

# 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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**To cite:** Liu J, Masiello I, Ponzer S, *et al.* Can interprofessional teamwork reduce patient throughput times? A longitudinal single-centre study of three different triage processes at a Swedish emergency department. *BMJ Open* 2018;**8**:e019744. doi:10.1136/bmjopen-2017-019744

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2017-019744>).

Received 22 September 2017  
Revised 8 March 2018  
Accepted 14 March 2018



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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 08:00 to 21:00 during three 1-year periods in the interval May 2012 to November 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 08:00 to 21:00 November 2014 to November 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 with 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 with 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 length of stay, a shorter time to physician than nurse-led triage, but a higher LWBS rate. Interprofessional teamwork may be a useful approach to reducing ED throughput times.

## INTRODUCTION

Emergency department (ED) crowding is a growing problem worldwide.<sup>1–5</sup> Patients risk suffering prolonged pain, inconvenience

## Strengths and limitations of this study

- Two interventions are analysed and three triage processes compared in the same emergency department (ED).
- The large study population allows an accurate comparison of the triage processes.
- The control and study periods of 1 year each compensate for seasonal fluctuations and allow each intervention to stabilise after the initial implementation.
- The results from a large urban ED may not be generalisable 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.

and poor outcomes due to delays in emergency care.<sup>2 6–8</sup> 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.<sup>9–11</sup> 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.<sup>12 6</sup>

In the 1950s, triage of patients became a key strategy to handle the crowding problem.<sup>12</sup> 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.<sup>13</sup> In nurse-led triage, the protocol may also allow nurses to order laboratory tests and

radiographs.<sup>12</sup> Comprehensive nurse-led triage using different standardised acuity protocols has been widely implemented since the 1990s. However, the evidence of its reliability and validity is scarce.<sup>12 14 15</sup>

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.<sup>16–20</sup> 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.<sup>21–25</sup>

Interprofessional teamwork, where health workers with different professional backgrounds work together with the goal of delivering the highest quality of care,<sup>26</sup> 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.<sup>27</sup> Studies of teamwork and interprofessional training have reported improvements in the quality of care, patient satisfaction and work environment,<sup>28–32</sup> but few studies report its impact on ED throughput times.<sup>33</sup>

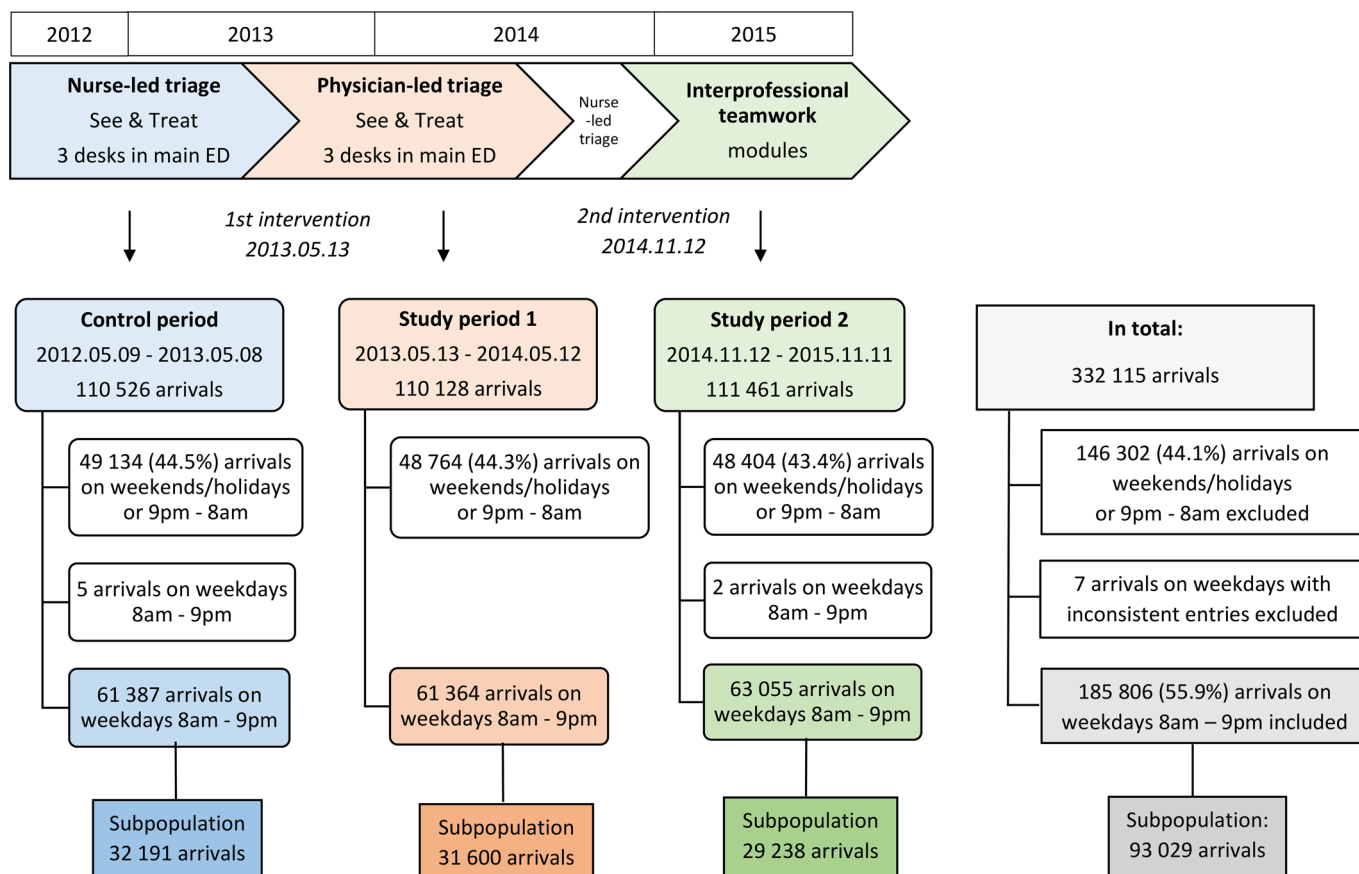
We describe two interventions. During the first intervention, senior physicians replaced senior nurses in the

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?

## MATERIALS AND METHODS

The study design was a single-centre before-and-after study. We conducted the study from May 2012 to November 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 08:00 to 21:00. We excluded patient arrivals between 21:00 to 08:00 since none of the study interventions was 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 1-year period after its implementation, with a 1-year period prior to the first intervention serving as the control period (figure 1). We



**Figure 1** Timeline of the interventions and the study flow diagram. ED, emergency department.

also excluded visits to our paediatric and gynaecology EDs because of differences in location and work processes.

### Nurse-led triage

During the control period from 9 May 2012 to 8 May 2013, 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 (RETTTS) protocol<sup>34 35</sup> developed in Sweden. The RETTTS protocol combines the vital signs and patient history to prioritise the patients in five emergency processes according to medical urgency. For most patients, the triage nurses sent blood samples for standardised laboratory work-up. A total of eight triage team shifts were scheduled daily from 08:00 to 21:00, corresponding to 58 hours each of registered nurses and nursing assistants. During peak hours from 10:00 to 18:00, 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 orthopaedic 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 13 May 2013 to 12 May 2014, three senior physician shifts were reassigned from each of the three desks from 08:00 to 21:00, 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

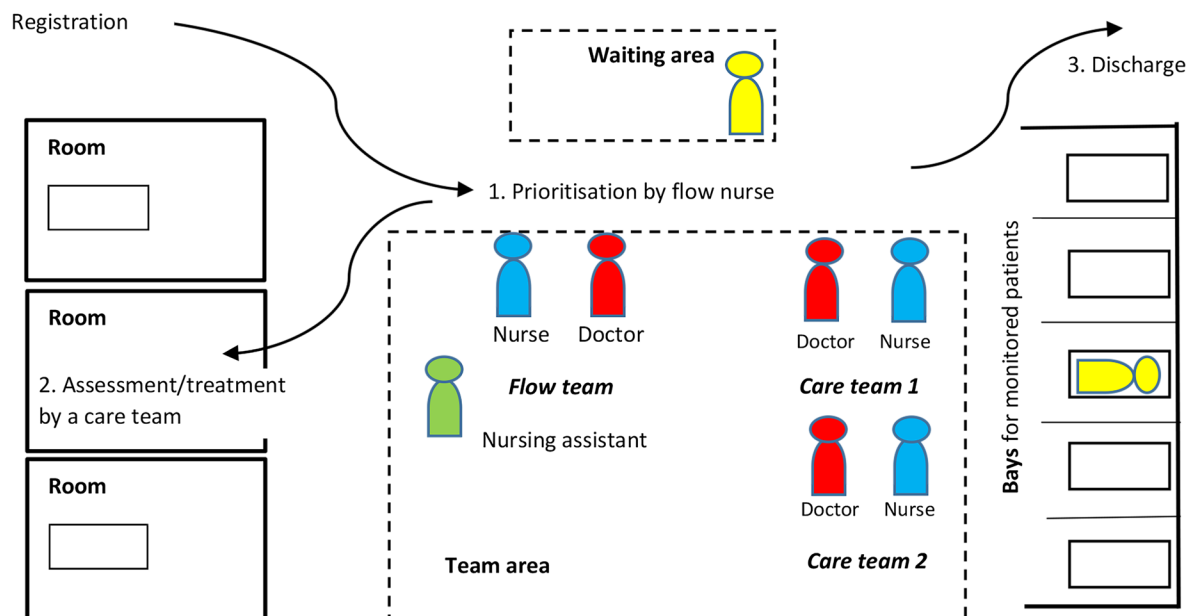
During the second intervention from 12 November 2014 to 11 November 2015, interprofessional teamwork in modules was introduced on weekdays from 08:00 to 21:00. The ED facilities, including the triage area and the See & Treat, were converted into nine modules, each equipped with two or three rooms for 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 08:00 to 21:00, with five additional modules added during peak hours from 10:00 to 18:00. Patients with orthopaedic 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 prioritised 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.

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<sup>36</sup> 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 08:00 21:00 were summed into a daily total number of hours. The ED was organised 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.



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

We collected registry data of available in-hospital beds and the number of admitted patients per ward weekdays at 06:00 from Belagging.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 November 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 were extracted from the ED tracking system Akusys, after replacing patient identification numbers by unique codes. We imported the data obtained from Akusys, Belagging.qvw and work schedules into R (The R Foundation for Statistical Computing, Vienna) for statistical analysis. We used descriptive statistics to summarise the general characteristics for each period and analysed differences between the periods using the  $\chi^2$  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% CIs 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 1-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  $\chi^2$  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 1-year periods, as illustrated in the flow diagram in figure 1. The 146 302 arrivals on weekends, holidays and during night shifts from 21:00 to 08:00 where the interventions were not implemented were excluded. We also excluded seven arrivals on weekdays 08:00 through 21:00 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 1, along with mean values of in-hospital bed occupancy

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

Triage process	(1) Nurse-led triage			(2) Physician-led triage			(3) Interprofessional teamwork		
Time period	9 May 2012 to 8 May 2013			13 May 2013 to 12 May 2014			12 November 2014 to 11 November 2015		
Triage protocol	Rapid Emergency Triage and Treatment System			None			None		
	n		Period 1 versus 2 (P values)	n		Period 2 versus 3 (P values)	n		Period 3 versus 1 (P values)
All arrivals	110 526			110 128			111 461		
Arrivals weekdays 08:00 to 21:00	61 387	55.5%	0.406	61 364	55.7%	<0.001	63 055	56.6%	<0.001
Female gender	31 933	52.0%	0.341	31 706	51.7%	0.354	32 413	51.4%	0.030
Mean age (years)	55.3 years	SD 21.8	0.019	55.6 years	SD 21.8	0.009	56.0 years	SD 21.5	<0.001
Arrival mode									
Ambulance no alert	14 587	23.8%	0.775	14 538	23.7%	0.156	15 156	24.0%	0.260
Prehospital ambulance alert	2952	4.8%	0.017	3 133	5.1%	0.662	3184	5.0%	0.051
In-beds on weekdays at 06:00									
Mean available beds	423			433			408		
Mean bed occupancy	391	92.6%	<0.001	408	94.3%	<0.001	398	97.8%	<0.001
Staffing weekdays 08:00 to 21:00									
Physician hours	249.0			270.8			313.0		
Nurse hours including assistants	509.8			508.7			553.6		

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.

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 2). In this subgroup, the total staffing per week varied over the 3-year period in an interval of -1.5% to +1.1% compared with a 3-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.

For the entire study population, the median length of stay was shortest for the teamwork period, 223min compared with 226min for nurse-led triage and 239min for physician-led triage. The median time to physician was shortest for physician-led triage, 54min compared with 66min for teamwork and 98min for nurse-led triage. The 95% CIs and p values are given in table 3, which shows that all differences between periods were significant with two-tailed p values <0.001.

For the subgroup, the median length of stay was shortest for the teamwork period, 228min compared with 232min for nurse-led triage and 250min for physician-led triage. The median time to physician was shortest

for physician-led triage, 56min compared with 74min for teamwork and 116min for nurse-led triage. The 95% CIs and p values are listed in table 4, which shows that all differences between periods were significant with two-tailed p values <0.01. Table 4 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.

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 64min longer for patients over 74 years, 20min longer for female patients, 80min longer for ambulance patients and 68min 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 0.6min 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 11min. Finally, we pooled all these explored predictors in a multivariable regression analysis and found that the

**Table 2** 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	9 May 2012 to 8 May 2013			13 May 2013 to 12 May 2014			12 November 2014 to 11 November 2015		
Triage protocol	Rapid Emergency Triage and Treatment System			None			None		
	n		Period 1 versus 2 (P values)	n		Period 2 versus 3 (P values)	n		Period 3 versus 1 (P values)
All arrivals	57 987			56 250			52 380		
Arrivals weekdays 08:00 to 21:00	32 191	55.5%	0.249	31 600	56.2%	0.243	29 238	55.8%	0.307
Female gender	16 375	50.9%	0.213	15 917	50.4%	0.161	14 438	49.4%	0.015
Mean age (years)	51.5 years	SD 21.9	0.001	52.1 years	SD 22.1	0.753	52.2 years	SD 22.0	<0.001
Arrival mode									
Ambulance no alert	5778	17.9%	0.187	5800	18.4%	<0.001	5954	20.4%	<0.001
Prehospital ambulance alert	1002	3.1%	0.322	940	3.0%	0.004	757	2.6%	<0.001
In-beds weekdays at 06:00									
Mean available beds	180			179			172		
Median bed occupancy	161	89.5%	<0.001	164	92.0%	<0.001	163	94.8%	<0.001
Staffing weekdays 08:00 to 21:00									
Physician hours	132.5			143.8			141.5		
Nurse hours including assistants	262.3			261.6			260.9		

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 SEs and p values from the simple and multivariable regression analyses in [table 5](#).

We also conducted regression analyses of the subgroup and present the estimates in [table 6](#), including SEs 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.

In the subgroup, the proportion of patients who left without being seen by a physician was smallest for physician-led triage, 1.2% compared with 1.9% for nurse-led triage and 3.2% for teamwork ([table 4](#)). The corresponding rate of the entire study population was also lowest for physician-led triage and highest for teamwork period ([table 3](#)). 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.<sup>37</sup> 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.<sup>38 39</sup> Welch *et al*<sup>38</sup> suggested reducing the volume of a large ED by creating smaller subsets or clinical microsystems as an approach to

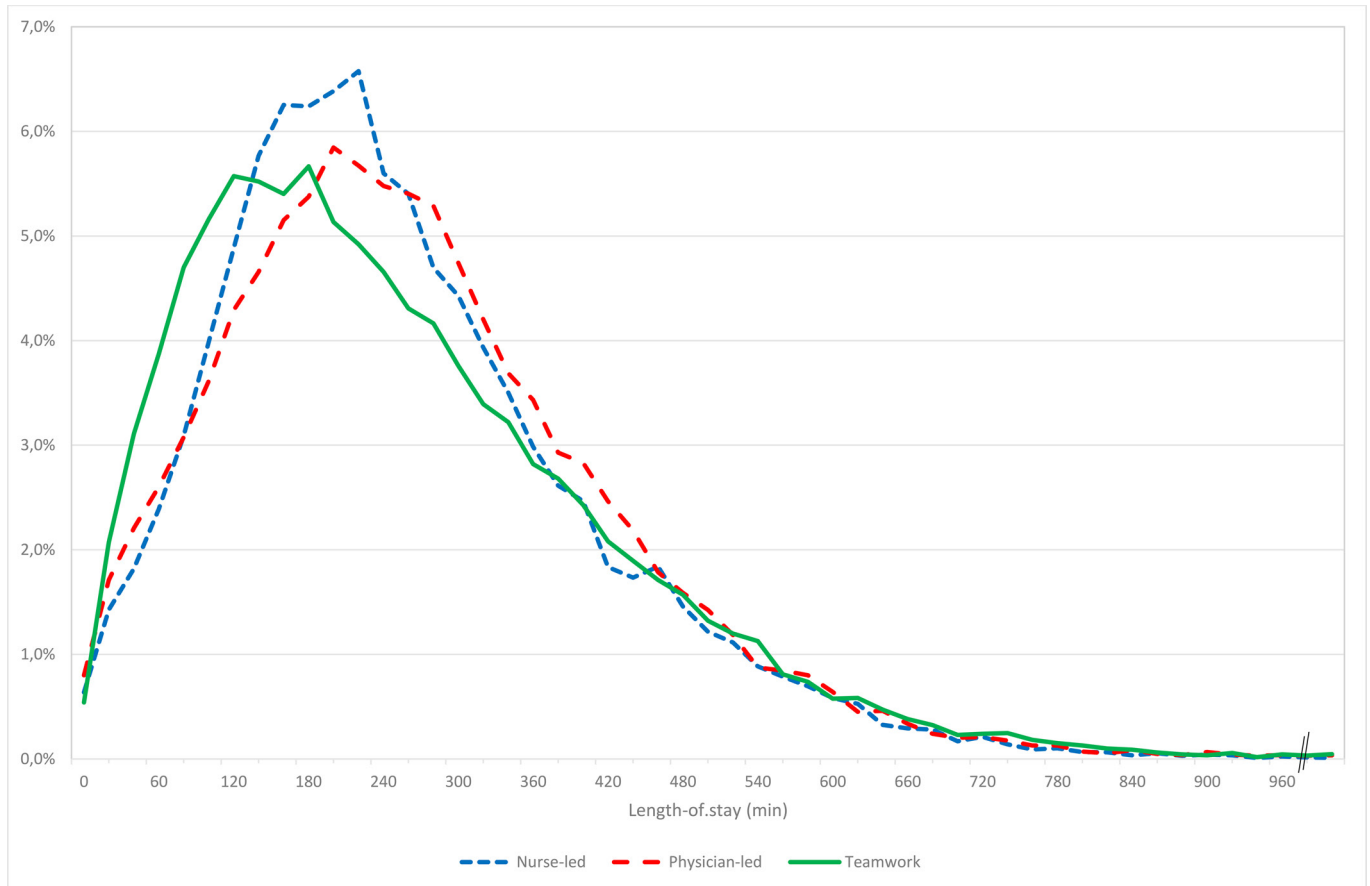
**Table 3** Outcome measures and patient dispositions for the entire study population

Triage process	(1) Nurse-led triage			(2) Physician-led triage			(3) Interprofessional teamwork		
	9 May 2012 to 8 May 2013	Period 1 versus 2 (P values)	13 May 2013 to 12 May 2014	Period 2 versus 3 (P values)	12 November 2014 to 11 November 2015	Period 3 versus 1 (P values)			
Period	Min	95% CI	Min	95% CI	Min	95% CI			
Median length of stay									
Overall	226	224.5 to 227.6	239	236.9 to 240.0	223	221.9 to 224.0			
Discharged home	210	208 to 211	223	221 to 224	198	197 to 200			
Admitted	253	250 to 255	267	264 to 270	263	261 to 266			
Median time to physician									
Overall	98	97.4 to 99.5	54	53.7 to 54.8	66	65.0 to 67.1			
Discharged home	114	113 to 115	60	59 to 60	70	69 to 71			
Admitted	73	72 to 74	42	41 to 43	56	54 to 57			
	n	%	n	%	n	%			
Patient disposition									
Left without being seen	1594	2.6	1366	2.2	2321	3.7			
Discharged home	36 953	60.2	36 370	59.3	37 350	59.2			
Admitted	19 338	31.5	19 494	31.8	19 273	30.6			
Admitted to satellite beds	190	0.3	286	0.5	439	0.7			
Transferred to other hospitals	2171	3.5	2193	3.6	2385	3.8			
Other dispositions	1141	1.3	1655	1.2	1287	1.3			

**Table 4** 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					
	9 May 2012 to 8 May 2013	13 May 2013 to 12 May 2014	12 November 2014 to 11 November 2015	Period 1 versus 2 (P values)	Period 2 versus 3 (P values)	Period 3 versus 1 (P values)	Min	95% CI	Min	95% CI	Min	95% CI
Median length of stay												
Overall	232	230.8 to 233.9	<0.001	250	248.5 to 252.6	<0.001	228	226.4 to 230.5	0.006			
Discharged home	212	210 to 214	<0.001	229	226 to 232	<0.001	200	197 to 203	<0.001			
Admitted	293	288 to 298	=0.002	302	298 to 306	<0.001	288	284 to 292	0.166			
Median time to physician												
Overall	116	114.4 to 117.5	<0.001	56	54.5 to 56.6	<0.001	74	72.7 to 74.8	<0.001			
Discharged home	125	124 to 127	<0.001	61	60 to 62	<0.001	76	75 to 78	<0.001			
Admitted	86	84 to 88	<0.001	43	42 to 44	<0.001	69	67 to 71	<0.001			
	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>
Patient disposition												
Left without being seen	597	1.9	<0.001	368	1.2	<0.001	933	3.2	<0.001			
Discharged home	22 875	71.1	<0.001	21 888	69.3	<0.001	19 126	65.4	<0.001			
Admitted	7337	22.8	0.001	7548	23.9	<0.001	7406	25.3	0.001			
Admitted to satellite beds	115	0.4	0.111	139	0.4	<0.001	197	0.7	<0.001			
Transferred to other hospitals	883	2.7	0.013	972	3.1	0.010	1009	3.5	<0.001			
Other dispositions	384	0.6	0.150	685	0.7	<0.001	567	1.2	<0.001			





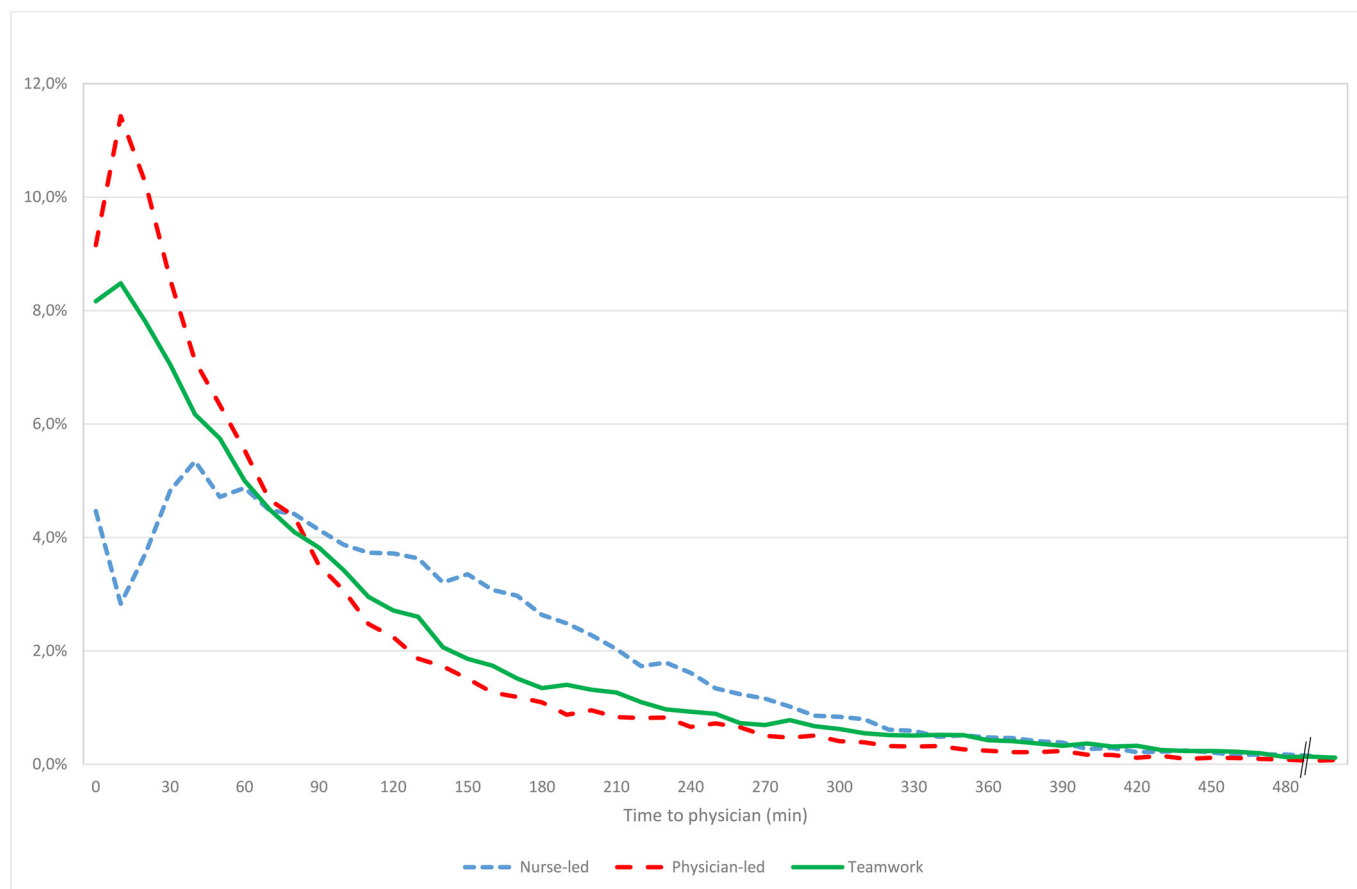
**Figure 3** Length-of-stay distribution per triage period of the subpopulation.

improve the efficiency. Improvement in communication and patient safety,<sup>29 31</sup> staff<sup>40</sup> and patient satisfaction<sup>28 30</sup> 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.<sup>33</sup>

One may note that a smaller proportion of patients in the subpopulation studied were discharged home during the teamwork period, 65.4% compared with 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 4). 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*<sup>25</sup> estimated a reduction by 26 min from two randomised controlled trials (RCTs)<sup>41 42</sup> and 15 min from nine non-RCTs. Our first intervention increased the median length of stay by 18 min, 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,<sup>19 43–45</sup> which may overestimate the effect size. Most studies reporting reduced length of stay introduced additional physicians in the triage interventions,<sup>16 17 19</sup> 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.<sup>18</sup> To our knowledge, two studies found no significant changes in length of stay,<sup>46 47</sup> while one study has reported a significant 15 min increase along with an 11% increase of orders for diagnostic radiology.<sup>48</sup> 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.<sup>20</sup>



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

Although Choi *et al* found significant reductions of the time to physician and length of stay, they also described ‘stressful, pressurised and risky’ working conditions for the senior physician in triage.<sup>18</sup> When Burström *et al* compared three EDs with different triage processes, they found the shortest length of stay for senior physician-led triage.<sup>49</sup> 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.<sup>16 45</sup> We observed the highest rate for the teamwork period, despite a 46 min shorter time to physician compared with

**Table 5** 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	SE	P values	Estimate	SE	P values
Age (per year)	1.42	0.02	<0.001	1.12	0.02	<0.001
Gender female (yes/no)	19.90	0.78	<0.001	14.69	0.75	<0.001
Arrival mode						
Ambulance without alert (yes/no)	79.92	0.89	<0.001	58.25	0.94	<0.001
Ambulance with prehospital alert (yes/no)	-68.02	1.78	<0.001	-64.34	1.77	<0.001
Daily occupancy rate at 06:00 (0–1)	217.42	7.39	<0.001	233.44	7.87	<0.001
Daily total arrival volume	0.60	0.01	<0.001	0.69	0.01	<0.001
Difference compared with teamwork period						
Nurse-led triage period (yes/no)				12.07	1.01	<0.001
Physician-led triage period (yes/no)				20.91	0.96	<0.001

**Table 6** 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	SE	P values	Estimate	SE	P values
Age (per year)	1.73	0.03	<0.001	1.19	0.02	<0.001
Gender female (yes/no)	26.70	1.07	<0.001	17.84	1.03	<0.001
Arrival mode						
Ambulance without alert (yes/no)	108.38	1.33	<0.001	84.26	1.40	<0.001
Ambulance with prehospital alert (yes/no)	-37.85	3.19	<0.001	-28.65	3.09	<0.001
Daily in-bed occupancy at 06:00 (0–1)	208.23	10.26	<0.001	224.44	10.76	<0.001
Daily total arrival volume	0.61	0.02	<0.001	0.70	0.02	<0.001
Difference compared with teamwork period						
Nurse-led triage period (yes/no)				15.56	1.39	<0.001
Physician-led triage period (yes/no)				23.46	1.33	<0.001

nurse-led triage. Although this rate is often used as an indicator of crowding, patients who leave without being seen by a physician have been shown to be at a lower risk of death or admission within 7 days compared with patients who were seen by physicians and discharged home.<sup>50</sup> 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 1 year each, which compensates for seasonal fluctuations and allows each intervention to stabilise after the initial implementation. We were only able to identify one other study of a similar population size and length of time.<sup>19</sup> 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 generalisable to other ED settings. EDs differ from each other in aspects of input, throughput and output.<sup>51</sup> 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 21:00, 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<sup>50 52 53</sup> and patient satisfaction.<sup>54 55</sup>

Future studies of interprofessional teamwork in EDs with a multicentre 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.

**Acknowledgements** Mats Nordahl provided statistical advice. Bo Herrlin facilitated the improvement groups, and members of these groups designed the interventions by repeated test cycles before they were implemented.

**Contributors** All authors 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 guarantor is JL.

**Funding** Stockholm County Council sponsored the study through research and development funds dedicated for the Department of Emergency Care at Södersjukhuset and through grants dedicated for work environment improvement.

**Disclaimer** The funder had no input to the study design, data collection or interpretation, writing of report or submission for publication.

**Competing interests** None declared.

**Patient consent** Not required.

**Ethics approval** The study was approved by the Regional Ethical Review Board of Stockholm, ref. no. 2016/109-31/5. I

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** Full dataset and statistical codes are available from the corresponding author.

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