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

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ABSTRACT

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.
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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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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 ≥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 ≥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,

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