International Journal of Infectious Diseases 72 (2018) 40–48

Contents lists available at ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Developing a decision support system for patients with severe infection conditions in pre-hospital care

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A R T I C L E I N F O

Article history:
Received 24 January 2018
Received in revised form 22 April 2018
Accepted 26 April 2018
Corresponding Editor: Eskild Petersen, Aarhus, Denmark

Keywords:
Emergency medical services
Triage
Nurses
Pneumonia
Sepsis
Central nervous system

A B S T R A C T

Objective: To develop and validate a pre-hospital decision support system (DSS) for the emergency medical services (EMS), enabling the identification and steering of patients with critical infectious conditions (i.e., severe respiratory tract infections, severe central nervous system (CNS) infections, and sepsis) to a specialized emergency department (ED) for infectious diseases.

Methods: The development process involved four consecutive steps. The first step was gathering data from the electronic patient care record system (ePCR) on patients transported by the EMS, in order to identify retrospectively appropriate patient categories for steering. The second step was to let a group of medical experts give advice and suggestions for further development of the DSS. The third and fourth steps were the evaluation and validation, respectively, of the whole pre-hospital DSS in a pilot study.

Results: A pre-hospital decision support tool (DST) was developed for three medical conditions: severe respiratory infection, severe CNS infection, and sepsis. The pilot study included 72 patients, of whom 60% were triaged to a highly specialized emergency department (ED-Spec) with an attending infectious disease physician (ID physician). The results demonstrated that the pre-hospital emergency nurses (PENs) adhered to the DST in 66 of 72 patient cases (91.6%). For those patients steered to the ED-Spec, the assessment made by PENs and the ID physician at the ED was concordant in 94% of cases.

Conclusions: The development of a specific DSS aiming to identify patients with three different severe infectious diseases appears to give accurate decision support to PENs when steering patients to the optimal level of care.

Introduction

Optimal treatment during the initial contact with patients suffering from acute severe infectious diseases is often decisive for the prognosis (Byl et al., 1999; Gaieski et al., 2010; Garnacho-Montero et al., 2006; Grace et al., 2010; Harbarth et al., 2007; Ibrahim et al., 2000; Iregui et al., 2002; Kollef et al., 1999; Kumar et al., 2006; Paul et al., 2010; Petrak et al., 2003; Puskarich et al., 2011). Three such conditions are severe respiratory tract infections, severe central nervous system (CNS) infections, and severe sepsis. Approximately 20% of patients with community-acquired pneumonia require hospitalization (Guest and Morris, 1997), of which 10–20% are defined as suffering from severe pneumonia with a 10–50% mortality rate (Spindler et al., 2012). Identifying and treating patients at high risk of a serious outcome is therefore crucial (BTS, 2001). Acute severe CNS infections are relatively rare. Delayed initial adequate treatment has been demonstrated to impair the prognosis of acute bacterial meningitis (Aronin et al., 1998; van de Beek et al., 2004). The mortality rate for patients with acute bacterial meningitis increases by about 30% for each hour that correct treatment is delayed (Koster-Rasmussen et al., 2008). Sepsis is a life-threatening condition caused by an uncontrolled immune response to severe infection. Mortality ranges between 10% and 40% depending on the severity (Singer et al., 2016). In-hospital data indicate that the early identification and initiation of treatment for severe sepsis substantially reduces mortality (Ferrer et al., 2014).

The three infectious disease syndromes described above are all known to be difficult to identify, which could result in inadequate processing (Dellinger, 2013). A qualified assessment by the

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https://doi.org/10.1016/j.ijid.2018.04.4321
1201-9712/

emergency medical services (EMS) and the emergency department (ED) is necessary to initiate correct diagnosis and treatment. Identifying infectious diseases at an early stage (EMS assessment) will help the infectious diseases physician (ID physician) in the initial care chain, which has been shown to reduce mortality significantly for patient groups, such as those with bacterial meningitis and severe pneumonia (Glimaker et al., 2013; Spindler and Ortqvist, 2006). ID physician involvement in the ED has also been demonstrated to improve the management of and reduce mortality in sepsis patients (Rosenqvist et al., 2017; Viale et al., 2017).

Steering protocols and processes in the EMS have been researched and implemented during the past 10 years. The main goal of these steering processes is to direct patients to the optimal level of healthcare based on their medical needs and to improve the quality of care (Vicente et al., 2014). The scientific support for such steering processes has also increased, especially regarding patients with acute myocardial infarctions or stroke (Herlitz et al., 2010), geriatric patients (Vicente et al., 2014), patients with hip trauma (Larsson et al., 2016), and trauma patients (Rubenson et al., 2016). Pre-hospital decision support systems in the EMS setting enable direct triage and steering of patients to an optimal level of healthcare.

In the city of Stockholm there are five different emergency hospitals. The presence of infection expertise in the EDs is unequally distributed across these hospitals and a specialized ED for patients with acute infections – with an ID physician responsible for the primary assessment of the patients – is only present at Karolinska University Hospital in Solna. However, there is currently no pre-hospital management of these patients, resulting in pre-hospital transportation of patients with these severe conditions to the nearest hospital rather than according to where the most appropriate level of care can be given.

The aim of this study was to develop and validate a pre-hospital decision support system (DSS) for the EMS, enabling the identification and steering of patients with critical infectious conditions (severe respiratory tract infections, severe CNS infections, and sepsis) to a specialized ED for infectious diseases.

Materials and methods

Study setting

The population of Sweden in 2015 was approximately 9.9 million inhabitants, with 2.3 million living in Stockholm (CBS, 2017). During 2015, the Stockholm area EMS had almost 200 000 assignments. The pilot study was conducted between December 2014 and March 2015 at one of three ambulance companies in Stockholm. There are three categories of personnel in the EMS in Sweden: emergency medical technicians (EMTs), registered nurses (RNs), and pre-hospital emergency nurses (PENs). The PENs are responsible for the medical management of the patients and the steering processes. In Sweden, PENs are registered nurses with advanced knowledge of prehospital emergency care (Karolinska Institutet, 2017). EMS personnel follow national medical guidelines with procedure and treatment protocols for specific symptoms and groups of diagnoses, categorized in a list of predetermined conditions (following the International Classification of Diseases Tenth revision (ICD-10) code system) (EMS Medical Guidelines, 2017).

PENs also grade the severity of each patient's medical condition using the National Advisory Committee for Aeronautics (NACA) score (Supplementary material, Table S1) (Baker et al., 1974; Tryba et al., 1980; Weiss et al., 2001). The priority level for each transport corresponds to the score shown in Table S2 of the Supplementary material (SOSFS, 2009).

The alternative levels of healthcare are as follows: (1) university hospital, emergency department not otherwise specified (ED-NOS); (2) highly specialized university hospital, specialized emergency department (ED-Spec).

Developing the pre-hospital DSS for pre-hospital infection patients

The creation of the pre-hospital DSS was divided into two major steps: (1) a decision support tool (DST), and (2) a validation process. These two steps were further divided into four consecutive steps (Figure 1). Each step generated data upon which the following step was dependent.

Step 1—Description of the study population and the creation of a preliminary DST

The goal of the first step was to retrospectively identify patients with severe infectious diseases in the EMS electronic patient care record system (ePCR). Data were collected from 2011 (Figure 2). Inclusion criteria for this study population were (1) adult patients (age $\geq$18 years), and (2) patients suffering from an acute infection.

A total of 6323 ePCR records fulfilling the inclusion criteria were identified. The researchers (VV, CS, and NJ) and a senior advisor and pre-hospital physician (RB) created a preliminary DST based on symptoms and at least one failing vital parameter out of the following four: systolic blood pressure <90 mmHg, respiratory rate >30/min, saturation <90%, confusion. Thereafter, these ePCR records were analyzed adjusting for the following exclusion criteria: (1) vital parameters outside the references stated above, (2) severity level (NACA score) 0–3 and 7, and (3) conditions that were not severe infectious diseases or that were potentially eligible for inclusion in other steering processes.

After the exclusion of patients meeting the exclusion criteria, 1921 retrospective ePCR records remained for further analysis. Analyses of the remaining patients demonstrated that respiratory tract infection/pneumonia, sepsis, and CNS infection accounted for 282, 276, and 63 patients, respectively.

Step 2—Peer review of the preliminary DST

The preliminary DST for the three conditions was based on severity scoring systems for pneumonia and sepsis (Lim et al., 2009; Singer et al., 2016) and typical symptoms of severe bacterial CNS infections (Glimaker et al., 2013; Heckenberg et al., 2014). The goal of the second step was to engage an expert group and a reference group, selected by written and oral requests to the clinic directors at the ED-Spec hospital and the ambulance service. Each director chose an expert. The three experts were all senior consultants within the department of infectious diseases at Karolinska University Hospital, with extensive research experience in their respective areas of expertise. All three were also members of the separate national committees responsible for writing the Swedish national guidelines concerning the diagnosis of these three conditions. The specialists contributed advice and suggestions for changing the content and structure of the preliminary DST for optimal identification of the conditions selected. After revision of the DST, the expert and reference groups confirmed the final product.

Final definition of the three infectious conditions for steering to the ED-Spec

The following definitions of the three conditions that would prompt EMS personnel to steer the patient to the ED-Spec were decided: (1) respiratory tract infection required a clinical suspicion and at least one of the following severity markers: confusion, respiratory rate $\geq$30/min, systolic blood pressure <90 mmHg, saturation <90% (Spindler et al., 2012); (2) CNS infection required a clinical suspicion, fever/chills, and at least one of the following symptoms: confusion, headache, neck stiffness/back pain,

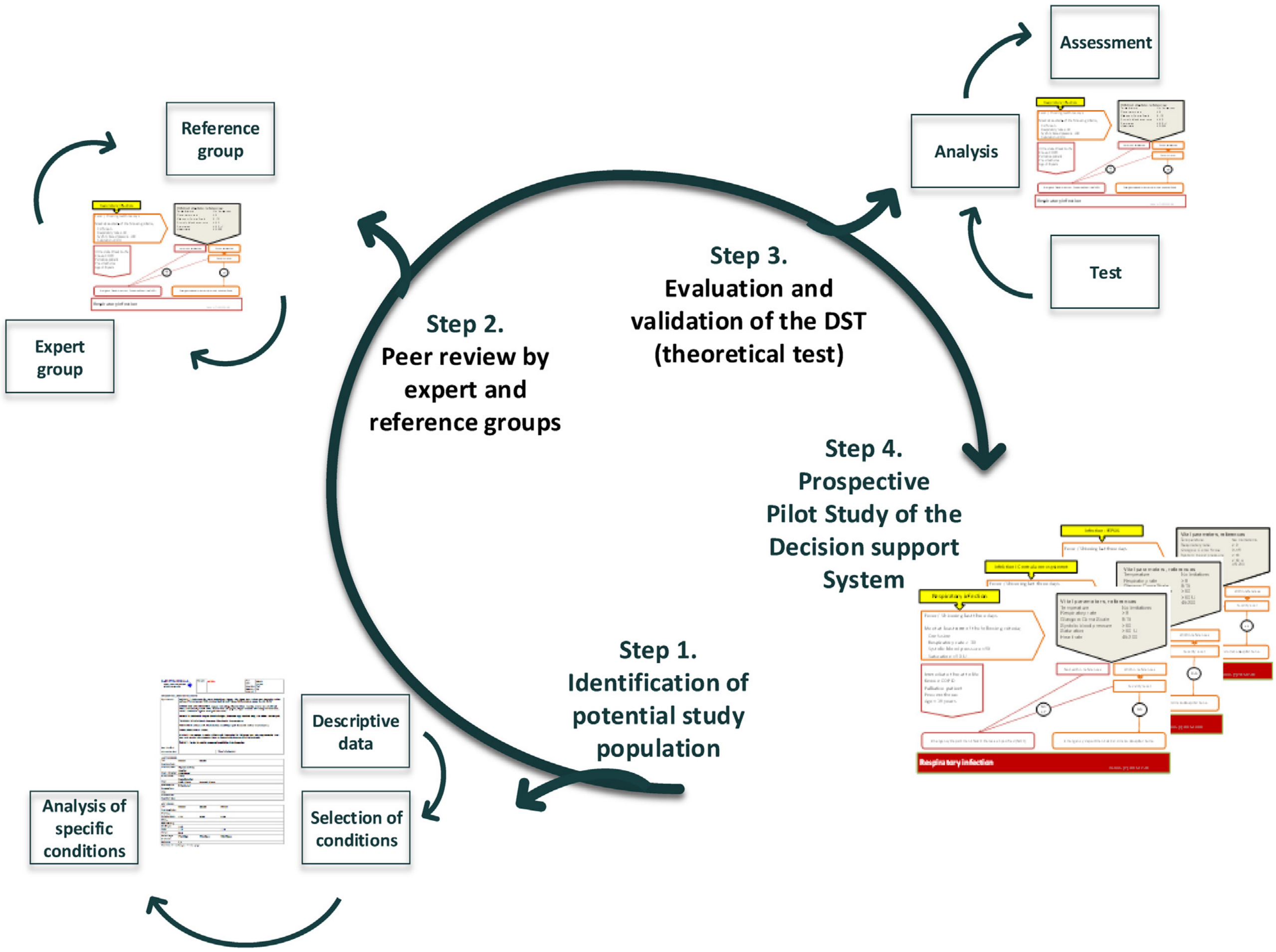

Figure 1. The four consecutive steps in developing the pre-hospital decision support system for acute infection patients.

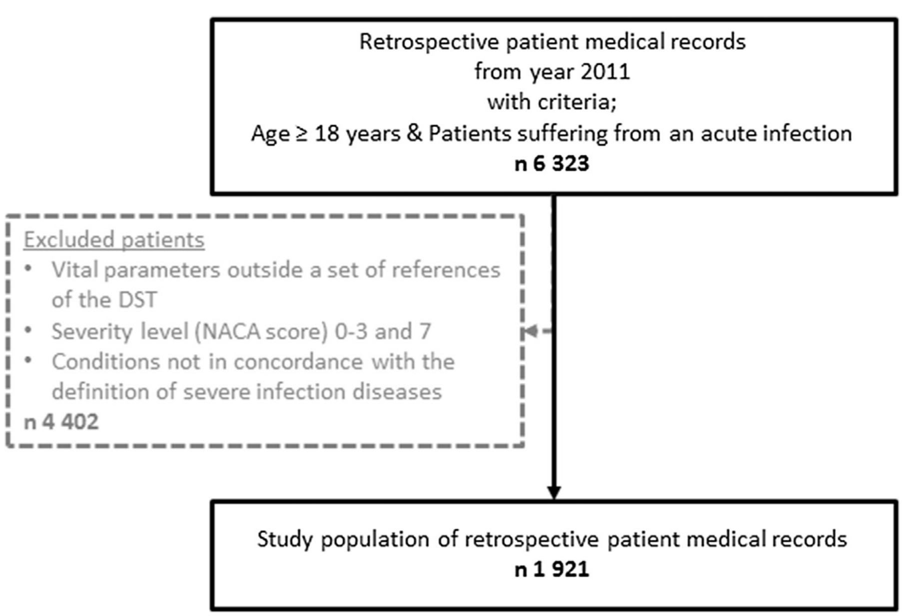

Figure 2. Patients with severe infections identified retrospectively in the EMS electronic patient care system (ePCR) with medical conditions that were hypothetically possible to triage to the specialist infection unit (at a trauma hospital).

petechiae (Glimaker et al., 2013; Heckenberg et al., 2014); and (3) sepsis required a clinical suspicion, fever/chills, and at least one of the following severity markers: respiratory rate ≥30/min, systolic blood pressure <90 mmHg, saturation <90% (Vårdprogram, 2013). At the hospital, the preliminary and final diagnoses of respiratory tract infection, CNS infection, or sepsis were made by the ID physician in charge.

Peer review of the preliminary DSS

Exclusion criteria included patients potentially having other conditions making them eligible for other steering processes: suspicion of cerebrovascular lesion/transient ischaemic attack, seizures, new neurological deficit, central chest pain, age <18 years, palliative patients. Moreover, even if patients fulfilled the criteria for steering to the ED-Spec, the PENs were still required to obtain the ID physician's telephone approval at the receiving ED-Spec in order to confirm their assessment and to rule out possible contraindications to transportation, according to the DST.

Step 3—Evaluation and validation of the DST (theoretical test)

The goal of the third step was to validate DST compliance and feasibility via a written test consisting of a questionnaire including 12 authentic clinical cases. The questionnaire was distributed to all PENs (n = 250) during a training scenario.

PENs were asked to complete all 12 cases. Each case had a set of five questions. They were to identify the relevant DST for each medical condition presented and then use it to triage the case. The questions were: (1) What medical condition do you assess the patient to have? (2) What severity level is applicable for this specific patient? (3) To which facility would you steer the patient: ED-NOS or ED-Spec? (4) Was there anything in the system that was difficult to understand or to use? (5) Any other comments?

The validity and reliability of the DST were agreed upon in consultation with the group of external peer reviewers.

Step 4—Validation of the pre-hospital DSS in a prospective pilot study

The goal of the fourth step was to validate the whole pre-hospital DSS (available in the Supplementary material, file 3) in a 4-month prospective pilot study. Before starting the study, all PENs involved received training and education. The curriculum included a case-based lecture about severe respiratory tract infections, CNS infections, and sepsis, a lecture on the pre-hospital DSS, a theoretical test, and a lecture on the clinical application and operation of the system.

Inclusion criteria in the pilot study were the following: (1) steering process during the hours of 8 a.m. to 4 p.m. weekdays (Monday to Friday; the time interval was chosen to ensure that an ID physician involved in the study would be present at the ED-Spec hospital during the study period); (2) ≥18 years of age; (3) resident in the specified geographical area; (4) priority level 1, 2, and 3 with level 1 being the most urgent; and (5) identified medical condition: lower respiratory tract infection/pneumonia, CNS infection, or sepsis.

The PENs followed the flowchart (DST), in paper form. Upon identification of one of the three predetermined conditions, the process in the DST was followed. This is described below for the example 'respiratory tract infection' (Figure 3).

After the PEN had identified a patient suspected of suffering from a respiratory tract infection, the patient was asked whether

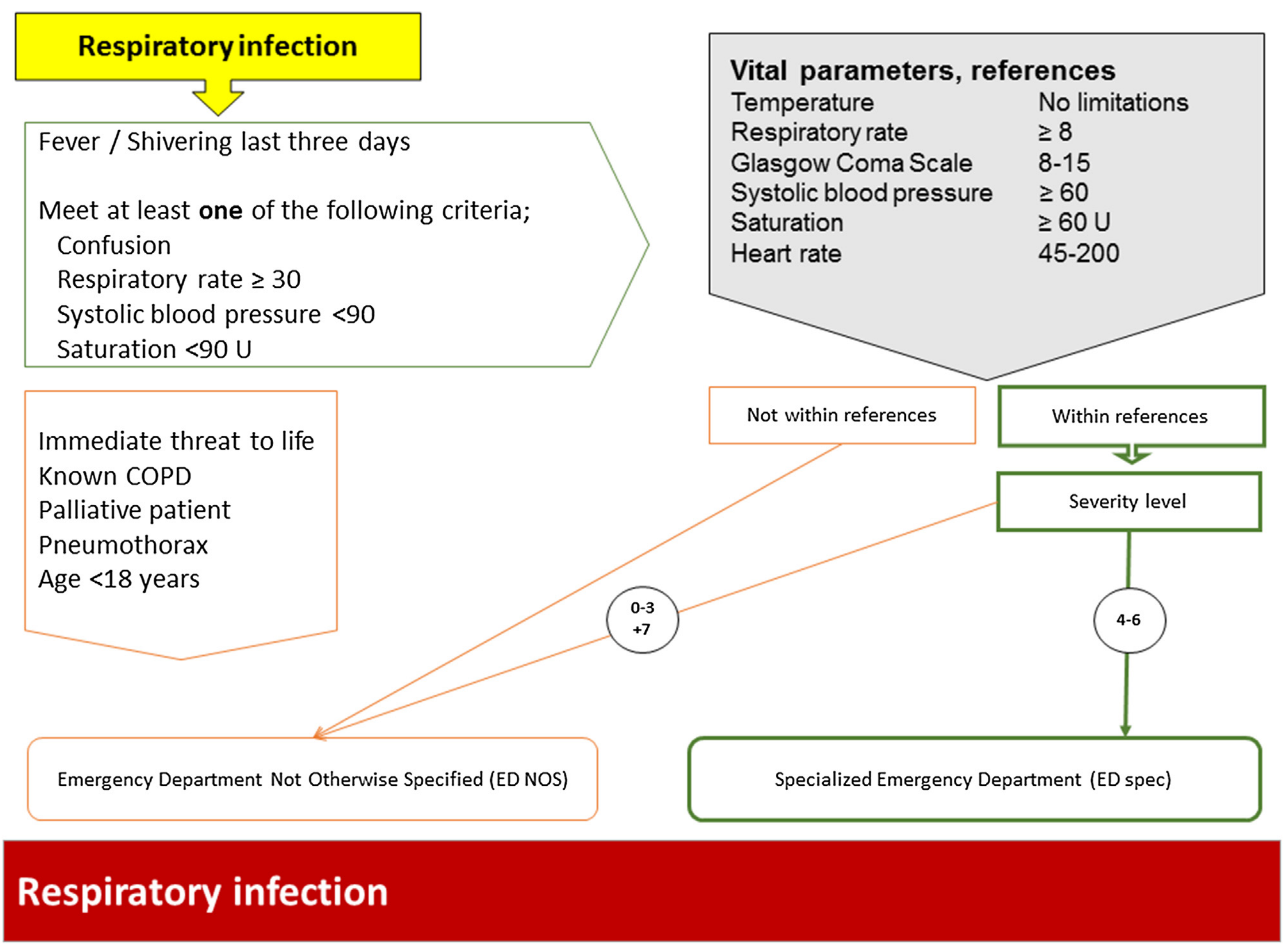

Figure 3. Pre-hospital decision support tool for 'respiratory infection disorder'.

they had experienced fever/shivering during the past 3 days. Furthermore, the patient was checked for the following criteria: confusion, respiratory rate ≥30/min, systolic blood pressure <90 mm/Hg, and/or saturation <90%. If the patient did not fulfil the criteria for transportation to the ED-Spec, he/she was transported to an ED-NOS. However, if the criteria were fulfilled, the PEN followed the flowchart and assessed the vital parameters and the severity level of the patient's illness (NACA score). Patients with a NACA score of 4–6 were to be transported to the ED-Spec. The exception was patients with a clinical condition at risk of impending immediate death. These patients were to be steered to the nearest hospital (load and go) regardless of steering processes. Patients with a severity level between 0 and 3 and those with a severity level of 7 were to be transported to the ED-NOS. If the patient did not have any of the three pre-identified conditions, they were excluded from the study. Palliative care patients were transported to the nearest ED-NOS.

Patients fulfilling the criteria for the ED-Spec were given written and oral information and their informed consent was obtained by the PEN. Before steering these patients, the PEN was also required to obtain telephone approval from the attending ID physician at the receiving ED-Spec. Ethical approval was obtained from the Regional Ethics Committee at Karolinska Institute, Stockholm (register number 2013/1558-2).

Data collection in the pilot study

All patients included in the study were registered prospectively. Data on vital signs, estimated pre-hospital condition, and transportation time to the hospital must always be registered by EMS personnel for all patients transported to the hospital by ambulance. These data were collected from the EMS record forms for all patients assessed as having one of the three infectious conditions, regardless of whether they were steered to the ED-Spec or the ED-NOS. The investigators (NJ and JV) collected data on the ID physicians' preliminary diagnosis at the ED-Spec, final diagnosis at discharge from the hospital, and on patient mortality from the ePCR.

Statistical analysis of the pilot study

Statistical analyses were performed using the Kruskal–Wallis test for non-parametric comparison of the median values of the groups. Additional results were expressed as risk ratios with 95% confidence intervals, and compared using the Chi-square test. All reported p-values are two-sided.

Results

Compliance with the DST in the theoretical test

In the evaluation and validation of the DST, all PENs ($n = 250$) answered the questionnaire, as described above. Of these 250 questionnaires (15 000 question responses), 58 were excluded (3480 responses) as being impossible to evaluate because of missing data. In all, 192 surveys (11 520 responses) were analyzed. Validation of the results showed 92.2% adherence to the protocol, with PENs correctly identifying the patients' medical conditions in all cases. In 15 cases (7.8%), adherence to the DST failed. Most PENs found the pre-hospital DSS comprehensible, feasible, and easy to use.

The prospective pilot study

Baseline characteristics of the different groups for pre-hospital steering

During the 4-month study period, 351 patient conditions were classified by the EMS as respiratory tract infection, CNS infection, or sepsis. However, 279 of these patients did not fulfil the inclusion criteria (patient age ≤17 years, referral of patients (transport between hospitals), identification of the three conditions outside the inclusion times for the study (weekends and evenings/nights), palliative patients, and patients already included in another steering process). Thus 72 patients were finally included in the study (Figure 4).

Of the 72 patients in the study population available for pre-hospital steering, 29 (40.3%) were steered to ED-NOS and 43 (59.7%) to ED-Spec, guided by the pre-hospital DST. However, after telephone contact with the ID physicians, nine of the 43 patients were denied (cross-over) and were redirected to ED-NOS. The physicians' reasons for denying these patients were as follows: personnel shortages in the ward ($n = 2$), bed shortage in the hospital ($n = 5$), and other reasons ($n = 2$). In accordance with the DST, immediate threat to a patient's life led to direct steering to the nearest hospital ($n = 4$).

The baseline characteristics of all of the patients in the study groups are presented in Table 1.

The compulsory confirmation telephone contact between the PENs and the ID physicians at the receiving ED-Spec was perceived by both parties as easy to use, often instructive, and as facilitating the process.

PEN compliance with the DST in the pilot study

In the 72 patients included in the study, respiratory tract infection was the most frequently suspected condition ($n = 41$, 56.9%), followed by sepsis ($n = 28$, 38.9%). CNS infections were only suspected in a few cases ($n = 3$, 4.2%). The PENs adhered to the DST in 66/72 patients (91.6%). Six patients were erroneously steered to the ED-NOS, five because the PEN did not follow the DST vital signs reference frame. One patient fulfilled the criteria for ED-NOS but was incorrectly transported to the ED-Spec.

Accuracy of steering with the DST

Of the 34 patients steered to the ED-Spec, assessment by the ID physicians was concordant with the PEN assessment in 32 cases, thus resulting in a positive predictive value of 94%. For 30 of the 34 patients (88%), the PEN and ID physician assessments were also congruent with the final diagnosis at discharge (Figure 5).

Transportation time and mortality

The median transportation time by ambulance to the ED-Spec was 53 min (range 29–87 min), compared to 47 min (range 32–71 min) for transportation to the ED-NOS ($p = 0.63$).

Three of the 34 patients steered to the ED-Spec died during their hospital stay. Two of these had the ED-Spec as their nearest hospital. The third patient had a transportation time to the ED-Spec of approximately 3 min longer than would have been required to arrive at the nearest ED-NOS. No patient admitted to the ED-Spec hospital was transported from the hospital within 24 h.

Discussion

The main findings of this study are (1) compliance with the DST was high overall, both regarding the questionnaire for the EMS and the pilot study; (2) the accuracy of the DSS was high, with an almost 90% congruence with the assessments and investigations in hospital; and (3) there was no difference in median transportation time to the ED-Spec vs. to the nearest hospital (ED-NOS).

The regionalization of emergency care has been discussed for many years but has not yet been widely developed in the EMS (Cone et al., 2010). Trauma steering protocols are still the most widely established (Cone et al., 2010; MacKenzie et al., 2006; Purtill et al., 2008; Fries et al., 1994), but pre-hospital triage of acute stroke to specific units for thrombolysis (Berglund et al.,

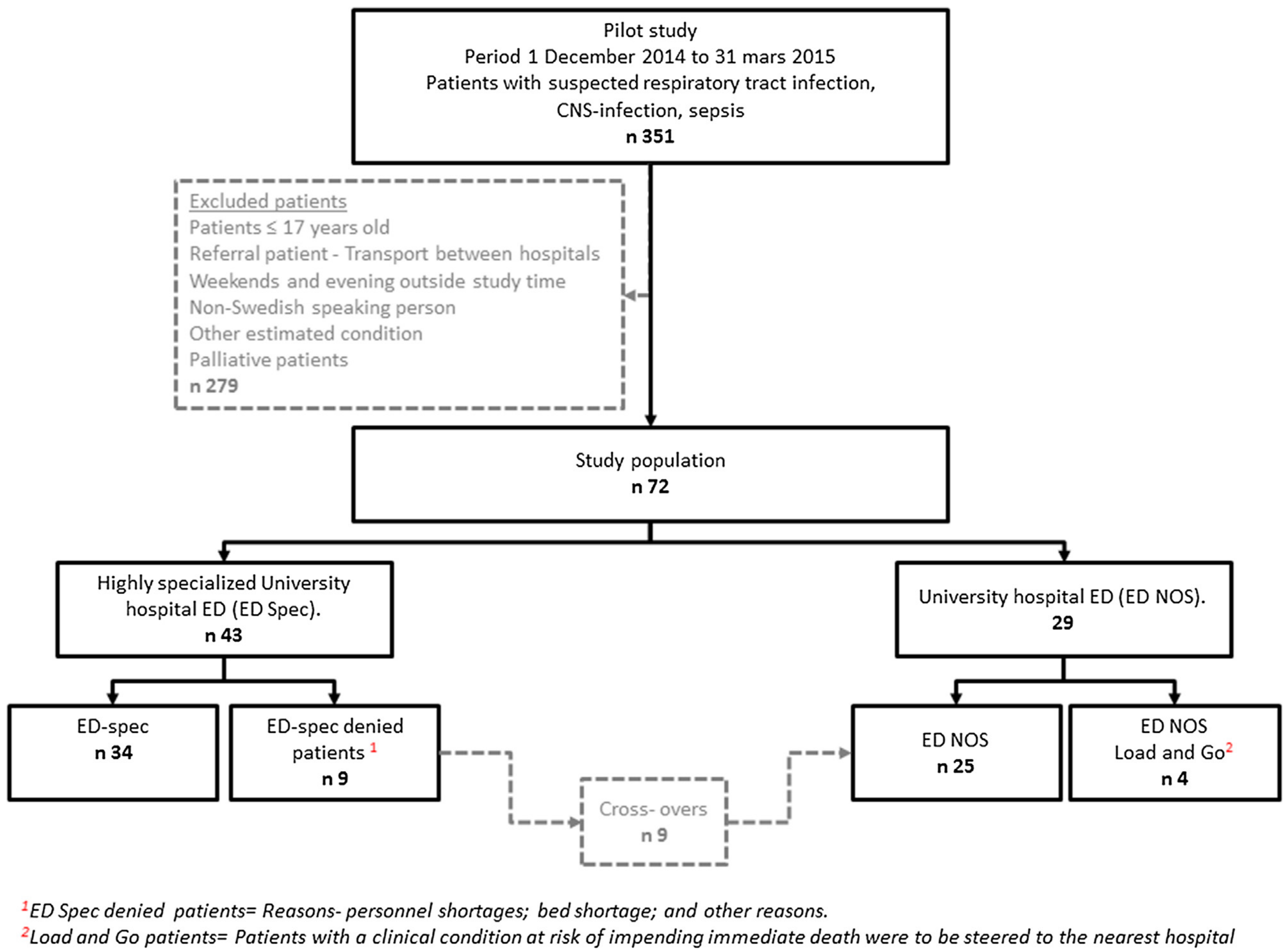

Figure 4. Inclusion process for the acute infection patients in the pilot study.

2012, Crocco et al., 2007) and of cardiac arrest to certain hospitals (Davis et al., 2007) has also been developed.

The care in all ambulances in Sweden has recently undergone major changes through the upgrading of medical skills and recruitment of specialized nurses. However, the only study in Stockholm County describing triage with decision support in the ambulance to obtain an optimal care level is one on geriatric patients; this previous study showed promising results (Vicente et al., 2013, 2014).

It appears that steering processes for severe infection conditions have not been investigated previously. The aim of this investigation was therefore to develop and evaluate a DSS for severe respiratory tract infections, CNS infections, and sepsis within a pilot study. The results of the present pilot study are promising enough to support a larger prospective study. Such a study should be designed to further investigate the possible pre-hospital steering of severe infectious conditions by use of a DSS, and also most importantly to evaluate the clinical implications of such a triaging.

The results of this pilot study show that PENs achieved high adherence to the DST (91.6%). In all but one of the incorrectly steered cases, the patients should have been steered to the ED-Spec instead of the ED-NOS.

The accuracy of PEN steering of patients when using the DST was high. Concordance between the PEN assessments and those of the ID physicians at the ED-Spec was 94% (32/34 patients). Furthermore, of the 34 patients suspected by the PENs to have a respiratory tract infection, sepsis, or CNS infection, 30 (88%) were discharged with a final diagnosis congruent with the suspected diagnosis. Maximum accuracy is crucial when steering severely ill patients to an optimized level of hospital care, both from a safety perspective and also because hospital resources are often limited. DSTs that over-triage patients may therefore potentially have a negative effect on optimal hospital care. The fact that the ID physician in the receiving unit denied nine patients fulfilling the inclusion criteria, who were then redirected to an ED-NOS, illustrates this dilemma.

Previous studies on sepsis have suggested that recognition of this condition by ambulance personnel is poor (Guerra et al., 2013; Wallgren et al., 2014). In a questionnaire-based investigation including patients with severe infections, Suffoletto et al. (2011) showed that subjective PEN assessment plus objective physiological data did not adequately indicate the patients' need for hospital admission. EMS personnel in the present study attended a specialized education programme focusing on severe respiratory tract infections, sepsis, and CNS infections, which might have contributed to the results in the pilot study. Green et al. (2016) recently showed a high ability of EMS personnel to recognize sepsis (78.2% accuracy compared with the emergency physicians' assessments) when supported by a prediction tool after specific education on sepsis. Moreover, the design of the present study made it compulsory for the PENs to call the ID physician in the receiving unit for confirmation before transportation of the patient, probably increasing the accuracy of correct steering.

Several earlier, mainly retrospective studies have evaluated different prediction tools for identifying septic patients pre-hospital. They showed only moderate sensitivity and specificity (Smyth et al., 2016; Lane et al., 2016; Seymour et al. 2010; Bayer

Table 1
Baseline characteristics of the acute infection patients: prospective study population ($N = 72$).

	Steered to ED-Spec ($n = 34$)	Denied steering to ED-Spec, so steered to ED-NOS ($n = 9$)	Steered to ED-NOS ($n = 25$)	Steered to ED-NOS due to immediate threat to life ($n = 4$)	p-Value for the comparison between ED-Spec and ED-NOS
Age (years), mean ± SD	72 ± 18	79 ± 11	76 ± 18	73 ± 15	0.327
Sex, n (%)					0.750
Female	16 (47.1%)	4 (44.4%)	14 (56.0%)	1 (25.0%)	
Male	18 (52.9%)	5 (55.6%)	11 (44.0%)	3 (75.0%)	
Vital parameters, mean ± SD					
Temperature (°C)	38.6 ± 0.8	38.7 ± 0.9	38.1 ± 1.1	39.0 ± 1.9	0.062
Respiratory rate (RT/min)	36.7 ± 8.2	29.7 ± 11.1	27.0 ± 8.8	41 ± 7.3	0.000
Systolic blood pressure (BP/mmHg)	120 ± 32.7	120 ± 35.6	127 ± 24.8	87 ± 22.1	0.442
Saturation (%)	86 ± 6	88 ± 3.4	90 ± 6.9	66 ± 21.8	0.019
Heart rate (HR/min)	107 ± 21.4	87 ± 28.4	106 ± 18.4	111 ± 20.1	0.756
VAS (0–10)	9 ± 23.8	Missing	Missing	Missing	
P-Glucose (mmol/l)	8.9 ± 4.0	7.5 ± 1.3	11.6 ± 4.6	13.2 ± 6.8	0.090
Glasgow Coma Scale (GCS), n (%)					0.446
Mild (GCS ≥13)	27 (79.4%)	6 (66.7%)	22 (88.0%)	0 (0.0%)	
Moderate (GCS 9–12)	6 (17.6%)	2 (22.2%)	2 (8.0%)	1 (25.0%)	
Severe (GCS ≤8)	0 (0.0%)	1 (11.1%)	0 (0.0%)	3 (75.0%)	
Missing	1 (2.9%)	0 (0.0%)	1 (4.0%)	0 (0.0%)	
NACA score[a], n (%)[a]					0.000
0–3	2 (5.9%)	2 (22.2%)	17 (68.0%)	0 (0.0%)	
4–6	32 (94.1%)	7 (66.6%)	8 (32.0%)	4 (100.0%)	
7	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Priority level out (EMCC): to the patient, n (%)[b]					0.351
1	17 (50.0%)	4 (44.4%)	8 (32.0%)	4 (100.0%)	
2	5 (44.1%)	5 (55.6%)	14 (56.0%)	0 (0.0%)	
3	2 (5.9%)	0 (0.0%)	3 (12.0%)	0 (0.0%)	
Priority level in (EMS): to the hospital, n (%)[b]					0.000
1	30 (88.2%)	4 (44.4%)	6 (24.0%)	4 (100.0%)	
2	4 (11.8%)	5 (55.6%)	17 (68.0%)	0 (0.0%)	
3	0 (0.0%)	0 (0.0%)	2 (8.0%)	0 (0.0%)	
Pre alerted the ED, n (%)					0.000
Yes	31 (91.2%)	4 (44.4%)	6 (24.0%)		
No	3 (8.8%)	5 (55.6%)	19 (76.0%)		
Ambulance assignment time to tertiary care hospital (min), mean ± SD					0.000
	53 (29–87)	53 (33–65)	47 (32–71)	37 (24–52)	0.063

ED, emergency department; ED-Spec, specialized emergency department; ED-NOS, emergency department not otherwise specified; SD, standard deviation; VAS, visual analogue scale score; NACA, National Advisory Committee for Aeronautics; EMCC, Emergency medical communication centre; EMS, emergency medical services.
[a] The NACA score, with levels 0–7, grades the illness and severity of the injury; see Supplementary material.
[b] The priority levels 1–4 for EMS transport; see Supplementary material.

et al., 2015). However, the design of these previous studies differed from that of the present study, making comparisons of the results difficult.

A possible problem with all steering processes is the potentially longer transportation time for patients with severe conditions. No major differences in transportation time were noted between the groups in this study. Since it could be argued that these two groups are not completely comparable, the transportation time for patients with these three conditions and the same inclusion criteria as for steering to ED-Spec were analysed during a corresponding time period 1 year later (December 2015 to March 2016) when the patients were transported to the nearest hospital. Again there was no major difference in transportation time (median time 45 min, range 14–107 min). A 3-min extra transportation time was observed for one of the patients with a fatal outcome, but it is difficult to establish whether this had any impact on the outcome.

This study has a number of limitations. It was relatively small – only one of three ambulance companies and only one large city were included. Furthermore, it was not designed to estimate the sensitivity and specificity of the DSS among these cohorts of patients. Gathering retrospective data from the ePCR might have resulted in incorrectly filled-in forms. Also, EMS personnel in different countries and even within one country have different qualifications. These facts must be taken into account when interpreting the results of the present study. Nevertheless, the aim of this investigation was to develop a DSS and evaluate whether it is possible for the EMS to follow it. A more thorough evaluation regarding the different implications of this steering process will be performed in a larger forthcoming prospective study that will also involve the other hospitals in Stockholm County. The high compliance of the EMS to the protocol could possibly have been confounded by the fact that the personnel were aware that there was a study going on. However the main question in this pilot study was only whether it is possible to identify and steer these conditions pre-hospital. Whether it will be possible to maintain this high level of adherence to the protocol over time will also be evaluated in the forthcoming prospective study.

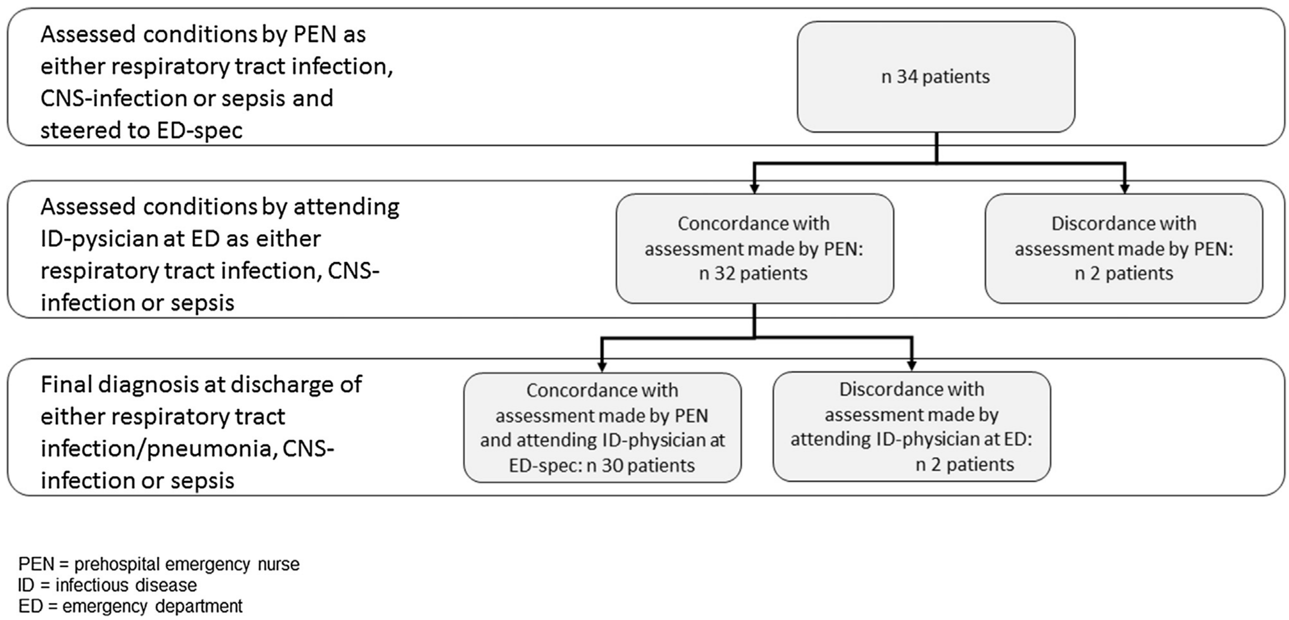

Figure 5. Conditions among the cohort of patients steered to the specialized emergency department (ED-Spec) according to the pre-hospital emergency nurses (PENs), the infectious diseases physician on call at the emergency department, and the final diagnosis on discharge from the hospital.

In summary, with the help of this pre-hospital DSS, Swedish PENs could correctly identify three severe infectious diseases and decide the optimal level of healthcare for transportation.

Acknowledgements

We gratefully acknowledge Ralph Bolander (RB), Senior Adviser and Physician, for his expert knowledge and cooperation, as well as the senior ID specialists and researchers Jonas Hedlund, Martin Glimåker, and Patrik Gille-Johnson for their valuable contributions in the expert group. We also thank AISAB and their personnel for their commitment to and participation in this study.

Ethical approval

Ethical approval was obtained from the Regional Ethics Committee of Karolinska Institute, Stockholm (register number 2013/1558-2).

Conflict of interest

No financial or other relationship that might lead to a conflict of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ijid.2018.04.4321.

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