	72% (n=260)	45% (n=3457)	13% (n=2054)	7% (n=260)
Neurology	93% (n=725)	86% (n=1844)	46% (n=3662)	28% (n=1588)	20% (n=139)
General surgery	93% (n=214)	78% (n=226)	57% (n=2690)	24% (n=1379)	11% (n=190)
Otorhinolaryngology	100% (n=13)	60% (n=70)	45% (n=822)	18% (n=970)	10% (n=151)
Urology	90% (n=9)	48% (n=45)	40% (n=872)	20% (n=714)	14% (n=75)
Orthopaedics	50% (n=2)	53% (n=10)	41% (n=329)	16% (n=546)	11% (n=113)
Gynaecology	100% (n=5)	58% (n=14)	29% (n=285)	16% (n=275)	6% (n=19)
Neurosurgery	95% (n=410)	84% (n=96)	68% (n=657)	54% (n=398)	54% (n=51)

Required care facility levels of admitted patients

Patients with ESI 1 and ESI 2 frequently required ICU or IMC (Figure 2). ESI 1 patients had the highest admission rates to ICU (27%), interventions (11%) or IMC (37%, including stroke unit, chest pain unit and emergency ward admission unit). Most patients assigned to ESI 4 and ESI 5 were discharged after treatment in the ED (76% and 86%) and only infrequently required ICU (ESI 4 0.1%, ESI 5 0.1%) or IMC (ESI 4 3.7%, ESI 5 1.3%). In numbers, nine patients triaged to ESI 5 and 59 patients triaged to ESI 4 needed intensive care. The patients who required intensive care despite initial triage to ESI 5 had presented with dehydration, headache, a common cold, suspected shunt infection (n=2) or problems not further specified at triage (n=4). Similarly, patients who were triaged to ESI 4 and required intensive care mainly suffered from a symptom indicating an internal medical (n=33) or a neurological/neurosurgical problem (n=10). Typical triage symptoms in this subgroup were for example abdominal pain (n=8), reduced general condition (n=6), headache (n=4), chest pain (n=2), nausea/vomiting (n=2), dehydration (n=2) or airway problems (n=2).

Mortality in the ED

Patients assessed to ESI 1 were at highest risk of death in the ED: 4% of all ESI 1 patients died in the ED. Four patients with ESI 4 deceased in the ED, all of them were suffering from medical problems such as heart failure (n=2), sepsis or hypovolemic shock. None of the patients appointed to ESI 5 died.

Analysis of medical subgroups

Specialty groups involved in the treatment according to the chief complaint were internal medicine, trauma surgery, neurology, general surgery, otorhinolaryngology, urology, orthopaedics, gynaecology and neurosurgery (Figure 1C). Patients assigned to the main conservative disciplines (internal medicine and neurology) were more likely to present via

the emergency service (37%) than patients of the main surgical disciplines (trauma surgery and general surgery, 26%, p<0.001). For conservative disciplines, referrals via practitioners were more common than for surgical disciplines (7% versus 3%, p<0.001).

All in all, ESI triage scores were associated with admission rates (Table 2) as patients with numerically low ESI scores had higher admission rates and contrariwise (p<0.001 for all single comparisons). This held true for all ESI subgroups of patients with symptoms assigned to internal medicine, trauma surgery, neurology, otorhinolaryngology and general surgery (p<0.001 for all single comparisons). In urology, orthopaedics, gynaecology and neurosurgery, admission rates did not differ between ESI 1 and ESI 2, but the absolute numbers of patients were low in these groups. In urology and orthopaedics differences in admission rates between patients triaged to ESI 2 and ESI 3 could also not be found. Furthermore, there were no significant differences between ESI 1 and ESI 3 or ESI 4 in orthopaedics, ESI 3 or ESI 4 and ESI 5 in neurosurgery.

Subgroup analysis showed, that the required in-house resources according to ESI differed between the medical specialties (Figure 2). ESI 1 patients with surgical problems (trauma surgery and general surgery) less often (17%) required immediate intensive care capacities than patients of conservative disciplines (internal medicine and neurology; 30%) (p<0.001). In turns, 19% of surgical ESI 1 patients required immediate interventions such as surgery compared to 6% in the conservative group (p<0.001).

Patients with neurological symptoms

In neurology and neurosurgery, admission rates were above the average admission rate of 39%: 46% of neurological and 69% of neurosurgical patients needed admission. Of interest, neurological and neurosurgical patients with low treatment priorities according to

ESI still had high admission rates (Table 2). Most important, admission rates for ESI 3, ESI 4 and ESI 5 patients to ICU and IMC were above average. Remarkably, five of the nine ESI 5 patients who required ICU presented with a symptom that was suspicious for a neurological or neurosurgical problem.

DISCUSSION

The main findings of our study were: (i) ESI scores were associated with mode of arrival, mortality in the ED and need for admission, (ii) individual patients required even intermediate or intensive care despite high ESI scores, (iii) the predicative value of ESI was high for most specialty subgroups (except urology, orthopaedics, gynaecology, and neurosurgery) and (iv) a significant number of patients with high ESI scores required admission when the chief complaint pointed at a neurosurgical, neurological and medical problem.

The distribution of ESI levels in our study cohort is comparable to those previously described.[6 9] We observed an association of ESI with mode of arrival, which goes along with the expected urgency of treatment and is supported by literature, showing that ambulance use is related to severity of injury or illness.[14 15] Regarding hospital admission and mortality, one retrospective observation with fairly large numbers of patients of four EDs (37.974 patients triaged with ESI and 34.258 patients triaged with MTS) found that both ESI and MTS predicted the necessity of hospital admission and mortality, which is in accordance with our data.[16] However, in this study, triage results were missing in many patients, the study period only involved a few weeks and there was no differentiation for specialties. From a general point of view, besides ESI and MTS also other triage scales are known to predict outcomes including mortality, hospital admission and resource

consumption within the ED but numbers were generally low and the relevance of the chief complaint was not assessed in most studies.[17]

Remarkably, admissions (even to intermediate or intensive care) in supposedly low-acuity ED patients assessed by ESI were observed. This is of particular interest in times of overcrowded EDs, when critics and politicians claim an inappropriate use of emergency resources by patients with low treatment priority. Our data shows that less urgent triage scores do not necessarily argue for an inappropriate attendance of an ED as often supposed in political discussions on emergency resources. For example, in Australia the ATS is not only used to assess treatment priority, but it is also the basis of Urgency Related Groups and thereby essential for the ED funding in the country.[3] Furthermore, even in the group of ED patients who are not admitted, a significant amount of medical support has to be applied within the ED to many of these patients to ensure a save discharge home. One reason for the need of an admission despite a high ESI score might be that patients presenting with subacute complaints may often be assigned to ESI scores with low priority but might turn out to suffer from electrolyte disturbance or subacute stroke (just to mention examples) and require further treatment at an IMC or stroke unit. The fact that these patients require IMC, however, does not necessarily mean that the high triage scores expose them to a medical risk within the ED. Reasons for ambulance use despite high ESI scores could be the recovery of patients by the time of triage as well as immobility due to age or pre-existing illness.[18] All in all, our data show that a profound emergency workup is needed irrespective of the triage level to distinguish patients who could be discharged (but still may have required emergency treatment) from those qualifying for admission.

The novelty about our data is the evaluation of the specialty group according to the presenting chief complaint in addition to ESI in a large number of emergency patients. Literature on ESI for specific patient groups is limited and usually restricted either to specific diseases or symptoms[19 20] or focussed on age groups such as adults, geriatric or paediatric patients.[10 13] Different specialties within one interdisciplinary study cohort have – to best of our knowledge – not been investigated before. The differences we found for the predicative power of ESI in some specialty groups need particular attention. We observed that required ICU capacities differed among patients with neurological or medical symptoms and patients with surgical symptoms. This could be of practical relevance: Knowing the responsible specialty group in case of an admission is essential in Germany, as wards are usually restricted to specific specialties and therefore patients cannot be assigned to any available bed within a hospital.

Patients with symptoms belonging to neurosurgery, neurology and internal medicine had high admission rates and ESI only poorly predicted the need for in-hospital care in neurological and neurosurgical patients with high ESI scores. First of all, the high admission rates in these specialties might be a result of the limited emergency workup capacities for the underlying diseases, which may lead to hospital admission for more elaborate investigation. Also, selection bias is likely as a large number of neurological patients with medium or low priority ESI scores was referred to our ED by practitioners (9% of ESI 3, 10% of ESI 4 and 8% of ESI 5 in neurological patients vs. 6% of ESI 3, 5% of ESI 4 and 2% of ESI 5 in general). The relatively high rate of neurological admissions to IMC is in part a result of the need for stroke unit care in many of these patients. Some attempts were made to overcome the limitations of the most common triage systems for neurological patients. One triage system designed for patients with neurological complaints to identify those with urgent need for medical treatment, thereby reducing

resource consumption and duration of treatment is the Heidelberg Neurological Triage System (HEINTS).[21 22] This neuro-specific triage system has been evaluated in a highly specialized neurological ED but also in an interdisciplinary emergency setting. However, study periods were short, the number of patients was limited and the restriction to four levels might affect its applicability in large EDs where 5-level triage scores are standard.[2] The authors made a great effort to integrate the score into ESI but this still needs evaluation.[22] Overall, it seems not feasible to use specialty specific triage systems in large multidisciplinary EDs. However, for some diseases like sepsis, combination of ESI with shock index or quick sepsis-related organ failure assessment (qSOFA) might improve validity and mortality.[20 23] Whether ESI triage for neurological patients might be improved by adding neurological scores, e.g. Glasgow Coma Scale (GCS) or the face arm speech test (FAST), still needs to be evaluated.

There are several limitations of our study. First of all, data was collected retrospectively and at a single tertiary care university hospital. Therefore our results cannot be generalised. Selection bias might have influenced the patient mix as a significant number of patients presents to the ED for specialized advice according to long-term treatment at the hospital. Our emergency setup includes the frequent use of specialized consultations, diagnostics and treatment at any time to avoid admission. As a consequence of the extended workup in the ED, admission rates might be lower than in other hospitals. Besides, resource consumption within the ED and discharged patients were not further analysed. However, this was not the aim of our investigation and has already been addressed by previous studies.[24] Furthermore, we did not control for other risk factors such as age or pre-existing illness. And, last but not least, other triage scales besides ESI were not evaluated, but would have been of major interest with regards to the variety of triage systems in use and the ambition for an international comparability.[3]

CONCLUSION

There are various approaches that aim to improve coordination of ED care by reducing time for triage, treatment and transfer of patients.[25-28] Our work suggests that ESI might be a promising tool to improve coordination of care by predicting type and amount of hospital beds required for specific ED patient groups. Patients with symptoms pointing at neurological problems need particular attention as ESI failed to sufficiently predict the care facility level needed in this patient group.

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Patient consent for publication: Not applicable.

Ethics approval: The study was approved by the Ethics Committee of the University of Munich (project number 18-409).

Data availability statement: Original data are available upon reasonable request.

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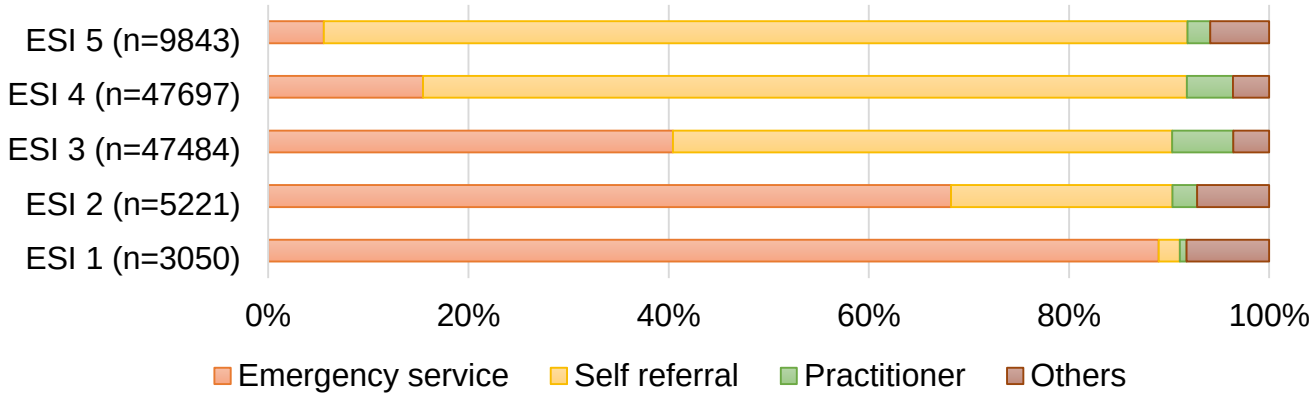
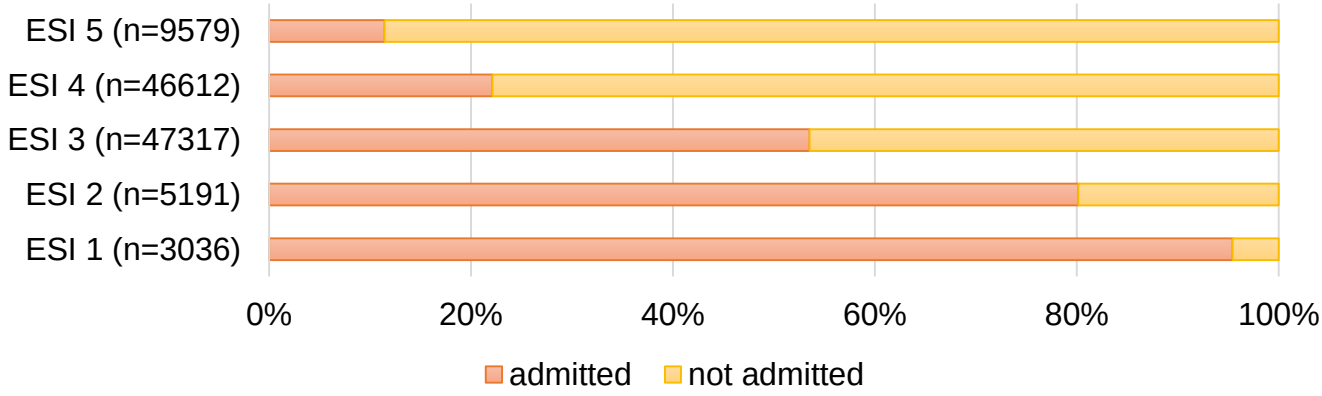
Figure 1: Analysis of the study population for mode of arrival (A), admission rate (B) and specialty according to the chief complaint (C). Data of all patients (n=113.694) was analysed for triage results according to the Emergency Severity Index (ESI) and is illustrated for ESI 1, ESI 2, ESI 3, ESI 4 and ESI 5. Possible manners of arrival (A) were via the emergency service, by self-referral, via a practitioner and others (e.g. police). After treatment in the ED, patients were either admitted or discharged (B). For further analysis, patients were grouped to medical specialties according to their chief complaint (C): internal medicine, trauma surgery, neurology, general surgery, otorhinolaryngology, urology, orthopaedics, gynaecology or neurosurgery.

Figure 2: Patient disposition in general and according to the responsible medical specialty. Patient disposition according to ESI for all patients (A) and for patients with chief complaints pointing at problems related to internal medicine (B), neurology (C), trauma surgery (D) or general surgery (E).

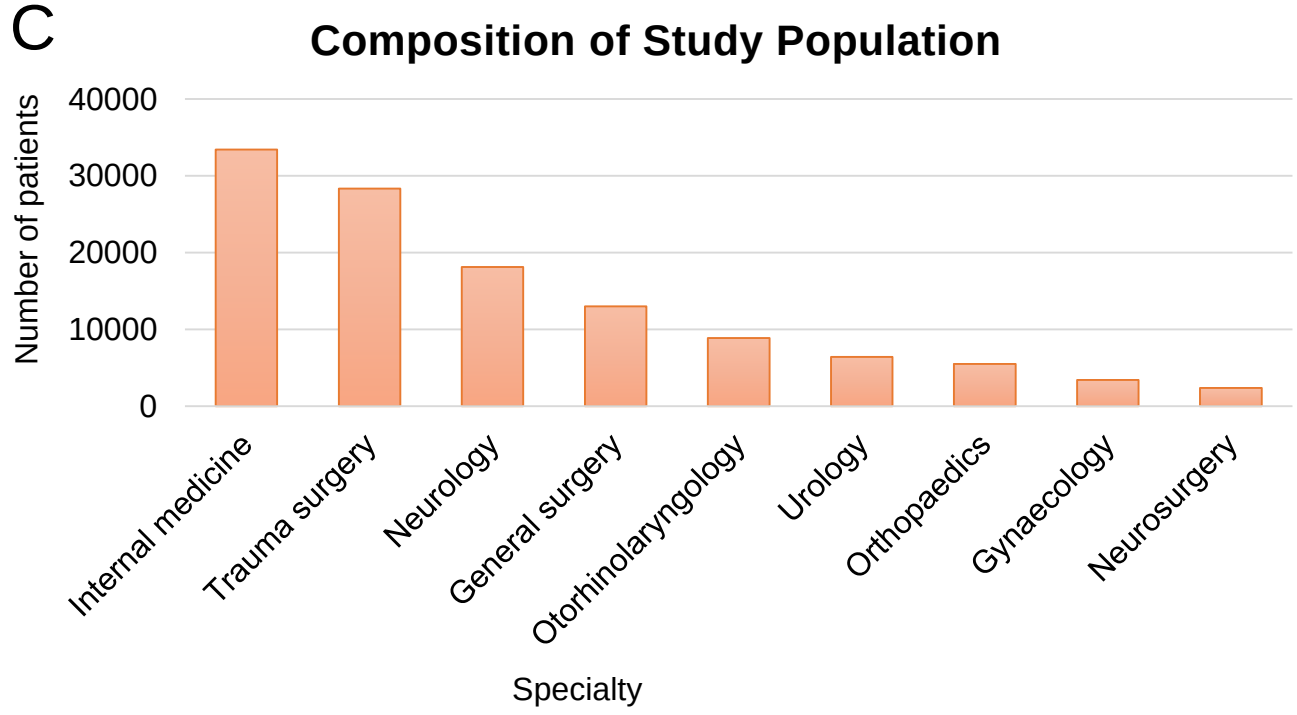
A

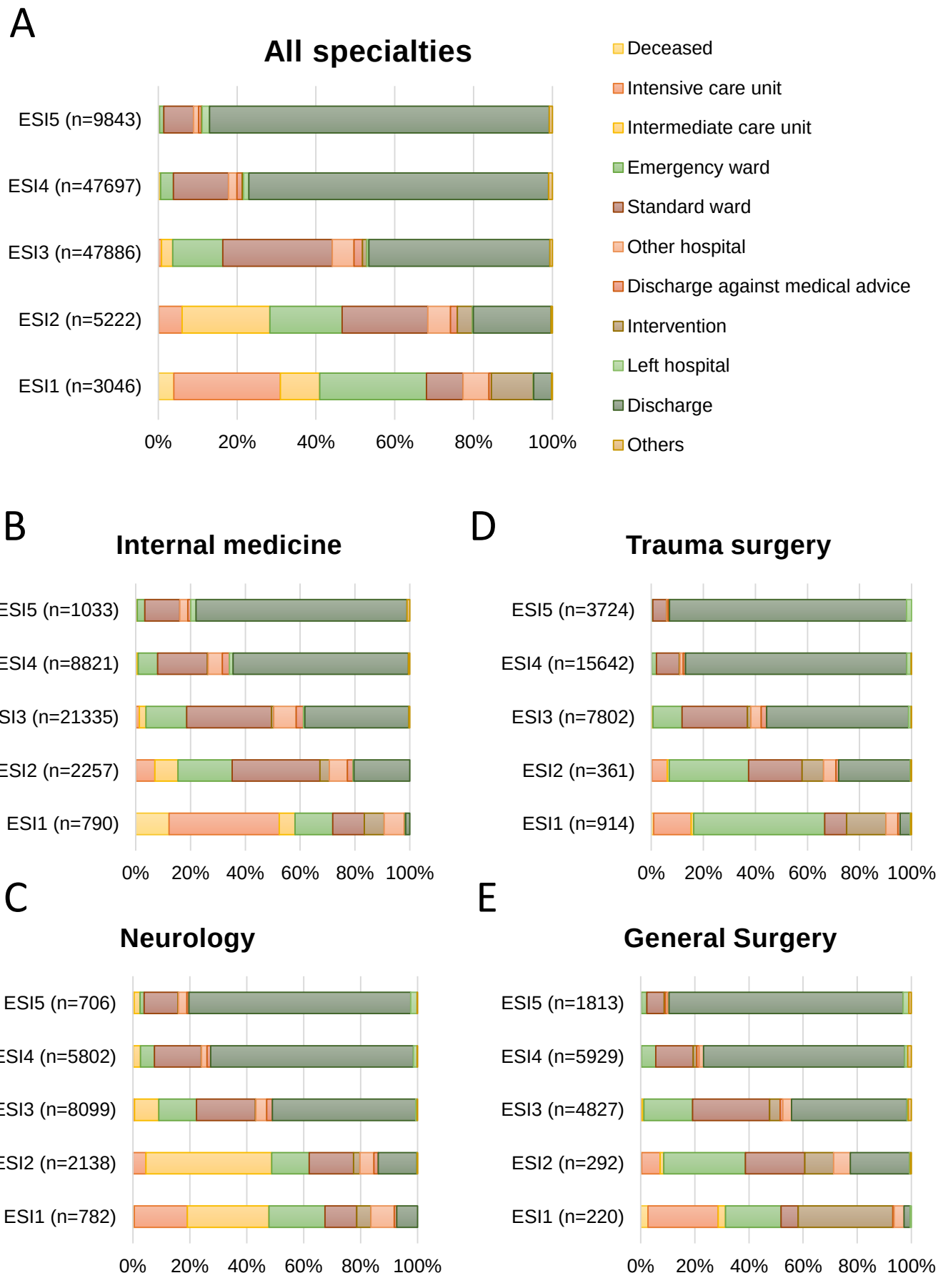

Mode of Arrival
ESI 5 (n=9843)
ESI 4 (n=47697)
ESI 3 (n=47484)
ESI 2 (n=5221)
ESI 1 (n=3050)
0%
20%
40%
60%
80%
100%
Emergency service
Self referral
Practitioner
Others

B


Admission Rates
ESI 5 (n=9579)
ESI 4 (n=46612)
ESI 3 (n=47317)
ESI 2 (n=5191)
ESI 1 (n=3036)
0%
20%
40%
60%
80%
100%
admitted
not admitted

C


Composition of Study Population
Number of patients
40000
30000
20000
10000
0
Internal medicine
Trauma surgery
Neurology
General surgery
Otorhinolaryngology
Urology
Orthopaedics
Gynaecology
Neurosurgery
Specialty


A
All specialties
ESI5 (n=9843)
ESI4 (n=47697)
ESI3 (n=47886)
ESI2 (n=5222)
ESI1 (n=3046)
0% 20% 40% 60% 80% 100%
Deceased
Intensive care unit
Intermediate care unit
Emergency ward
Standard ward
Other hospital
Discharge against medical advice
Intervention
Left hospital
Discharge
Others
B
Internal medicine
ESI5 (n=1033)
ESI4 (n=8821)
ESI3 (n=21335)
ESI2 (n=2257)
ESI1 (n=790)
0% 20% 40% 60% 80% 100%
D
Trauma surgery
ESI5 (n=3724)
ESI4 (n=15642)
ESI3 (n=7802)
ESI2 (n=361)
ESI1 (n=914)
0% 20% 40% 60% 80% 100%
C
Neurology
ESI5 (n=706)
ESI4 (n=5802)
ESI3 (n=8099)
ESI2 (n=2138)
ESI1 (n=782)
0% 20% 40% 60% 80% 100%
E
General Surgery
ESI5 (n=1813)
ESI4 (n=5929)
ESI3 (n=4827)
ESI2 (n=292)
ESI1 (n=220)
0% 20% 40% 60% 80% 100%

List of all symptoms available at triage for different specialties.

Specialty	Triage symptoms
Internal medicine	abdominal pain, airway problem, allergy and anaphylaxis, ascites and oedema, blood glucose derailment, cardiac arrhythmia, chest pain, coma, common cold, dehydration, diarrhoea, electrical accident, fever, flank pain, foreign material, gastrointestinal bleeding, hypertension, impaired consciousness, intoxication, jaundice, micturition problems, nausea and vomiting, other problems, problem of care, reduced general condition, resuscitation, skin and mucosal disease, swollen leg, syncope
Trauma surgery	accident at work, back pain with radicular symptoms, back pain without radicular symptoms, craniocerebral injury, fall with injury, hand injury, joint problems, limb injury, muscle problem, needlestick injury, other problems, polytrauma, spinal injury, wound control
Neurology	coma, double vision, facial palsy, gait disturbance, headache, hemiparesis, impaired consciousness, impaired vision, other problems, paraesthesia, paresis, problem of care, seizure, speech disorder, vertigo
General surgery	acute abdominal pain, catheter and drainage complications, chest injury, flank pain, circulatory disturbance, craniocerebral injury, polytrauma, postoperative problems and controls, rectal and stoma problems, skin and soft tissue injuries, skin and soft tissue problems, transfer from other hospital
Otorhinolaryngology	bleeding, common cold, epistaxis, ear noise, ear pain, foreign material, hearing loss, nose injury, other problems, skin and mucosal disease, sore throat, vertigo
Urology	catheter exchange, flank pain, foreign material, micturition problem, other problems, scrotal pain, skin and mucosal disease, urological bleeding
Orthopaedics	accident at work, back pain with radicular symptoms, back pain without radicular symptoms, craniocerebral injury, fall with injury, hand injury, joint problems, limb injury, muscle problem, needlestick injury, other problems, polytrauma, spinal injury, wound control

Gynaecology	abdominal pain, ascites and oedema, foreign material, gynaecological bleeding, morning-after pill, micturition problem, other gynaecological problems, pregnancy complications, rape, reduced general condition, skin and mucosal disease
Neurosurgery	back pain, headache, impaired consciousness, other problems, reduced general condition, seizure, shunt-dysfunction, wound healing disorder

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1, lines 1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2, lines 6-20
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 3, lines 8 ff.
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 4, lines 7-9
Methods			
Study design	4	Present key elements of study design early in the paper	Page 4, lines 12 ff.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 4, lines 12 ff.
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Page 4, lines 12 ff.
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 4, lines 20 ff.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*Page 4, lines 20 ff.*
Bias	9	Describe any efforts to address potential sources of bias	n/a
Study size	10	Explain how the study size was arrived at	Page 4, lines 12-18.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 5, lines 4-9

(*b*) Describe any methods used to examine subgroups and interactions	Page 5, lines 4-10
(*c*) Explain how missing data were addressed	n/a
(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	n/a
(*e*) Describe any sensitivity analyses	n/a

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 5, lines 16 ff.
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 5, lines 16 ff.
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*n/a*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*n/a*
		Cross-sectional study—Report numbers of outcome events or summary measures	*n/a*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	n/a
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 8, lines 22 ff.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 9, lines 7 ff.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 13, lines 14-26
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 10, lines 15 ff.
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 13, line 14-16.
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P. 15, lines 5-6

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.