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A longitudinal study of three different triage processes and their impact on patient flow at an emergency department

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Abstract

Objectives - Interprofessional teamwork in emergency department (ED) compared to nurse-led triage and physician-led triage. Can the patients´ waiting times be reduced?

Design - A single center before-and-after study.

Setting – The adult ED of a Swedish urban hospital.

Participants – Patients arriving on weekdays from 8 am to 9 pm during three one-year periods in the interval May 2012 to Nov 2015. A total of 185 806 arrivals were included.

Interventions - From May 2013 to May 2014, senior physicians replaced the triage nurses. In the second intervention from Nov 2014 to Nov 2015, the triage process was replaced by interprofessional teamwork on weekdays from 8 am to 9 pm.

Main outcome measures – The primary outcomes were median time to physician (TTP) and median length-of-stay (LOS). The secondary outcome was the proportion of patients who left the ED without been seen by a physician (LWBS).

Results – The crude median LOS was shortest for teamwork, 228 min (95% CI 226.4 to 230.5) compared to 232 min (95% CI 230.8 to 233.9) for nurse-led and 250 min (95% CI 248.5 to 252.6) for physician-led triage. The adjusted LOS for the teamwork period was 11 min shorter than nurse-led triage and 19 min shorter than physician-led triage. The median TTP was shortest for physician-led triage, 56 min (95% CI 54.5 to 56.6) compared to 116 (95% CI 114.4 to 117.5) for nurse-led triage and 74 min (95% CI 72.7 to 74.8) for teamwork. The LWBS rate was 1.9% for nurse-led triage, 1.2% for physician-led triage and 3.2% for teamwork. All differences in outcome measures had two-tailed p-values <0.01.

Conclusions – Interprofessional teamwork had the shortest LOS and a considerably shorter TTP than nurse-led triage. Interprofessional teamwork may be a useful approach to reducing waiting times in EDs.

Strengths and limitations of this study

- + The large study population enables the evaluation of the processes studied.
- + The control and study periods of one year each compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation.
- - The results from a large urban ED may not be generalizable to other ED settings.
- - The before and after design may not claim a causality between the interventions and the outcomes, although no other changes took place during the study period.

Introduction

Emergency department (ED) crowding is a growing problem worldwide.[1-5] Patients may suffer prolonged pain, inconvenience and poor outcome from delays in emergency care.[2 6-8] Crowding is also associated with staff dissatisfaction and high turnover as well as increased aggression and violence from frustrated patients.[9-11] Many external factors can contribute to crowding, such as an increase in patient volume, increased complexity and acuity of patients' diseases, and a lack of beds for patients admitted from the ED into the hospital's other wards or departments.[1 2 6] Already in the 1950s, triage of patients became a key strategy to handle the crowding problem within the ED.[12]

The objective of any ED triage process is to quickly sort patients by their priority of care. It is performed as either a quick or a comprehensive check. A quick triage check is typically performed by a nurse and is a simple visual assessment of the patient's medical urgency. Comprehensive triage systems, usually also performed by a nurse, typically involve taking vital signs and the history of the patient before the priority of care is determined.[13] In nurse-led triage, the protocol may also permit nurses to order laboratory tests and radiographs.[12] Comprehensive nurse-led triage using different standardized acuity protocols has been widely implemented since the 1990s. However, the evidence of its reliability and validity is scarce.[12 14 15]

During the last two decades, physicians have been introduced in the triage process to improve the throughput and patient flow. This triage system is characterized by either adding the physician to the process or replacing the standardized triage protocols. These interventions have reported reduced waiting time to physician assessment, fewer patients leaving the ED without being seen by a physician and shorter length-of-stay.[16-20] However, several systematic reviews, including meta-analyses, have concluded that the evidence is not robust due to a great variation in the study design and quality, intervention type and outcome measures.[21-25]

Interprofessional teamwork, where health workers with different professional backgrounds work together to deliver the highest quality of care,[26] is an alternative approach to improve patient flow. The triage is replaced and the patient is assessed and treated directly by an interprofessional team. Teamwork has been shown to improve patient safety in health care, though the unpredictability of the ED context poses special demands on effective team functioning and requires formal training.[27] Studies of teamwork and interprofessional training have reported improvements in the quality of care, patient satisfaction and work environment,[28-32] but few studies report its impact on ED lead times.[33]

This study aims to evaluate the impacts on patient flow of interprofessional teamwork compared to nurse-led and senior physician-led triage. Patient flow is examined in terms of ED waiting times. The research question is: Can the patients' waiting times at the ED be reduced by implementing interprofessional teamwork?

Material and methods

The study design was a single center before-and-after study. It was conducted from May 2012 to Nov 2015 at the adult ED at Södersjukhuset, a 600-bed urban public teaching hospital in central Stockholm, Sweden. With 110 000 annual visits, this ED is one of the largest in Scandinavia. The study material included all arrivals on weekdays from 8 am to 9 pm. Visits to the pediatric and gynecology EDs of the hospital were excluded due to differences in location and work processes. Patient arrivals between 9 pm to 8 am were excluded, since none of the study interventions were adopted for the night shifts. Arrivals on weekends and holidays were also excluded, because the second intervention was only implemented on

weekdays. Each intervention was studied during a one-year period following its implementation, with the one-year period prior to the first intervention as the control period (Figure 1).

Insert Figure 1 here

Nurse-led triage

During the control period from 2012.05.09 to 2013.05.08 a comprehensive nurse-led triage process was in use, with triage teams consisting of a registered nurse and a nursing assistant applying the Rapid Emergency Triage and Treatment System (RETTS) protocol.[27 28] This protocol was developed in Sweden and combines the vital signs and patient history to prioritize the patients in five emergency processes according to medical urgency. For most patients, the triage nurses sent blood samples for standardized laboratory work-up. A total of eight triage team shifts, 58 hours each of registered nurses and nursing assistants, were scheduled daily from 8 am to 9 pm. During peak hours from 10 am to 6 pm, an additional registered nurse triaged the ambulance patients. A physician was available on demand by the triage nurses.

After registration, ambulant patients with minor injuries and symptoms were sent to the fast track section, See & Treat, while other patients were directed to the triage section unless they needed immediate care. After completing a comprehensive triage, the patient was sent to either of three desks: Internal medicine, cardiology, or the emergency medicine desk for surgery and orthopedic complaints. Physicians rotating between the See & Treat and emergency medicine desk belonged to the ED, while most doctors at the internal medicine and cardiology desks primarily worked at their home clinics with sporadic shifts in the ED. Thus, three departments were responsible for the physician budgets and schedules.

Physician-led triage

During the first intervention from 2013.05.13 to 2014.05.12, three senior physician shifts were reassigned from each of the three desks from 8 am to 9 pm, corresponding to a total of 63 hours per day. The senior physicians formed intake teams in the triage area together with nine nursing assistant shifts, 64 hours, and two registered nurse shifts, 14 hours. The intake teams differed in their composition: Two of three cardiology intake teams included a registered nurse instead of nursing assistant, while the intake doctor of emergency medicine alternated between two rooms each staffed by a nursing assistant. Intake teams were instructed to assess all patients arriving to the ED, except those with prehospital alerts. The intake team could either discharge the patient immediately after a brief assessment, or initiate radiology and laboratory work up and request an in-hospital bed before the patient was moved to one of the three desks. At the desks, doctors started work shifts at different hours than nurses. After assessing a new patient alone, doctors put written orders in a basket to be carried out by any available desk nurse, who had to look for the doctors in separate back offices.

Teamwork in modules

During the second intervention from 2014.11.12 to 2015.11.11, interprofessional teamwork in modules was introduced on weekdays from 8 am to 9 pm. The ED facilities including the triage area were converted into nine modules, each equipped with 2 or 3 rooms for assessment and treatment, several bays for monitored patients and one team area. Doctors were moved from the back offices and each placed next to a nurse. A module was staffed by a flow team

and two care teams, where each team consisted of a doctor and a nurse with the most competent pair in the flow team. An additional nursing assistant in each module helped all three teams, except in the two modules replacing See & Treat (Figure 2). All members in a module started and ended the work shift together. Four parallel modules operated from 8 am to 9 pm, with five additional modules during peak hours from 10 am to 6 pm. Patients with orthopedic and surgery complaints were streamed into separate modules, although these modules remained flexible to treat patients with other complaints when needed.

After registration, a new patient was directed to an appropriate module, where the flow nurse prioritized and re-evaluated the queuing patients with support from the flow doctor. The responsibility was transferred to the doctor and nurse in a care team once they started the assessment of a new patient together. They collaborated in carrying out the patient history, physical examination, radiology and laboratory orders, and treatment in immediate sequence. The care teams were supported by the flow doctor, who ensured that correct plans were decided for the patients.

Insert Figure 2 here

The interventions were the results of improvement efforts made by interprofessional and multidisciplinary groups of physicians, nurses and nursing assistants. A total of ten Plan-Do-Study-Act cycles[34] were carried out before implementation of the interventions.

Potential sources of bias

Data of the staffing during each period was collected from the work schedules for physicians and nursing staff. The working hours during weekdays from 8 am to 9 pm were summed into a daily total number of hours. Registry data of the number of available in-hospital beds and the number of admitted patients per ward each weekday at 6 am were collected from Belaggning.qvw, a Qlikview® (QlikTech International, Radnor, Pennsylvania, USA) application used for bed occupancy reports sent to various healthcare authorities on a regular basis. The daily bed occupancy rate for the wards receiving patients admitted from the adult ED was calculated by dividing the number of admitted patients with the available number of beds and imported to R (The R Foundation for Statistical Computing, Vienna) for statistical analysis. From May 2012 to Nov 2015 no process change other than the studied interventions took place.

Patient involvement

Patients were not involved in setting the research question or the outcome measures, nor in the study design or implementation. Patients were not engaged in the interpretation or writing of results. The research results may be disseminated to the study population and relevant patient community through the local press.

Statistics

The electronic registry data of all visits to the adult ED during the study period was extracted from the ED tracking system Akusys, after replacing patient identification numbers with unique codes. The data was imported to R for statistical analysis. Descriptive statistics were used to summarize the general population characteristics for each period, i.e. the age and gender of patients, their arrival mode and the occupancy rate of in-hospital beds. Differences

of these between the periods were analyzed using the chi squared test for proportions and the Mann-Whitney-Wilcoxon test for mean values.

The primary outcome measures were the total ED length-of-stay and the waiting time to be seen by a physician, measured from the registration time on arrival. The distributions of these variables are heavily skewed since the times are short for most patients, but a few may wait very long for transports or in-hospital beds. Therefore, medians of time to physician and length-of-stay were used for comparison of the periods, and the 95% confidence intervals were obtained by bootstrap simulation. The p-values for differences of medians were calculated using Moon´s test, because of differences in variance between the periods. This study had the statistical power of 0.80 at an alpha of 0.05 to detect differences of four minutes between the periods. The relationships between length-of-stay and each individual background characteristic were explored by scatterplot and simple linear regression. Finally, the adjusted length-of-stay for each one-year period was calculated by pooling these predictors in a multivariable regression. The secondary outcome measure was the proportion of patients who left without been seen by a physician, which was analyzed using the chi squared test. The statistical significance level was set at a two-tailed p-value of 0.05 for all outcomes.

Results

A total of 332 115 arrivals were registered during the three one-year periods. After excluding 146 302 arrivals on weekends, holidays and during night shifts from 9 pm to 8 am, seven more arrivals occurring on weekdays 8 am through 9 pm were excluded due to inconsistencies in registry entries. A total of 185 806 arrivals were included (Figure 1). The general characteristics of the study population for each period are presented in Table 1a. The in-hospital bed occupancy rate increased significantly between each period, with mean occupancy rates of 92.6%, 94.3% and 97.8% respectively.

The total number of working hours for physicians and for nurses also increased, but only in one of the two ED corridors. To achieve a more accurate comparison between the different triage processes, only arrivals dispositioned from ED sections where the total working hours remained approximately unchanged were chosen for comparison between the periods. These consisted of the emergency medicine desk, where patients with surgery or orthopedic complaints were treated, and the fast track See & Treat, where ambulant patients with internal medicine complaints were seen along with minor surgery and orthopedic problems. Physicians working at these sections belonged to the ED. A total of 93 029 arrivals were dispositioned from these sections, i.e. 50.1% of the entire study population. For the teamwork period, the working hours for nurses at these sections decreased due to transfer of some ambulant patients and prehospital alerts to the internal medicine modules in the other corridor. The general characteristics of this subpopulation are listed in Table 1b.

Insert Table 1a & 1b here

For the subpopulation chosen for comparison, the median length-of-stay was shortest for the teamwork period, 228 min compared to 232 min for nurse-led triage and 250 min for

physician-led triage. The median time to physician was shortest for physician-led triage, 56 min compared to 74 min for teamwork and 116 min for nurse-led triage. The 95% confidence intervals and p-values are listed in Table 2b, along with outcome measures specified for discharged and admitted patients. All differences between periods were significant with two-tailed p-values <0.01. The length-of-stay distribution per study period is visualized in Figure 3 and the time to physician distribution in Figure 4. Both distributions are heavily skewed. The asymmetry of the length-of-stay distribution increased from period to period, with a skewness of 1.35 for nurse-led triage, 1.46 for physician-led triage, and 1.55 for teamwork.

Insert Figure 3 & 4 here

For the entire study population, the median length-of-stay was also shortest for the teamwork period, 223 min compared to 226 min for nurse-led triage and 239 min for physician-led triage. Similarly, the median time to physician was shortest for physician-led triage, 54 min compared to 66 min for teamwork and 98 min for nurse-led triage (Table 2a).

Insert Table 2a & 2b here

Data from all three periods of the comparison population were pooled in a linear regression to analyze each population characteristic as a predictor of the length-of-stay. The resulting estimates indicate a length-of-stay 86 min longer for patients over 74 years, 27 min longer for female patients, 108 min longer for ambulance patients and 38 min shorter for ambulance patients arriving with prehospital alert. The length-of-stay estimate increased by 10 min when taking into account the observed increase of the inpatient bed occupancy rate from 89.5% for nurse-led triage to 94.8% for teamwork. When all explored predictors were pooled in a multivariable regression analysis, the adjusted length-of-stay estimate for teamwork was 11 min shorter than nurse-led triage and 19 min shorter than physician-led triage (Table 3).

Insert Table 3 here

In the subpopulation chosen for comparison, the proportion of patients who left without been seen by a physician was smallest for physician-led triage, 1.2% compared to 1.9% for nurse-led triage and 3.2% for teamwork (Table 2b). The corresponding rate of the entire study population was also lowest for physician-led triage and highest for teamwork period (Table 2a). All differences were of statistical significance.

Discussion

This study evaluated the impacts on patient flow of interprofessional teamwork compared to nurse-led and senior physician-led triage in terms of ED waiting times. The main finding was the shortest median length-of-stay observed during the teamwork period. Another main

finding was the longest length-of-stay observed during physician-led triage, despite the shortest time to physician.

Interprofessional teamwork is based on the following principles, which we believe contribute to the increased efficiency found in this study: reducing the number of patients each staff member was responsible for, reducing the number of staff members encountered by the patient, deciding appropriate treatment plans from the start, and carrying out the plans immediately. For this to happen, work shifts started and ended at the same time, and roles and responsibilities were clearly defined for all members in a module. Each module had own fully equipped rooms and team area, thus creating smaller subsets inside the large ED to enhance interprofessional teamwork. This may be particularly relevant to large EDs, since a correlation has been found between longer length-of-stay and increasing annual ED volumes.[35 36] Welch et al[35] suggested reducing the volume of a large ED by creating smaller subsets or clinical microsystems as an approach to improve the efficiency. Improvement in communication and patient safety,[29 31] staff[37] and patient satisfaction[28 30] are documented effects of interprofessional teamwork. The present study shows that teamwork can also improve ED lead times. To the best of our knowledge, only one previous study has reported a small but significant reduction of the length-of-stay of physician-nurse teamwork.[33]

One may note that a smaller proportion of patients in the comparison subpopulation were discharged home during the teamwork period, 65.4% compared to 71.1% for nurse-led triage and 69.3% for physician-led triage. This may be due to the fast track See & Treat having been replaced by modules for ambulant patients, one in each ED corridor. Internal medicine complaints previously treated at See & Treat were transferred to modules in the other corridor. The median length-of-stay was shorter for patients discharged home than those admitted for all periods, 88 min shorter for teamwork, 73 min for physician-led triage and 20 min for nurse-led triage (Table 2b). This observed shift towards more serious complaints may provide further support for a higher efficiency of the teamwork process. Another observation supporting this view was the increasing skewness of the length-of-stay distribution from period to period, which implies an increasing proportion of patients with a short length-of-stay in the presence of a smaller number of patients with increasing length-of-stay. The increasing skewness observed may have been caused by the increasing inpatient bed occupancy from period to period.

When senior physicians replaced nurses in triage, the observed 60 min decrease of time to physician was larger than in the studies included by Abdulwahid et al in a meta-analysis.[25] These authors estimated a reduction of 26 min from two randomized controlled trials (RCTs) [38 39] and of 15 min from nine non-RCTs. On the other hand, in this study the median length-of-stay increased by 18 minutes, in contrast to the reduction of 29 min in the meta-analysis. Four of the publications included in the meta-analysis appear to report different follow-up lengths of an identical intervention in the same ED,[19 40-42] which may overestimate the effect size. To our knowledge, two studies found no significant changes in length-of-stay,[43 44] while one study has reported a significant 15 min increase along with an 11% increase of orders for diagnostic radiology.[45] For patients dispositioned by a second physician at the main ED after senior physician assessment at triage, Traub et al found a 25 min longer length-of-stay.[20] Choi et al found significant reductions of the time to physician and length-of-stay, but also described "stressful, pressurized and risky" working conditions for the senior physician in triage.[18]. When Burström et al compared three EDs with different triage processes, the shortest length-of-stay was found for senior physician-led triage.[46] But this ED also applied interprofessional teamwork with a senior physician at triage planning the patients´ ED stay

and communicating the plan to teams consisting of a junior physician and a nurse working in parallel. At the other two EDs, doctors and nurses worked separately and sequentially.

The proportion of patients who left without been seen by a physician was smallest for physician-led triage in the present study, which is in line with the significant decrease reported by previous studies of physicians at triage.[16 17 42] The highest rate was observed for the teamwork period, despite a 46 min shorter time to physician compared to nurse-led triage. Although this rate is often used as an indicator of crowding, patients who leave without been seen by a physician has been shown to be at a lower risk of death or admission within seven days compared to patients seen and discharged home.[47] These authors found no association between EDs with high annual leaving rate and risk of death or admission. Nonetheless, the higher walkout rate for the teamwork process calls for further exploration and should be addressed.

Strengths and limitations

The main strength of this study is the large population which enables the evaluation of the process rather than the performance of individual doctors or nurses. Another strength is the control and study periods of one year each, which compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation. We were only able to identify one other study of a similar population size and length.[19]

This study has several limitations. First, this is a single-center study in one large, busy urban ED and the results may not be generalizable to other ED settings. EDs differ from each other in aspects of input, throughput and output.[48] In addition, before-and-after studies may not claim a causality between the intervention and the outcomes, although in the present study, the studied periods have been chosen so that no other simultaneous process changes took place. Finally, a third limitation shared by previous studies may be the use of lead times as surrogate outcome measures for ED quality. However, the outcome measures chosen have been shown to be indicators of patient outcome[47 49 50] and patient satisfaction.[51 52]

Conclusion

The shortest median length-of-stay was observed for interprofessional teamwork in modules. It was longest for physician-led triage, despite the shortest time to physician of all studied periods. Interprofessional teamwork in modules may be an interesting approach to improve timeliness in large busy EDs. Therefore, we will also study teamwork behaviors to understand whether further improvements in patient flow can be obtained.

What this paper adds

What is already known on this topic

- Different triage processes, e. g. nurse-led triage using comprehensive protocols and senior physicians at triage have been implemented to manage crowding in emergency departments.
- The evidence of these triage interventions is either scarce or not robust.
- Interprofessional teamwork has been shown to improve communication and patient safety, as well as the satisfaction of staff and patients.

What this study adds

- The adjusted length-of-stay for teamwork process was 11 min shorter than protocol based nurse triage and 19 min shorter than senior physician-led triage.

- Interprofessional teamwork may be an alternative approach to improve the timeliness of emergency department care.

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Ethics: The study was approved by the Regional Ethical Review Board of Stockholm, ref. no. 2016/109-31/5. Informed consent was not obtained since all patients were assessed and treated according the process implemented during that period.

Data sharing: Full dataset and statistical codes are available from the corresponding author. Patient consent was not obtained but the presented data are anonymized and risk of identification is low.

Transparency declaration
The present manuscript is an honest, accurate and transparent account of the study being reported. No important aspects of the study have been omitted and any discrepancies from the study as planned have been explained.

All authors had full access to all the data in the study, including statistical reports and tables, and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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Figure 1. **Timeline of the interventions and the study flow diagram.** For 3 one-year periods, arrivals on weekends/holidays or during night shifts were excluded along with 7 additional arrivals with inconsistent registry entries. A subpopulation was chosen for comparison between the periods.

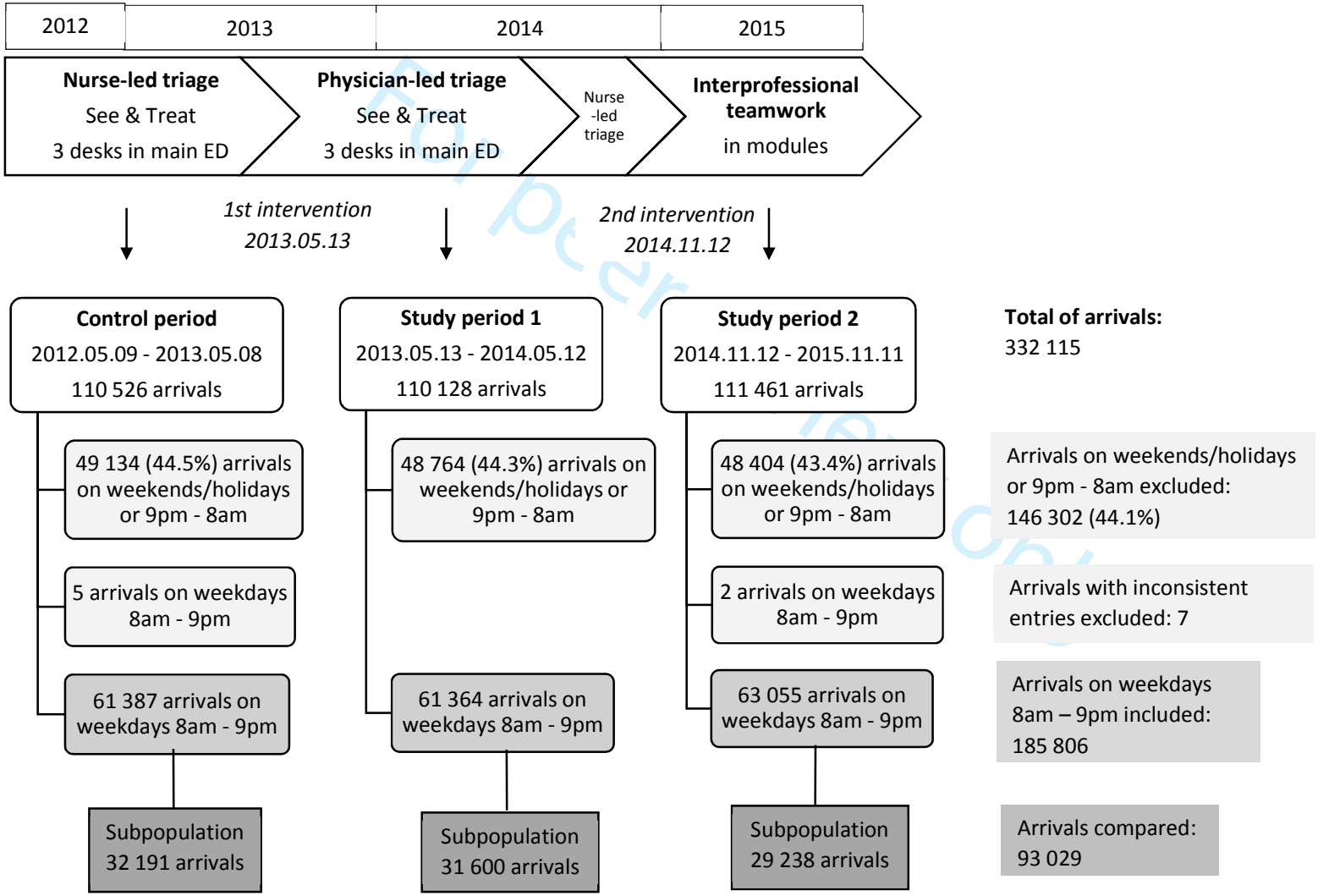

Figure 2. Interprofessional teamwork in a module - Team members, work space and patient flow.

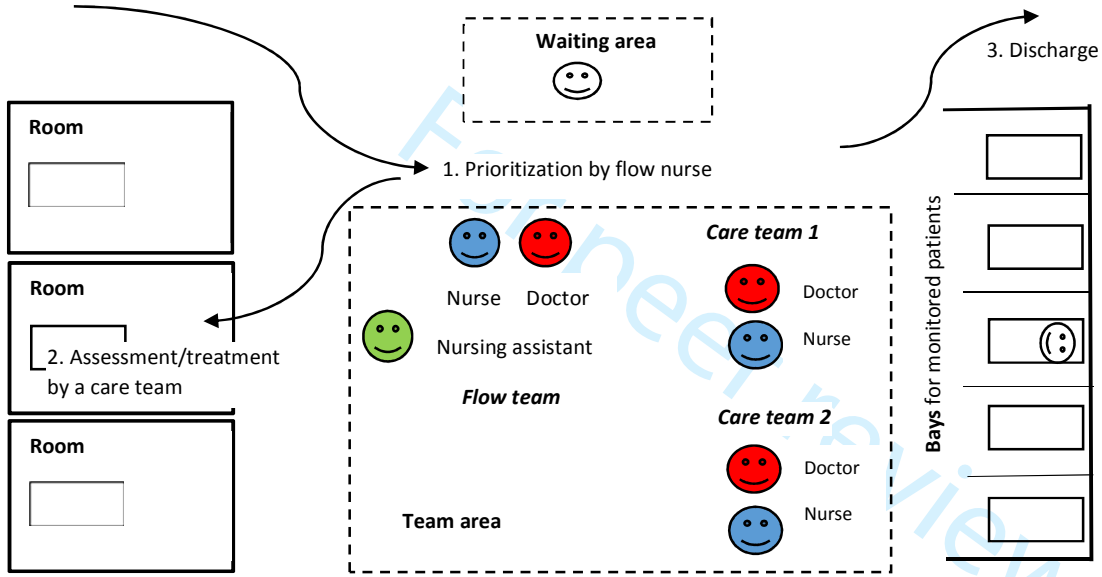

Figure 3. Length-of-stay distribution - per triage period of the compared subpopulation

Figure 4. Time to physician distribution - per triage period in the compared subpopulation

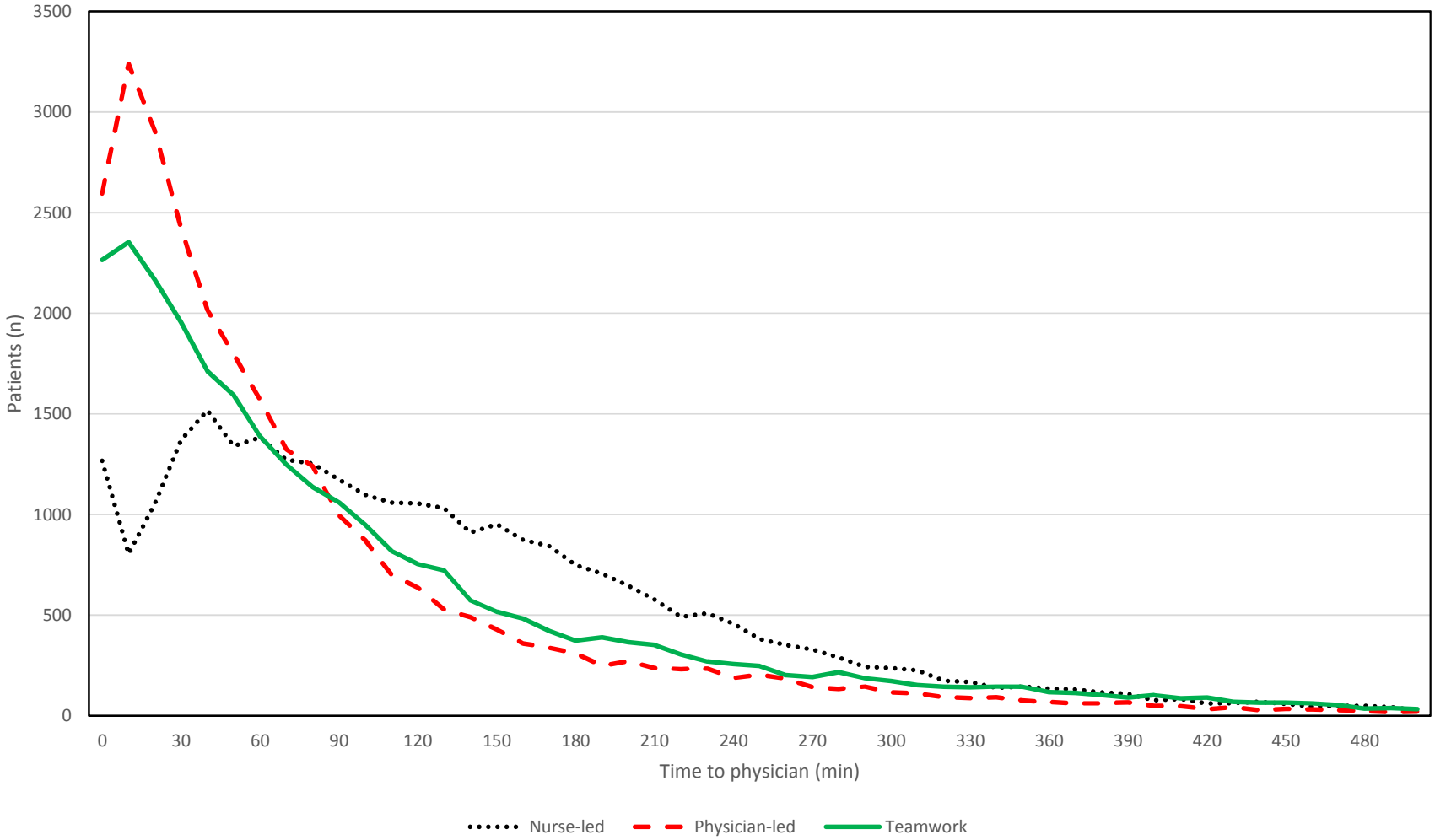

Table 1a. General characteristics of the entire study population - per one-year period of three different triage processes

	Nurse-led triage 2012.05.09 - 2013.05.08		Physician-led vs nurse-led	**Physician-led triage** 2013.05.13 - 2014.05.12		Teamwork vs physician-led	**Teamwork in modules** 2014.11.12 - 2015.11.11		Teamwork vs nurse-led
Triage protocol	RETTS			None			None		
All arrivals	110 526			110 128			111 461		
Arrivals on weekdays 8 am - 9 pm	61 387	55.5%	p=0.406	61 364	55.7%	*p<0.001*	63 055	56.6%	*p<0.001*
Female gender	31 933	52.0%	p=0.341	31 706	51.7%	p=0.354	32 413	51.4%	*p=0.030*
Mean age (y)	55.3	SD 21.8	*p=0.019*	55.6	SD 21.8	*p=0.009*	56.0	SD 21.5	*p<0.001*
Arrival mode									
Ambulance no alert	14 587	23.8%	p=0.775	14 538	23.7%	p=0.156	15 156	24.0%	p=0.260
Prehospital ambulance alert	2 952	4.8%	*p=0.017*	3 133	5.1%	p=0.662	3 184	5.0%	p=0.051
In-hospital beds on weekdays at 6 am									
Mean available beds	423			433			408		
Medan bed occupancy	391	92.6%	*p<0.001*	408	94.3%	*p<0.001*	398	97.8%	*p<0.001*
Staffing on weekdays 8 am - 9 pm									
Physician hours	265.5			285.0			324.0		
Nurse hours incl. nursing assistants	512.6			508.3			548.5		

Table 1b. General characteristics of the 50.1% subpoplation chosen for comparison - per one-year period of three different triage processes

	Nurse-led triage 2012.05.09 - 2013.05.08		Physician-led vs nurse-led	**Physician-led triage** 2013.05.13 - 2014.05.12		Teamwork vs physician-led	**Teamwork in modules** 2014.11.12 - 2015.11.11		Teamwork vs nurse-led
Triage protocol	RETTS			None			None		
All arrivals	57 987			56 250			52 380		
Arrivals on weekdays 8 am - 9 pm	32 191	55.5%	p=0.249	31 600	56.2%	p=0.243	29 238	55.8%	p=0.307
Female gender	16 375	50.9%	p=0.213	15 917	50.4%	p=0.161	14 438	49.4%	*p=0.015*
Mean age (y)	51.5	SD 21.9	*p=0.001*	52.1	SD 22.1	p=0.753	52.2	SD 22.0	*p<0.001*
Arrival mode									
Ambulance no alert	5 778	17.9%	p=0.187	5 800	18.4%	*p<0.001*	5 954	20.4%	*p<0.001*
Prehospital ambulance alert	1 002	3.1%	p=0.322	940	3.0%	*p=0.004*	757	2.6%	*p<0.001*
In-hospital beds on weekdays at 6 am									
Mean available beds	180			179			172		
Medan bed occupancy	161	89.5%	*p<0.001*	164	92.0%	*p<0.001*	163	94.8%	*p<0.001*
Staffing on weekdays 8 am - 9 pm									
Physician hours	149.0			158.0			152.5		
Nurse hours incl. nursing assistants	221.6			215.6			206.9		

Table 2a. Results - the outcome measures and patient disposition for the entire study population per one-year period of three different triage processes

	Nurse-led triage 2012.05.09 - 2013.05.08		Physician-led vs nurse-led	Physician-led triage 2013.05.13 - 2014.05.12		Teamwork vs physician-led	Teamwork in modules 2014.11.12 - 2015.11.11		Teamwork vs nurse-led
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	226	224.5 - 227.6	*p<0.001*	239	236.9 - 240.0	*p<0.001*	223	221.9 - 224.0	*p<0.001*
Discharged home/Admitted	210/253			223/267			198/263		
Median time to physician									
Overall	98	97.4 - 99.5	*p<0.001*	54	53.7 - 54.8	*p<0.001*	66	65.0- 67.1	*p<0.001*
Discharged home/Admitted	114/73			60/42			70/56		
	n	**%**		**n**	**%**		**n**	**%**	
Left without been seen by a physician	1594	2.6%	*p<0.001*	1366	2.2%	*p<0.001*	2321	3.7%	*p<0.001*
Discharged home	36 953	60.2%	*p=0.001*	36 370	59.3%	p=0.904	37 350	59.2%	*p=0.001*
Admitted	19 338	31.5%	p=0.319	19 494	31.8%	*p<0.001*	19 273	30.6%	*p<0.001*
Admitted to satellite beds	190	0.3%	*p<0.001*	286	0.5%	*p<0.001*	439	0.7%	*p<0.001*
Transferred to other secondary care sites	2 171	3.5%	p=0.737	2 193	3.6%	p=0.052	2 385	3.8%	*p=0.022*
Other dispositions	1 141	1.3%	p=0.763	1 655	1.2%	p=0.149	1 287	1.3%	p=0.265

Table 2b. Results - the outcome measures and patient disposition for the compared subpopulation per one-year period of three different triage processes

	Nurse-led triage 2012.05.09 - 2013.05.08		Physician-led vs nurse-led	Physician-led triage 2013.05.13 - 2014.05.12		Teamwork vs physician-led	Teamwork in modules 2014.11.12 - 2015.11.11		Teamwork vs nurse-led
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	232	230.8 - 233.9	*p<0.001*	250	248.5 -252.6	*p<0.001*	228	226.4 - 230.5	*p=0.006*
Discharged home/Admitted	212/293			229/302			200/288		
Median time to physician									
Overall	116	114.4 - 117.5	*p<0.001*	56	54.5 - 56.6	*p<0.001*	74	72.7 - 74.8	*p<0.001*
Discharged home/Admitted	125/86			61/43			76/69		
	n	**%**		**n**	**%**		**n**	**%**	
Left without been seen by a physician	597	1.9%	*p<0.001*	368	1.2%	*p<0.001*	933	3.2%	*p<0.001*
Discharged home	22 875	71.1%	*p<0.001*	21 888	69.3%	*p<0.001*	19 126	65.4%	*p<0.001*
Admitted	7 337	22.8%	*p=0.001*	7 548	23.9%	*p<0.001*	7 406	25.3%	*p=0.001*
Admitted to satellite beds	115	0.4%	P=0.111	139	0.4%	*p<0.001*	197	0.7%	*p<0.001*
Transferred to other secondary care sites	883	2.7%	*p=0.013*	972	3.1%	*p=0.010*	1009	3.5%	*p<0.001*
Other dispositions	384	0.6%	p=0.150	685	0.7%	*p<0.001*	567	1.2%	*p<0.001*

Table 3. Regression analysis - predictors of length-of-stay explored individually by simple linear regression and pooled in multivariable regression

Predictor	Simple linear regression				Multivariable regression			
	Estimate (min)	Std error (min)	t value	p-value	Estimate (min)	Std error (min)	t value	p-value
Age								
Overall (Per year)	1.73	0.03	72.04	*p<0.001*	1.18	0.03	47.07	*p<0.001*
75 years or older (Yes/No)	86.17	1.35	63.97	*p<0.001*				
Gender								
Female (Yes or No)	26.70	1.07	24.97	*p<0.001*	17.93	1.04	17.32	*p<0.001*
Arrival mode								
Ambulance without alert (Yes/No)	108.38	1.33	81.81	*p<0.001*	83.83	1.41	59.45	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-37.85	3.19	-11.85	*p<0.001*	-29.43	3.11	-9.47	*p<0.001*
In-hospital bed occupancy								
Daily occupancy rate at 6 am (0 - 1)	208.23	10.26	20.30	*p<0.001*	238.71	10.82	22.07	*p<0.001*
Difference compared to teamwork period								
Nurse-led triage (Yes/No)					11.40	1.39	8.21	*p<0.001*
Physician-led triage (Yes/No)					19.09	1.33	14.34	*p<0.001*

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	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-5
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	3-5
		(*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	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-6
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	5-6
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5-6
		(*b*) Describe any methods used to examine subgroups and interactions	5-6
		(*c*) Explain how missing data were addressed	6
		(*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	NA
		(*e*) Describe any sensitivity analyses	NA

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	6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Tab.1
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
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	7, Tab. 3
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	7-8
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	9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-9
Generalisability	21	Discuss the generalisability (external validity) of the study results	9
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	10

*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.

BMJ Open

Can interprofessional teamwork reduce patient waiting times? A longitudinal single-center study of three different triage processes at a Swedish emergency department

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Abstract

Objective – To evaluate whether interprofessional teamwork can reduce emergency department (ED) waiting times, compared to nurse-led triage and physician-led triage.

Design - A single center before-and-after study.

Setting – The adult ED of a Swedish urban hospital.

Participants – Patients arriving on weekdays from 8 am to 9 pm during three one-year periods in the interval May 2012 to Nov 2015. A total of 185 806 arrivals were included.

Interventions - From May 2013 to May 2014, senior physicians replaced the triage nurses. In the second intervention from Nov 2014 to Nov 2015, the triage process was replaced by interprofessional teamwork on weekdays from 8 am to 9 pm.

Main outcome measures – The primary outcomes were the median time to physician (TTP) and the median length-of-stay (LOS). The secondary outcome was the proportion of patients who left the ED without being seen by a physician (LWBS).

Results – The crude median LOS was shortest for teamwork, 228 min (95% CI 226.4 to 230.5) compared to 232 min (95% CI 230.8 to 233.9) for nurse-led and 250 min (95% CI 248.5 to 252.6) for physician-led triage. The adjusted LOS for the teamwork period was 13 min shorter than for nurse-led triage and 25 min shorter than for physician-led triage. The median TTP was shortest for physician-led triage, 56 min (95% CI 54.5 to 56.6) compared to 116 min (95% CI 114.4 to 117.5) for nurse-led triage and 74 min (95% CI 72.7 to 74.8) for teamwork. The LWBS rate was 1.9% for nurse-led triage, 1.2% for physician-led triage and 3.2% for teamwork. All differences in outcome measures had two-tailed p-values <0.01.

Conclusions – Interprofessional teamwork had the shortest LOS and a considerably shorter TTP than nurse-led triage. Interprofessional teamwork may be a useful approach to reducing waiting times in EDs.

Strengths and limitations of this study

- + Two interventions are analyzed and three triage processes compared in the same ED.
- + The large study population allows an accurate comparison of the triage processes.
- + The control and study periods of one year each compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation.
- - The results from a large urban ED may not be generalizable to other ED settings.
- - The before and after design may not claim a causality between the interventions and the outcomes, although no other changes took place during the study period.

Introduction

Emergency department (ED) crowding is a growing problem worldwide.[1-5] Patients risk suffering prolonged pain, inconvenience and poor outcomes due to delays in emergency care.[2 6-8] ED crowding can also lead to dissatisfaction among staff and a high rate of turnover as well as increased aggression and violence from frustrated patients.[9-11] Many external factors can contribute to ED crowding, such as an increasing patient volume, increased complexity and acuity of patients' diseases, and a lack of beds for patients admitted from the ED into the hospital's other wards or departments.[1 2 6]

Already in the 1950s, triage of patients became a key strategy to handle the crowding problem.[12] The objective of an ED triage process is to quickly sort patients according to their priority of care. A quick triage check is typically performed by a nurse and consists of a simple visual assessment of the patient's medical urgency. More comprehensive triage systems, also typically carried out by a nurse, involve taking vital signs and patient history before the priority of care is determined.[13] In nurse-led triage, the protocol may also allow nurses to order laboratory tests and radiographs.[12] Comprehensive nurse-led triage using different standardized acuity protocols has been widely implemented since the 1990s. However, the evidence of its reliability and validity is scarce.[12 14 15]

During the last two decades, some EDs have introduced physicians in the triage process in order to improve throughput and patient flow. These interventions have been reported to result in a reduced waiting time to physician assessment, fewer patients leaving the ED without being seen by a physician, and a shorter length-of-stay.[16-20] However, several systematic reviews, including meta-analyses, have concluded that the evidence is not robust due to a large degree of variation in the study design and quality, intervention type and outcome measures.[21-25]

Interprofessional teamwork, where health workers with different professional backgrounds work together to deliver the highest quality of care,[26] is an alternative approach to improving patient flow. We describe an intervention where the triage process is replaced by the patient being assessed and treated directly by an interprofessional team. Teamwork has been shown to improve patient safety in health care, though the unpredictability of the ED context poses special demands on effective team functioning and requires formal training.[27] Studies of teamwork and interprofessional training have reported improvements in the quality of care, patient satisfaction and work environment,[28-32] but few studies report its impact on ED lead times.[33]

The aim of this study is to evaluate the impact on patient flow of interprofessional teamwork compared to nurse-led and senior physician-led triage. We examine the patient flow in terms of ED waiting times. The research question is: Can the patients' waiting times at the ED be reduced by implementing interprofessional teamwork?

Material and methods

The study design was a single center before-and-after study. We conducted the study from May 2012 to Nov 2015 at the adult ED at Södersjukhuset, a 600-bed urban public teaching

hospital in central Stockholm, Sweden. With 110 000 annual visits, this ED is one of the largest in Scandinavia. The study material included all arrivals on weekdays from 8 am to 9 pm. We excluded patient arrivals between 9 pm to 8 am, since none of the study interventions were adopted for the night shifts. Arrivals on weekends and holidays were also excluded, since the teamwork intervention was only implemented on weekdays. Each intervention was studied during a one-year period after its implementation, with a one-year period prior to the first intervention serving as the control period (Figure 1). We also excluded visits to our pediatric and gynecology EDs because of differences in location and work processes.

Insert Figure 1 here

Nurse-led triage

During the control period from 2012.05.09 to 2013.05.08 a comprehensive nurse-led triage process was in use. The triage teams consisted of a registered nurse and a nursing assistant who applied the Rapid Emergency Triage and Treatment System (RETTS) protocol[34 35] developed in Sweden. The RETTS protocol combines the vital signs and patient history to prioritize the patients in five emergency processes according to medical urgency. For most patients, the triage nurses sent blood samples for standardized laboratory work-up. A total of eight triage team shifts were scheduled daily from 8 am to 9 pm, corresponding to 58 hours each of registered nurses and nursing assistants. During peak hours from 10 am to 6 pm, an additional registered nurse triaged the ambulance patients. A physician was available on demand by the triage nurses.

After registration, ambulant patients with minor injuries and symptoms were sent to a fast track section, See & Treat, while other patients were directed to the triage section unless they needed immediate care. After completing a comprehensive triage, the patient was sent to one of three desks: internal medicine, cardiology, or the emergency medicine desk for surgery and orthopedic complaints. At the desk, nursing assistants placed the patient in a room to wait for a doctor. The next available doctor assessed the patient on his or her own and left written orders for the nurses. The patient then had to wait for the next available nurse to carry out the orders, while the doctor either proceeded with documentation in a back office or took on another patient. Rooms were often occupied by patients waiting for the next step in the process. Since the work shifts started at different hours for the different professions, each doctor worked with several nurses and each nurse with several doctors during a shift.

Physician-led triage

During the first intervention from 2013.05.13 to 2014.05.12, three senior physician shifts were reassigned from each of the three desks from 8 am to 9 pm, corresponding to a total of 63 hours per day. The senior physicians formed intake teams in the triage area together with nine nursing assistant shifts, 64 hours, and two registered nurse shifts, 14 hours. Two of three cardiology intake teams included a registered nurse instead of nursing assistant, while the intake doctor of emergency medicine alternated between two rooms each staffed by a nursing assistant. Intake teams were instructed to assess all patients arriving at the ED, except those with prehospital alerts. The intake team could either discharge the patient after a brief assessment, or initiate radiology and laboratory work up and request an in-hospital bed before moving the patient to one of the three desks. The work process at the three desks was the same as described for the nurse-led triage period.

Interprofessional teamwork in modules

During the second intervention from 2014.11.12 to 2015.11.11, interprofessional teamwork in modules was introduced on weekdays from 8 am to 9 pm. The ED facilities, including the triage area, were converted into nine modules, each equipped with 2 or 3 rooms for assessment and treatment, several bays for monitored patients, and one team area. Doctors moved from the back offices so that each doctor was placed next to a nurse in the team area. A module was staffed by a flow team and two care teams. Each team consisted of a doctor and a nurse with the most senior doctor and nurse forming the flow team. An additional nursing assistant in each module helped all three teams, except in the two modules replacing See & Treat (see Figure 2). The entire staff within a module started and ended the work shift together. Four parallel modules were in operation from 8 am to 9 pm, with five additional modules added during peak hours from 10 am to 6 pm. Patients with orthopedic and surgery complaints were streamed into separate modules, although these modules had flexibility to treat patients with other complaints when needed.

After registration, a new patient was directed to the appropriate module, where the flow nurse prioritized and re-evaluated the queuing patients with support from the flow doctor. The responsibility was transferred from the flow nurse when a care team started the assessment. The doctor and nurse in the care team collaborated to carry out the patient interview, physical examination, radiology and laboratory orders, and treatment in immediate sequence. The flow doctor supported the care teams in deciding on correct care plans for the patients.

Insert Figure 2 here

The interventions were the results of improvement efforts made by interprofessional and multidisciplinary groups of physicians, nurses and nursing assistants. A number of Plan-Do-Study-Act cycles[36] were carried out before the implementation of the interventions.

Potential sources of bias

We collected staffing data for each period from the work schedules for physicians and nursing staff. The scheduled working hours during weekdays from 8 am to 9 pm were summed into a daily total number of hours. We collected registry data of available in-hospital beds and the number of admitted patients per ward weekdays at 6 am from Belaggning.qvw, a Qlikview® (QlikTech International, Radnor, Pennsylvania, USA) application used for bed occupancy reports to healthcare authorities. The daily bed occupancy rate for the wards receiving patients admitted from the adult ED was calculated as the ratio between the number of admitted patients and the available number of beds. From May 2012 to Nov 2015 no other process change than the studied interventions took place.

Statistics

Electronic registry data of all visits to the adult ED during the study period was extracted from the ED tracking system Akusys, after replacing patient identification numbers by unique codes. We imported the data obtained from Akusys, Belaggning.qvw and work schedules into R (The R Foundation for Statistical Computing, Vienna) for statistical analysis. We used descriptive statistics to summarize the general characteristics for each period and analyzed differences between the periods using the chi squared test for proportions and the Mann-Whitney-Wilcoxon test for mean values.

The primary outcome measures were the total ED length-of-stay and the waiting time to be seen by a physician, measured from the registration time on arrival. The distributions of these variables are heavily skewed with short times for most patients, and a smaller number of very long times resulting from patients waiting for transportation or in-hospital beds. Therefore, we used the median of the time to physician and length-of-stay to compare the periods. We obtained 95% confidence intervals by bootstrap simulation and calculated p-values using Moon´s test due to differences in variance between the periods. We explored the relationship between the length-of-stay and each individual background characteristic using scatterplots and simple linear regression. Finally, we calculated the adjusted length-of-stay for each one-year period by pooling these predictors into a multivariable regression. The secondary outcome measure was the proportion of patients who left without being seen by a physician, which we analyzed with the chi squared test. The statistical significance level was set at a two-tailed p-value of 0.05 for all outcomes.

Patient involvement

We did not involve patients in determining the research question and outcome measures, nor in the study design and implementation. Likewise, patients were not engaged in the interpretation and written documentation of the results. The research results may be disseminated to the study population and the relevant patient community through the local press.

Results

A total of 332 115 arrivals were registered during the three one-year periods, as illustrated in the flow diagram in Figure 1. The 146 302 arrivals on weekends, holidays, and during night shifts from 9 pm to 8 am where the interventions were not implemented were excluded. We also excluded seven arrivals on weekdays 8 am through 9 pm because of inconsistencies in registry entries. This meant that a total of 185 806 arrivals were included. We present the population characteristics for each period in Table 1a, along with mean values of in-hospital bed occupancy rate and staffing for each period. The in-hospital bed occupancy rate increased significantly during the study period, with mean occupancy rates of 92.6%, 94.3% and 97.8% for the respective periods.

Table 1a General characteristics of the study population per one-year period of three different triage processes.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3 Interprofessional teamwork**		
Time period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Triage protocol	RETTS			None			None		
	n			**n**			**n**		
All arrivals	110 526			110 128			111 461		
Arrivals weekdays 8am-9pm	61 387	55.5%	p=0.406	61 364	55.7%	*p<0.001*	63 055	56.6%	*p<0.001*
Female gender	31 933	52.0%	p=0.341	31 706	51.7%	p=0.354	32 413	51.4%	*p=0.030*
Mean age (y)	55.3y	SD 21.8	*p=0.019*	55.6y	SD 21.8	*p=0.009*	56.0y	SD 21.5	*p<0.001*

Arrival mode:									
Ambulance no alert	14 587	23.8%	p=0.775	14 538	23.7%	p=0.156	15 156	24.0%	p=0.260
Prehospital ambulance alert	2 952	4.8%	*p=0.017*	3 133	5.1%	p=0.662	3 184	5.0%	p=0.051
In-beds on weekdays at 6 am:									
Mean available beds	423			433			408		
Mean bed occupancy	391	92.6%	*p<0.001*	408	94.3%	*p<0.001*	398	97.8%	*p<0.001*
Staffing weekdays 8am-9pm:									
Physician hours	249.0			270.8			313.0		
Nurse hours incl. assistants	509.8			508.7			553.6		

Three different departments were responsible for the budgets and schedules of the physicians, which caused staffing discrepancies. The number of working hours for physicians and nurses increased significantly during the study period in one of the two ED corridors, where patients with internal medicine and cardiology complaints were treated by physicians from these departments. On the other hand, the total number of working hours for physicians and nurses remained approximately constant in the second corridor and the fast track See & Treat, where patients were treated by physicians belonging to the ED. Within each period of the study, schedules remained constant, except for one minor increase of physician hours within the nurse-led triage period and of nursing hours within the physician-led triage period. In Table 1a, the average daily staffing is shown for each period.

In order to obtain an accurate comparison between the different triage processes, where the amount of resources available is kept as constant as possible, we consider patients dispositioned from the ED sections with approximately constant total working hours as a subpopulation in Table 1b. A total of 93 029 arrivals were dispositioned from these sections, which corresponds to 50.1% of the entire study population.

Table 1b General characteristics of the subpopulation with approximately constant staffing resources for the different triage processes.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Time period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Triage protocol	RETTS			None			None		
	n			**n**			**n**		
All arrivals	57 987			56 250			52 380		
Arrivals weekdays 8am-9pm	32 191	55.5%	p=0.249	31 600	56.2%	p=0.243	29 238	55.8%	p=0.307
Female gender	16 375	50.9%	p=0.213	15 917	50.4%	p=0.161	14 438	49.4%	*p=0.015*
Mean age (y)	51.5y	SD 21.9	*p=0.001*	52.1y	SD 22.1	p=0.753	52.2y	SD 22.0	*p<0.001*
Arrival mode:									
Ambulance no alert	5 778	17.9%	p=0.187	5 800	18.4%	*p<0.001*	5 954	20.4%	*p<0.001*

Prehospital ambulance alert	1 002	3.1%	p=0.322	940	3.0%	*p=0.004*	757	2.6%	*p<0.001*
In-beds weekdays at 6 am:									
Mean available beds	180			179			172		
Medan bed occupancy	161	89.5%	*p<0.001*	164	92.0%	*p<0.001*	163	94.8%	*p<0.001*
Staffing weekdays 8am-9pm:									
Physician hours	132.5			143.8			141.5		
Nurse hours incl. assistants	262.3			261.6			260.9		

For this subpopulation, the median length-of-stay was shortest for the teamwork period, 228 min compared to 232 min for nurse-led triage and 250 min for physician-led triage. The median time to physician was shortest for physician-led triage, 56 min compared to 74 min for teamwork and 116 min for nurse-led triage. The 95% confidence intervals and p-values are listed in Table 2a, which shows that all differences between periods were significant with two-tailed p-values <0.01. Table 2a also shows that the differences in outcome measures were similar both for discharged and admitted patients. The length-of-stay distribution for each study period is shown in Figure 3 and the distribution of the time to physician in Figure 4. Both distributions are heavily skewed. The asymmetry of the length-of-stay distribution increased from period to period, with a skewness of 1.35 for nurse-led triage, 1.46 for physician-led triage, and 1.55 for teamwork.

Table 2a Outcome measures and patient dispositions of the subpopulation with approximately constant staffing resources for the three triage periods.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	232	230.8 - 233.9	*p<0.001*	250	248.5 - 252.6	*p<0.001*	228	226.4 - 230.5	*p=0.006*
Discharged home	212			229			200		
Admitted	293			302			288		
Median time to physician									
Overall	116	114.4 - 117.5	*p<0.001*	56	54.5 - 56.6	*p<0.001*	74	72.7 - 74.8	*p<0.001*
Discharged home	125			61			76		
Admitted	86			43			69		
Patient disposition:	**n**	**%**		**n**	**%**		**n**	**%**	
Left without being seen	597	1.9%	*p<0.001*	368	1.2%	*p<0.001*	933	3.2%	*p<0.001*
Discharged home	22 875	71.1%	*p<0.001*	21 888	69.3%	*p<0.001*	19 126	65.4%	*p<0.001*
Admitted	7 337	22.8%	*p=0.001*	7 548	23.9%	*p<0.001*	7 406	25.3%	*p=0.001*
Admitted to satellite beds	115	0.4%	P=0.111	139	0.4%	*p<0.001*	197	0.7%	*p<0.001*
Transferred to other	883	2.7%	*p=0.013*	972	3.1%	*p=0.010*	1 009	3.5%	*p<0.001*

hospitals									
Other dispositions	384	0.6%	p=0.150	685	0.7%	*p<0.001*	567	1.2%	*p<0.001*

Insert Figure 3 & 4 here

For the entire study population, the outcome measures were similar to those of the subpopulation, see Table 2b. The median length-of-stay was shortest for the teamwork period in this case as well, 223 min compared to 226 min for nurse-led triage and 239 min for physician-led triage. The median time to physician was shortest for physician-led triage, 54 min compared to 66 min for teamwork and 98 min for nurse-led triage. The 95% confidence intervals and p-values are also given in Table 2b, which shows that all differences between periods were significant with two-tailed p-values <0.001.

Table 2b Outcome measures and patient dispositions for the entire study population.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	226	224.5 - 227.6	*p<0.001*	239	236.9 - 240.0	*p<0.001*	223	221.9 - 224.0	*p<0.001*
Discharged home	210			223			198		
Admitted	253			267			263		
Median time to physician									
Overall	98	97.4 - 99.5	*p<0.001*	54	53.7 - 54.8	*p<0.001*	66	65.0-67.1	*p<0.001*
Discharged home	114			60			70		
Admitted	73			42			56		
Patient disposition:	**n**	**%**		**n**	**%**		**n**	**%**	
Left without being seen	1 594	2.6%	*p<0.001*	1 366	2.2%	*p<0.001*	2 321	3.7%	*p<0.001*
Discharged home	36 953	60.2%	*p=0.001*	36 370	59.3%	p=0.904	37 350	59.2%	*p=0.001*
Admitted	19 338	31.5%	p=0.319	19 494	31.8%	*p<0.001*	19 273	30.6%	*p<0.001*
Admitted to satellite beds	190	0.3%	*p<0.001*	286	0.5%	*p<0.001*	439	0.7%	*p<0.001*
Transferred to other hospitals	2 171	3.5%	p=0.737	2 193	3.6%	p=0.052	2 385	3.8%	*p=0.022*
Other dispositions	1 141	1.3%	p=0.763	1 655	1.2%	p=0.149	1 287	1.3%	p=0.265

After pooling data from all three periods of the subpopulation, we explored each population characteristic as a predictor of the length-of-stay using simple linear regression analysis. The resulting estimates indicate a length-of-stay which is 86 min longer for patients over 74 years, 27 min longer for female patients, 108 min longer for ambulance patients and 38 min shorter for ambulance patients arriving with prehospital alert. We have chosen these arrival modes as

more reliable indicators of patient severity, since triage severity was registered in different ways in the different intervention periods. The length-of-stay estimate increased by 0.6 min with each unit increase in daily arrival volume. The observed increase of the inpatient bed occupancy rate from 89.5% for nurse-led triage to 94.8% for teamwork was estimated to increase the length-of-stay by 10 min, while it decreased by 0.32 min by each hour of increased staffing. Finally, we pooled all these explored predictors in a multivariable regression analysis and found that the adjusted length-of-stay estimate for teamwork was 13.3 min shorter than for nurse-led triage and 24.6 min shorter than for physician-led triage. We have listed the estimates with standard errors and p-values from the simple and multivariable regression analyzes in Table 3a. We also conducted regression analyzes of the entire population and present the results in Table 3b.

Table 3a Regression analysis of the subpopulation: predictors of length-of-stay explored individually by linear regression and pooled in multivariable regression.

	Simple regression			Multivariable regression		
	Estimate	**Std error**	**p-value**	**Estimate**	**Std error**	**p-value**
Age (Per year)	1.73	0.03	*p<0.001*	1.19	0.02	*p<0.001*
Gender female (Yes/No)	26.70	1.07	*p<0.001*	17.93	1.03	*p<0.001*
Arrival mode:						
Ambulance without alert (Yes/No)	108.38	1.33	*p<0.001*	84.20	1.40	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-37.85	3.19	*p<0.001*	-29.01	3.09	*p<0.001*
Daily in-bed occupancy at 6 am (0 - 1)	208.23	10.26	*p<0.001*	220.67	10.76	*p<0.001*
Daily total arrival volume	0.61	0.02	*p<0.001*	0.68	0.02	*p<0.001*
Daily total staffing hours 8 am – 9 pm	0.35	0.05	*p<0.001*	-0.32	0.05	*p<0.001*
Difference compared to teamwork period:						
Nurse-led triage period (Yes/No)				13.25	1.45	*p<0.001*
Physician-led triage period (Yes/No)				24.56	1.34	*p<0.001*

Table 3b Regression analysis of the entire study population: predictors of length-of-stay explored individually by linear regression and pooled in multivariable regression.

	Simple regression			Multivariable regression		
	Estimate	**Std error**	**p-value**	**Estimate**	**Std error**	**p-value**
Age (Per year)	1.42	0.02	*p<0.001*	1.12	0.02	*p<0.001*
Gender female (Yes/No)	19.90	0.78	*p<0.001*	14.72	0.75	*p<0.001*
Arrival mode:						
Ambulance without alert (Yes/No)	79.92	0.89	*p<0.001*	58.25	0.94	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-68.02	1.78	*p<0.001*	-64.38	1.77	*p<0.001*
Daily occupancy rate at 6 am (0 - 1)	217.42	7.39	*p<0.001*	230.29	7.87	*p<0.001*
Daily total arrival volume	0.60	0.01	*p<0.001*	0.62	0.01	*p<0.001*

Daily total staffing hours 8 am – 9 pm	0.04	0.01	*p<0.001*	-0.02	0.03	p=0.572
Difference compared to teamwork period:						
Nurse-led triage period (Yes/No)				10.19	3.78	*p=0.007*
Physician-led triage period (Yes/No)				19.36	3.09	*p<0.001*

In the subpopulation studied, the proportion of patients who left without being seen by a physician was smallest for physician-led triage, 1.2% compared to 1.9% for nurse-led triage and 3.2% for teamwork (Table 2a). The corresponding rate of the entire study population was also lowest for physician-led triage and highest for teamwork period (Table 2b). All differences were of statistical significance.

Discussion

This study evaluated the impacts on patient flow of interprofessional teamwork compared to nurse-led and senior physician-led triage in terms of ED waiting times. The main finding was the shortest median length-of-stay observed for the teamwork period. Another main finding was the longest length-of-stay observed for physician-led triage, despite the shortest time to physician for this period.

Interprofessional teamwork is based on the following principles, which we believe contribute to the increased efficiency found in this study: reducing the number of patients each staff member is responsible for, reducing the number of staff members encountered by the patient, deciding appropriate treatment plans from the start, and carrying out the plans immediately. For this to happen, work shifts started and ended at the same time, and roles and responsibilities were clearly defined for all members in a module. Each module had its own fully equipped rooms and team area, thus creating smaller subsets within the large ED in order to enhance interprofessional teamwork. This may be particularly relevant to large EDs, since a correlation has been found between longer length-of-stay and increasing annual ED volumes.[37 38] Welch et al[37] suggested reducing the volume of a large ED by creating smaller subsets or clinical microsystems as an approach to improve the efficiency. Improvement in communication and patient safety,[29 31] staff[39] and patient satisfaction[28 30] are documented effects of interprofessional teamwork. The present study shows that teamwork can also improve ED lead times. To the best of our knowledge, only one previous study has reported a small but significant reduction of the length-of-stay in the case of physician-nurse teamwork.[33]

One may note that a smaller proportion of patients in the subpopulation studied were discharged home during the teamwork period, 65.4% compared to 71.1% for nurse-led triage and 69.3% for physician-led triage. This may be due to the fast track See & Treat having been replaced by two modules for ambulant patients, one in each ED corridor. Internal medicine complaints previously treated at See & Treat were transferred to modules in the other corridor. The median length-of-stay was shorter for patients discharged home than those admitted for all periods, 88 min shorter for teamwork, 73 min for physician-led triage and 20 min for nurse-led triage (Table 2b). This observed shift towards more serious complaints could be interpreted as providing further support for a higher efficiency of the teamwork process. Another observation supporting this view was the increasing skewness of the length-of-stay distribution from period to period, which implies an increasing proportion of patients with a short length-of-stay in the presence of a smaller number of patients with increasing

length-of-stay. This may have been caused by the increasing inpatient bed occupancy from period to period.

When senior physicians replaced nurses in triage in the first intervention, the median time to physician decreased by 60 min. In a meta-analysis, Abdulwahid et al.[25] estimated a reduction by 26 min from two randomized controlled trials (RCTs) [40 41] and 15 min from nine non-RCTs. Our first intervention increased the median length-of-stay by 18 minutes, in contrast to the estimated reduction by 29 min of the meta-analysis. Four of the publications included in the meta-analysis appear to report different follow-up lengths of an identical intervention in the same ED,[19 42-44] which may overestimate the effect size. Most studies reporting reduced length-of-stay introduced additional physicians in the triage interventions[16 17 19], while in the first intervention of this study the senior physicians were reassigned to the triage. This may explain the increased length-of-stay in our study. However, Choi et al. reduced the waiting time and processing time by reassigning a senior physician to the triage process.[18] To our knowledge, two studies found no significant changes in length-of-stay,[45 46] while one study has reported a significant 15 min increase along with an 11% increase of orders for diagnostic radiology.[47] For patients dispositioned by a second physician at the main ED after senior physician assessment at triage, Traub et al found a 25 min longer length-of-stay.[20] Although Choi et al found significant reductions of the time to physician and length-of-stay, they also described "stressful, pressurized and risky" working conditions for the senior physician in triage.[18]. When Burström et al compared three EDs with different triage processes, they found the shortest length-of-stay for senior physician-led triage.[48] However, this ED also applied interprofessional teamwork. The senior physician at triage planned the patients´ ED stay and communicated the plan to teams consisting of a junior physician and a nurse who worked in parallel. At the other two EDs, physicians and nurses worked separately and sequentially.

The smallest proportion of patients who left without being seen by a physician was observed for physician-led triage, which is in line with the significant decrease reported by previous studies of physicians at triage.[16 44] We observed the highest rate for the teamwork period, despite a 46 min shorter time to physician compared to nurse-led triage. Although this rate is often used as an indicator of crowding, patients who leave without being seen by a physician has been shown to be at a lower risk of death or admission within seven days compared to patients who were seen by physicians and discharged home.[49] These authors found no association between EDs with high annual left without being seen rate and risk of death or admission. Nonetheless, the higher rate for the teamwork process calls for further exploration and should be addressed.

Strengths and limitations

The main strength of this study is the large population which enables the evaluation of the process rather than the performance of individual doctors or nurses. Another strength is the control and study periods of one year each, which compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation. We were only able to identify one other study of a similar population size and length of time.[19] Furthermore, analyzes of multiple interventions and studies comparing several triage processes are rare.

This study has several limitations. First, this is a single-center study in one large, busy urban ED and the results may not be generalizable to other ED settings. EDs differ from each other in aspects of input, throughput and output.[50] In addition, before-and-after studies may not claim a causality between the intervention and the outcomes, although we have chosen the periods with no other simultaneous process changes. We did not include patients who arrived

during night shifts or on weekends and holidays, since the interventions did not include these work shifts. However, we analyzed outcome measures for all patients arriving before 9 pm, including those treated by the night shift. The second intervention was a deeper redesign of the entire ED to enable a new approach to the triage process. Finally, a limitation shared by previous studies is the use of lead times as surrogate outcome measures for ED quality and patient safety. However, the outcome measures we chose have been shown to be indicators of patient outcome[49 51 52] and patient satisfaction.[53 54]

Future studies of interprofessional teamwork in EDs with a multi-center design are of value to confirm our findings, as well as studies with cost-effectiveness evaluations.

Conclusion

The median length-of-stay was shortest for interprofessional teamwork in modules. It was longest for physician-led triage, despite the shortest time to physician of all studied periods. Interprofessional teamwork in modules may be an interesting approach to improve timeliness in large busy EDs. Therefore, we will also study teamwork behaviour to understand whether further improvements in patient flow can be obtained.

Figure legends:
Figure 1 Timeline of the interventions and the study flow diagram.
Figure 2 Interprofessional teamwork in a module – team members, work space, and patient flow.
Figure 3 Length-of-stay distribution per triage period of the subpopulation
Figure 4 Time to physician distribution per triage period of the subpopulation

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Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation except Stockholm County Council for the submitted work; no financial relationships with any organization except Stockholm County Council that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethics: The study was approved by the Regional Ethical Review Board of Stockholm, ref. no. 2016/109-31/5. Informed consent was not obtained since all patients were assessed and treated according the process implemented during that period.

Data sharing: Full dataset and statistical codes are available from the corresponding author. Patient consent was not obtained but the presented data are anonymized and risk of identification is low.

Transparency declaration
The present manuscript is an honest, accurate and transparent account of the study being reported. No important aspects of the study have been omitted and any discrepancies from the study as planned have been explained.

All authors had full access to all the data in the study, including statistical reports and tables, and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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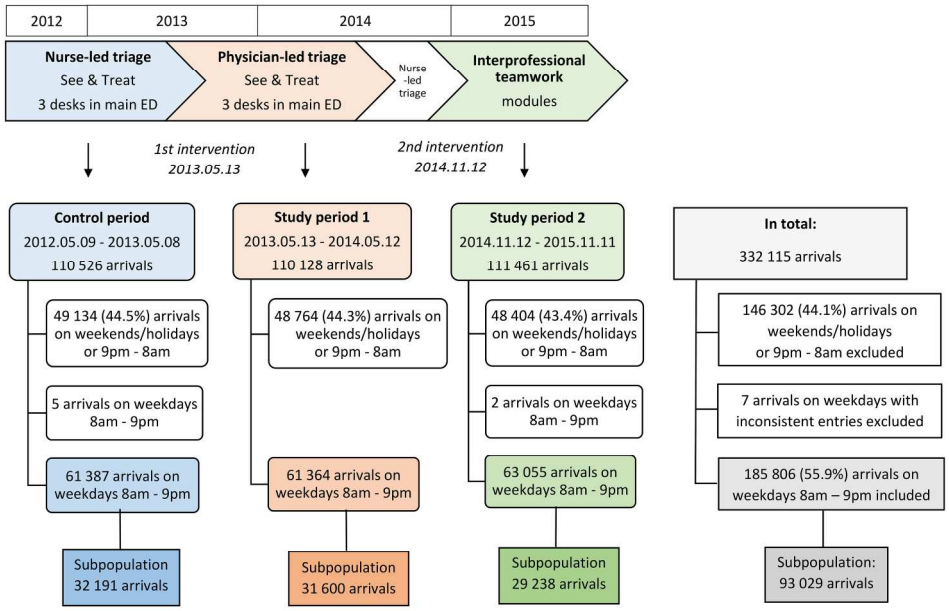

Figure 1 Timeline of the interventions and the study flow diagram.

107x72mm (600 x 600 DPI)

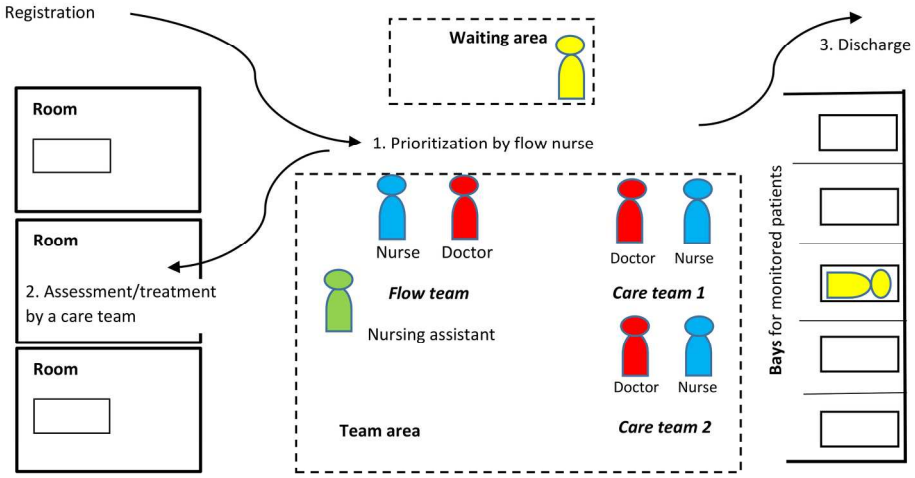

Figure 2 Interprofessional teamwork in a module - team members, work space, and patient flow.

95x56mm (600 x 600 DPI)

Figure 3 Length-of-stay distribution per triage period of the subpopulation

106x70mm (600 x 600 DPI)

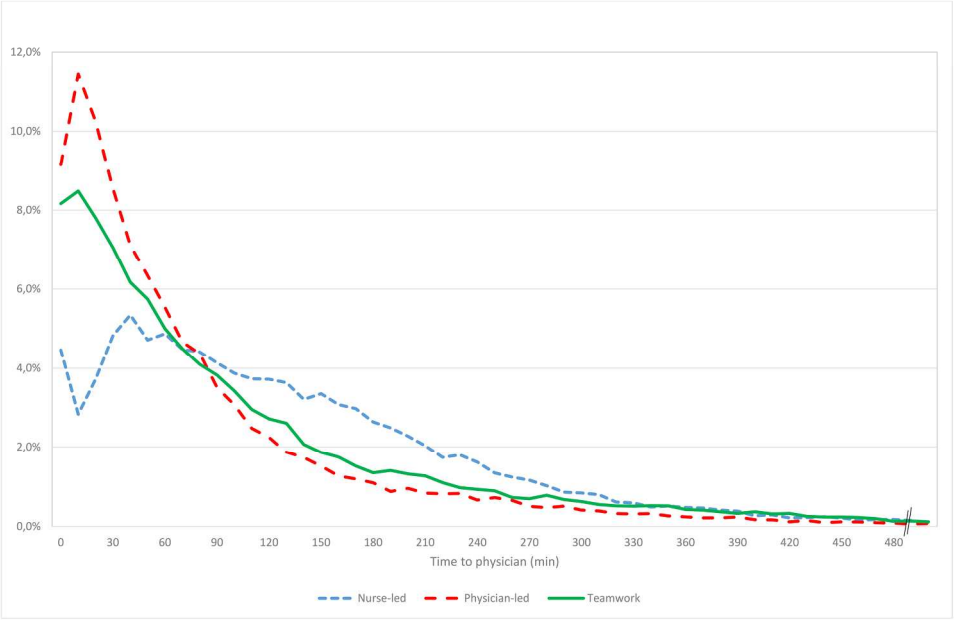

Figure 4 Time to physician distribution per triage period of the subpopulation

108x72mm (600 x 600 DPI)

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	1, 3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
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	4-6
		(*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	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	6-7
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	7
		(*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	NA
		(*e*) Describe any sensitivity analyses	NA

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	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Tab.1a Tab.1b
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
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	9-11, Tab.3a Tab.3b
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
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	14

*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.

BMJ Open

Can interprofessional teamwork reduce patient throughput times? A longitudinal single-centre study of three different triage processes at a Swedish emergency department

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Can interprofessional teamwork reduce patient throughput times? A longitudinal single-centre study of three different triage processes at a Swedish emergency department

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Abstract

Objective – Impacts on emergency department (ED) throughput times and proportion of patients who leave without being seen by a physician (LWBS) of two triage interventions, where protocol-based comprehensive nurse-led triage was first replaced by senior physician-led triage and then by interprofessional teamwork.

Design - A single-centre before-and-after study.

Setting – Adult ED of a Swedish urban hospital.

Participants – Patients arriving on weekdays 8 am - 9 pm during three one-year periods in the interval May 2012 to Nov 2015. A total of 185 806 arrivals were included.

Interventions - From May 2013 to May 2014, senior physicians replaced the triage nurses. From Nov 2014 to Nov 2015, interprofessional teamwork replaced the triage process on weekdays 8 am - 9 pm.

Main outcome measures – Primary outcomes were the median time to physician (TTP) and the median length-of-stay (LOS). Secondary outcome was the LWBS rate.

Results – The crude median LOS was shortest for teamwork, 228 min (95% CI 226.4 to 230.5) compared to 232 min (95% CI 230.8 to 233.9) for nurse-led and 250 min (95% CI 248.5 to 252.6) for physician-led triage. The adjusted LOS for the teamwork period was 16 min shorter than for nurse-led triage and 23 min shorter than for physician-led triage. The median TTP was shortest for physician-led triage, 56 min (95% CI 54.5 to 56.6) compared to 116 min (95% CI 114.4 to 117.5) for nurse-led triage and 74 min (95% CI 72.7 to 74.8) for teamwork. The LWBS rate was 1.9% for nurse-led triage, 1.2% for physician-led triage and 3.2% for teamwork. All differences in outcome measures had two-tailed p-values <0.01.

Conclusions – Interprofessional teamwork had the shortest LOS, a shorter TTP than nurse-led triage, but a higher LWBS rate. Interprofessional teamwork may be a useful approach to reducing ED throughput times.

Strengths and limitations of this study

- + Two interventions are analysed and three triage processes compared in the same ED.
- + The large study population allows an accurate comparison of the triage processes.
- + The control and study periods of one year each compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation.
- − The results from a large urban ED may not be generalizable to other ED settings.
- − The-before-and-after design may not claim a causality between the interventions and the outcomes, although no other changes took place during the study period.

Introduction

Emergency department (ED) crowding is a growing problem worldwide.[1-5] Patients risk suffering prolonged pain, inconvenience and poor outcomes due to delays in emergency care.[2 6-8] ED crowding can also lead to dissatisfaction among staff and a high rate of turnover as well as increased aggression and violence from frustrated patients.[9-11] Many external factors can contribute to ED crowding, such as an increasing patient volume, increased complexity and acuity of patients' diseases, and a lack of beds for patients admitted from the ED into the hospital's other wards or departments.[1 2 6]

In the 1950s, triage of patients became a key strategy to handle the crowding problem.[12] The objective of an ED triage process is to quickly sort patients according to their priority of care. A quick triage check is typically performed by a nurse and consists of a simple visual assessment of the patient's medical urgency. More comprehensive triage systems, also typically carried out by a nurse, involve taking vital signs and patient history before the priority of care is determined.[13] In nurse-led triage, the protocol may also allow nurses to order laboratory tests and radiographs.[12] Comprehensive nurse-led triage using different standardized acuity protocols has been widely implemented since the 1990s. However, the evidence of its reliability and validity is scarce.[12 14 15]

During the last two decades, some EDs have introduced physicians in the triage process to improve throughput and patient flow. These interventions have been reported to result in a reduced waiting time to physician assessment, fewer patients leaving the ED without being seen by a physician, and a shorter length-of-stay.[16-20] However, several systematic reviews, including meta-analyses, have concluded that the evidence is not robust due to a large degree of variation in the study design and quality, intervention type and outcome measures.[21-25]

Interprofessional teamwork, where health workers with different professional backgrounds work together to deliver the highest quality of care,[26] is an alternative approach to improving patient flow. We describe an intervention where the triage process is replaced by the patient being assessed and treated directly by an interprofessional team. Teamwork has been shown to improve patient safety in health care, though the unpredictability of the ED context poses special demands on effective team functioning and requires formal training.[27] Studies of teamwork and interprofessional training have reported improvements in the quality of care, patient satisfaction and work environment,[28-32] but few studies report its impact on ED throughput times.[33]

The aim of this study is to evaluate the impact on patient flow of three different triage processes: comprehensive nurse-led triage, senior physician-led triage and triage replaced by interprofessional teamwork. We examine the patient flow in terms of ED throughput times. The research question is: Can the patients' throughput times at the ED be reduced by implementing interprofessional teamwork?

Material and methods

The study design was a single-centre before-and-after study. We conducted the study from May 2012 to Nov 2015 at the adult ED at Södersjukhuset, a 600-bed urban public teaching

hospital in central Stockholm, Sweden. With 110 000 annual visits, this ED is one of the largest in Scandinavia. The study material included all arrivals on weekdays from 8 am to 9 pm. We excluded patient arrivals between 9 pm to 8 am, since none of the study interventions were adopted for the night shifts. Arrivals on weekends and holidays were also excluded, since the teamwork intervention was only implemented on weekdays. Each intervention was studied during a one-year period after its implementation, with a one-year period prior to the first intervention serving as the control period (Figure 1). We also excluded visits to our pediatric and gynecology EDs because of differences in location and work processes.

Insert Figure 1 here

Nurse-led triage

During the control period from 2012.05.09 to 2013.05.08 a comprehensive nurse-led triage process was in use. The triage teams consisted of a registered nurse and a nursing assistant who applied the Rapid Emergency Triage and Treatment System (RETTS) protocol[34 35] developed in Sweden. The RETTS protocol combines the vital signs and patient history to prioritize the patients in five emergency processes according to medical urgency. For most patients, the triage nurses sent blood samples for standardized laboratory work-up. A total of eight triage team shifts were scheduled daily from 8 am to 9 pm, corresponding to 58 hours each of registered nurses and nursing assistants. During peak hours from 10 am to 6 pm, an additional registered nurse triaged the ambulance patients. A physician was available on demand by the triage nurses.

After registration, ambulant patients with minor injuries and symptoms were sent to a fast track section, See & Treat, while other patients were directed to the triage section unless they needed immediate care. After completing a comprehensive triage, the patient was sent to one of three desks: internal medicine, cardiology, or the emergency medicine desk for surgery and orthopedic complaints. At the desk, nursing assistants placed the patient in a room to wait for a doctor. The next available doctor assessed the patient on his or her own and left written orders for the nurses. The patient then had to wait for the next available nurse to carry out the orders, while the doctor either proceeded with documentation in a back office or took on another patient. Rooms were often occupied by patients waiting for the next step in the process. Since the work shifts started at different hours for the different professions, each doctor worked with several nurses and each nurse with several doctors during a shift.

Physician-led triage

During the first intervention from 2013.05.13 to 2014.05.12, three senior physician shifts were reassigned from each of the three desks from 8 am to 9 pm, corresponding to a total of 63 hours per day. The senior physicians formed intake teams in the triage area together with nine nursing assistant shifts, 64 hours, and two registered nurse shifts, 14 hours. Two of three cardiology intake teams included a registered nurse instead of nursing assistant, while the intake doctor of emergency medicine alternated between two rooms each staffed by a nursing assistant. Intake teams were instructed to assess all patients arriving at the ED, except those with prehospital alerts. The intake team could either discharge the patient after a brief assessment, or initiate radiology and laboratory work up and request an in-hospital bed before moving the patient to one of the three desks. The work processes at the three desks and the See & Treat were the same as described for the nurse-led triage period.

Interprofessional teamwork in modules

During the second intervention from 2014.11.12 to 2015.11.11, interprofessional teamwork in modules was introduced on weekdays from 8 am to 9 pm. The ED facilities, including the triage area and the See & Treat, were converted into nine modules, each equipped with 2 or 3 rooms for assessment and treatment, several bays for monitored patients, and one team area. Doctors moved from the back offices so that each doctor was placed next to a nurse in the team area. A module was staffed by a flow team and two care teams. Each team consisted of a doctor and a nurse with the most senior doctor and nurse forming the flow team. An additional nursing assistant in each module helped all three teams, except in the two modules replacing See & Treat (see Figure 2). The entire staff within a module started and ended the work shift together. Four parallel modules were in operation from 8 am to 9 pm, with five additional modules added during peak hours from 10 am to 6 pm. Patients with orthopedic and surgery complaints were streamed into separate modules, although these modules had flexibility to treat patients with other complaints when needed.

After registration, a new patient was directed to the appropriate module, where the flow nurse prioritized and re-evaluated the queuing patients with support from the flow doctor. The responsibility was transferred from the flow nurse when a care team started the assessment. The doctor and nurse in the care team collaborated to carry out the patient interview, physical examination, radiology and laboratory orders, and treatment in immediate sequence. The flow doctor supported the care teams in deciding on correct care plans for the patients.

Insert Figure 2 here

The interventions were the results of improvement efforts made by interprofessional and multidisciplinary groups of physicians, nurses and nursing assistants. Many Plan-Do-Study-Act cycles[36] were carried out before the implementation of the interventions.

Potential sources of bias

We collected staffing data for each period from the work schedules for physicians and nursing staff. The scheduled working hours during weekdays from 8 am to 9 pm were summed into a daily total number of hours. The ED was organized in two separate corridors. In the first corridor, physicians belonging to the departments of internal medicine and cardiology were responsible for their respective patient categories. In the second corridor, physicians belonging to the ED were responsible for all other patients in the main ED and the fast track See & Treat. Three different departments were thus responsible for the physician budgets and schedules, which caused staffing discrepancies. The number of working hours for physicians and nurses increased significantly in the first corridor during the study period, while it remained approximately constant in the second corridor and the See & Treat.

We collected registry data of available in-hospital beds and the number of admitted patients per ward weekdays at 6 am from Belaggning.qvw, a Qlikview® (QlikTech International, Radnor, Pennsylvania, USA) application used for bed occupancy reports to healthcare authorities. The daily bed occupancy rate for the wards receiving patients admitted from the adult ED was calculated as the ratio between the number of admitted patients and the available number of beds. From May 2012 to Nov 2015 no other process change than the studied interventions took place.

Statistics

Electronic registry data of all visits to the adult ED during the study period was extracted from the ED tracking system Akusys, after replacing patient identification numbers by unique codes. We imported the data obtained from Akusys, Belaggning.qvw and work schedules into R (The R Foundation for Statistical Computing, Vienna) for statistical analysis. We used descriptive statistics to summarize the general characteristics for each period and analysed differences between the periods using the chi squared test for proportions and the Mann-Whitney-Wilcoxon test for mean values.

The primary outcome measures were the total ED length-of-stay and the waiting time to be seen by a physician, measured from the registration time on arrival. The distributions of these variables are heavily skewed with short times for most patients, and a smaller number of very long times resulting from patients waiting for transportation or in-hospital beds. Therefore, we used the median of the time to physician and length-of-stay to compare the periods. We obtained 95% confidence intervals by bootstrap simulation and calculated p-values using Mood´s test due to differences in variance between the periods. We explored the relationship between the length-of-stay and each individual background characteristic using scatterplots and simple linear regression. Finally, we calculated the adjusted length-of-stay for each one-year period by pooling these predictors into a multivariable regression. The secondary outcome measure was the proportion of patients who left without being seen by a physician, which we analysed with the chi squared test. The statistical significance level was set at a two-tailed p-value of 0.05 for all outcomes.

Patient involvement

We did not involve patients in determining the research question and outcome measures, nor in the study design and implementation. Likewise, patients were not engaged in the interpretation and written documentation of the results. The research results may be disseminated to the study population and the relevant patient community through the local press.

Results

A total of 332 115 arrivals were registered during the three one-year periods, as illustrated in the flow diagram in Figure 1. The 146 302 arrivals on weekends, holidays, and during night shifts from 9 pm to 8 am where the interventions were not implemented were excluded. We also excluded seven arrivals on weekdays 8 am through 9 pm because of inconsistencies in registry entries. This meant that a total of 185 806 arrivals were included. We present the population characteristics for each period in Table 1a, along with mean values of in-hospital bed occupancy rate and staffing for each period. The in-hospital bed occupancy rate increased significantly during the study period, with mean occupancy rates of 92.6%, 94.3% and 97.8% for the respective periods.

Table 1a General characteristics of the study population per one-year period of three different triage processes.

Triage process	**1.Nurse-led triage**		**2.Physician-led triage**		**3.Interprofessional teamwork**	
Time period	2012.05.09 - 2013.05.08	**Period 1 vs 2**	2013.05.13 - 2014.05.12	**Period 2 vs 3**	2014.11.12 - 2015.11.11	**Period 3 vs 1**

Triage protocol	RETTS			None			None		
	n			**n**			**n**		
All arrivals	110 526			110 128			111 461		
Arrivals weekdays 8am-9pm	61 387	55.5%	p=0.406	61 364	55.7%	*p<0.001*	63 055	56.6%	*p<0.001*
Female gender	31 933	52.0%	p=0.341	31 706	51.7%	p=0.354	32 413	51.4%	*p=0.030*
Mean age (y)	55.3y	SD 21.8	*p=0.019*	55.6y	SD 21.8	*p=0.009*	56.0y	SD 21.5	*p<0.001*
Arrival mode:									
Ambulance no alert	14 587	23.8%	p=0.775	14 538	23.7%	p=0.156	15 156	24.0%	p=0.260
Prehospital ambulance alert	2 952	4.8%	*p=0.017*	3 133	5.1%	p=0.662	3 184	5.0%	p=0.051
In-beds on weekdays at 6 am:									
Mean available beds	423			433			408		
Mean bed occupancy	391	92.6%	*p<0.001*	408	94.3%	*p<0.001*	398	97.8%	*p<0.001*
Staffing weekdays 8am-9pm:									
Physician hours	249.0			270.8			313.0		
Nurse hours incl. assistants	509.8			508.7			553.6		

To obtain an accurate comparison between the different triage processes, where the amount of resources available was kept as constant as possible, we also consider patients dispositioned from the emergency medicine corridor and the See & Treat as a subgroup (Table 1b). In this subgroup, the total staffing per week varied over the three-year period in an interval of -1.5% to +1.1% compared to a three-year average. Nurse staffing was constant to within 0.4% of the average, while physician staffing varied in an interval of -4.8% to +3.3% around the average. A total of 93 029 arrivals were dispositioned from these sections, which corresponds to 50.1% of the entire study population.

Table 1b General characteristics of the subgroup with approximately constant staffing resources for the different triage processes.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Time period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Triage protocol	RETTS			None			None		
	n			**n**			**n**		
All arrivals	57 987			56 250			52 380		
Arrivals weekdays 8am-9pm	32 191	55.5%	p=0.249	31 600	56.2%	p=0.243	29 238	55.8%	p=0.307
Female gender	16 375	50.9%	p=0.213	15 917	50.4%	p=0.161	14 438	49.4%	*p=0.015*
Mean age (y)	51.5y	SD	*p=0.001*	52.1y	SD	p=0.753	52.2y	SD	*p<0.001*

		21.9			22.1			22.0	
Arrival mode:									
Ambulance no alert	5 778	17.9%	p=0.187	5 800	18.4%	*p<0.001*	5 954	20.4%	*p<0.001*
Prehospital ambulance alert	1 002	3.1%	p=0.322	940	3.0%	*p=0.004*	757	2.6%	*p<0.001*
In-beds weekdays at 6 am:									
Mean available beds	180			179			172		
Medan bed occupancy	161	89.5%	*p<0.001*	164	92.0%	*p<0.001*	163	94.8%	*p<0.001*
Staffing weekdays 8am-9pm:									
Physician hours	132.5			143.8			141.5		
Nurse hours incl. assistants	262.3			261.6			260.9		

For the entire study population, the median length-of-stay was shortest for the teamwork period, 223 min compared to 226 min for nurse-led triage and 239 min for physician-led triage. The median time to physician was shortest for physician-led triage, 54 min compared to 66 min for teamwork and 98 min for nurse-led triage. The 95% confidence intervals and p-values are given in Table 2a, which shows that all differences between periods were significant with two-tailed p-values <0.001.

Table 2a Outcome measures and patient dispositions for the entire study population.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	226	224.5 - 227.6	*p<0.001*	239	236.9 - 240.0	*p<0.001*	223	221.9 - 224.0	*p<0.001*
Discharged home	210	208 - 211	*p<0.001*	223	221 - 224	*p<0.001*	198	197 - 200	*p<0.001*
Admitted	253	250 - 255	*p<0.001*	267	264 - 270	*p=0.044*	263	261 - 266	*p<0.001*
Median time to physician									
Overall	98	97.4 - 99.5	*p<0.001*	54	53.7 - 54.8	*p<0.001*	66	65.0 - 67.1	*p<0.001*
Discharged home	114	113 - 115	*p<0.001*	60	59 - 60	*p<0.001*	70	69 - 71	*p<0.001*
Admitted	73	72 - 74	*p<0.001*	42	41 - 43	*p<0.001*	56	54 - 57	*p<0.001*
Patient disposition:	**n**	**%**		**n**	**%**		**n**	**%**	
Left without being seen	1 594	2.6%	*p<0.001*	1 366	2.2%	*p<0.001*	2 321	3.7%	*p<0.001*
Discharged home	36 953	60.2%	*p=0.001*	36 370	59.3%	p=0.904	37 350	59.2%	*p=0.001*
Admitted	19 338	31.5%	p=0.319	19 494	31.8%	*p<0.001*	19 273	30.6%	*p<0.001*
Admitted to satellite beds	190	0.3%	*p<0.001*	286	0.5%	*p<0.001*	439	0.7%	*p<0.001*
Transferred to other hospitals	2 171	3.5%	p=0.737	2 193	3.6%	p=0.052	2 385	3.8%	*p=0.022*

Other dispositions	1 141	1.3%	p=0.763	1 655	1.2%	p=0.149	1 287	1.3%	p=0.265

For the subgroup, the median length-of-stay was shortest for the teamwork period, 228 min compared to 232 min for nurse-led triage and 250 min for physician-led triage. The median time to physician was shortest for physician-led triage, 56 min compared to 74 min for teamwork and 116 min for nurse-led triage. The 95% confidence intervals and p-values are listed in Table 2b, which shows that all differences between periods were significant with two-tailed p-values <0.01. Table 2b also shows that the differences in outcome measures were similar both for discharged and admitted patients. The length-of-stay distribution for each study period is shown in Figure 3 and the distribution of the time to physician in Figure 4. Both distributions are heavily skewed. The asymmetry of the length-of-stay distribution increased from period to period, with a skewness of 1.35 for nurse-led triage, 1.46 for physician-led triage, and 1.55 for teamwork.

Table 2b Outcome measures and patient dispositions of the subgroup with approximately constant staffing resources for the three triage periods.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	232	230.8 - 233.9	*p<0.001*	250	248.5 - 252.6	*p<0.001*	228	226.4 - 230.5	*p=0.006*
Discharged home	212	210 - 214	*p<0.001*	229	226 - 232	*p<0.001*	200	197 - 203	*p<0.001*
Admitted	293	288 - 298	*p<0.002*	302	298 - 306	*p<0.001*	288	284 - 292	p=0.166
Median time to physician									
Overall	116	114.4 - 117.5	*p<0.001*	56	54.5 - 56.6	*p<0.001*	74	72.7 - 74.8	*p<0.001*
Discharged home	125	124 - 127	*p<0.001*	61	60 - 62	*p<0.001*	76	75 - 78	*p<0.001*
Admitted	86	84 - 88	*p<0.001*	43	42 - 44	*p<0.001*	69	67 - 71	*p<0.001*
Patient disposition:	**n**	**%**		**n**	**%**		**n**	**%**	
Left without being seen	597	1.9%	*p<0.001*	368	1.2%	*p<0.001*	933	3.2%	*p<0.001*
Discharged home	22 875	71.1%	*p<0.001*	21 888	69.3%	*p<0.001*	19 126	65.4%	*p<0.001*
Admitted	7 337	22.8%	*p=0.001*	7 548	23.9%	*p<0.001*	7 406	25.3%	*p=0.001*
Admitted to satellite beds	115	0.4%	P=0.111	139	0.4%	*p<0.001*	197	0.7%	*p<0.001*
Transferred to other hospitals	883	2.7%	*p=0.013*	972	3.1%	*p=0.010*	1 009	3.5%	*p<0.001*
Other dispositions	384	0.6%	p=0.150	685	0.7%	*p<0.001*	567	1.2%	*p<0.001*

Insert Figure 3 & 4 here

After pooling data from all three periods, we explored each population characteristic as a predictor of the length-of-stay using simple linear regression analysis. The resulting estimate indicates a length-of-stay which is 64 min longer for patients over 74 years, 20 min longer for female patients, 80 min longer for ambulance patients and 68 min shorter for ambulance patients arriving with prehospital alert. We have chosen these arrival modes as more reliable indicators of patient severity, since triage severity was registered in different ways in the different intervention periods. The length-of-stay estimate increased by 0.6 min with each unit increase in daily arrival volume. The observed increase of the inpatient bed occupancy rate from 92.6% for nurse-led triage to 97.8% for teamwork was estimated to increase the length-of-stay by 11 min. Finally, we pooled all these explored predictors in a multivariable regression analysis and found that the adjusted length-of-stay estimate for teamwork was 12 min shorter than for nurse-led triage and 21 min shorter than for physician-led triage. We have listed the estimates with standard errors and p-values from the simple and multivariable regression analyses in Table 3a.

Table 3a Regression analysis of the entire study population: predictors of length-of-stay explored individually by linear regression and pooled in multivariable regression.

	Simple regression			Multivariable regression		
	Estimate	**Std error**	**p-value**	**Estimate**	**Std error**	**p-value**
Age (Per year)	1.42	0.02	*p<0.001*	1.12	0.02	*p<0.001*
Gender female (Yes/No)	19.90	0.78	*p<0.001*	14.69	0.75	*p<0.001*
Arrival mode:						
Ambulance without alert (Yes/No)	79.92	0.89	*p<0.001*	58.25	0.94	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-68.02	1.78	*p<0.001*	-64.34	1.77	*p<0.001*
Daily occupancy rate at 6 am (0 - 1)	217.42	7.39	*p<0.001*	233.44	7.87	*p<0.001*
Daily total arrival volume	0.60	0.01	*p<0.001*	0.69	0.01	*p<0.001*
Difference compared to teamwork period:						
Nurse-led triage period (Yes/No)				12.07	1.01	*P<0.001*
Physician-led triage period (Yes/No)				20.91	0.96	*p<0.001*

We also conducted regression analyses of the subgroup and present the estimates in Table 3b, including standard errors and p-values. In the final multivariable regression analysis, we found that the adjusted length-of-stay estimate for teamwork was 16 min shorter than for nurse-led triage and 23 min shorter than for physician-led triage.

Table 3b Regression analysis of the subgroup: predictors of length-of-stay explored individually by linear regression and pooled in multivariable regression.

	Simple regression			Multivariable regression		
	Estimate	**Std error**	**p-value**	**Estimate**	**Std error**	**p-value**
Age (Per year)	1.73	0.03	*p<0.001*	1.19	0.02	*p<0.001*
Gender female (Yes/No)	26.70	1.07	*p<0.001*	17.84	1.03	*p<0.001*
Arrival mode:						

Ambulance without alert (Yes/No)	108.38	1.33	*p<0.001*	84.26	1.40	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-37.85	3.19	*p<0.001*	-28.65	3.09	*p<0.001*
Daily in-bed occupancy at 6 am (0 - 1)	208.23	10.26	*p<0.001*	224.44	10.76	*p<0.001*
Daily total arrival volume	0.61	0.02	*p<0.001*	0.70	0.02	*p<0.001*
Difference compared to teamwork period:						
Nurse-led triage period (Yes/No)				15.56	1.39	*p<0.001*
Physician-led triage period (Yes/No)				23.46	1.33	*p<0.001*

In the subgroup, the proportion of patients who left without being seen by a physician was smallest for physician-led triage, 1.2% compared to 1.9% for nurse-led triage and 3.2% for teamwork (Table 2b). The corresponding rate of the entire study population was also lowest for physician-led triage and highest for teamwork period (Table 2a). All differences were of statistical significance.

Discussion

This study evaluated the impacts on patient flow of three different triage processes in terms of ED throughput times: nurse-led triage, senior physician-led triage, and interprofessional teamwork. The main finding was the shortest median length-of-stay observed for the teamwork period. Another main finding was the longest length-of-stay observed for physician-led triage, despite the shortest time to physician for this period.

In the multivariable regression analysis, staffing was not included as an independent variable. This is due to the structure of the staffing data, where schedules were constant in the teamwork period, and only a single minor adjustment was made in each of the other periods. This results in a very high degree of correlation between the staffing and triage period variables, which causes a collinearity problem when including both variables in the regression.[37] The restriction to a subgroup of approximately constant resources was introduced to provide a more accurate comparison of working processes in this situation.

Interprofessional teamwork is based on the following principles, which we believe contribute to the increased efficiency found in this study: reducing the number of patients each staff member is responsible for, reducing the number of staff members encountered by the patient, deciding appropriate treatment plans from the start, and carrying out the plans immediately. For this to happen, work shifts started and ended at the same time, and roles and responsibilities were clearly defined for all members in a module. Each module had its own fully equipped rooms and team area, thus creating smaller subsets within the large ED to enhance interprofessional teamwork. This may be particularly relevant to large EDs, since a correlation has been found between longer length-of-stay and increasing annual ED volumes.[38 39] Welch et al[38] suggested reducing the volume of a large ED by creating smaller subsets or clinical microsystems as an approach to improve the efficiency. Improvement in communication and patient safety,[29 31] staff[40] and patient satisfaction[28 30] are documented effects of interprofessional teamwork. The present study shows that teamwork can also improve ED throughput times. To the best of our knowledge, only one previous study has reported a small but significant reduction of the length-of-stay in the case of physician-nurse teamwork.[33]

One may note that a smaller proportion of patients in the subpopulation studied were discharged home during the teamwork period, 65.4% compared to 71.1% for nurse-led triage and 69.3% for physician-led triage. This may be due to the fast track See & Treat having been replaced by two modules for ambulant patients, one in each ED corridor. Internal medicine complaints previously treated at See & Treat were transferred to modules in the other corridor. The median length-of-stay was shorter for patients discharged home than those admitted for all periods, 88 min shorter for teamwork, 73 min for physician-led triage and 81 min for nurse-led triage (Table 2b). This observed shift towards more serious complaints could be interpreted as providing further support for a higher efficiency of the teamwork process. Another observation supporting this view was the increasing skewness of the length-of-stay distribution from period to period, which implies an increasing proportion of patients with a short length-of-stay in the presence of a smaller number of patients with increasing length-of-stay. This may have been caused by the increasing inpatient bed occupancy from period to period.

When senior physicians replaced nurses in triage in the first intervention, the median time to physician decreased by 60 min. In a meta-analysis, Abdulwahid et al.[25] estimated a reduction by 26 min from two randomized controlled trials (RCTs) [41 42] and 15 min from nine non-RCTs. Our first intervention increased the median length-of-stay by 18 minutes, in contrast to the estimated reduction by 29 min of the meta-analysis. Four of the publications included in the meta-analysis appear to report different follow-up lengths of an identical intervention in the same ED,[19 43-45] which may overestimate the effect size. Most studies reporting reduced length-of-stay introduced additional physicians in the triage interventions[16 17 19], while in the first intervention of this study the senior physicians were reassigned to the triage. This may explain the increased length-of-stay in our study. However, Choi et al. reduced the waiting time and processing time by reassigning a senior physician to the triage process.[18] To our knowledge, two studies found no significant changes in length-of-stay,[46 47] while one study has reported a significant 15 min increase along with an 11% increase of orders for diagnostic radiology.[48] For patients dispositioned by a second physician at the main ED after senior physician assessment at triage, Traub et al found a 25 min longer length-of-stay.[20] Although Choi et al found significant reductions of the time to physician and length-of-stay, they also described "stressful, pressurized and risky" working conditions for the senior physician in triage.[18]. When Burström et al compared three EDs with different triage processes, they found the shortest length-of-stay for senior physician-led triage.[49] However, this ED also applied interprofessional teamwork. The senior physician at triage planned the patients´ ED stay and communicated the plan to teams consisting of a junior physician and a nurse who worked in parallel. At the other two EDs, physicians and nurses worked separately and sequentially.

The smallest proportion of patients who left without being seen by a physician was observed for physician-led triage, which is in line with the significant decrease reported by previous studies of physicians at triage.[16 45] We observed the highest rate for the teamwork period, despite a 46 min shorter time to physician compared to nurse-led triage. Although this rate is often used as an indicator of crowding, patients who leave without being seen by a physician has been shown to be at a lower risk of death or admission within seven days compared to patients who were seen by physicians and discharged home.[50] These authors found no association between EDs with high annual left without being seen rate and risk of death or admission. Nonetheless, the higher rate for the teamwork process calls for further exploration and should be addressed.

Strengths and limitations

The main strength of this study is the large population which enables the evaluation of the process rather than the performance of individual doctors or nurses. Another strength is the control and study periods of one year each, which compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation. We were only able to identify one other study of a similar population size and length of time.[19] Furthermore, analyses of multiple interventions and studies comparing several triage processes are rare.

This study has several limitations. First, this is a single-centre study in one large, busy urban ED and the results may not be generalizable to other ED settings. EDs differ from each other in aspects of input, throughput and output.[51] In addition, before-and-after studies may not claim a causality between the intervention and the outcomes, although we have chosen the periods with no other simultaneous process changes. We did not include patients who arrived during night shifts or on weekends and holidays, since the interventions did not include these work shifts. However, we analysed outcome measures for all patients arriving before 9 pm, including those treated by the night shift. The second intervention was a deeper redesign of the entire ED to enable a new approach to the triage process. Finally, a limitation shared by previous studies is the use of throughput times as surrogate outcome measures for ED quality and patient safety. However, the outcome measures we chose have been shown to be indicators of patient outcome[50 52 53] and patient satisfaction.[54 55]

Future studies of interprofessional teamwork in EDs with a multi-centre design are of value to confirm our findings, as well as studies with cost-effectiveness evaluations.

Conclusion

The median length-of-stay was shortest for interprofessional teamwork in modules. It was longest for physician-led triage, despite the shortest time to physician of all studied periods. Interprofessional teamwork in modules may be an interesting approach to improve timeliness in large busy EDs. Therefore, we will also study teamwork behavior to understand whether further improvements in patient flow can be obtained.

Figure legends:
Figure 1 Timeline of the interventions and the study flow diagram.
Figure 2 Interprofessional teamwork in a module – team members, work space, and patient flow.
Figure 3 Length-of-stay distribution per triage period of the subpopulation
Figure 4 Time to physician distribution per triage period of the subpopulation

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Contributors: Jenny Liu (JL), Italo Masiello (IM), Sari Ponzer (SP), and Nasim Farrokhnia (NF) participated in the initiation and development of the study design. JL performed the literature search with inputs from IM, SP, and NF. JL collected and analyzed the data and wrote the initial draft. IM, SP, and NF participated in critical revisions and have approved the final manuscript. The corresponding author and guarantor is JL.

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Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation except Stockholm County Council for the submitted work; no financial relationships with any organization except Stockholm County Council that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethics: The study was approved by the Regional Ethical Review Board of Stockholm, ref. no. 2016/109-31/5. Informed consent was not obtained since all patients were assessed and treated according the process implemented during that period.

Data sharing: Full dataset and statistical codes are available from the corresponding author. Patient consent was not obtained but the presented data are anonymized and risk of identification is low.

Transparency declaration
The present manuscript is an honest, accurate and transparent account of the study being reported. No important aspects of the study have been omitted and any discrepancies from the study as planned have been explained.

All authors had full access to all the data in the study, including statistical reports and tables, and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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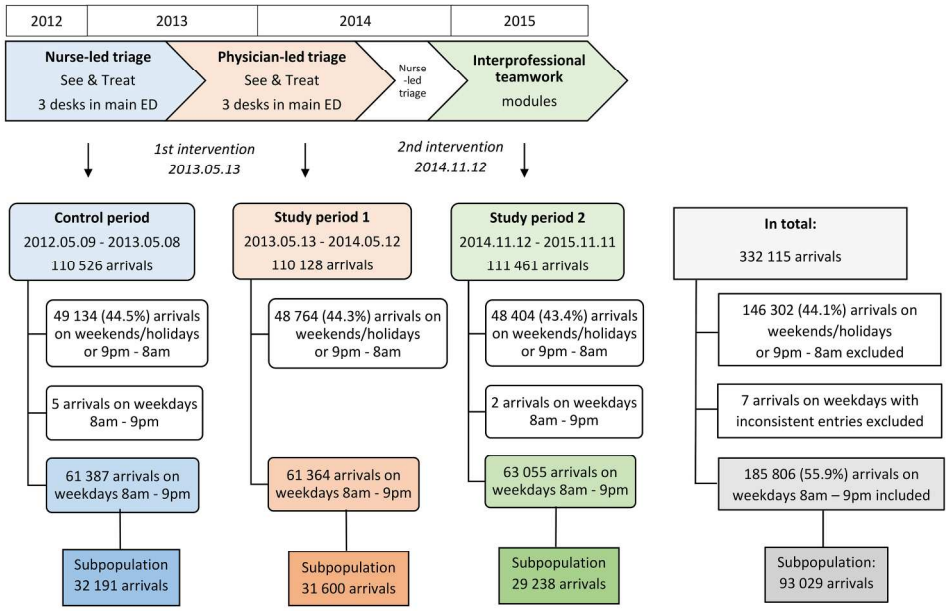

Figure 1 Timeline of the interventions and the study flow diagram.

107x72mm (600 x 600 DPI)

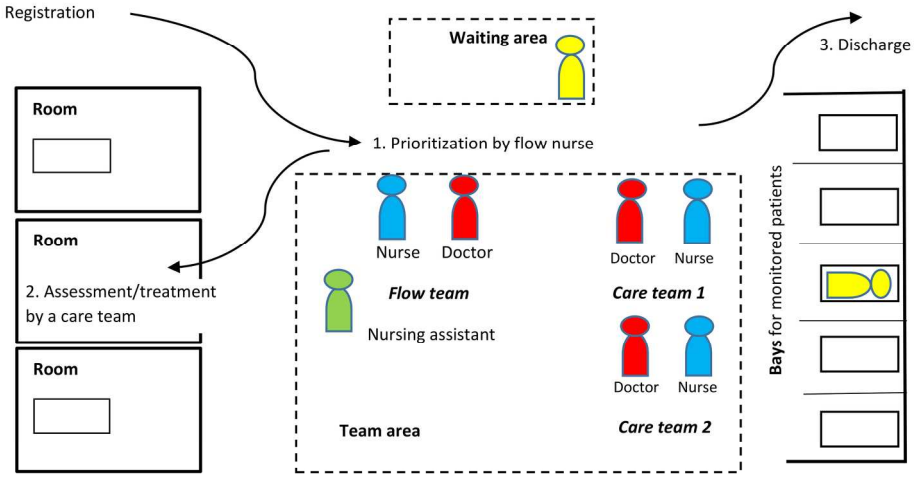

Figure 2 Interprofessional teamwork in a module - team members, work space, and patient flow.

95x56mm (600 x 600 DPI)

Figure 3 Length-of-stay distribution per triage period of the subpopulation

106x70mm (600 x 600 DPI)

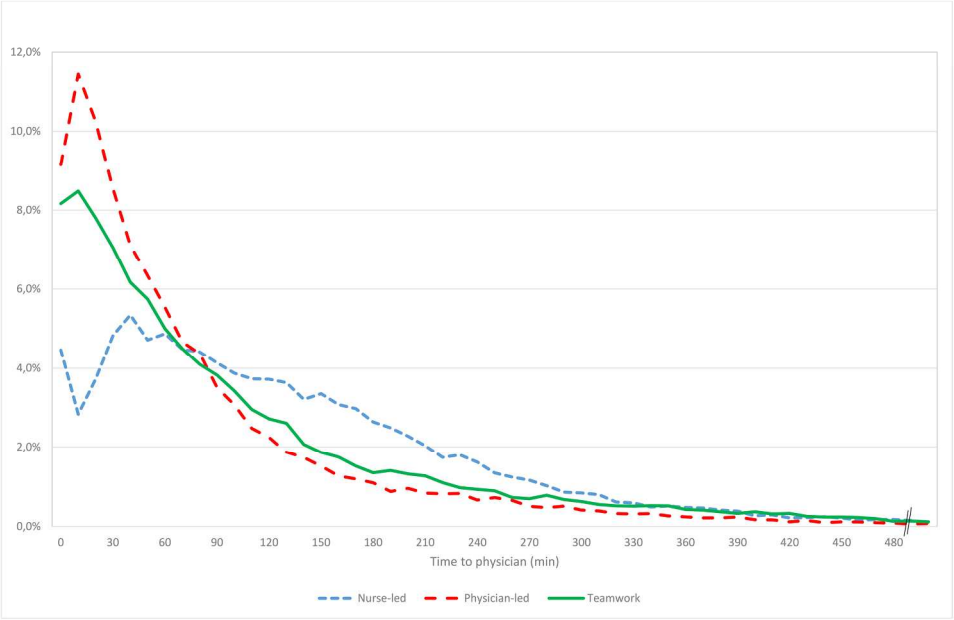

Figure 4 Time to physician distribution per triage period of the subpopulation

108x72mm (600 x 600 DPI)

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	1, 3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
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	4-6
		(*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	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	6-7
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	7
		(*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	NA
		(*e*) Describe any sensitivity analyses	NA

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	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Tab.1a Tab.1b
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
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	9-12, Tab.3a Tab.3b
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
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	14

*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.

BMJ Open

Can interprofessional teamwork reduce patient throughput times? A longitudinal single-centre study of three different triage processes at a Swedish emergency department

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Can interprofessional teamwork reduce patient throughput times? A longitudinal single-centre study of three different triage processes at a Swedish emergency department

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Abstract

Objective – To determine the impact on emergency department (ED) throughput times and proportion of patients who leave without being seen by a physician (LWBS) of two triage interventions, where comprehensive nurse-led triage was first replaced by senior physician-led triage and then by interprofessional teamwork.

Design - Single-centre before-and-after study.

Setting – Adult ED of a Swedish urban hospital.

Participants – Patients arriving on weekdays 8 am - 9 pm during three one-year periods in the interval May 2012 to Nov 2015. A total of 185 806 arrivals were included.

Interventions - Senior physicians replaced triage nurses May 2013 to May 2014. Interprofessional teamwork replaced the triage process on weekdays 8 am - 9 pm Nov 2014 to Nov 2015.

Main outcome measures – Primary outcomes were the median time to physician (TTP) and the median length-of-stay (LOS). Secondary outcome was the LWBS rate.

Results – The crude median LOS was shortest for teamwork, 228 min (95% CI 226.4 to 230.5) compared to 232 min (95% CI 230.8 to 233.9) for nurse-led and 250 min (95% CI 248.5 to 252.6) for physician-led triage. The adjusted LOS for the teamwork period was 16 min shorter than for nurse-led triage and 23 min shorter than for physician-led triage. The median TTP was shortest for physician-led triage, 56 min (95% CI 54.5 to 56.6) compared to 116 min (95% CI 114.4 to 117.5) for nurse-led triage and 74 min (95% CI 72.7 to 74.8) for teamwork. The LWBS rate was 1.9% for nurse-led triage, 1.2% for physician-led triage and 3.2% for teamwork. All outcome measure differences had two-tailed p-values <0.01.

Conclusions – Interprofessional teamwork had the shortest LOS, a shorter TTP than nurse-led triage, but a higher LWBS rate. Interprofessional teamwork may be a useful approach to reducing ED throughput times.

Strengths and limitations of this study

- \+ Two interventions are analysed and three triage processes compared in the same ED.
- \+ The large study population allows an accurate comparison of the triage processes.
- \+ The control and study periods of one year each compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation.
- − The results from a large urban ED may not be generalizable to other ED settings.
- − The-before-and-after design may not claim a causality between the interventions and the outcomes, although no other changes took place during the study period.

Introduction

Emergency department (ED) crowding is a growing problem worldwide.[1-5] Patients risk suffering prolonged pain, inconvenience and poor outcomes due to delays in emergency care.[2 6-8] ED crowding can also lead to dissatisfaction among staff and a high rate of turnover as well as increased aggression and violence from frustrated patients.[9-11] Many external factors can contribute to ED crowding, such as an increasing patient volume, increased complexity and acuity of patients' diseases, and a lack of beds for patients admitted from the ED into the hospital's other wards or departments.[1 2 6]

In the 1950s, triage of patients became a key strategy to handle the crowding problem.[12] The objective of an ED triage process is to quickly sort patients according to their priority of care. A quick triage check is typically performed by a nurse and consists of a simple visual assessment of the patient's medical urgency. More comprehensive triage systems, also typically carried out by a nurse, involve taking vital signs and patient history before the priority of care is determined.[13] In nurse-led triage, the protocol may also allow nurses to order laboratory tests and radiographs.[12] Comprehensive nurse-led triage using different standardized acuity protocols has been widely implemented since the 1990s. However, the evidence of its reliability and validity is scarce.[12 14 15]

During the last two decades, some EDs have introduced physicians in the triage process to improve throughput and patient flow. These interventions have been reported to result in a reduced waiting time to physician assessment, fewer patients leaving the ED without being seen by a physician, and a shorter length-of-stay.[16-20] However, several systematic reviews, including meta-analyses, have concluded that the evidence is not robust due to a large degree of variation in the study design and quality, intervention type and outcome measures.[21-25]

Interprofessional teamwork, where health workers with different professional backgrounds work together with the goal of delivering the highest quality of care,[26] is an alternative approach to improving patient flow. Teamwork has been shown to improve patient safety in health care, though the unpredictability of the ED context poses special demands on effective team functioning and requires formal training.[27] Studies of teamwork and interprofessional training have reported improvements in the quality of care, patient satisfaction and work environment,[28-32] but few studies report its impact on ED throughput times.[33]

We describe two interventions. During the first intervention, senior physicians replaced senior nurses in the triage process. During the second intervention, the triage process was replaced by the patient being assessed and treated directly by an interprofessional team.

The aim of this study is to evaluate the impact on patient flow of three different triage processes: comprehensive nurse-led triage, senior physician-led triage and triage replaced by interprofessional teamwork. We examine patient flow in terms of ED throughput times. The research question is: Can the patients' throughput times at the ED be reduced by implementing interprofessional teamwork?

Material and methods

The study design was a single-centre before-and-after study. We conducted the study from May 2012 to Nov 2015 at the adult ED at Södersjukhuset, a 600-bed urban public teaching hospital in central Stockholm, Sweden. With 110 000 annual visits, this ED is one of the largest in Scandinavia. The study material included all arrivals on weekdays from 8 am to 9 pm. We excluded patient arrivals between 9 pm to 8 am, since none of the study interventions were adopted for the night shifts. Arrivals on weekends and holidays were also excluded, since the teamwork intervention was only implemented on weekdays. Each intervention was studied during a one-year period after its implementation, with a one-year period prior to the first intervention serving as the control period (Figure 1). We also excluded visits to our pediatric and gynecology EDs because of differences in location and work processes.

Insert Figure 1 here

Nurse-led triage

During the control period from 2012.05.09 to 2013.05.08 a comprehensive nurse-led triage process was in use. The triage teams consisted of a registered nurse and a nursing assistant who applied the Rapid Emergency Triage and Treatment System (RETTS) protocol[34 35] developed in Sweden. The RETTS protocol combines the vital signs and patient history to prioritize the patients in five emergency processes according to medical urgency. For most patients, the triage nurses sent blood samples for standardized laboratory work-up. A total of eight triage team shifts were scheduled daily from 8 am to 9 pm, corresponding to 58 hours each of registered nurses and nursing assistants. During peak hours from 10 am to 6 pm, an additional registered nurse triaged the ambulance patients. A physician was available on demand by the triage nurses.

After registration, ambulant patients with minor injuries and symptoms were sent to a fast track section, See & Treat, while other patients were directed to the triage section unless they needed immediate care. After completing a comprehensive triage, the patient was sent to one of three desks: internal medicine, cardiology, or the emergency medicine desk for surgery and orthopedic complaints. At the desk, nursing assistants placed the patient in a room to wait for a doctor. The next available doctor assessed the patient on his or her own and left written orders for the nurses. The patient then had to wait for the next available nurse to carry out the orders, while the doctor either proceeded with documentation in a back office or took on another patient. Rooms were often occupied by patients waiting for the next step in the process. Since the work shifts started at different hours for the different professions, each doctor worked with several nurses and each nurse with several doctors during a shift.

Physician-led triage

During the first intervention from 2013.05.13 to 2014.05.12, three senior physician shifts were reassigned from each of the three desks from 8 am to 9 pm, corresponding to a total of 63 hours per day. The senior physicians formed intake teams in the triage area together with nine nursing assistant shifts, 64 hours, and two registered nurse shifts, 14 hours. Two of three cardiology intake teams included a registered nurse instead of nursing assistant, while the intake doctor of emergency medicine alternated between two rooms each staffed by a nursing assistant. Intake teams were instructed to assess all patients arriving at the ED, except those with prehospital alerts. The intake team could either discharge the patient after a brief assessment, or initiate radiology and laboratory work up and request an in-hospital bed before moving the patient to one of the three desks. The work processes at the three desks and the See & Treat were the same as described for the nurse-led triage period.

Interprofessional teamwork in modules

During the second intervention from 2014.11.12 to 2015.11.11, interprofessional teamwork in modules was introduced on weekdays from 8 am to 9 pm. The ED facilities, including the triage area and the See & Treat, were converted into nine modules, each equipped with 2 or 3 rooms for assessment and treatment, several bays for monitored patients, and one team area. Doctors moved from the back offices so that each doctor was placed next to a nurse in the team area. A module was staffed by a flow team and two care teams. Each team consisted of a doctor and a nurse with the most senior doctor and nurse forming the flow team. An additional nursing assistant in each module helped all three teams, except in the two modules replacing See & Treat (see Figure 2). The entire staff within a module started and ended the work shift together. Four parallel modules were in operation from 8 am to 9 pm, with five additional modules added during peak hours from 10 am to 6 pm. Patients with orthopedic and surgery complaints were streamed into separate modules, although these modules had flexibility to treat patients with other complaints when needed.

After registration, a new patient was directed to the appropriate module, where the flow nurse prioritized and re-evaluated the queuing patients with support from the flow doctor. The responsibility was transferred from the flow nurse when a care team started the assessment. The doctor and nurse in the care team collaborated to carry out the patient interview, physical examination, radiology and laboratory orders, and treatment in immediate sequence. The flow doctor supported the care teams in deciding on correct care plans for the patients.

Insert Figure 2 here

The interventions were the results of improvement efforts made by interprofessional and multidisciplinary groups of physicians, nurses and nursing assistants. Multiple Plan-Do-Study-Act cycles[36] were carried out before the implementation of the interventions.

Potential sources of bias

We collected staffing data for each period from the work schedules for physicians and nursing staff. The scheduled working hours during weekdays from 8 am to 9 pm were summed into a daily total number of hours. The ED was organized in two separate corridors. In the first corridor, physicians belonging to the departments of internal medicine and cardiology were responsible for their respective patient categories. In the second corridor, physicians belonging to the ED were responsible for all other patients in the main ED and the fast track See & Treat. Three different departments were thus responsible for the physician budgets and schedules, which caused staffing discrepancies. The number of working hours for physicians and nurses increased significantly in the first corridor during the study period, while it remained approximately constant in the second corridor and the See & Treat.

We collected registry data of available in-hospital beds and the number of admitted patients per ward weekdays at 6 am from Belaggning.qvw, a Qlikview® (QlikTech International, Radnor, Pennsylvania, USA) application used for bed occupancy reports to healthcare authorities. The daily bed occupancy rate for the wards receiving patients admitted from the adult ED was calculated as the ratio between the number of admitted patients and the available number of beds. From May 2012 to Nov 2015 no other process change than the studied interventions took place.

Statistics

Electronic registry data of all visits to the adult ED during the study period was extracted from the ED tracking system Akusys, after replacing patient identification numbers by unique codes. We imported the data obtained from Akusys, Belaggning.qvw and work schedules into R (The R Foundation for Statistical Computing, Vienna) for statistical analysis. We used descriptive statistics to summarize the general characteristics for each period and analysed differences between the periods using the chi squared test for proportions and the Mann-Whitney-Wilcoxon test for mean values.

The primary outcome measures were the total ED length-of-stay and the waiting time to be seen by a physician, measured from the registration time on arrival. The distributions of these variables are heavily skewed with short times for most patients, and a smaller number of very long times resulting from patients waiting for transportation or in-hospital beds. Therefore, we used the median of the time to physician and length-of-stay to compare the periods. We obtained 95% confidence intervals by bootstrap simulation and calculated p-values using Mood´s test due to differences in variance between the periods. We explored the relationship between the length-of-stay and each individual background characteristic using scatterplots and simple linear regression. Finally, we calculated the adjusted length-of-stay for each one-year period by pooling these predictors into a multivariable regression. The secondary outcome measure was the proportion of patients who left without being seen by a physician, which we analysed with the chi squared test. The statistical significance level was set at a two-tailed p-value of 0.05 for all outcomes.

Patient involvement

We did not involve patients in determining the research question and outcome measures, nor in the study design and implementation. Likewise, patients were not engaged in the interpretation and written documentation of the results. The research results may be disseminated to the study population and the relevant patient community through the local press.

Results

A total of 332 115 arrivals were registered during the three one-year periods, as illustrated in the flow diagram in Figure 1. The 146 302 arrivals on weekends, holidays, and during night shifts from 9 pm to 8 am where the interventions were not implemented were excluded. We also excluded seven arrivals on weekdays 8 am through 9 pm because of inconsistencies in registry entries. This meant that a total of 185 806 arrivals were included. We present the population characteristics for each period in Table 1a, along with mean values of in-hospital bed occupancy rate and staffing for each period. The in-hospital bed occupancy rate increased significantly during the study period, with mean occupancy rates of 92.6%, 94.3% and 97.8% for the respective periods.

Table 1a General characteristics of the study population per one-year period of three different triage processes.

Triage process	**1.Nurse-led triage**		**2.Physician-led triage**		**3.Interprofessional teamwork**	
Time period	2012.05.09 -	**Period**	2013.05.13 -	**Period**	2014.11.12 -	**Period**

	2013.05.08		1 vs 2	2014.05.12		2 vs 3	2015.11.11		3 vs 1
Triage protocol	RETTS			None			None		
	n			**n**			**n**		
All arrivals	110 526			110 128			111 461		
Arrivals weekdays 8am-9pm	61 387	55.5%	p=0.406	61 364	55.7%	*p<0.001*	63 055	56.6%	*p<0.001*
Female gender	31 933	52.0%	p=0.341	31 706	51.7%	p=0.354	32 413	51.4%	*p=0.030*
Mean age (y)	55.3y	SD 21.8	*p=0.019*	55.6y	SD 21.8	*p=0.009*	56.0y	SD 21.5	*p<0.001*
Arrival mode:									
Ambulance no alert	14 587	23.8%	p=0.775	14 538	23.7%	p=0.156	15 156	24.0%	p=0.260
Prehospital ambulance alert	2 952	4.8%	*p=0.017*	3 133	5.1%	p=0.662	3 184	5.0%	p=0.051
In-beds on weekdays at 6 am:									
Mean available beds	423			433			408		
Mean bed occupancy	391	92.6%	*p<0.001*	408	94.3%	*p<0.001*	398	97.8%	*p<0.001*
Staffing weekdays 8am-9pm:									
Physician hours	249.0			270.8			313.0		
Nurse hours incl. assistants	509.8			508.7			553.6		

To obtain an accurate comparison between the different triage processes, where the amount of resources available was kept as constant as possible, we also consider patients dispositioned from the emergency medicine corridor and the See & Treat as a subgroup (Table 1b). In this subgroup, the total staffing per week varied over the three-year period in an interval of -1.5% to +1.1% compared to a three-year average. Nurse staffing was constant to within 0.4% of the average, while physician staffing varied in an interval of -4.8% to +3.3% around the average. A total of 93 029 arrivals were dispositioned from these sections, which corresponds to 50.1% of the entire study population.

Table 1b General characteristics of the subgroup with approximately constant staffing resources for the different triage processes.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Time period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Triage protocol	RETTS			None			None		
	n			**n**			**n**		
All arrivals	57 987			56 250			52 380		
Arrivals weekdays 8am-9pm	32 191	55.5%	p=0.249	31 600	56.2%	p=0.243	29 238	55.8%	p=0.307
Female gender	16 375	50.9%	p=0.213	15 917	50.4%	p=0.161	14 438	49.4%	*p=0.015*

Mean age (y)	51.5y	SD 21.9	*p=0.001*	52.1y	SD 22.1	p=0.753	52.2y	SD 22.0	*p<0.001*
Arrival mode:									
Ambulance no alert	5 778	17.9%	p=0.187	5 800	18.4%	*p<0.001*	5 954	20.4%	*p<0.001*
Prehospital ambulance alert	1 002	3.1%	p=0.322	940	3.0%	*p=0.004*	757	2.6%	*p<0.001*
In-beds weekdays at 6 am:									
Mean available beds	180			179			172		
Medan bed occupancy	161	89.5%	*p<0.001*	164	92.0%	*p<0.001*	163	94.8%	*p<0.001*
Staffing weekdays 8am-9pm:									
Physician hours	132.5			143.8			141.5		
Nurse hours incl. assistants	262.3			261.6			260.9		

For the entire study population, the median length-of-stay was shortest for the teamwork period, 223 min compared to 226 min for nurse-led triage and 239 min for physician-led triage. The median time to physician was shortest for physician-led triage, 54 min compared to 66 min for teamwork and 98 min for nurse-led triage. The 95% confidence intervals and p-values are given in Table 2a, which shows that all differences between periods were significant with two-tailed p-values <0.001.

Table 2a Outcome measures and patient dispositions for the entire study population.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	226	224.5 - 227.6	*p<0.001*	239	236.9 - 240.0	*p<0.001*	223	221.9 - 224.0	*p<0.001*
Discharged home	210	208 - 211	*p<0.001*	223	221 - 224	*p<0.001*	198	197 - 200	*p<0.001*
Admitted	253	250 - 255	*p<0.001*	267	264 - 270	*p<0.044*	263	261 - 266	*p<0.001*
Median time to physician									
Overall	98	97.4 - 99.5	*p<0.001*	54	53.7 - 54.8	*p<0.001*	66	65.0 - 67.1	*p<0.001*
Discharged home	114	113 - 115	*p<0.001*	60	59 - 60	*p<0.001*	70	69 - 71	*p<0.001*
Admitted	73	72 - 74	*p<0.001*	42	41 - 43	*p<0.001*	56	54 - 57	*p<0.001*
Patient disposition:	**n**	**%**		**n**	**%**		**n**	**%**	
Left without being seen	1 594	2.6%	*p<0.001*	1 366	2.2%	*p<0.001*	2 321	3.7%	*p<0.001*
Discharged home	36 953	60.2%	*p=0.001*	36 370	59.3%	p=0.904	37 350	59.2%	*p=0.001*
Admitted	19 338	31.5%	p=0.319	19 494	31.8%	*p<0.001*	19 273	30.6%	*p<0.001*
Admitted to satellite beds	190	0.3%	*p<0.001*	286	0.5%	*p<0.001*	439	0.7%	*p<0.001*
Transferred to other	2 171	3.5%	p=0.737	2 193	3.6%	p=0.052	2 385	3.8%	*p=0.022*

hospitals									
Other dispositions	1 141	1.3%	p=0.763	1 655	1.2%	p=0.149	1 287	1.3%	p=0.265

For the subgroup, the median length-of-stay was shortest for the teamwork period, 228 min compared to 232 min for nurse-led triage and 250 min for physician-led triage. The median time to physician was shortest for physician-led triage, 56 min compared to 74 min for teamwork and 116 min for nurse-led triage. The 95% confidence intervals and p-values are listed in Table 2b, which shows that all differences between periods were significant with two-tailed p-values <0.01. Table 2b also shows that the differences in outcome measures were similar both for discharged and admitted patients. The length-of-stay distribution for each study period is shown in Figure 3 and the distribution of the time to physician in Figure 4. Both distributions are heavily skewed. The asymmetry of the length-of-stay distribution increased from period to period, with a skewness of 1.35 for nurse-led triage, 1.46 for physician-led triage, and 1.55 for teamwork.

Table 2b Outcome measures and patient dispositions of the subgroup with approximately constant staffing resources for the three triage periods.

Triage process	**1.Nurse-led triage**			**2.Physician-led triage**			**3.Interprofessional teamwork**		
Period	2012.05.09 - 2013.05.08		**Period 1 vs 2**	2013.05.13 - 2014.05.12		**Period 2 vs 3**	2014.11.12 - 2015.11.11		**Period 3 vs 1**
Median length-of-stay	**min**	**95% CI**		**min**	**95% CI**		**min**	**95% CI**	
Overall	232	230.8 - 233.9	*p<0.001*	250	248.5 - 252.6	*p<0.001*	228	226.4 - 230.5	*p=0.006*
Discharged home	212	210 - 214	*p<0.001*	229	226 - 232	*p<0.001*	200	197 - 203	*p<0.001*
Admitted	293	288 - 298	*p<0.002*	302	298 - 306	*p<0.001*	288	284 - 292	p=0.166
Median time to physician									
Overall	116	114.4 - 117.5	*p<0.001*	56	54.5 - 56.6	*p<0.001*	74	72.7 - 74.8	*p<0.001*
Discharged home	125	124 - 127	*p<0.001*	61	60 - 62	*p<0.001*	76	75 - 78	*p<0.001*
Admitted	86	84 - 88	*p<0.001*	43	42 - 44	*p<0.001*	69	67 - 71	*p<0.001*
Patient disposition:	**n**	**%**		**n**	**%**		**n**	**%**	
Left without being seen	597	1.9%	*p<0.001*	368	1.2%	*p<0.001*	933	3.2%	*p<0.001*
Discharged home	22 875	71.1%	*p<0.001*	21 888	69.3%	*p<0.001*	19 126	65.4%	*p<0.001*
Admitted	7 337	22.8%	*p=0.001*	7 548	23.9%	*p<0.001*	7 406	25.3%	*p=0.001*
Admitted to satellite beds	115	0.4%	P=0.111	139	0.4%	*p<0.001*	197	0.7%	*p<0.001*
Transferred to other hospitals	883	2.7%	*p=0.013*	972	3.1%	*p=0.010*	1 009	3.5%	*p<0.001*
Other dispositions	384	0.6%	p=0.150	685	0.7%	*p<0.001*	567	1.2%	*p<0.001*

Insert Figure 3 & 4 here

After pooling data from all three periods, we explored each population characteristic as a predictor of the length-of-stay using simple linear regression analysis. The resulting estimate indicates a length-of-stay which is 64 min longer for patients over 74 years, 20 min longer for female patients, 80 min longer for ambulance patients and 68 min shorter for ambulance patients arriving with prehospital alert. We have chosen these arrival modes as more reliable indicators of patient severity, since triage severity was registered in different ways in the different intervention periods. The length-of-stay estimate increased by 0.6 min with each unit increase in daily arrival volume. The observed increase of the inpatient bed occupancy rate from 92.6% for nurse-led triage to 97.8% for teamwork was estimated to increase the length-of-stay by 11 min. Finally, we pooled all these explored predictors in a multivariable regression analysis and found that the adjusted length-of-stay estimate for teamwork was 12 min shorter than for nurse-led triage and 21 min shorter than for physician-led triage. We have listed the estimates with standard errors and p-values from the simple and multivariable regression analyses in Table 3a.

Table 3a Regression analysis of the entire study population: predictors of length-of-stay explored individually by linear regression and pooled in multivariable regression.

	Simple regression			Multivariable regression		
	Estimate	**Std error**	**p-value**	**Estimate**	**Std error**	**p-value**
Age (Per year)	1.42	0.02	*p<0.001*	1.12	0.02	*p<0.001*
Gender female (Yes/No)	19.90	0.78	*p<0.001*	14.69	0.75	*p<0.001*
Arrival mode:						
Ambulance without alert (Yes/No)	79.92	0.89	*p<0.001*	58.25	0.94	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-68.02	1.78	*p<0.001*	-64.34	1.77	*p<0.001*
Daily occupancy rate at 6 am (0 - 1)	217.42	7.39	*p<0.001*	233.44	7.87	*p<0.001*
Daily total arrival volume	0.60	0.01	*p<0.001*	0.69	0.01	*p<0.001*
Difference compared to teamwork period:						
Nurse-led triage period (Yes/No)				12.07	1.01	*P<0.001*
Physician-led triage period (Yes/No)				20.91	0.96	*p<0.001*

We also conducted regression analyses of the subgroup and present the estimates in Table 3b, including standard errors and p-values. In the final multivariable regression analysis, we found that the adjusted length-of-stay estimate for teamwork was 16 min shorter than for nurse-led triage and 23 min shorter than for physician-led triage.

Table 3b Regression analysis of the subgroup: predictors of length-of-stay explored individually by linear regression and pooled in multivariable regression.

	Simple regression			Multivariable regression		
	Estimate	**Std error**	**p-value**	**Estimate**	**Std error**	**p-value**
Age (Per year)	1.73	0.03	*p<0.001*	1.19	0.02	*p<0.001*
Gender female (Yes/No)	26.70	1.07	*p<0.001*	17.84	1.03	*p<0.001*

Arrival mode:						
Ambulance without alert (Yes/No)	108.38	1.33	*p<0.001*	84.26	1.40	*p<0.001*
Ambulance with prehospital alert (Yes/No)	-37.85	3.19	*p<0.001*	-28.65	3.09	*p<0.001*
Daily in-bed occupancy at 6 am (0 - 1)	208.23	10.26	*p<0.001*	224.44	10.76	*p<0.001*
Daily total arrival volume	0.61	0.02	*p<0.001*	0.70	0.02	*p<0.001*
Difference compared to teamwork period:						
Nurse-led triage period (Yes/No)				15.56	1.39	*p<0.001*
Physician-led triage period (Yes/No)				23.46	1.33	*p<0.001*

In the subgroup, the proportion of patients who left without being seen by a physician was smallest for physician-led triage, 1.2% compared to 1.9% for nurse-led triage and 3.2% for teamwork (Table 2b). The corresponding rate of the entire study population was also lowest for physician-led triage and highest for teamwork period (Table 2a). All differences were of statistical significance.

Discussion

This study evaluated the impacts on patient flow of three different triage processes in terms of ED throughput times: nurse-led triage, senior physician-led triage, and interprofessional teamwork. The main finding was the shortest median length-of-stay observed for the teamwork period. Another main finding was the longest length-of-stay observed for physician-led triage, despite the shortest time to physician for this period.

In the multivariable regression analysis, staffing was not included as an independent variable. This is due to the structure of the staffing data, where schedules were constant in the teamwork period, and only a single minor adjustment was made in each of the other periods. This results in a very high degree of correlation between the staffing and triage period variables, which causes a collinearity problem when including both variables in the regression.[37] The restriction to a subgroup of approximately constant resources was introduced to provide a more accurate comparison of working processes in this situation.

Interprofessional teamwork is based on the following principles, which we believe contribute to the increased efficiency found in this study: reducing the number of patients each staff member is responsible for, reducing the number of staff members encountered by the patient, deciding appropriate treatment plans from the start, and carrying out the plans immediately. For this to happen, work shifts started and ended at the same time, and roles and responsibilities were clearly defined for all members in a module. Each module had its own fully equipped rooms and team area, thus creating smaller subsets within the large ED to enhance interprofessional teamwork. This may be particularly relevant to large EDs, since a correlation has been found between longer length-of-stay and increasing annual ED volumes.[38 39] Welch et al[38] suggested reducing the volume of a large ED by creating smaller subsets or clinical microsystems as an approach to improve the efficiency. Improvement in communication and patient safety,[29 31] staff[40] and patient satisfaction[28 30] are documented effects of interprofessional teamwork. The present study shows that teamwork can also improve ED throughput times. To the best of our knowledge, only one previous study has reported a small but significant reduction of the length-of-stay in the case of physician-nurse teamwork.[33]

One may note that a smaller proportion of patients in the subpopulation studied were discharged home during the teamwork period, 65.4% compared to 71.1% for nurse-led triage and 69.3% for physician-led triage. This may be due to the fast track See & Treat having been replaced by two modules for ambulant patients, one in each ED corridor. Internal medicine complaints previously treated at See & Treat were transferred to modules in the other corridor. The median length-of-stay was shorter for patients discharged home than those admitted for all periods, 88 min shorter for teamwork, 73 min for physician-led triage and 81 min for nurse-led triage (Table 2b). This observed shift towards more serious complaints could be interpreted as providing further support for a higher efficiency of the teamwork process. Another observation supporting this view was the increasing skewness of the length-of-stay distribution from period to period, which implies an increasing proportion of patients with a short length-of-stay in the presence of a smaller number of patients with increasing length-of-stay. This may have been caused by the increasing inpatient bed occupancy from period to period.

When senior physicians replaced nurses in triage in the first intervention, the median time to physician decreased by 60 min. In a meta-analysis, Abdulwahid et al.[25] estimated a reduction by 26 min from two randomized controlled trials (RCTs) [41 42] and 15 min from nine non-RCTs. Our first intervention increased the median length-of-stay by 18 minutes, in contrast to the estimated reduction by 29 min of the meta-analysis. Four of the publications included in the meta-analysis appear to report different follow-up lengths of an identical intervention in the same ED,[19 43-45] which may overestimate the effect size. Most studies reporting reduced length-of-stay introduced additional physicians in the triage interventions[16 17 19], while in the first intervention of this study the senior physicians were reassigned to the triage. This may explain the increased length-of-stay in our study. However, Choi et al. reduced the waiting time and processing time by reassigning a senior physician to the triage process.[18] To our knowledge, two studies found no significant changes in length-of-stay,[46 47] while one study has reported a significant 15 min increase along with an 11% increase of orders for diagnostic radiology.[48] For patients dispositioned by a second physician at the main ED after senior physician assessment at triage, Traub et al found a 25 min longer length-of-stay.[20] Although Choi et al found significant reductions of the time to physician and length-of-stay, they also described "stressful, pressurized and risky" working conditions for the senior physician in triage.[18]. When Burström et al compared three EDs with different triage processes, they found the shortest length-of-stay for senior physician-led triage.[49] However, this ED also applied interprofessional teamwork. The senior physician at triage planned the patients´ ED stay and communicated the plan to teams consisting of a junior physician and a nurse who worked in parallel. At the other two EDs, physicians and nurses worked separately and sequentially.

The smallest proportion of patients who left without being seen by a physician was observed for physician-led triage, which is in line with the significant decrease reported by previous studies of physicians at triage.[16 45] We observed the highest rate for the teamwork period, despite a 46 min shorter time to physician compared to nurse-led triage. Although this rate is often used as an indicator of crowding, patients who leave without being seen by a physician has been shown to be at a lower risk of death or admission within seven days compared to patients who were seen by physicians and discharged home.[50] These authors found no association between EDs with high annual left without being seen rate and risk of death or admission. Nonetheless, the higher rate for the teamwork process calls for further exploration and should be addressed.

Strengths and limitations

The main strength of this study is the large population which enables the evaluation of the process rather than the performance of individual doctors or nurses. Another strength is the control and study periods of one year each, which compensates for seasonal fluctuations and allows each intervention to stabilize after the initial implementation. We were only able to identify one other study of a similar population size and length of time.[19] Furthermore, analyses of multiple interventions and studies comparing several triage processes are rare.

This study has several limitations. First, this is a single-centre study in one large, busy urban ED and the results may not be generalizable to other ED settings. EDs differ from each other in aspects of input, throughput and output.[51] In addition, before-and-after studies may not claim a causality between the intervention and the outcomes, although we have chosen the periods with no other simultaneous process changes. We did not include patients who arrived during night shifts or on weekends and holidays, since the interventions did not include these work shifts. However, we analysed outcome measures for all patients arriving before 9 pm, including those treated by the night shift. The second intervention was a deeper redesign of the entire ED to enable a new approach to the triage process. Finally, a limitation shared by previous studies is the use of throughput times as surrogate outcome measures for ED quality and patient safety. However, the outcome measures we chose have been shown to be indicators of patient outcome[50 52 53] and patient satisfaction.[54 55]

Future studies of interprofessional teamwork in EDs with a multi-centre design are of value to confirm our findings, as well as studies with cost-effectiveness evaluations.

Conclusion

The median length-of-stay was shortest for interprofessional teamwork in modules. It was longest for physician-led triage, despite the shortest time to physician of all studied periods. Interprofessional teamwork in modules may be an interesting approach to improve timeliness in large busy EDs.

Figure legends:

Figure 1 Timeline of the interventions and the study flow diagram.
Figure 2 Interprofessional teamwork in a module – team members, work space, and patient flow.
Figure 3 Length-of-stay distribution per triage period of the subpopulation
Figure 4 Time to physician distribution per triage period of the subpopulation

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Contributors: Jenny Liu (JL), Italo Masiello (IM), Sari Ponzer (SP), and Nasim Farrokhnia (NF) participated in the initiation and development of the study design. JL performed the literature search with inputs from IM, SP, and NF. JL collected and analysed the data and wrote the initial draft. IM, SP, and NF participated in critical revisions and have approved the final manuscript. The corresponding author and guarantor is JL.

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Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation except Stockholm County Council for the submitted work; no financial relationships with any organization except Stockholm County Council that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethics: The study was approved by the Regional Ethical Review Board of Stockholm, ref. no. 2016/109-31/5. Informed consent was not obtained since all patients were assessed and treated according the process implemented during that period.

Data sharing: Full dataset and statistical codes are available from the corresponding author. Patient consent was not obtained but the presented data are anonymised and risk of identification is low.

Transparency declaration
The present manuscript is an honest, accurate and transparent account of the study being reported. No important aspects of the study have been omitted and any discrepancies from the study as planned have been explained.

All authors had full access to all the data in the study, including statistical reports and tables, and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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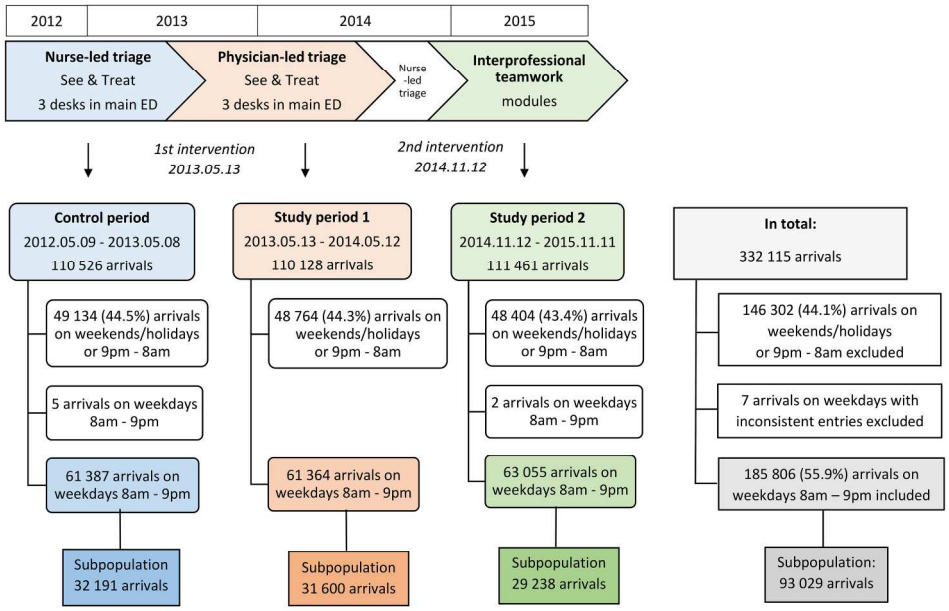

Figure 1 Timeline of the interventions and the study flow diagram.

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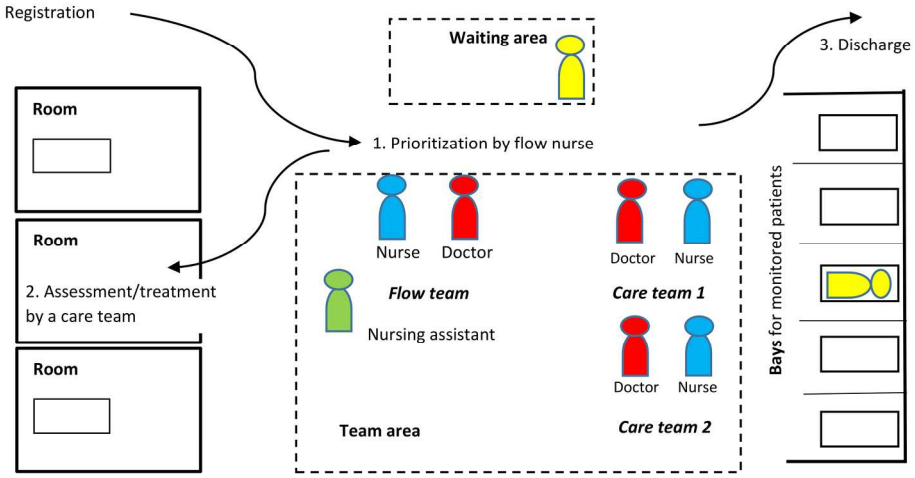

Figure 2 Interprofessional teamwork in a module - team members, work space, and patient flow.

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Figure 3 Length-of-stay distribution per triage period of the subpopulation

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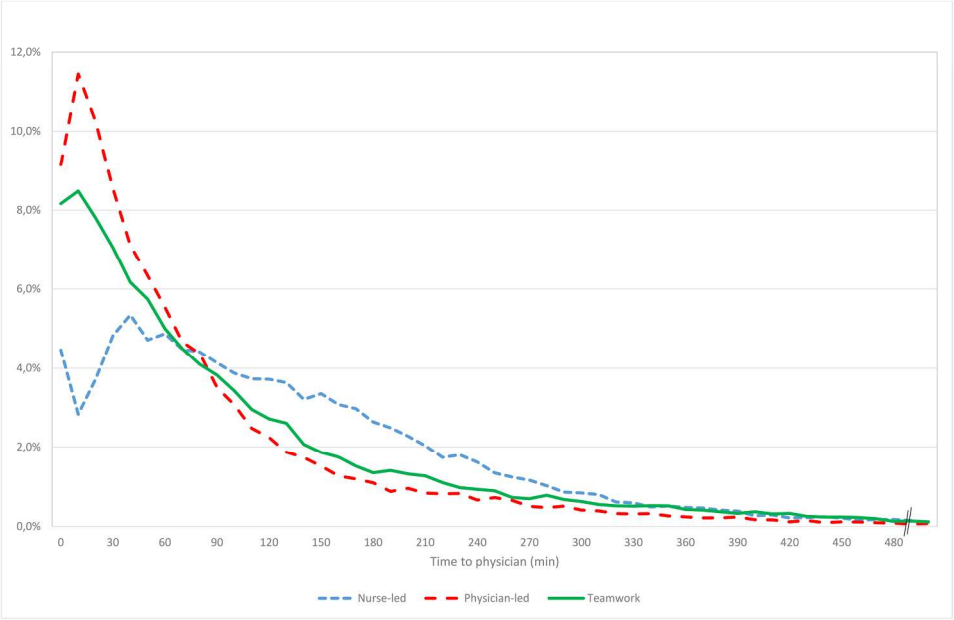

Figure 4 Time to physician distribution per triage period of the subpopulation

108x72mm (600 x 600 DPI)

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	1, 3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
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	4-6
		(*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	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	6-7
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	7
		(*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	NA
		(*e*) Describe any sensitivity analyses	NA

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	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Tab.1a Tab.1b
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	NA
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	9-12, Tab.3a Tab.3b
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
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	14

*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.