TURUN
YLIOPISTO
UNIVERSITY
OF TURKU

NON-CONVEYANCE AND PATIENT SAFETY IN PREHOSPITAL EMERGENCY CARE

Jani Paulin

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
SARJA – SER. D OSA – TOM. 1656 | MEDICA – ODONTOLOGICA | TURKU 2022

TURUN
YLIOPISTO
UNIVERSITY
OF TURKU

NON-CONVEYANCE AND PATIENT SAFETY IN PREHOSPITAL EMERGENCY CARE

Jani Paulin

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
SARJA – SER. D OSA – TOM. 1656 | MEDICA – ODONTOLOGICA | TURKU 2022

University of Turku

Faculty of Medicine
Anaesthesiology, Intensive Care, Emergency Care and Pain Medicine
Prehospital Emergency Care
Doctoral Programme in Clinical Research

Supervised by

Timo Iirola, MD, PhD
Emergency Medical Services
Turku University Hospital and
University of Turku
Turku, Finland

Professor, Jouni Kurola, MD, PhD
Prehospital Emergency Medicine
University of Eastern Finland
Kuopio, Finland

Reviewed by

Docent Annika Takala, MD, PhD
Unit of Quality and Patient Safety
Hospital District of Helsinki
Helsinki, Finland and
Tampere University
Tampere, Finland

Docent Antti Kämäräinen, MD, PhD
Emergency Department, Hyvinkää
Hospital, Hyvinkää, Finland and
Tampere University
Tampere, Finland

Opponent

Docent Sanna Hoppu, MD, PhD
Emergency Medical Services
Tampere University Hospital and
Tampere University
Tampere, Finland

ISBN 978-951-29-8959-1 (PRINT)
ISBN 978-951-29-8960-7 (PDF)
ISSN 0355-9483 (Print)
ISSN 2343-3213 (Online)
Painosalama, Turku, Finland 2022

To my family

UNIVERSITY OF TURKU
Faculty of Medicine
Anaesthesiology, Intensive Care, Emergency Care and Pain Medicine
JANI PAULIN: Non-conveyance and patient safety in prehospital emergency care
Doctoral Dissertation, 128 pp.
Doctoral Programme in Clinical Research
August 2022

ABSTRACT

Emergency medical services (EMS) and emergency departments (EDs) have reported increased attendance rates and numbers of patients without urgent need for treatment. Because of controversy about the unnecessary conveyance to the ED, EMS has increasingly discharged patients at the scene, although it is unclear how non-conveyance ensures patient safety.

This was a prospective cohort study with three sub-studies from three regions in Finland. The overall aim was to explore whether EMS non-conveyance ensures patient safety. EMS re-contact, unscheduled visits to a primary health care facility or ED, and hospitalization within 0–24 and 24–48 h were the primary outcomes, and mortality in 28 days was the secondary outcome. Multivariable logistic regressions analyses, machine learning in the form of text classification, and manual analyses were used to identify predictors of adverse events.

The study data comprise 40,263 EMS patients, 42% of whom were discharged at the scene. Among the included non-conveyed patients (n=11,861), 6.3% re-contacted EMS, 8.3% visited a primary health care facility and 4.2% the ED, 1.6% were admitted to the hospital, 0.3% were treated in intensive care, and 0.1% died within 0–24 h after the non-conveyance. These rates were lower within 24–48 h than within 0–24 h. Factors associated with non-conveyance and a subsequent primary health care visit were non-urgent mission priority, involvement of an advanced life support unit (ALS), EMS arrival at night, and rural location. FastText-model (area under the curve (AUC), 0.654) and manual analyses indicated that several health care re-contacts were planned before between the patient and EMS personnel.

In conclusion, most patients did not have events after EMS non-conveyance. Post-non-conveyance re-contacts do not necessarily indicate that patient safety was jeopardized, as these contacts can represent previously planned visits to health care facilities. Non-conveyance by EMS does not appear to compromise patient safety, but further studies are warranted.

KEYWORDS: Emergency medical service, Non-conveyance, Adverse outcome, Patient safety, Machine learning, Adjusted ICPC-2, NEWS2

TURUN YLIOPISTO
Lääketieteellinen tiedekunta
Anestesiologia, tehohoito, ensihoito ja kivunhoito
JANI PAULIN: Kuljettamatta jättämisen potilasturvallisuus ensihoidossa
Väitöskirja, 128 s.
Turun kliininen tohtoriohjelma
Elokuu 2022

TIIVISTELMÄ

Ensihoitopalvelun ja päivystysten suuret potilasmäärät ja turhat päivystyskäynnit on tunnistettu laajasti. Ensihoitajat jättävät paljon potilaita kuljettamatta jatkohoitoon, jos välitöntä päivystyksellistä hoidon tarvetta ei ole. Menettelyn potilasturvallisuus on kuitenkin epäselvä.

Tämän prospektiivisen kohorttitutkimuksen aineisto kerättiin kolmen sairaanhoitopiirin alueelta Suomessa. Tutkimuskokonaisuuden tarkoituksena oli selvittää, onko ensihoitajien tekemä päätös potilaan kuljettamatta jättämisestä potilasturvallista. Ensisijaisia päätetapahtumia olivat uusi ensihoitotehtävä, päivystyskäynti perusterveydenhuollossa tai erikoissairaanhoidossa, sekä sisäänotto sairaalaan 0–24 ja 24–48 h kuljettamatta jättämisen jälkeen. Potilaan kuolema 28 vuorokauden aikana oli toissijainen päätetapahtuma. Logistista regressioanalyysiä (monimuuttujamalli), tekstin louhintaa ja koneoppimista, sekä manuaali- ja sisällön analyyseja käytettiin haittatapahtumia ennustavien tekijöiden tunnistamisessa.

Ensihoidon potilaista (n=40,263) 42 % jätettiin kuljettamatta jatkohoitoon. Mukaan otetuista potilaista (n=11,861) 6.3 % oli uusi ensihoitotehtävä, 8.3 % käynti perusterveydenhuollossa, 4.2 % käynti erikoissairaanhoidossa, 1.6 % otettiin sisälle sairaalaan, 0.3 % hoidettiin teho-osastolla ja 0.1 % menehtyi 0–24 h. Vastaavat prosentit olivat matalampia 24–48 h kuljettamatta jättämisen jälkeen. Kiireetön ensihoitotehtävä, hoitotason yksikkö, ilta-yöaika ja haja-asutusalue lisäsivät perusterveydenhuollon käynnin todennäköisyyttä. FastText-mallin (AUC 0.654) ja manuaalisten analyysien mukaan moni päätetapahtumista oli suunniteltu etukäteen.

Suurimmalla osalla potilaista ei ollut päätetapahtumia seurantajakson aikana ja terveydenhuollon kontakteista moni oli suunniteltu etukäteen. Ensihoitajien tekemä hoidon tarpeen arvio ja päätös kuljettamatta jättämisestä näyttää olevan potilasturvallista, mutta lisätutkimuksia tarvitaan.

AVAINSANAT: Ensihoitopalvelu, kuljettamatta jättäminen, haittatapahtuma, potilasturvallisuus, koneoppiminen, muokattu ICPC-2, NEWS2

Table of Contents

Abbreviations

ABCDE	Airway, Breathing, Circulation, Disability, Exposure
aOR	Adjusted Odds Ratio
ALS	Advanced Life Support
ACVPU	Alert, Confusion, Verbal, Pain, Unresponsive
AUC	Area Under the Curve
BLS	Basic Life Support
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
ED	Emergency Department
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
ePCR	Electronic Patient Care Reporting
ERC	Emergency Response Center
EWS	Early Warning Score
GCS	Glasgow Coma Scale
HEMS	Helicopter Emergency Services
ICD-10	International Classification of Diseases
ICPC-2	International Classification of Primary Care, Second Edition
IQR	Interquartile Range
LSTM	Long Short-Term Memory
OR	Odds Ratio
NEWS2	National Early Warning Score
SpO_2	Blood Oxygen Saturation
STROBE	The Strengthening the Reporting of Observational Studies in Epidemiology
WHO	World Health Organization

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Paulin J, Kurola J, Salanterä S, Moen H, Guragain N, Koivisto M, Käyhkö N, Aaltonen V, Iirola T. Changing role of EMS – analyses of non-conveyed and conveyed patients in Finland. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2020;28:45.

II Paulin J, Kurola J, Koivisto M, Iirola T. EMS non-conveyance: A safe practise to decrease ED crowding or a threat to patient safety? BMC Emergency Medicine 2021;21:115.

III Paulin J, Reunamo A, Kurola J, Moen H, Salanterä S, Riihimäki H, Vesanen T, Koivisto M, Iirola T. Using machine learning to predict subsequent events after EMS non-conveyance decisions. BMC Medical Informatics and Decision Making 2022;22:166.

1 Introduction

Patient safety is a priority in health care (Kohn et al. 1999), and every patient has the right to receive good care (Act on the Status and Rights of Patients 785/1992, The National Advisory Board on Social Welfare and Health Care Ethics 2012). However, according to the World Health Organization (WHO) (2021), unsafe care and patient harm are a global challenge and one of the factors contributing to patient death and disability. It has been reported that 1 in 10 care events occurs as an error in both in-hospital (WHO 2021) and prehospital care (O'Connor et al. 2021b). The cost of unsafe care in developed countries is more than $606 billion US annually, even as a human capital approach suggests that harm elimination could boost global economic growth by more than 0.7% per year (Slawomirski et al. 2020).

Emergency medical services (EMS) interact directly or indirectly with large number of people, and in Finland, EMS completes more than 800 000 missions annually, at a cost of 300 million (National Audit Office of Finland 2019). Traditionally, EMS provides prehospital health care to patients with sudden and life-threatening injuries or emergencies (Al-Shaqsi 2010). However, because of the aging population and limited access to primary health care, the number of non-urgent patients and the EMS workload have increased (Lowthian et al. 2011, Andrew et al. 2019). As a result, patients are increasingly being discharged at the scene after EMS assessment and treatment (Fisher et al. 2015). Although EMS structure varies globally, non-conveyance is a part of every EMS system (Ebben et al. 2017). In Finland, approximately 40% of patients are not conveyed to a health care facility (Hoikka 2017, Pekanoja 2018, Laukkanen et al. 2021). This practice decreases ED crowding (Fisher et al. 2015), but an inappropriate non-conveyance decision may risk patient safety. On the other hand, unnecessary conveyances to EDs waste limited resources (Khorram-Manesh et al. 2011), and a crowded ED is also a threat to patient safety (Berg et al. 2019, Boyle et al. 2021, Jones et al. 2022).

Finally, patient safety needs greater consideration in prehospital emergency care (O'Connor et al. 2021b). According to recent reviews, limited evidence is available regarding patient safety when it relates to EMS non-conveyance (Ebben et al. 2017, Yeung et al. 2019, Blodgett et al. 2021).

2 Review of the Literature

2.1 Emergency medical services in general

The history of prehospital emergency care originates with wars and the care needed by the wounded. In the 19th century, the first transport services started in England, and for a long time, patients were simply taken to the hospital without more specific assessment and treatment (Pozner et al. 2004, Shah 2006, Fisher et al. 2015). However, in the last four decades, hospital practices have been modified for use in prehospital emergency care (Bigham et al. 2015, Fisher et al. 2015). EMS now includes deteriorated or injured patient assessment and treatment and when needed, conveyance to a health care facility (Roudsari et al. 2007). Two historical models of prehospital emergency care persist today. The Franco-German model is based on an EMS "stay and stabilize" -philosophy focused on providing hospital treatment in the prehospital phase. The philosophy is widely applied in Europe and has expanded from emergency physician treatments at the scene to other units. The basis of the Anglo-American model is more of a "scoop and run" -philosophy that focuses on delivering the patient as fast as possible to the hospital. In this model, which is used in the United States, treatment in prehospital emergency care is more limited. (Dick 2003, Pozner et al. 2004.)

In general, EMS is a key part of a health care system (American College of Emergency Physicians 2018), but its place in the system varies among countries (WHO 2005, Roudsari et al. 2007, Pickering et al. 2009, Booker et al. 2015, Sun et al. 2017) and between rural versus urban areas (Alanazy et al. 2019). Although the challenges and possibilities are mainly identical (Pickering et al. 2009), analysis of the systems is difficult because of important dissimilarities (Booker et al. 2015). For example, funding can be tax-based as in Nordic countries or in the UK (Langhelle et al. 2004, Black et al. 2005, Lindskou et al. 2019), voluntary-based as in Mexico, or based on privately funded service or a mixed funding model (WHO 2005). If the funding system is privately supported, as is mainly the case in the United States, health insurance is required because of the high cost of the service (Pozner et al. 2004).

The EMS systems often involve at least two tiers, including units of basic life support (BLS) and advanced life support (ALS). The classification is based on EMS

personnel education level, training, and the treatment the units perform. (Al-Shaqsi 2010.) BLS units are mainly crewed by emergency medical technicians (EMTs) and ALS units by paramedics, but in the United States, EMT is a generic term for three levels of EMS personnel (EMT-basic, EMT-intermediate, and EMT-paramedic) (Pozner et al. 2004, Van Gelder et al. 2005). EMS personnel's education varies among countries (Bos et al. 2015, Brooks et al. 2016) from college level to the university level (Dúason et al. 2021). In Sweden, for example, EMS units are staffed by at least one registered nurse who has additional specialization for prehospital emergency care (Lederman 2021). However, co-ordinate bachelor level education for paramedics within European countries with a common curriculum has been requested because of the increasing need for highly educated paramedics (Dúason et al. 2021).

An emergency dispatch center, a key element of EMS systems, dispatches EMS units after emergency calls and risk assessment (Ornato 2009). The organization of the dispatch service and platforms also varies as well (Lyon et al. 2013). In addition to the two-tier EMS system, many countries rely on volunteer-based first responders, especially in rural areas (Pozner et al. 2004), and on units with a physician that are operated by helicopter emergency services (HEMS) or by ground units (Booker et al. 2015). In Scandinavia, EMS physicians often are senior anesthesiologists who provide advanced critical care as well as telemedicine consultation services for paramedics at the scene (Van Schuppen et al. 2011, Friberg et al. 2018).

The number of EMS missions and pressure on EDs both have increased (Lowthian et al. 2011, Carter et al. 2014, Andrew et al. 2019, Hegenberg et al. 2019, Boyle et al. 2021) because of an aging population, limited access to primary health care, and absence of social support, among other factors (Lowthian et al. 2011, Coster et al. 2017). There also are more non-urgent patients without need for medical intervention (Andrew et al. 2019) instead of patients in traditionally critical emergencies such as cardiac arrest, myocardial infarction, trauma, stroke, and severe breathing difficulty, known as the "first-hour quintet" (Krafft et al. 2003). Moreover, patients may call an ambulance for primary care problems. Thus, the meaning of "emergency" may differ between patients and health care providers, although what constitutes "inappropriate use" of EMS is unclear. (Morgans et al. 2012, Booker et al. 2015.) Regardless, there now are established community paramedic units whose expanded role includes, for instance, management of chronic disease, preventive care, and better follow-up care after the visit to ensure a better response to non-urgent patients and fill the gaps between primary health care and EDs (Choi et al. 2016, Rasku et al. 2019, Chan et al. 2019, Patton et al. 2021, Rasku 2022).

2.2 Structure of emergency care in Finland

The health care system in Finland is divided into primary and secondary care and funded by the government. Due to patients with unpredictable complaints, EMS and hospital ED services play vital roles in ensuring patient safety (Ministry of Social Affairs and Health 2019). Global trends such as an aging population and centralization of health care facilities are challenges in Finland as they are elsewhere. In the future, patients will likely be treated increasingly at home. (Ministry of Social Affairs and Health 2016, Ministry of Social Affairs and Health and Ministry of the Interior 2021.) Medical helpline services (tel. 116 117) gives guidance and assessment of the patient's need for services (Ministry of Social Affairs and Health 2022), but notably, EMS is a central part of emergency services in health care (Health Care Act).

Currently in Finland, the 21 hospital districts, including five university hospital districts, organize the EMS. The service can be provided by hospital districts themselves, in cooperation with rescue services, through purchase from private service providers, or as a hybrid (Ministry of Social Affairs and Health 2017). However, based on health and social services reforms of the well-being services, counties will organize all health care services beginning in 2023 (Finnish Government 2022).

2.3 EMS in Finland

In Finland, six governmental emergency response centers (ERCs) respond to the common emergency number 112, including all emergencies (medical, rescue, police, or social). The service is administered by a national dispatch authority. A criteria-based standardized dispatch protocol, guided by medical keywords and pre-set questions, is used for all incoming calls. After a risk assessment, four urgency categories (A, B, C, and D) are used for prioritizing the calls for EMS. A indicates the highest priority and a life-threatening condition; B means an urgent mission with lights and sirens as with priority A, but with the patient's condition unclear; C indicates an urgent mission with minor symptoms; and D represents an acute situation without urgent need for help. The formal education of a dispatcher takes 18 months without a health care professional qualification. It is notable that traditionally, dispatchers have a crucial role in the chain of care and correct risk assessment and dispatching of EMS and other resources (Dami et al. 2015). However, over-triage and challenges related to non-urgent missions have been discussed (Hoikka et al. 2016, Booker et al. 2018, Raatiniemi et al. 2018). There is evidence that secondary telephone triage after ERC assessment reduces EMS and ED workloads and improves patient safety and satisfaction (Eastwood et al. 2015, Krumperman et al. 2015, Eastwood et al. 2016, Ebert et al. 2017, Roivainen 2022).

Therefore, some pilots of secondary telephone triage also have started in Finland (e.g. Roivainen et al. 2020).

According to the Decree on the Emergency Medical Services, a four-tier EMS exists, including requirements for personnel training and education (Ministry of Social Affairs and Health 2017). First responders can be professional firefighters from the fire department or volunteers from the local fire brigade. The units can supply first aid and cardiopulmonary resuscitation (CPR) with automated external defibrillation, for example. BLS units are staffed by a registered nurse or college level educated person such as EMTs, a practical nurse, or a firefighter. The BLS units operate mostly in non-urgent missions and for inter-facility conveyances. Their capacities for treatment are limited, but they may, for example, provide intravenous medication in case of cardiac arrest, intravenous glucose 10% for hypoglycemia, intranasal fentanyl and midazolam, and drug inhalation by standing protocol or by teleconsultation. ALS units are crewed by at least one advanced level paramedic-nurse with 4 years of education (240 European Credit Transfer and Accumulation System) in University of Applied Sciences (dual degree; paramedic and registered nurse qualification) or by a registered nurse with one year of additional education for prehospital emergency care. Usually, the second crew member in an ALS unit is a registered nurse without additional specialization or is college level educated, as described above. The advanced level of care allows the units to provide critical care procedures and medications according to national or local instructions, including approximately 40 drugs such as intravenous oxycodone, fentanyl, midazolam, beta-blockers, adenosine, nitroglycerin, tranexamic acid, naloxone, and flumazenil, as well as intermediate or advanced airway management (Rehn et al. 2016) and non-invasive ventilation.

After assessment and treatment of care needs, a non-conveyance decision, described in more detail below, can be made independently by EMS personnel. Related to non-conveyance, the National Health Care Act provides the legal basis. However, teleconsultation with an EMS physician, or a physician from ED or from primary health care facility is always possible and in certain situations mandatory. Patients can be conveyed to central or regional hospitals or to primary health care units such as municipal health care centers. In some cases, patients may be conveyed to university hospitals located in other areas. In Finland's EMS, there are on-duty medical supervisor units staffed by an experienced paramedic-nurse with additional training and leadership education, and physician-staffed units (HEMS and ground units). Dispatch of these units is done according to the guidelines, but the personnel in BLS or ALS units can request additional help and units, as well. Moreover, community paramedic units exist in some areas. In general, the EMS units operate 24/7.

2.4 Patient safety

2.4.1 Patient safety culture

WHO (2021) defines patient safety as "a framework of organized activities that creates cultures, processes, procedures, behaviors, technologies and environments in health care that consistently and sustainably lower risks, reduce the occurrence of avoidable harm, make errors less likely and reduce the impact of harm when it does occur". The "To Err Is Human" report points out that instead of focusing on bad personnel, the whole system needs to be safer (Kohn et al. 1999). Patient safety can be seen as the heart of quality health care (Vincent 2010). According to Hagiwara et al. (2019), most errors are based on deviations from the standard of care. Crew resource management (CRM) and non-technical skills have been seen as a solution to increase patient safety in health care (Flin et al. 2010, Gross et al. 2019, Bennett et al. 2021). Although patient safety culture and safety climate vary among organizations (Lee et al. 2019), quality and patient safety should be integrated as part of the daily work and practices in health care organizations (Ministry of Social Affairs and Health 2019). Improvements in patient safety culture require, for instance, leadership support, staff involvement, and patient safety related programs and education (Campione & Famolaro 2018). Researchers should also turn more attention to using appropriate methods to obtain reliable results of patient safety (Lee et al. 2019).

2.4.2 Patient safety in EMS

A patient safety incident has been defined as an event that could have resulted, or did result, in unnecessary harm to a patient (Runciman et al. 2009), but there is no standard for determining patient safety incidents in EMS (O'Connor et al. 2021b). Thus, monitoring and measuring of patient safety in prehospital emergency care varies from reliance on record reviews and incident reporting systems to surveys and interviews (O'Connor et al. 2021a). Patient record review has been seen as a "gold standard" research method related to patient safety (Shojania et al. 2020), but there is no single method for the safety measures (O'Connor et al. 2021a). High-quality clinical registries and valid and reliable data are essential (Dreyer et al. 2009, O'Connor et al. 2021b), and trigger tools seem to be useful for capturing adverse events (Howard et al. 2017).

Risk for harm is high in prehospital emergency care due to challenging and unpredictable environment and hectic and rushed situations (Bigham et al. 2015). A recent review showed that globally, 5.9 adverse events occur per 100 EMS missions, with a higher rate in record review studies (9.9 per 100) and lower rate in incident

report studies (0.3 per 100) (O'Connor et al. 2021b). On the other hand, poor reporting has been identified, together with the fact that errors are not recognized (Fisher et al. 2015, Shojania et al. 2020). Even if the risk for an adverse event is higher among patients with life-threatening conditions (Hagiwara et al. 2019), non-conveyance has been seen as a central issue in the context of patient safety (Fisher et al. 2015). In addition to non-conveyance, Fisher et al. (2015) concluded, the focus of patient safety should be on patient assessment and management, communications, equipment, and resources.

2.4.3 Key processes related to patient safety in EMS

2.4.3.1 Detecting deteriorating patients

Assessment, triaging, and detecting deteriorating patients are essential in prehospital emergency care (Fisher et al. 2015). The purpose of a primary survey is to identify life-threatening problems, and the more detailed secondary survey includes specific history, incident, anamnesis, and vital signs recording. Different kind of algorithms are used, such as the Airway, Breathing, Circulation, Disability, Exposure (i.e. ABCDE) framework, which can be used for a structured approach (Blaber et al. 2016, Resuscitation Council UK 2021). New methods and equipment, such as point-of-care testing, also have been suggested (Blanchard et al. 2019). For instance, biomarkers such as lactate (Tobias et al. 2014, Martín-Rodríguez et al. 2020, Galvagno et al. 2020, Magnusson et al. 2021a) and soluble urokinase plasminogen activator receptor (suPAR) (Haupt et al. 2012, Rasmussen et al. 2016, Ivic et al. 2021) may offer additional benefit for assessment and decision making, although results are contradictory (Jousi et al. 2021). However, according to Patel et al. (2018), early warning scores (EWS) help identify patients at risk for deterioration and patients who can be safely discharged at the scene.

2.4.3.2 Early warning scores (EWS)

Several warning scores, such as the Modified EWS (MEWS), Standardized EWS (SEWS), National EWS (NEWS2), and Vitalpac EWS (VEWS), are used in different settings to identify deteriorating patients (Nannan Panday et al. 2017, Haniffa et al. 2018) as well as, e.g. RETTS-A (Rapid Emergency Triage and Treatment System) in Sweden (Magnusson et al. 2020b). However, NEWS2 is the most commonly used score (Nannan Panday et al. 2017), created by the Royal College of Physicians (2017). It scores six physiological parameters (breathing rate, oxygen saturation, systolic blood pressure, pulse, level of consciousness [ACVPU: Alert, Confusion, Verbal, Pain, Unresponsive] and temperature), and the overall score indicates the

risk for deterioration as low, low-medium, medium, or high. NEWS2 also is meant for use in prehospital emergency care. (Royal College of Physicians 2017.) Some validation has been performed (Silcock et al. 2015, Kievlan et al. 2016, Dziadzko et al. 2018), and results are promising in-hospital (Smith et al. 2013, Kivipuro et al. 2018), and prehospital (Shaw et al. 2017, Hoikka et al. 2018, Abbott et al. 2018, Martín-Rodríguez et al. 2019a, Martín-Rodríguez et al. 2019b, Pirneskoski et al. 2019, Endo et al. 2020), as well as in patients with COVID-19 (Myrstad et al. 2020, Veldhuis et al. 2021). Nevertheless, more evidence is needed (Williams et al. 2016, Patel et al. 2018), because other values such as glucose measurement might improve score performance (Vihonen et al. 2020). In addition, blood oxygen saturation (SpO_2) should be analyzed in relation to patient's diseases, although the overall benefit and influence on the NEWS2 score is unclear (Tirkkonen et al. 2019).

2.5 Practice of non-conveyance in EMS

2.5.1 Non-conveyance and reason for care in EMS

Non-conveyance is a term for discharge of the patient at the scene by EMS after assessment and treatment. The EMS provider usually makes the non-conveyance decision, but sometimes it is based on the patient's own perceptions or on patient refusal (Shaw et al. 2006). In Finland, the process is planned together with EMS and EDs based on the Health Care Act. According to Ebben et al. (2017), non-conveyance is globally very common and an increasing trend in many systems to avoid needless conveyances to EDs (Fisher et al. 2015). Cost-saving possibilities have been reported (Gupta et al. 2020), but cost-efficiency between non-conveyance and conveyance is not clear (CADTH 2014). It seems that patients tend to be satisfied after a non-conveyance decision, but the choice requires advanced competence by EMS (Krumperman et al. 2015, Rantala et al. 2016, Breeman et al. 2018, Salminen-Tuomaala et al. 2018, van Doorn et al. 2021, Larsson et al. 2022), and more studies are needed (King et al. 2021). Moreover, EMS personnel need organizational support (Knowless et al. 2018, Lederman et al. 2019), education, and feedback for professional development related to non-conveyance (Lederman et al. 2019).

Patients in prehospital emergency care present a variety of initial complaints and conditions (Ebben et al. 2017), and non-specific complaints are common in general (Kemp et al. 2020). Different terms such as "main reason for care", "work diagnosis" and "preliminary diagnosis" are used in the literature. However, after assessment and treatment, EMS care providers must determine the patient's main reason for care and a hypothesis of the underlying cause (Olsen et al. 2018). The final diagnosis will be made by a physician, but the role of the work diagnosis is important to set the urgency of conveyance and direct the care that follows (Wilson et al. 2018,

Koivulahti et al. 2020). A correct work diagnosis is also an important factor related to adverse events and patient safety (Jensen et al. 2011, Christie et al. 2016, Seymour et al. 2017, Reya et al. 2018). Results related to EMS personnel competence for making a correct work diagnosis vary (Cummins et al. 2013, Brandler et al. 2015, Christie et al. 2016, Green et al. 2016, Davis et al. 2017, Wilson et al. 2018), but a recent Finnish study demonstrated that the ability is at satisfactory levels (Koivulahti et al. 2020).

Different kinds of classifications of reasons for care are used in the prehospital setting that were not originally developed for EMS. For instance, the International Classification of Diseases (ICD-10) provides the diagnosis, but not even the ICD-10 favorite list by the National Emergency Medical Services Information System (NEMSIS) has been completely adopted (Olsen et al. 2018). ICD-10 also has been used at the chapter level, and challenges have been reported (Højfeldt et al. 2014, Vloet et al. 2018). The classification system in Nordic countries is based on dispatch coding or is completely lacking (Olsen et al. 2018). Originally, the International Classification of Primary Care (ICPC) was planned for use in primary health care and is published by WHO and mapped to ICD-10 -codes (WHO 2003, World Organization of Family Doctors 2016). The ICPC includes a more general description of signs and symptoms and thus can be useful in the prehospital setting (WHO 2003), although this utility has been questioned (Moll van Charante et al. 2007, Heino et al. 2020). An adjusted ICPC-2 was developed by the Nordic Collaboration (Benchmarking) Group for prehospital emergency care (Olsen et al. 2018), and a more detailed description of the adjusted ICPC-2 classification codes is given in section 4.21.

2.5.2 Decision making

The decision-making process related to EMS non-conveyance is complex and multifactorial, influenced by many factors from EMS care providers, patients, and relatives to the health care system perspective (Ebben et al. 2017). EMS personnel use different methods of thinking to solve problems and make decisions (Andersson et al. 2019). According to an explanatory model by Reay et al. (2018), decision making in prehospital emergency care is highly contextual, with a dynamic interaction occurring among the environment, patient characteristics, available resources, and EMS personnel experience and knowledge. The authors stated that it is challenging for a model or theory to fully capture the complexities of prehospital emergency care. The model also highlights that EMS personnel's "initial instincts" and "gut feeling" are central to decision making. Shared decision making with greater involvement of the patient also has been requested, especially in case of non-urgent missions (Rantala 2017, Sundström et al. 2019, Venesoja et al. 2020) or non-

conveyance (Leikkola et al. 2016). Issues related to ethical decision making have also been reported (Braithwaite 2014). Oosterwold et al. (2018) built a conceptual framework of factors that influence the non-conveyance decision, but their study population consisted of elderly patients, and these authors concluded that relevant and high-quality studies are lacking. Finally, in the context of EMS non-conveyance, evidence-based theory is lacking.

Guidelines, protocols, and supportive tools are used to guide EMS personnel decision making (Ebben et al. 2017) and implementation of new technology (Porter et al. 2018, Blanchard et al. 2019). In Finland, a non-conveyance decision is based on national and regional guidelines. There is evidence that supportive tools should be used more (Ebben et al. 2017, Johansson et al. 2022, Magnusson et al. 2022), but the decision-making process also requires flexible thinking, which does not necessarily match with tight adherence to protocol (Reay et al. 2018). It also is obvious that protocols and guidelines cannot cover the full scope of EMS daily practice (Oosterwold et al. 2018). Thus, both systematic assessment and intuition are needed (Croskerry 2009). Furthermore, evidence suggests that experienced EMS personnel decisions are based more on personal judgment than an algorithm (Arbon et al. 2008, Newgard et al. 2011) and that the protocol is not always followed (Höglund et al. 2020), even though EMS providers tend to have a positive attitude about the guidelines (Hagiwara et al. 2013). However, a lack of evidence-based guidelines has been highlighted (Tohira et al. 2016b, Ebben et al. 2017).

2.5.3 Characteristics and factors associated with non-conveyance

In the general population, according to a quite recent review (Ebben et al. 2017), rates of non-conveyance vary from 3.7% to 94%. In Finland, as mentioned above, the rate is about 40% (Hoikka et al. 2017, Pekanoja et al. 2018, Laukkanen et al. 2021), or a bit lower (Heinonen et al. 2022). The rates also vary in specific patient populations, from 14% to 84% in patients with hypoglycemia (Andersson et al. 2002, Carter et al. 2002, Cain et al. 2003, Strote et al. 2008, Tohira et al. 2016b, Moffet et al. 2017, Sinclair et al. 2019), 25% to 56% in patients who have fallen (Simpson et al. 2013, Mikolaizak et al. 2013, Snooks et al. 2014, Simpson et al. 2014), 63% to 69% in patients with opioid overdose (Rudolph et al. 2011, Wichmann et al. 2013, Stam et al. 2018), and 13% to 27% in pediatric patients (Haines et al. 2006, Kannikeswaran et al. 2007). Non-conveyance rates related to pediatric patients were even higher at 46% in a Finnish study and 30% in a Swedish study (Oulasvirta et al. 2019, Magnusson et al. 2018). Among elderly patient, rates of 12% (Persse et al. 2002) and 9% (Forsgärde et al. 2020) have been reported, although Lederman et al. (2021) found that 48% of non-conveyed patients were elderly. However, it is typical

that non-conveyance rates commonly vary among different EMS systems (O'Cathain et al. 2018).

Other findings related to non-conveyed patients also are contradictory (Ebben et al. 2017). Some studies indicate, for example, that female gender is more common (Goldstein et al. 2015, Tohira et al. 2016a, Coster et al. 2019, Magnusson et al. 2020a, Forsell et al. 2021, Laukkanen et al. 2021) than male (O'Cathain et al. 2018), whereas others report a more or less similar rate between the two (Vloet et al. 2018, Höglund et al. 2020, Lederman et al. 2020b). However, Forsell et al. (2021) suggested the need for more detailed studies and evaluation of a potential gender bias effect in EMS assessment. Compared to conveyed patients, previous studies have reported that non-conveyed patients are younger (Vloet et al. 2018, Magnusson et al. 2020a, Lederman 2020b), although O'Cathain et al. (2018) concluded that non-conveyed patients are older. Dispatch level as related to non-conveyance varies from the highest (Magnusson et al. 2020a, Lederman et al. 2020b) to lower levels (O'Cathain et al. 2018). According to many studies, non-specific reasons for care are the most common among non-conveyed patients (Höglund et al. 2020, Lederman et al. 2020b, Forsell et al. 2021), although variation has been seen. Other common causes include abdominal pain and breathing difficulties (Höglund et al. 2020), psychiatric problems (Vloet et al. 2018, Lederman et al. 2020b), alcohol misuse (Pekanoja et al. 2018), injuries (Tohira et al. 2016a, Vloet et al. 2018), and falls (O'Cathain et al. 2018). Some studies suggested that initially abnormal vital signs such as low blood glucose are typical with non-conveyed patients (Vloet et al. 2018, Lederman et al. 2020b), but others have found that the vital signs are mostly normal (Tohira et al. 2016a, Höglund et al. 2020).

Other factors associated with non-conveyance include urban location (Goldstein et al. 2015, Vloet et al. 2018, Hegenberg et al. 2019), region-specific differences, lower income of residents (Aitavaara-Anttila et al. 2020), areas with social deprivation (O'Cathain et al. 2018), EMS arrival time outside office hours (Hoikka et al. 2016, Tohira et al. 2016a, O'Cathain et al. 2018, Magnusson et al. 2020a, Forsell et al. 2021), having access to a patient's medical history (Oosterwold et al. 2018), and EMS personnel competence (O'Cathain et al. 2018, Oosterwold et al. 2018). An increasing number of patients who do not need any treatment has also been reported (Andrew et al. 2019), in some cases explained by frequent callers, i.e. patients who repeatedly alert the EMS (Hoikka et al. 2017, Søvsø et al. 2019, Aitavaara-Anttila et al. 2020). Although a non-conveyance mission takes more time at the scene (Goldstein et al. 2015, Oosterwold et al. 2018) and involves more doctor consultations (Oosterwold et al. 2018), in most cases, the EMS unit becomes available sooner compared with conveying a patient to the health care facility. It is also noteworthy that especially in evenings and nights, the EMS in many areas is the only health care service obtainable, and alternative care options are limited

(Pekanoja et al. 2018, Blodgett et al. 2021). During the COVID-19 pandemic, calls to dispatch centers increased exponentially (Al Amiry et al. 2021), although EMS missions declined, even as numbers of non-conveyances were reported to increase (Satty et al. 2021).

2.5.4 The safety of non-conveyance

The inappropriate non-conveyance decision can jeopardize patient safety and even lead to patient's death. To identify adverse events after EMS non-conveyance, patient follow-up has been reported with separate or combined outcomes such as EMS re-contact, ED visits and hospital admission, primary care visits, walk-in clinic attendance, private physician visits, mortality (Jensen et al. 2015, Ebben et al. 2017, Yeung et al. 2019), and admission to an intensive care unit (Magnusson et al. 2020a). Rates of adverse outcomes vary in the general population because of heterogeneity in study designs. The follow-up periods ranged from <24 h to 30 days. Some authors have also concluded that relevant studies are lacking. Some studies are old, sample sizes can be quite small, and patient follow-up sometimes has been conducted using an unreliable method such as telephone interviews, which involve high loss to follow-up. These limitations risk introducing bias in the results. (Ebben et al. 2017, Yeung et al. 2019.) However, results of four recent single-center retrospective or prospective cohort studies with at least reasonable sample sizes indicate that rates of EMS re-contact range from 6.1% (<24 h) to 13% (<72 h), visits in ED from 4.6% (<24 h) to 13% (<72 h), and hospital admission from 1.8% (<48 h) to 3.3% (<24 h) to 6.6% (<72 h). Mortality rates were 0.2% (<24 h), 0.3% (<72 h), 1.0% (30 days), and 2.1% (<7 days). (Tohira et al. 2016a, Coster et al. 2019, Magnusson 2020a, Laukkanen et al. 2021.) Of note, recorded outcomes also varied in these studies. For example, 2 in 4 EMS re-contacts were not recorded, and visits to a primary health care facility were not recorded at all. In addition, the number of excluded patients ranged from a small fraction up to 44%. It is also unclear whether the reported adverse outcomes were related to the initial non-conveyance mission. Pathway analyses of patients with multiple re-contacts were reported only in one study even though such analyses reveal more information about rates of adverse outcomes.

A number of studies have reported outcomes related to specific patient groups such as cases that were non-urgent (Todd et al. 2021, Forsell et al. 2021), involved elderly (Lederman et al. 2020a) or pediatric (Magnusson et al. 2018, Oulasvirta et al. 2019) patients, opioid overdose (Greene et al. 2018, McLeod et al. 2021), and hypoglycemia (Sinclair et al. 2019). A small portion of the non-conveyed patients later were in critical condition (Magnusson et al. 2020a), but whether the re-contact was related to the initial non-conveyance decision is not clear (Ebben et al. 2017). Challenges related to clinical judgment are a common reason for adverse events

(Bigham et al. 2012). Evidence also suggests that EMS arrival at night (Laukkanen et al. 2021), older patient age, etiology, and abnormal vital signs (Tohira et al. 2016a) such as fever and hyperglycemia (Laukkanen et al. 2021) predict adverse outcomes after EMS non-conveyance.

Machine learning seems to be a useful method for identifying high-risk patients (Spangler et al. 2019, Kang et al. 2020, Al-Dury et al. 2020, Pirneskoski 2020, Tamminen et al. 2021), but no studies have used this technique to address non-conveyance. Overall, results of existing studies are controversial, and the safety of non-conveyance is unclear.

3 Aims

The overall aim of the thesis was to evaluate the safety of EMS non-conveyance. The specific aims were as follows:

1. to describe EMS patients and compare differences between non-conveyed and conveyed patients in Finland (I);
2. to analyze factors related to decision making in EMS non-conveyance (I);
3. to identify the rate and predictors of adverse outcomes after EMS non-conveyance (II, III);
4. to determine whether the current practice of non-conveyance ensures patient safety (II); and
5. to study whether machine learning can be used in the context of non-conveyance (III).

4 Materials and Methods

4.1 Design

4.1.1 Study design and setting

This was a prospective cohort study. The EMS data used in the thesis and in the sub-studies were collected 1.6.2018–30.11.2018 from the Finnish hospital districts of Kanta-Häme, Päijät-Häme, and South-Savo (Figure 1). The timetable for data collection was determined for practical reasons: the adjusted ICPC-2 classification was published in spring 2018, and the data from the National Health Care registers are available 6 months after a calendar year. Whether the data collection had continued in 2019, the data collection for re-contacts would have taken at least one year longer. Patient follow-up and the registries are described later in the thesis.

The population in the study areas was 482,805 inhabitants in 2018, representing 8.8% of the Finnish population, with an average density of 26.1 inhabitants per square kilometer. The study region with 32 municipalities comprised both rural and urban areas.

Figure 1. Study areas.

4.1.2 Study patients (I–III)

The description of the included and excluded EMS patients is shown in Figure 2.

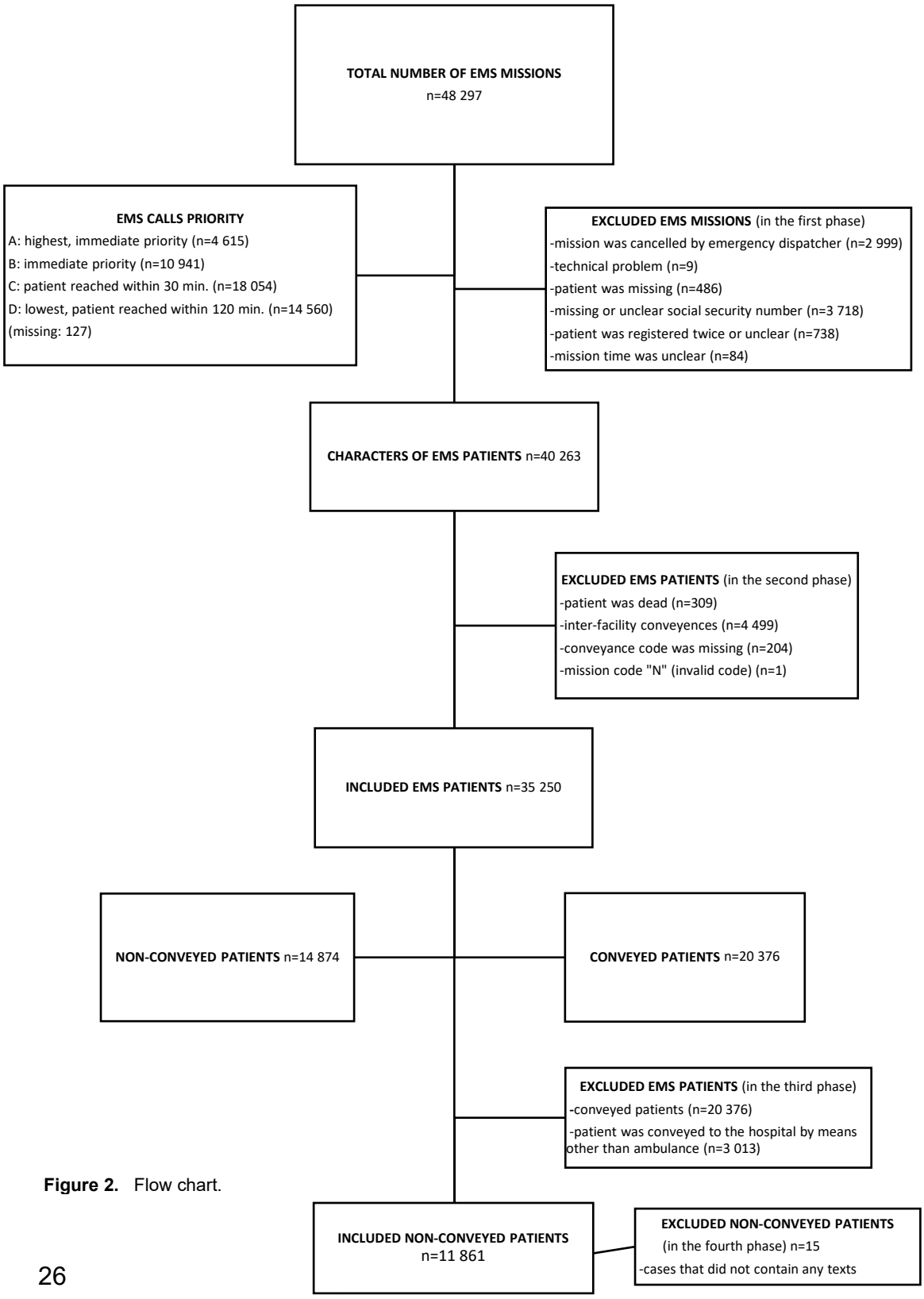

Figure 2. Flow chart.

4.2 Patient data collection (I–III)

Data from different registries were combined using immutable and unique 10-digit personal identification numbers. The registries used in this study are presented in Figure 3.

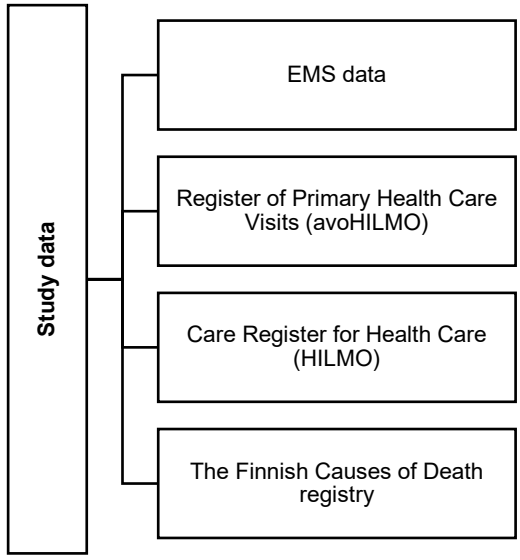

Figure 3. Databases.

4.2.1 EMS missions and patient data (I–III)

In the study region, the EMS personnel use electronic patient care reporting (ePCR) for the documentation. Two different systems were used: Merlot Medi (CGI Suomi Oy, Finland) and Codea (Codea Oy, Finland). In this study, the data from the systems were combined for further analyses. The ePCRs include many different patient demographic variables, such as personal identity number, age, gender, and residential address. There is also information related to the EMS mission, including date and several time variables, the address where the mission occurred, dispatch priority and code, vital signs (e.g. pulse rate, blood pressure, breathing sound and rate, oxygen saturation, Glasgow Coma Scale (GCS), temperature), and conveyance or non-conveyance code. The data also consist of narrative text sections, where the case, status, former diseases and medication, treatment, supplementary information, and clinical reasoning related to non-conveyance decision making are reported.

In this study, as the main reason for EMS care, the adjusted ICPC-2 classification was taken into use and the EMS databases were updated accordingly. The adjusted ICPC-2 code list consists of around 100 ICPC codes. It is mapped to ICD-10 codes

and is available in the code server of the Finnish Institute for Health and Welfare (2022). Before the data collection started, the EMS personnel were educated in the use of the adjusted ICPC-2 codes. Supervisors and key persons received face-to-face training from a researcher, the use of the codes was addressed in shift trainings, and the EMS personnel had the opportunity to watch a related video recording. Before the study period, several test data sets were collected, and the data also were tested one month after data collection started to ensure that they were as accurate as possible.

For calculation of NEWS2 scores, the first recorded values were used, and the missing values were decoded as "normal". The cut-offs for incorrect measurement were respiration rate <4/min or >70/min, oxygen saturation <50% or >100%, systolic blood pressure <40 mmHg or >280 mmHg, pulse <20/min, and temperature <25 °C or >45 °C. The GCS was used in the ePCRs for assessment of the level of consciousness, which was converted to the ACVPU scale (GCS 15=Alert (A); GCS 14–3=CVPU: confusion (C), verbal (V), pain (P), unresponsive (U), as done previously (Smith et al. 2013, Pirneskoski et al. 2019).

The NEWS2 scores require information about use of supplementary oxygen and whether the patient had chronic obstructive pulmonary disease (COPD) or other hypercapnic respiratory failure. Thus, a semi-supervised information extraction method was used to detect and extract relevant expressions from the narrative texts of the ePCRs. In the beginning, the word2vec toolkit (Mikolov et al. 2016) was used to train two semantic word space models in an unsupervised manner. One model was trained on a corpus of hospital clinical text based on 0.9 million physician and nursing notes, and the other model was trained based on the narrative text from the EMS data. With a keyword list (contributed by domain experts) related to oxygen administration, hypercapnic respiratory failure, and COPD as the starting point, the semantic models to extract words including similar meanings were applied. Then, the domain experts analyzed the keyword candidates to identify common synonyms and misspelled variants. The approach was similar to that of interactive rapid vocabulary exploration, which has been used previously (Topaz 2019). Based on the occurrence of the keywords, all narrative texts of the ePCRs were searched and labeled with the revised list. In cases of COPD, scale 2 was used to analyze SpO_2, where the lower oxygen saturation of these patients is noted (Table 1) (Royal College of Physicians 2017).

Table 1. NEWS2 scoring system (Royal College of Physicians 2017).

Physiological parameter	Score						
	3	2	1	0	1	2	3
Respiration rate (per minute)	≤8		9–11	12–20		21–24	≥25
SpO2 Scale 1 (%)	≤91	92–93	94–95	≥96			
SpO2 Scale 2 (%)	≤83	84–85	86–87	88–92 ≥93 on air	93–96 on oxygen	95–96 on oxygen	≥97 on oxygen
Air or oxygen?		Oxygen		Air			
Systolic blood pressure (mmHg)	≤90	91–100	101–110	111–219			≥220
Pulse (per minute)	≤40		41–50	51–90	91–110	111–130	≥131
Consciousness				Alert			CVPU
Temperature (°C)	≤35.0		35.1–36.0	36.1–38.0	38.1–39.0	≥39.1	

The influence of alcohol was measured with a breathalyzer test or clinically by EMS, and cases were coded as yes or no in further analyses. The urban–rural classification was analyzed based on the Finnish Environment Institute (SYKE) classification, with urban areas set to three parts and rural areas to four (Figure 4) (Finnish Environment Institute 2010). A spatial network analysis was executed for every EMS mission observation for further statistical analysis (Wang 2014a, McLafferty et al. 2018). The fastest route was calculated from the location of every EMS mission to the nearest (non-conveyed patients) or realized (conveyed patients) health care facility, with the spatial network analysis taking into account the opening hours of the facilities.

Three data sets were used in the analyses: EMS missions with coordinates and time variables and other additional information; health care facilities with coordinates and opening hours; and Digiroad (CC BY 4.0), the national road and street database (The Finnish Transport Agency 2019). All of these datasets were quality evaluated by the locations and attribute information and modified when needed. The missions were assessed for anomalies by examination of cases that were not within 500 m from the road network. Their location was compared to other case attributes, for instance the address and description of the mission, and when these pieces of information did not correspond, that was noted. Because it is not certain that these outlier EMS missions really happened in the middle of water bodies or if the geolocation did not work correctly, these missions were not included in the network analysis.

The fastest route from the location of the EMS mission to the nearest health care facility was counted by the Closest Facility method (Wang 2014b). Digiroad (CC BY 4.0), the Finnish national road and street database, was used as the network dataset for the analysis. Speed limits were defined as the cost attribute so that the analysis considered different speed limits. (The Finnish Transport Agency 2019.) Hierarchy and restriction attributes were defined so that the routing from EMS mission location to the nearest health care facility favored larger principal roads and avoided pedestrian lanes and small forest roads if possible.

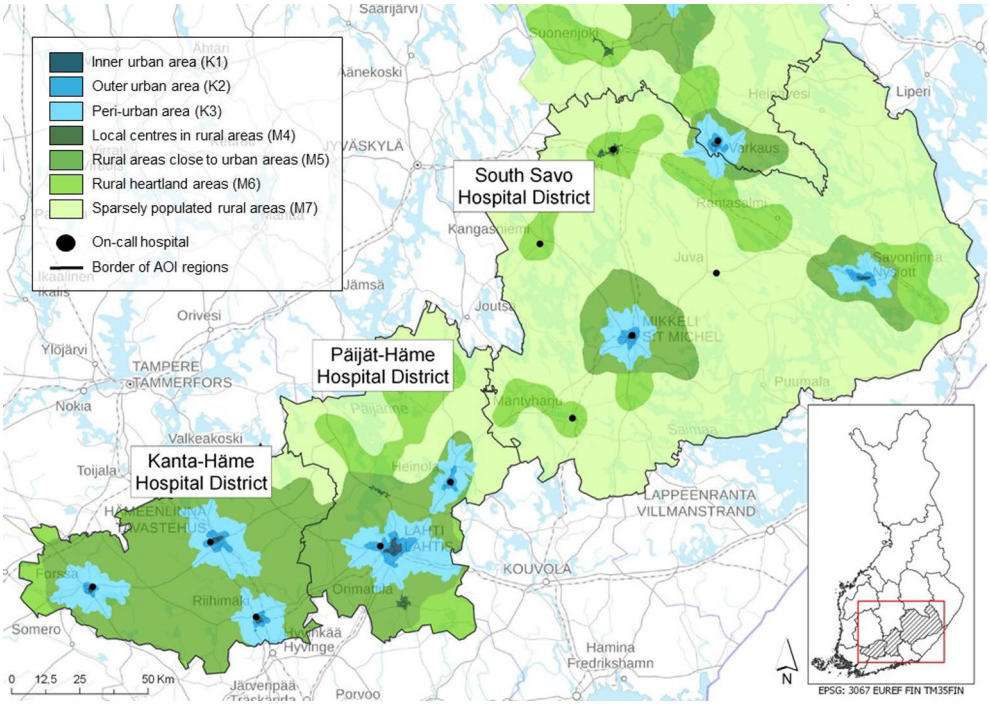

Figure 4. Urban–rural classification in the study areas (Finnish Environment Institute 2010) (I, published with permission).

4.2.2 Data for subsequent events in primary health care and EDs (II-III)

Visits to primary health care and EDs, including hospitalization, are available from the Register of Primary Health Care Visits (avoHILMO) and Care Register for Health Care (HILMO), both maintained by the Finnish Institute for Health and Welfare (THL). The national health care registers record all treatment episodes from the primary health care and hospitals nationwide in Finland, and hospital districts are obligated to report all treatment periods after discharging a patient. (Finnish Institute

for Health and Welfare 2018a, 2018b.) In this study, visits to primary health care or EDs (0–24 h or 24–48 h) were collected from all of Finland's hospital districts in order to record all subsequent visits.

The registries of care notifications included the basic information for the patient (personal identity number, age, gender), detailed information about the visit (health care unit, length of visit, whether the patient was hospitalized – including treatment in an intensive care or high-dependency unit), and the discharge diagnoses according to the ICD-10. No record was taken of whether patients went to primary health care or hospital by ambulance or by other means. In cases where the exact time of the visit was missing, the initial non-conveyance mission was determined to have occurred first and the 0–24 h subsequent visit to have occurred the same day or the day after. If the patient had many subsequent visits, the first visit was analyzed and combined with the latest non-conveyance mission. Only unscheduled visits and the doctor's appointments were reviewed, but the Register of Primary Health Care Visits also includes chronic disease monitoring. The adjusted ICPC-2 code chosen by EMS was compared to the main discharge diagnosis (ICD-10) according to ICPC-2 and ICD-10 mapping charts to determine if the visit was for the same or a related complaint (WHO 2003).

4.2.3 Mortality data (II-III)

Patients who died were evaluated using the Finnish Causes of Death registry and death certificates administered by Statistics Finland, one of the statistical authorities (Official Statistics of Finland 2018). The registry covers 100% of deceased patients in Finland during the calendar year. According to Finnish law (1973/459), a cause of death investigation, is requested for all deceased patients who live in Finland at the time of death (autopsy when needed). A medico-legal investigation must be done if the death is suspected to be caused by a crime, suicide, accident, poisoning, or treatment, or is unexpected and without causative disease, for example.

The treating physician defines the cause of death using the ICD classification, and a physician also writes the death certificate confirming the death. This certificate includes a description of the patient history, examination and treatment given, and place of death, for instance. In Finland, all death certificates are manually checked and validated by forensic pathologists employed by the Finnish Institute for Health and Welfare (THL) (Lahti et al. 2001). In cases where an autopsy is required, a forensic pathologist writes the death certificate.

In this study, the deaths were reviewed during a 28-day period from the initial non-conveyance mission to yield deeper insight into the deceased patients. In the register, the time of death is only by date and not by hour, so all deaths occurring on the same or the next day of the initial non-conveyance mission were included in the

0–24 h mortality. Unexpected deaths were analyzed, and end of life -patients were excluded, as they normally have formal arrangements to die at home. The latest non-conveyance mission and the death were connected for the analysis. All cases were analyzed independently by two experienced emergency physicians. When the opinions differed, the case was discussed in the study group until consensus was reached. Finally, deceased patients were evaluated for whether the death was connected to an end-of life condition, whether the patient refused the conveyance to the ED or primary health care facility, whether the death was credibly related to the initial non-conveyance mission, and whether conveyance to an ED or primary health care facility would likely have benefited the patient.

4.3 Machine learning and experimental setup (III)

Artificial intelligence can be seen as an umbrella term for teaching a machine (Robert 2019). Machine learning is used for different purposes (Rajkomar et al. 2019), but a recent review indicates that most related studies used descriptive study designs and that study quality needs improvement (von Gerich et al. 2021). Nevertheless, machine learning seems to be a useful tool for identifying deteriorating patients in a prehospital setting (Spangler et al. 2019, Kang et al. 2020, Pirneskoski et al. 2020, Tamminen et al. 2021). In this study, the data for machine learning (text classification) and experimental setup included the narrative texts from ePCRs related to the initial EMS non-conveyance mission. The aim was to find predictors of adverse outcomes in addition to statistical analyses. Examples of narrative texts from an ePCR are shown in Figure 5, presented without structured data and abbreviations. Narrative texts are also seen as a rich source of information, and several text classification models are used to make predictions in in-hospital studies (Minaee et al. 2021).

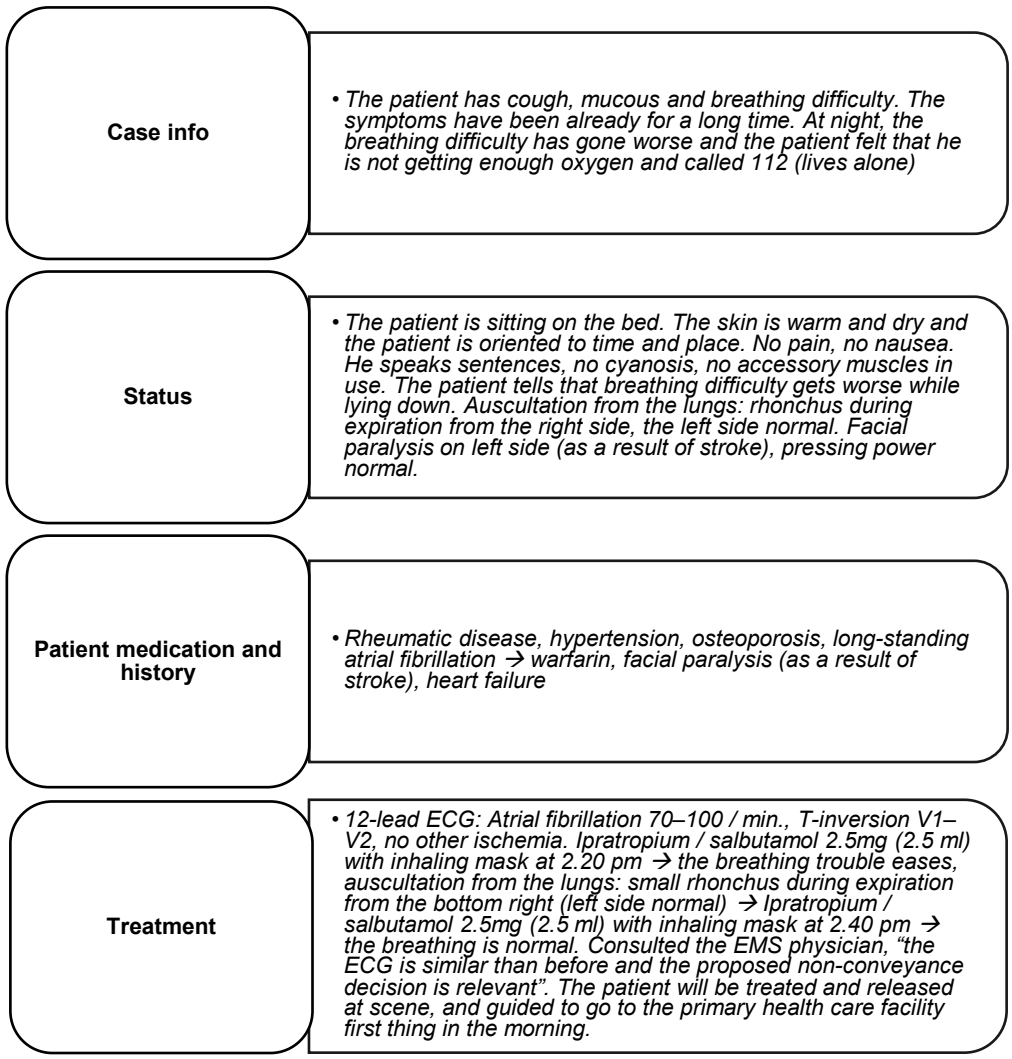

Figure 5. Example of narrative texts from an ePCR (III, published with permission).

The data also included information about whether the patient had subsequent events after EMS non-conveyance. Each patient was assigned either 1, representing a "subsequent event", or 0, representing a "non-subsequent event". Fifteen cases were excluded because of missing narrative texts. In the preprocessing stage, the text was lowercase, and special characters that were not alphabetical (UTF-8) or numbers, were removed. Altogether, the data comprise 1.17 million tokens, with a minimum of four, maximum of 479, and median of 94.

Three text classification models were chosen for a performance evaluation to give the truest possible estimation of classification performance. The long short-term memory (LSTM) model (Hochreiter et al. 1997), Bidirectional-LSTM-model (Schuster et al. 1997), and FastText-model (Joulin et al. 2017) all have shown good performance in comparable tasks to classify sentences from nursing documentation (Moen et al. 2020). Cross-validation is an easy way to choose models and evaluate performance. Thus, 5-fold nested cross-validation with five parameters were used to yield an unbiased and robust evaluation. The LSTM-model and Bidirectional-LSTM models were carried out with Tensorflow (Abadi et al. 2016) as the backend, and the performance was measured by area under the receiver operating characteristic curve (AUC).

The FastText-model was the best performing model and was optimized with 5-fold cross-validation. Overall, 225 hyperparameter combinations were tested based on learning rate (how fast the model learns), number of epochs (how long the model is trained) and max length of word n-grams (how large word combinations are included). The parameters of the final explanatory model were decided to be hyperparameters with the best mean AUC. To train the model, 90% of the data were used, and the remaining 10% was used for the explanatory analysis described below, together with the parameters, which were found in the hyperparameter optimization.

The LIME technique (local interpretable model-agnostic explanations, "explainable AI") was used to find the importance of words relative to each prediction. Explanatory analysis was done with the LIME package module using the LimeTextExplainer with default parameters, except that top_labels was determined to 1, num_feature to a number of tokens per sample, and num_samples was determined to 10 000. Of the tokens, 10% together with positive coefficients were used as keywords. In case of the keywords next to each other were combined into keyphrases to retain the semantic information.

The extracted keywords and keyphrases also were analyzed manually for a better understanding of the algorithm's results and to gain insight into whether the results were relevant and comprehensible. Altogether, 80 patients were randomly selected. There were four different scenarios (subsequent or non-subsequent event for correct or incorrect predictions of the model), so that 20 patients represented each scenario. Domain experts evaluated whether the cases agreed with the algorithm's results, whether the keywords were relevant, and whether the result of the algorithm was understandable. The cases were analyzed independently by two researchers using a three-class scale (1=I disagree, 2=unclear / more text is needed, 3=I agree). For cases where evaluations differed (n=15, 20%), a third independent assessment was conducted, and the cases were discussed until consensus was achieved. As a part of the manual evaluation, inductive content analyses were performed. This method

enables categorization and calculation of the frequency of words, phrases, and expression frequency.

4.4 Statistical analyses (I–III)

All statistical analyses were performed with SAS for Windows version 9.4 (SAS Institute Inc., Cary, NC, USA). Data collection in this thesis includes all EMS patients from the defined period, and a separate sample size calculation was not conducted. The age groups in this study were set according to Finnish national classification by Statistics Finland. For analysis, the distance to the nearest health care facility was categorized. Statistical significant level (p value) was considered at 0.05. Descriptive statistics such as categorical variables are presented as frequencies and percentages and continuous variables as medians and interquartile ranges (IQRs).

In Study I, the Chi-square test (categorical variables) or Mann-Whitney U -test (continuous variables) was used to test differences between the non-conveyance and conveyance patient groups. Logistic regression analysis was used to analyze univariate associations between these groups. Based on univariate analysis, clinically and statistically significant variables were included in multiple logistic regression analysis. Because rural–urban area partly measures the same thing as distance to a health care facility, rural–urban classification was excluded from this analysis. Moreover, the NEWS2 score is appropriate only for patients over age 16 years, who were analyzed separately. Results are presented with p-values and odds ratios (ORs), together with 95% confidence intervals (CIs; Study I).

In Study II, logistic regression was used to analyze univariate associations between outcome variables and categorical study variables. As in Study I, clinically and statistically significant variables after univariate analysis were included in multiple logistic regression analysis. NEWS2 scores were excluded from the model as well, but rural–urban classification instead of distance to a health care facility was included. Non-specific reasons for care (ICPC-2) (categorical variable) and hospitalization (24–48 h) and 28-day mortality (dependent variables) were rare in the data set, so these analyses were not conducted. Results are shown with univariate and adjusted ORs (aORs) together with 95% CIs and p-values (Study II).

4.5 Outcome measures (II-III)

To find adverse events after EMS non-conveyance, primary outcomes of this study were EMS re-contact, unscheduled visits to a primary health care facility or ED, and following hospitalization within 0–24 and 24–48 h. The secondary outcome was 28-day mortality.

4.6 Study permissions and ethical considerations

The study was approved by the Finnish Institute for Health and Welfare, including assessment by the Data Protection Ombudsman (EMS data, and visits to primary health care or ED and hospitalization) and by Statistics Finland (deceased patients). In addition, the Finnish Social and Health Data Permit Authority approved the extensions of the study group. The 10-digit personal identity numbers were changed to codes because the information from the registries was combined. In this way, individual patients could not be identified in the study, although the deceased patients were analyzed and reported case by case because of important information related to patient safety.

According to Finnish law, ethical permission is not needed for registry studies without contact with patients. However, because the data set in this study was large and included sensitive information about the patients, and the prospective part of the study included an educational intervention for EMS personnel because of introduction of the adjusted ICPC-2 classification, written approval was requested from the Ethics Committee of the Hospital District of Southwest Finland (Approval no: DNRO: 70 /1802/2018). Based on Finnish legislation (1050/2018) and registry-based study design, informed consent was waived. The studies in this thesis were conducted according to guidance of the responsible conduct of research by The Finnish Advisory Board on Research Integrity (TENK) (2012). The Strengthening the Reporting of Observational Studies in Epidemiology (i.e. STROBE) checklist was also followed.

5 Results

5.1 EMS patient characteristics and differences between non-conveyed and conveyed patients (I)

Overall, the analyses included 40,263 patients (Fig. 2). After second-phase exclusion (mainly inter-facility conveyances), 42% of the patients (n=14,874) were not conveyed to a health care facility but were discharged at the scene. Table 2 provides an overview of characteristics of the EMS patients and description of differences between non-conveyed and conveyed patients. In general, over 99% of the missions were performed by EMS units without a physician, and 29% of the missions were urgent with light and sirens. The patients were older (60% were >65 years), and most had only one mission during the study period, although some had several, and 1 in 10 were under the influence of alcohol. In case of non-conveyance, the EMS unit spent longer at the scene (28 min vs 24 min), and there were more doctors' consultations in these missions (39% vs 18%). Altogether, NEWS2 scores were low (Table 3).

Table 2. EMS patient characteristics and differences between non-conveyed and conveyed patients.

Characteristics of EMS missions	**EMS patients total (n=40,263)**			**Conveyed patients (n=20,376) (without inter-facility conveyances)**			**Non-conveyed patients (n=14,874)**		
	Missing	n	%	Missing	n	%	Missing	n	%
Mission priority	6						6		
A		2,355	5.9		1,600	7.9		480	3.2
B		9,344	23.2		5,553	27.3		3,113	20.9
C		16,019	39.8		8,037	39.4		6,774	45.6
D		12,539	31.1		5,186	25.5		4,501	30.3
EMS units									
ALS		31,238	77.6		16,146	79.2		11,806	81.9
BLS		8,491	21.1		4,229	20.8		2,606	18.1
Community Paramedic		509	1.3					451	3.0
Field Supervisor		25	0.1		1	0.0		11	0.07
Doctor at scene		265	0.7		163	0.8		38	0.3
Doctor consulted by phone		9,670	24.0		3,638	17.9		5,780	38.9
Weekday									
Monday		5.687	14.1		2,939	14.4		1,942	13.1
Tuesday		5,483	13.6		2,835	13,9		1,876	12.6
Wednesday		5,582	13.9		2,798	13.7		1,993	13.4
Thursday		5,584	13.9		2,764	13.6		2,014	13.5
Friday		6,200	15.4		3,030	14.9		2,306	15.5
Saturday		6,172	15.3		3,110	15.3		2,533	17.0
Sunday		5,555	13.8		2,900	14.2		2,210	14.9

EMS arrival time	47			10			17		
08:00–16:00		17,958	44.7		9,597	47.1		5,341	36.0
16:00–00:00		14,795	36.8		7,214	35.4		5,886	39.6
00:00–08:00		7,463	18.6		3,555	17.5		3,630	24.4
Urban–rural classification	5,733			1,024			256		
Urban area		22,175	64.2		13,192	68.2		8,679	59.4
Rural area		12,355	35.8		6,160	31.8		5,939	40.6
Distance to health care facility	5,741			1,030			258		
<5 km		10,969	31.8		6,215	32.0		4,634	31.7
5-20 km		11,897	34.5		6,827	35.2		4,892	33.5
21-40 km		7,250	21.0		3,787	19.5		3,351	22.9
>40 km		4,406	12.8		2,589	13.3		1,739	11.9
Median distance		8 km, IQR 3.2–25.5			8 km, IQR 3.3–25.4			8 km, IQR 3.2–25.6	
Mission duration (median)		72 min., IQR 51–103			83 min., IQR 63–113			52 min., IQR 39–70	
Age (median)		71 (IQR 51–82)			72 (IQR 53–83)			68 (IQR 45–81)	
<15		1,237	3.1		512	2.5		602	4.1
15–64		14,927	37.1		7,225	35.4		6,074	41.1
65-84		16,363	40.6		8,391	41.1		5,647	38.2
>85		7,736	19.2		4,283	21.0		2,448	16.6
Female		20,776	51.6		10,501	51.5		7,843	52.7
One contact		18,449	71.7		12,539	80.5		9,635	83.8
2–6 contacts		6,971	27.1		2,986	19.2		1,789	15.6
>7 contacts		318	1.2		50	0.3		69	0.6
Time spent at the scene (median)	310	24 min., IQR 16–34		31	24 min, IQR 17–32		72	28 min, IQR 20–37	
Patient was under influence of alcohol		4,032	10.0		1,832	9.0		2,148	14.4
Doctor was consulted		24%			18%			39%	

Table 3. National Early Warning Score (NEWS2 score) (age over 16 years) (I, published with permission).

		All patients (n=38,788)	**Non-conveyed patients (n=13,723) (missing 134)**	**Conveyed patients (n=19,727) (missing 134)**
NEWS2 score	**Clinical risk**	**n (%)**	**n (%)**	**n (%)**
Aggregate score 0–4	Low	31,397 (81.0)	13,160 (90.8)	18,055 (74.9)
Red score; Score of 3 in any individual parameter	Low–medium	4,049 (10.4)	983 (6.8%)	3,058 (12.7)
Aggregate score 5–6	Medium	2,076 (5.4)	265 (1.8)	1,805 (7.5)
Aggregate score 7 or more	High	1,256 (3.2)	79 (0.6)	1,176 (4.9)
Median + IQR		median 1, IQR 0–2	median 0, IQR 0–1	median 1, IQR 0–3

The different causes of non-conveyance are shown in Table 4. The most common reasons for EMS care based on adjusted ICPC-2 classification are listed in Table 5. The main reasons for care between the groups were quite similar, a non-specific reason for care was the most common. Head injury was common among conveyed patients and no disease among non-conveyed patients.

Table 4. Reasons for non-conveyance (n=14,874) (I, published with permission).

	n (n=14,874)	**% (100%)**
Non-conveyed EMS patients were treated at scene or there was no need for conveyance.	10,713	72.0
Patients were taken to health care facilities in their own or relatives' car or by taxi, for example.	3,013	20.3
Patients refused conveyance.	736	5.0
Patients were handed over to the police.	306	2.1
Patients received other help, such as homecare.	106	0.7

Table 5. Most common ICPC-2 codes (n=37,575, missing 2688).

EMS patients total (n=37,575, missing 2688)				**Conveyed patients (n=20,376) (without inter-facility conveyances)**				**Non-conveyed patients (n=14,874)**			
		n	%			n	%			n	%
A04	Weakness/tiredness, general	5060	13.5	A04	Weakness/tiredness, general	2,614	27.1	A04	Weakness/tiredness, general	1,929	24.2
D01	Acute abdomen	1663	4.4	P29	Psychological symptom / complaint other	1,049	10.9	A97	No disease	1,412	17.7
P29	Psychological symptom / complaint other	1660	4.4	R02	Shortness of breath / dyspnoea	987	10.2	P16	Acute alcohol abuse	966	12.1
A97	No disease	1635	4.4	D01	Acute abdomen	861	8.9	D01	Acute abdomen	574	7.2
R02	Shortness of breath / dyspnoea	1607	4.3	A03	Fever	826	8.6	A11	Chest pain	571	7.2
P16	Acute alcohol abuse	1597	4.3	N80	Head injury	663	6.9	L02	Back symptom/complaint	492	6.2
A03	Fever	1269	3.4	S18	Laceration/cut	589	6.1	N17	Vertigo/dizziness	422	5.3
N17	Vertigo/dizziness	1033	2.8	P16	Acute alcohol abuse	586	6.1	S18	Laceration/cut	408	5.1
S18	Laceration/cut	1024	2.7	N17	Vertigo/dizziness	560	5.8	P29	Psychological symptom / complaint other	358	4.5
A11	Chest pain	985	2.6	L02	Back symptom/complaint	441	4.6	A03	Fever	319	4.0
L02	Back symptom/complaint	983	2.6	A11	Chest pain	378	3.9	R02	Shortness of breath / dyspnoea	311	3.9

5.2 Factors related to non-conveyance decision making (I)

Multivariate analyses showed that non-urgent missions, ALS units, EMS arrival time in the evening or night, younger patient age, and patient alcohol use increased the likelihood of non-conveyance (Table 6). Moreover, the results based on univariate analyses indicate that rural area (OR 1.465, 95% CI 1.401–1.533) and a low NEWS2 score (0–4 vs 5–6; OR 5.222, 95% CI 4.555–5.987; 0–4 vs score of 3 in any individual parameter, OR 2.713, 95% CI 2.501–2.944) were associated with non-conveyance. In contrast, conveyed patients were older (65–84 vs 15–64 years; OR 1.282, 95% CI 1.218–1.349), and the likelihood of conveyance increased if the mission was in an urban area (OR 1.465, 95% CI 1.401–1.533) or the NEWS2 score increased by one point (OR 1.377, 95% CI 1.357–1.398) or two points (OR 1.897, 95% CI 1.842–1.954). In addition, the results showed that having less than an hour to complete a shift was not related to whether personnel opted for non-conveyance versus conveyance (p=0.491).

Table 6. Multivariate logistic regression analyses of non-conveyance predictors (n=14,874) (I, published with permission).

	Missing	Univariate			Multivariate		
		OR	95% CI	p	OR	95% CI	p
Mission priority	210						
C vs B		1.504	1.424-1.588	<0.001	1.520	1.436-1.608	<0.001
D vs B		1.548	1.459-1.643	<0.001	1.629	1.527-1.736	<0.001
B vs A		1.869	1.672-2.088	<0.001	1.916	1.708-2.150	<0.001
C vs A		2.810	2.524-3.127	<0.001	2.912	2.605-3.256	<0.001
D vs A		2.893	2.593-3.228	<0.001	3.121	2.780-3.503	<0.001
EMS units ALS vs BLS	142	1.187	1.124-1.253	<0.001	1.240	1.170-1.315	<0.001
EMS arrival time	231						
16:00–00.00 vs 08:00–16.00		1.466	1.397-1.538	<0.001	1.310	1.245-1.379	<0.001
00:00–08:00 vs 08:00–16:00		1.835	1.733-1.943	<0.001	1.711	1.610-1.818	<0.001
00:00–08:00 vs 16:00–00:00		1.252	1.181-1.326	<0.001	1.306	1.230-1.387	<0.001
Distance to health care facilities	1492						
21-40km vs <5km		1.188	1.118-1.261	<0.001	1.147	1.077–1.221	<0.001
21-40km vs 5-20km		1.238	1.167-1.314	<0.001	1.233	1.159-1.311	<0.001
21-40km vs >40km		1.317	1.219-1.421	<0.001	1.263	1.167-1.367	<0.001
Age	204						
<15 vs 15-64		1.392	1.232-1.574	<0.001	1.723	1.515-1.960	<0.001
<15 vs 65-85		1.727	1.528-1.952	<0.001	2.078	1.828-2.363	<0.001
<15 vs >85		2.027	1.784-2.303	<0.001	2.419	2.114-2.768	<0.001
15-64 vs 65-84		1.241	1.183-1.301	<0.001	1.206	1.145-1.271	<0.001
15-64 vs >85		1.456	1.371-1.546	<0.001	1.404	1.313-1.501	<0.001
65-84 vs >85		1.173	1.105-1.246	<0.001	1.164	1.092-1.240	<0.001
Gender female vs male	204	1.049	1.006-1.094	<0,027	1.128	1.077-1.181	<0.001
Alcohol		1.708	1.599-1.826	<0.001	1.473	1.370-1.585	<0.001

5.3 Events after non-conveyance (II)

After exclusion of patients who were treated and released at the scene but were advised to go to a health care facility by other means than ambulance, there were 11,861 non-conveyed patients who met the final inclusion criteria in this study. Their demographics were roughly similar to those of patients described in Table 2. The median age was 67 years (IQR 44–80), and NEWS2 scores were low; 55% of the patients had a score of zero.

The subsequent event rates after EMS non-conveyance were as follows: 6.3% for EMS re-contact within 0–24 h and 2.6% within 24–48 h; 8.3% with visits to a primary health care facility within 0–24 h and 2.6% within 24–48 h; 4.4% with ED visits within 0–24 h and 0.8% within 24–48 h; 1.6% with hospitalization after ED visits within 0–24 h and 0.3% within 24–48 h; and 0.1% who died within 0–24 h, 0.03% within 24–48 h, and 1.1% within 28 days. Of the patients, 84% did not have a subsequent event (within 0–24 h) after a non-conveyance mission. Table 7 gives more information about patients with multiple types of subsequent events.

Table 7. Pathway analyses of subsequent events within 0–24 h (II, published with permission).

	EMS	Primary health care	ED	Hospitalization	Death	n	%
Did not have any re-contact	x	x	x	x	x	9951	83.9
Primary health care attendance	x	✓	x	x	x	805	6.8
EMS re-contact	✓	x	x	x	x	478	4.0
ED attendance	x	x	✓	x	x	233	2.0
EMS re-contact and primary health care attendance	✓	✓	x	x	x	80	0.7
EMS re-contact and ED attendance	✓	x	✓	x	x	74	0.6
ED attendance and hospitalization	x	x	✓	✓	x	73	0.6
EMS re-contact, ED attendance and hospitalization	✓	x	✓	✓	x	65	0.6
Primary health care and ED attendance and hospitalization	x	✓	✓	✓	x	35	0.3
Primary health care and ED attendance	x	✓	✓	x	x	20	0.2
Death	x	x	x	x	✓	17	0.1
EMS re-contact, primary health care and ED attendance and hospitalization	✓	x	✓	✓	x	11	0.1
EMS re-contact and death	✓	x	x	x	✓	9	0.1
EMS re-contact, primary health care and ED attendance	✓	✓	✓	x	x	5	0.04
EMS re-contact, ED attendance and death	✓	x	✓	x	✓	3	0.03
Primary health care attendance and death	x	✓	x	x	✓	2	0.02

Subsequent event = ✓, no re-contact = x

The reasons for EMS care in the initial non-conveyance mission, before the subsequent events, are shown in Table 8. Non-specific reasons for care were most common.

Table 8. The initial ICPC-2 codes in non-conveyance missions leading to subsequent events (II, published with permission).

EMS re-contacts 0-24 h (n=652, missing 73)				**EMS re-contacts 24–48 h (n=262, missing 31)**			
ICPC2		**n**	**%**	**ICPC2**		**n**	**%**
A04	Weakness/tiredness, general	118	13.5	A04	Weakness/tiredness, general	38	14.5
L02	Back symptom/complaint	52	5.9	A97	No disease	21	8.0
D01	Acute abdomen	52	5.9	D01	Acute abdomen	18	6.8
A11	Chest pain	49	5.6	K80	Other cardiac arrhythmia	16	6.1
A97	No disease	48	5.5	L02	Back symptom/complaint	14	5.3
P16	Acute alcohol abuse	33	3.8	A11	Chest pain	12	4.6
N17	Vertigo/dizziness	32	3.7	A01	Pain general	11	4.2
A03	Fever	30	3.4	N17	Vertigo/dizziness	9	3.4
K85	High blood pressure	29	3.3	P29	Psychological symptom/complaint other	9	3.4
A01	Pain general	23	2.6	P16	Acute alcohol abuse	8	3.0
Visit to ED 0–24 h (n=438, missing 81)				**Visit to ED 24–48 h (n=78, missing 8)**			
ICPC2		**n**	**%**	**ICPC2**		**n**	**%**
A04	Weakness/tiredness, general	49	11.2	A04	Weakness/tiredness, general	11	14.1
A97	No disease	46	10.5	L02	Back symptom/complaint	8	10.3
D01	Acute abdomen	28	6.4	A97	No disease	6	7.7
L02	Back symptom/complaint	27	6.2	A11	Chest pain	6	7.7
P16	Acute alcohol abuse	25	5.7	D01	Acute abdomen	4	5.1
P29	Psychological symptom/complaint other	15	3.4	P16	Acute alcohol abuse	3	3.9

A01	Pain general	15	3.4	A03	Fever	3	3.9
L17	Foot/toe symptom/complaint	13	3.0	A06	Fainting/syncope	3	3.9
A03	Fever	12	2.7	P29	Psychological symptom/complaint other	2	2.6
A11	Chest pain	11	2.5	A92	Allergy/allergic reaction NOS	2	2.6
Hospitalization 0–24h (n=155, missing 29)				**Hospitalization 24–48 h (n=26, missing 1)**			
ICPC2		**n**	**%**	**ICPC2**		**n**	**%**
A04	Weakness/tiredness, general	24	15.5	A04	Weakness/tiredness, general	5	17.2
A97	No disease	16	10.3	A11	Chest pain	2	6.9
L02	Back symptom/complaint	11	7.1	A97	No disease	2	6.9
P16	Acute alcohol abuse	10	6.5	A87	Complication of surgical procedure	2	6.9
L17	Foot/toe symptom/complaint	10	6.5	D01	Acute abdomen	2	6.9
D01	Acute abdomen	8	5.2	L02	Back symptom/complaint	2	6.9
A11	Chest pain	6	3.9	A06	Fainting/syncope	2	6.9
A03	Fever	6	3.9	L04	Chest symptom/complaint	2	6.9
P29	Psychological symptom/complaint other	6	3.9	A01	Pain general	1	3.5
A01	Pain general	5	3.2	K74	Ischemic chest pain	1	3.5

EMS re-contacts were often non-urgent (80% within 0–24 h and 80% within 24–48 h) and ended in a new non-conveyance decision (40% within 0–24 and 51% within 24–48 h). NEWS2 scores were low: 51% had zero points, and 83% had 0–4 points (0–24 h), and corresponding figures within 24–48 h were 53% and 86%. The visits in primary health care were short (median 15 min). In case of ED visits, 65% were discharged within 24 h, 0.3% were treated in an intensive care unit within 0–24 h (0.03% within 24–48 h), and 0.5% were treated in high-dependency units (0.1% within 24–48 h). In approximately 1 in 3 of the EMS re-contacts, the adjusted ICPC-2 code was the same as in the initial non-conveyance mission, but most often, the discharge diagnosis (ICD-10) in primary health care or the ED did not map to the initial ICPC-2 code chosen by EMS (Table 9).

Table 9. Characteristics of the thesis outcomes (II, published with permission).

	0–24 h, n	0–24 h, %	24–48 h, n	24–48 h, %
EMS re-contacts	725	**6.3**	293	2.6
Mission priority				
non-urgent	583	**80.4**	222	75.8
urgent	142	**19.6**	71	24.2
ended in a non-conveyance decision	288	**39.7**	148	50.6
NEWS2 points				
zero	366	**50.8**	156	53.8
0–4	600	**83.3**	248	85.5
EMS re-contact association with initial non-conveyance mission				
ICPC-2 code same	262	**36.1**	85	29.0
ICPC-2 code different	366	**50.5**	161	55.0
ICPC-2 code missing	97	**13.4**	47	16.0
Visit to primary health care facility	958	**8.3**	286	2.6
Visit duration: median 15 min [IQR 0–20] (0–24 h) and 20 min [IQR 0–30] (24–48 h)				
Primary health care visit associated with initial non-conveyance mission				
ICPC-2 code mapped to ICD-10 code	95	**9.9**	25	8.8
ICPC-2 code does not map to ICD-10 code	785	**81.7**	237	83.2
ICPC-2 code mapped to ICD-10 category	154	**16.0**	41	14.4
ICPC-2 code does not map to ICD-10 category	726	**75.5**	221	77.5
ICPC-2 code or ICD-10 code missing	81	**8.4**	23	8.1
Visit to ED	519	**4.4**	86	0.8
Visit duration: 65% of visits less than 1 day				

ED visit associated with initial non-conveyance mission				
ICPC-2 code mapped to ICD-10 code	63	**12.1**	10	11.8
ICPC-2 code does not map to ICD-10 code	376	**72.3**	67	78.8
ICPC-2 code mapped to ICD-10 category	85	**16.3**	17	20.0
ICPC-2 code does not map to ICD-10 category	354	**68.1**	60	70.6
ICPC-2 code or ICD-10 code missing	81	**15.6**	8	9.4
Hospitalization	184	**1.6**	30	0.3
Visit duration: median 2 days [IQR 1-4.5] (0–24 h) and 1 day [IQR 1–2] (24–48 h)				
Intensive care	32	**0.3**	3	0.03
High dependency unit	62	**0.5**	12	0.1
Hospitalization associated with initial non-conveyance mission				
ICPC-2 code mapped to ICD-10 code	6	**3.3**	5	16.7
ICPC-2 code does not map to ICD-10 code	178	**96.7**	25	83.3
ICPC-2 code mapped to ICD-10 category	16	**8.7**	7	23.3
ICPC-2 code does not map to ICD-10 category	168	**91.3**	23	76.6
ICPC-2 code or ICD-10 code missing	29	**15.8**	1	3.3

Without the excluded end of life -patients (n=55, median age 85 years), 126 patients (median age 83 years) died within 28 days (Figure 6). The deaths occurred mostly at health care or social service units (81%, n=102), but for 17% (n=22), death occurred at home, and 2% (n=2) died in a public place. The initial non-conveyance mission occurred mainly at home (61%, n=77), but 37% (n=47) occurred at health care or social service units, and 2% (n=2) in public places. Emergency physicians or physicians in the ED or in primary health care were consulted in 51% of the missions. Overall, 10 patients declined conveyance to the ED, including one patient who would have clearly benefited from treatment in the ED. With retrospective clinical re-evaluation, 32 deaths (25%) were related to the initial non-conveyance mission, and in four cases (0.03% of the initial non-conveyance missions), the non-conveyance decision was not appropriate (Table 10). A physician was consulted in two of these four cases.

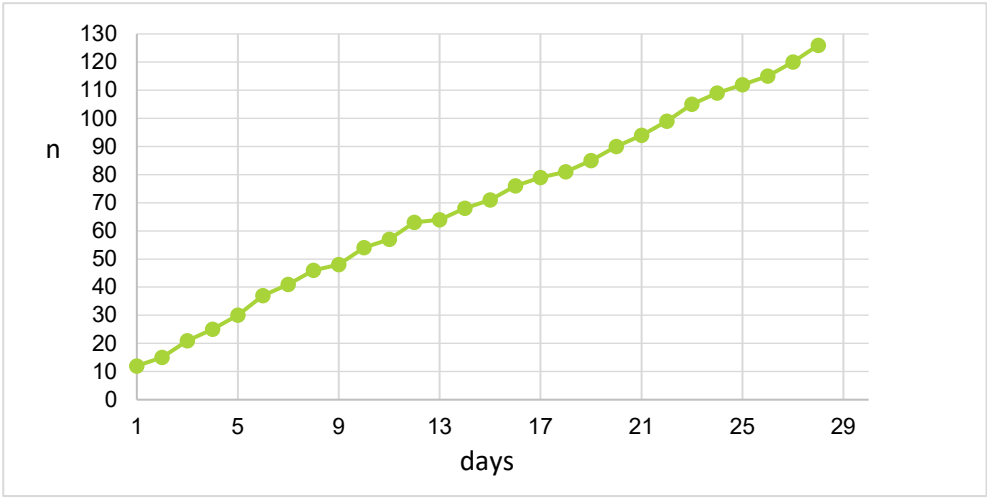

Figure 6. Deceased patients up to 28 days (II, published with permission).

Table 10. Deaths related to inappropriate non-conveyance.

Deceased patients after incorrect non-conveyance decision (n=4)	
Patient 1	The patient's gastroesophageal reflux symptom was ST-elevation myocardial infarction – 12-lead ECG was not recorded.
Patient 2	The patient's shortness of breath and swelling of the foot were due to coronary disease and heart failure.
Patient 3	The reason for patient's non-specific complaints was pneumonia.
Patient 4	The patient had aortic dissection with typical back pain.

5.4 Predictors of subsequent events (II-III)

Results of the multivariable logistic regression model of predictors of adverse outcomes are presented in Table 11. In cases where the patient refused conveyance (aOR 1.79, 95% CI 1.37–2.34) or had used alcohol (aOR 1.37, 95% CI 1.10–1.71), the likelihood of EMS re-contact increased. Univariate analyses also indicated increased likelihood of re-contact with a high NEWS2 score (7 vs 3 in any individual parameter: OR 3.16, 95% CI 1.54–6.48; 7 vs 0–4: OR 3.44, 95% CI 1.78–6.67) or a 1-point increase in NEWS2 score (OR 1.09, 95% CI 1.04–1.15). Non-conveyed missions in which the patient was handed over to police were associated with a subsequent ED visit (0–24 h) (aOR 2.16, 95% CI 1.34–3.49). According to univariate analyses, being a BLS vs ALS unit was also related to further ED visits within 0–24 h (OR 1.50, 95% CI 1.21–1.85). Factors related to subsequent visits to a primary health care facility included non-urgent EMS mission, ALS unit attendance, EMS arrival at night, rural area, older patient age, and longer distance to a primary health care facility or ED (univariate analysis: within 0–24 h, >40 km vs 21–40 km: OR 1.30, 95% CI 1.05–1.61; >40 km vs 5–20 km: OR 2.26, 95% CI 1.83–2.79; >40 km vs <5 km: OR 1.82, 95% CI 1.48–2.24; within 24–48 h, >40 km vs 21–40 km: OR 1.54, 95% CI 1.08–2.21; >40 km vs 5–20 km: OR 2.42, 95% CI 1.69–3.45; >40 km vs <5 km: OR 2.14, 95% CI 1.51–3.03). Overall, EMS arrival at night and older patient age predicted many subsequent events. Non-specific complaints were associated with EMS re-contact within 24–48 h (OR 1.304, 95% CI 1.00–1.70). Gender (p=0.054) and less than an hour to complete a shift (p=0.094) were not related to any outcomes in this study.

In the context of text classification and machine learning, according to nested cross-validation, the FastText model performed best in identifying predictors of adverse outcomes (mean AUC 0.654; Figure 7). Manual evaluation indicated that the algorithm's results were clinically relevant, but the model's extracted keywords, with many conjunctions such as "or" and "if", were partly irrelevant and difficult to understand. However, "tomorrow to health center" or "morning to ED" and non-specific complaints such as "malaise" were the most comprehensible keywords. Based on the model, manual, and content analyses, the most common signs and symptoms as predictors were musculoskeletal, psychological, infection-related, and non-specific complaints. In almost 1 in 5 (18%) of the cases, narrative texts from EMS ePCRs were particularly short, and over a third of these missions led to subsequent events. Moreover, some patients called EMS again with minor symptoms. Finally, in the case of subsequent events, 4 in 5 of EMS personnel and patients had an agreement that the patient would visit a primary health care facility or ED the next or following days after the initial non-conveyance mission.

Table 11. Logistic regression model of EMS re-contact, visits in primary health care facility / ED, and hospitalization (II, published with permission).

Odds Ratio Estimates	EMS re-contact 0–24 h	EMS re-contact 24–48 h	Visit to primary health care 0–24 h	Visit to primary health care 24–48 h	Visit to ED 0–24 h	Visit to ED 24–48 h	Hospitalization 0–24 h
	Adjusted OR (95%)	Adjusted OR (95%)	Adjusted OR (95%)	Adjusted OR (95%)	Adjusted OR (95%)	Adjusted OR (95%)	Adjusted OR (95%)
Mission priority							
CD vs. AB	0.975 (0.814–1.168)	1.249 (0.930–1.676)	1.488 (1.254–1.767)	1.585 (1.167–2.155)	1.258 (1.007–1.571)	0.935 (0.570–1.534)	1.214 (0.752–1.961)
EMS arrival time							
20:00-8:00 vs. 8:00-20:00	1.180 (1.007–1.383)	0.913 (0.714–1.168)	1.818 (1.579–2.094)	1.113 (0.872–1.420)	1.530 (1.269–1.845)	1.068 (0.685–1.664)	1.235 (0.838–1.819)
EMS units							
ALS vs. BLS	0.933 (0.759–1.147)	0.972 (0.709–1.333)	1.431 (1.155–1.773)	1.123 (0.805–1.566)	0.612 (0.489–0.766)	0.737 (0.423–1.284)	1.132 (0.712–1.799)
Rural vs. urban	0.835 (0.709–0.983)	1.011 (0.790–1.293)	1.735 (1.511–1.993)	1.497 (1.175–1.907)	1.008 (0.834–1.219)	1.346 (0.866–2.090)	1.188 (0.802–1.761)
Age, years							
<15 vs. 15–64	0.241 (0.099–0.590)	0.341 (0.107–1.086)	0.545 (0.341–0.871)	0.618 (0.284–1.347)	0.898 (0.552–1.459)	0.963 (0.289–3.211)	0.429 (0.119–1.543)
65-84 vs. 15–64	1.594 (1.326–1.917)	1.561 (1.177–2.071)	1.411 (1.203–1.656)	1.339 (1.015–1.765)	0.836 (0.676–1.033)	1.039 (0.616–1.753)	1.442 (0.918–2.267)
>85 vs. 15–64	1.712 (1.354–2.165)	1.507 (1.045–2.173)	1.147 (0.931–1.412)	0.994 (0.686–1.439)	0.828 (0.626–1.095)	1.427 (0.772–2.639)	2.139 (1.204–3.799)
Alcohol	1.370 (1.100–1.707)	1.376 (0.977–1.938)	0.373 (0.284–0.489)	0.433 (0.273–0.685)	0.567 (0.422–0.760)	0.622 (0.299–1.290)	0.723 (0.381–1.374)
Reason for non-conveyance							
Patient was handed over to police vs. treatment at scene	1.086 (0.665–1.773)	0.836 (0.359–1.948)	0.539 (0.262–1.106)	0.211 (0.029–1.527)	2.161 (1.338–3.489)	2.157 (0.632–7.358)	0.773 (0.268–2.223)
Patient refused conveyance vs. treatment at scene	1.792 (1.370–2.344)	1.324 (0.837-2.093)	0.776 (0.544-1.107)	1.100 (0.653–1.853)	1.292 (0.899–1.856)	1.669 (0.746–3.733)	2.190 (1.073–4.471)

	Univariate OR (95%)	Univariate OR (95%)	Univariate OR (95%)	Univariate OR (95%)	Univariate OR (95%)	Univariate OR (95%)	Univariate OR (95%)
Mission Priority							
Non-urgent vs. urgent	1.089 (0.915–1.295)	1.367 (1.028–1.818)	1.493 (1.267–1.760)	1.587 (1.177–2.141)	1.217 (0.987–1.500)	0.981 (0.607–1.583)	1.402 (0.899–2.186)
EMS arrival time							
20:00-8:00 vs. 8:00-20:00	1.160 (0.998–1.349)	0.951 (0.753–1.201)	1.748 (1.528–1.999)	1.079 (0.852–1.365)	1.433 (1.201–1.710)	0.984 (0.642–1.507)	1.199 (0.834–1.723)
EMS units							
ALS vs. BLS	0.895 (0.736–1.089)	0.877 (0.649–1.184)	1.574 (1.285–1.928)	1.139 (0.825–1.572)	0.668 (0.542–0.824)	0.717 (0.430–1.196)	1.094 (0.713–1.680)
Rural vs. urban	0.874 (0.746–1.024)	0.952 (0.751–1.208)	1.763 (1.542–2.016)	1.541 (1.217–1.951)	0.928 (0.770–1.117)	1.229 (0.835–1.990)	1.249 (0.857–1.821)
Age, years							
<15 vs. 15-64	0.191 (0.079–0.466)	0.299 (0.095–0.947)	0.720 (0.462–1.121)	0.745 (0.344–1.614)	0.894 (0.561–1.425)	0.947 (0.290–3.094)	0.420 (0.119–1.478)
65-84 vs. 15-64	1.381 (1.166–1.635)	1.535 (1.182–1.994)	1.681 (1.449–1.953)	1.645 (1.265–2.139)	0.851 (0.698–1.036)	1.000 (0.611–1.637)	1.587 (1.056–2.384)
>85 vs. 15-64	1.425 (1.154–1.760)	1.439 (1.032–2.007)	1.363 (1.121–1.657)	1.209 (0.846–1.727)	0.848 (0.654–1.100)	1.440 (0.820–2.532)	2.206 (1.310–3.715)
Alcohol	1.307 (1.080–1.581)	1.157 (0.854–1.569)	0.372 (0.290-0.479)	0.768 (0.591–0.998)	0.682 (0.352-1.321)	0.682 (0.352-1.321)	0.689 (0.391-1.211)
Reason for non-conveyance							
Patient was handed over to police vs. treatment at scene	1.065 (0.665–1.707)	0.804 (0.355–1.822)	0.357 (0.189–0.672)	0.121 (0.017–0.866)	1.851 (1.198–2.861)	1.455 (0.456–4.642)	0.657 (0.254–1.699)
Patient refused conveyance vs. treatment at scene	1.794 (1.390–2.315)	1.293 (0.831–2.012)	0.537 (0.380–0.760)	0.834 (0.501–1.390)	1.205 (0.854–1.699)	1.374 (0.631–2.992)	1.763 (0.899–3.455)

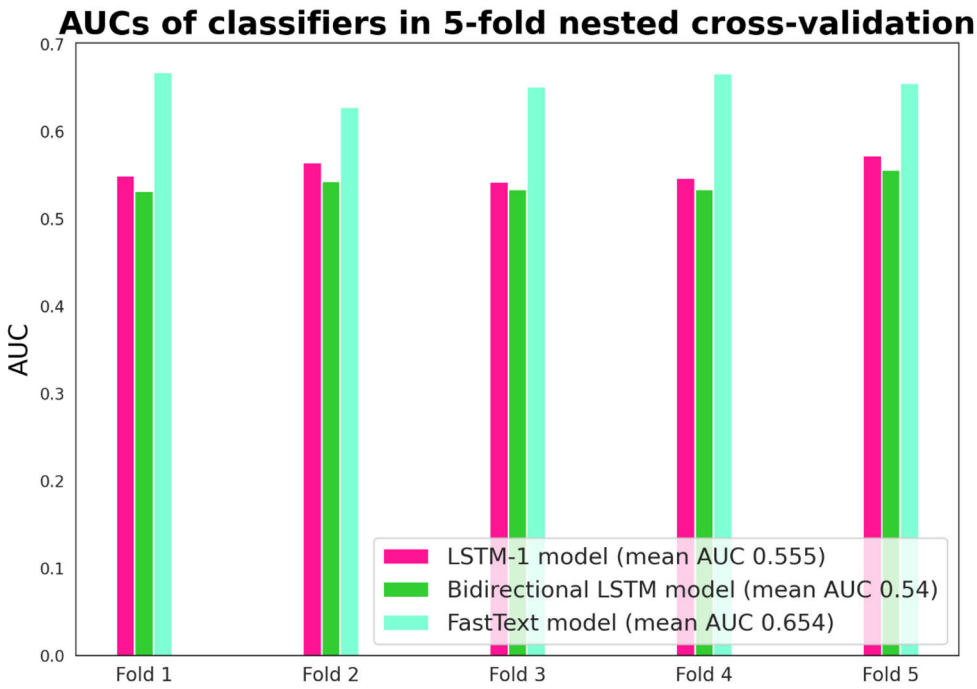

Figure 7. Performance of classifiers in nested cross-validation (III, published with permission).

6 Discussion

6.1 Main findings

Non-urgent patients with minor and non-specific complaints represent a large number of EMS patients, and overall, the results showed that 42% of EMS missions led to a non-conveyance decision. In general, the EMS decisions for non-conveyance seem to be safe and appropriate. Among the non-conveyed patients, most did not have adverse events in the follow-up period. Of note, in case of subsequent events in primary health care or ED, the re-contact was mostly arranged together by EMS personnel and the patient. The results highlight many factors related to non-conveyance decisions and subsequent events.

6.2 The increasing role of non-conveyance

This thesis confirms previous findings that non-conveyance is a central part of EMS work. Of the EMS patients, 42% were treated and released at the scene by EMS. Internationally, the rates of EMS non-conveyance vary (Tohira et al. 2016a, Ebben et al. 2017, Vloet et al. 2018, O'Cathain et al. 2018, Coster et al. 2019, Höglund et al. 2020, Magnusson 2020a, Lederman et al. 2020b), but rates in the present study are similar to those reported in previous Finnish studies (Hoikka 2017, Pekanoja 2018, Laukkanen et al. 2021, Heinonen et al. 2022).

In this study, the adjusted ICPC-2 classification was introduced into use in the study areas. More studies and validations are needed, but it seems that this adjusted classification is a good option for the prehospital setting to determine a patient's main reason for care and for example enables more specific analyses of these patients comparing to dispatch codes. It is unclear, however, whether the large number of patients with non-specific reasons for care indicates non-specific complaints instead of the absence of an appropriate code. According to the adjusted ICPC-2 classification, the results show that among non-conveyed patients, non-specific complaints, no disease, and alcohol misuse represent more than half (54%) of the main problems in this group. That said, chest pain (7.2%) and acute abdominal pain (7.2%) were relatively common as well. However, the non-conveyed patients were in good condition: in 55% of cases, the NEWS2 score was zero, which is comparable

to other studies (Tohira et al. 2016a, Hoikka et al. 2017, Höglund et al. 2020, Lederman et al. 2020b).

Based on the univariable and multivariable regression analyses, several factors were associated with non-conveyance. Understandably, a non-urgent mission priority increased the likelihood of EMS non-conveyance, as did EMS arrival time in the evening or night. A number of studies have reported similar findings (Tohira et al. 2016a, Hoikka et al. 2017, Magnusson et al. 2020a, Höglund et al. 2020), although Lederman et al. (2020b) found that the split by time of day was relatively even. In the current study, rural area was also associated with non-conveyance, which is in contrast to the results of a Dutch study (Vloet et al. 2018). One explanation might be that Finland is a sparsely populated country and that a rural–urban classification is not necessarily comparable to other countries. However, because of health care centralization and limited access to primary health care, for instance, EMS units are often the only health care service available (Pekanoja et al. 2018), and many factors other than a patient's critical condition lead to calling 112. Thus, EMS missions without any need for treatment have increased (Andrew et al. 2019). Although Booker et al. (2015) concluded that judging the mission as "inappropriate" or not is useless, both internationally (Booker et al. 2018) and nationally (Hoikka et al. 2016, Raatiniemi et al. 2018), challenges have been identified related to over-triage and non–life-threatening situations in dispatch protocol. Thus, the dispatch system needs to be refined (Hoikka et al. 2016, Ilkka 2022). It is also noteworthy that in Finland, the dispatchers are not necessarily health care professionals. A secondary telephone triage system could be a feasible option to decrease attendance rates of EMS (Eastwood et al. 2015, Krumperman et al. 2015, Eastwood et al. 2016, Ebert et al. 2017, Roivainen et al. 2020).

Understandably, younger patients were most likely discharged at the scene, as has been found before (Vloet et al. 2018, Magnusson et al. 2020a, Lederman 2020b). Surprisingly, elderly patients also were a common patient group in the non-conveyed population (Ebben et al. 2017, O'Cathain et al. 2018), although challenges related to elderly patients have been reported (Eastwood et al. 2018, Oosterwold et al. 2018). As described above, this study shows that non-conveyed patients were in good shape, and a low NEWS2 score was associated with non-conveyance, as Hoikka et al. also reported (2017). The current study reveals that if the NEWS2 score increased by one or two points, the likelihood of conveyance increased. Vloet et al. (2018) reported that 2 in 3 conveyed patients had abnormal vital signs. However, the missions leading to a non-conveyance decision were more time consuming and there were more physician consultations, which has been found in other studies as well (Goldstein et al. 2015, Oosterwold et al. 2018). There is a possibility that these results indicate that assessment of the patients was thorough and that patients were also advised with respect to further treatment and health care re-contact possibilities,

and if necessary, consultation gave another opinion for the conveyance decision making. The current study also shows that ALS units were associated with the likelihood of EMS non-conveyance. It has been reported before that appropriate non-conveyance requires competence (Ebben et al. 2017, O'Cathain et al. 2018, Oosterwold et al. 2018).

Finally, these findings indicate that EMS treats many non-urgent patients without immediate need for a doctor. Obviously, the EMS core mission is to treat critically ill or injured patients in the prehospital setting (Al-Shaqsi 2010). However, health care resources are limited, and EMS often is the only or at least the easiest option for a patient to receive help, especially in the evenings and nights. Thus, achieving a balance between non-conveyance safety margins and unnecessary conveyances is crucial (Khorram-Manesh et al. 2011), particularly given the reported lack of alternative pathways (Yeung et al. 2019, Blodgett et al. 2021). Based on promising results with community paramedic units, perhaps such units could provide a better response for non-urgent patients and be a cost-effective solution (Choi et al. 2016, Rasku et al. 2019, Chan et al. 2019, Patton et al. 2021, Rasku 2022). On the other hand, preventive health care to address cognitive impairment and nutritional and fall risk assessment, for example, also has been requested from EMS (Saario et al. 2021).

6.3 Patient safety and non-conveyance decisions

The safety of EMS non-conveyance has been unclear (Ebben et al. 2017, Yeung et al. 2019, Blodgett et al. 2021). In the present study patient safety was assessed based on adverse events after non-conveyance decision. The thesis indicate that 4 in 5 (84% within 0–24 h) of the non-conveyed patients had no adverse outcomes after the EMS decision not to convey the patient to health care facility. Rates of EMS re-contact (6.3%), primary health care contact (8.3%), ED attendance (4.4%), hospital admission (1.6%), and mortality (0.1%) within 24 hours are roughly similar to those previously reported (Tohira et al. 2016a, Coster et al. 2019, Magnusson 2020a, Laukkanen et al. 2021), as are rates for long-term mortality (Heinonen et al. 2022). Based on pathway analyses, some non-conveyed patients had multiple types of subsequent events in the follow-up period, as also previously reported (Coster et al. 2019). Thus, adverse events were relatively rare after EMS non-conveyance. From a patient safety perspective, the first 24 h after a non-conveyance decision seem to be critical, as demonstrated in the current findings and in earlier work (Tohira et al. 2016a), as event rates within 24 h were higher compared with longer follow-up time. Moreover, a longer follow-up period gives a broader understanding of outcomes for non-conveyed patients, but it is obvious that re-contact within the first 48 h is the better indicator of whether the adverse event was related to the initial non-conveyance mission (Yeung et al. 2019).

In case of EMS re-contact, 4 in 5 of dispatch priority assessments were non-urgent, and approximately 40% of missions ended with a new non-conveyance decision (within 0–24 h). NEWS2 scores were low, and visits to a primary health care facility or ED were short. A small proportion of the non-conveyed patients needed treatment in intensive care or in a high-dependency unit. These findings are similar to those of a Swedish study (Magnusson et al. 2020a) showing that non-conveyed patients were mostly in good condition. However, evidence is lacking regarding whether the re-contact is related to the initial non-conveyance mission (Ebben et al. 2017). In this thesis, if the patient had EMS re-contact, the initial adjusted ICPC-2 code chosen by EMS was compared with the new adjusted ICPC-2 code. Whether the patient had primary health care, ED attendance, or further hospital admission, the adjusted ICPC-2 code was compared with the discharge diagnosis (ICD-10). Based on the findings, the re-contacts were mainly unrelated to an initial EMS mission in which the patient was treated and released at the scene. However, based on the text classification and further manual and content analyses, which are described in more detail below, the re-contacts after non-conveyance decisions were often planned beforehand. These contradictory results can partly be explained by the fact that only the patient's main reason for care, in this case one adjusted ICPC-2 code, was analyzed. It is also noteworthy that the adjusted ICPC-2 code indicates the signs and symptoms at that moment in the prehospital setting. Time frame, more specific examination, and in-hospital treatment may have influenced the discharge diagnosis. On the other hand, adjusted ICPC-2 classification has not been validated, and diagnostic discrepancy is possible in the prehospital setting (Wilson et al. 2018) as well as in EDs (Hautz et al. 2020). After exclusion of end of life -patients, 126 patients (1.1%) died within 28 days. According to a clinical re-evaluation by the study group, four of these patients (0.03% of the initial non-conveyance missions) would have needed conveyance to the hospital, in keeping with recent findings by Magnusson et al. (2020a).

Decision making in the prehospital setting is challenging because of the uncontrolled environment and limited information about the patient's medical history, for example (O'Hara et al. 2015, Andersson et al. 2019). Understandably, EMS care providers fear erroneous assessments and making an inappropriate non-conveyance decision, which could harm the patient (Lederman et al. 2019). On the other hand, there is evidence that a large percentage of ED patients conveyed by EMS do not need any treatment or hospital resources (Magnusson et al. 2021b), and EMS patients do not end up at the most appropriate level of care (Nordberg et al. 2015). Furthermore, a crowded ED is a high-risk place for patients (Berg et al. 2019, Boyle et al. 2021, Jones et al. 2022). Thus, a balance between safety margins and limited resources is essential (Khorram-Manesh et al. 2011). Finally, this thesis highlights with relevant outcome measures (Coster et al. 2018) that non-conveyance

seems to be a safe choice in order to avoid unnecessary conveyances to a primary health care facility or ED.

6.4 Predictors of subsequent events

According to univariable and multivariable regression analyses, a number of factors predicted subsequent events after a patient was discharged at the scene. The study reveals that high or increased NEWS2 scores were related to EMS re-contact. Indeed, abnormal vital signs have been seen as predictors of several outcomes (Tohira et al. 2016a), but as Laukkanen et al. (2021) reported, elevated NEWS2 surprisingly did not predict subsequent visits to the ED, suggesting the need for further studies. A patient's refusal of conveyance and alcohol usage were also associated with EMS re-contact (within 0–24 h), likely indicating a patient's challenges in life management and the fact that EMS is often the easiest option for getting health care. EMS-refusal patients suffer mostly psychiatric symptoms or alcohol intoxication (Hjälte et al. 2007) and seek further care in the ED (Knight et al. 2003). In this study, patients who were handed over to the police were likelier to present at the ED within 24 hours. Additionally, EMS missions in which the patient was treated and released at the scene by a BLS unit were associated with an increased likelihood of an ED visit. Clearly, educational background is connected to the ability to make appropriate decisions (Koivulahti et al. 2020), and as noted, non-conveyance requires competence (Ebben et al. 2017, O'Cathain et al. 2018, Oosterwold et al. 2018). It is unclear, however, whether the re-contacts indicate error in non-conveyance decision making, and more studies are needed. As this thesis has revealed, older patient age predicted several outcomes after the patient was discharged at the scene, as has been reported before (Tohira et al. 2016a, Lederman et al. 2020a, Höglund et al. 2022). This fact may be explained by comorbidities, complex complaints, and use of a high number of medications common among older patients.

The findings of this thesis indicate, based on statistical analyses, that the likelihood of a subsequent visit to a primary health care facility increased when the initial EMS mission was non-urgent, located in rural area with a long distance to a health care facility, or involved an ALS unit arrival at night. Nevertheless, based on machine learning (FastText model, AUC 0.654) and further manual and content analyses, 4 in 5 of the visits to a primary health care facility or ED were planned beforehand between EMS personnel and the patient. Even if the clinical benefit of many procedures by EMS are unclear (Bigham 2015) and making a correct decision at night is challenging (O'Hara et al. 2015), these findings show appropriate use of resources by EMS to avoid ED crowding. The crucial roles of guidance and instructions in prehospital emergency care have been previously described (Pekanoja

et al. 2018). Earlier studies found that about half of non-conveyed patients were advised to contact a primary health care facility the next day (Hoikka et al. 2017, Breeman et al. 2018). Moreover, patients in the prehospital setting followed the instructions well (Krumperman et al. 2015). Thus, these results may explain that not all re-contacts with a health care facility were events associated with harm to patients (Runciman et al. 2009). In contrast, however, Tohira et al. (2016a) reported that EMS patients discharged at the scene have more adverse events compared with patients discharged from the ED, partly questioning the safety related to an EMS treat and release protocol. Clearly, patients in the ED most often receive the final diagnosis and related treatment, but in the prehospital setting, further contact, arranged together between the patient and EMS, is more common. Moreover, already a timeframe can change patient's condition and etiology, and lead to re-contact to health care. However, as described, most of the non-conveyed patients did not seek any further help after the EMS decision not to convey them to a health care facility. O'Conner et al. (2021b) also concluded that a standardized taxonomy related to incidents and patient safety in prehospital emergency care is essential.

To the best of the author's knowledge, this is the first study to use machine learning in the context of EMS non-conveyance. Machine learning (FastText-model, AUC 0.654) seems promising at predicting subsequent events from the narrative texts of EMS ePCRs. Also, based on manual analyses, the results were understandable and clinically appropriate. AUC was less than 0.700, however, and the extracted keywords included several conjunctions. Thus, further studies are needed.

EMS medical and care needs assessment seems to do well in identifying patients who need immediate treatment, patients whose treatment can wait, and patients who do not require further treatment. In association with this pattern, an ALS unit increased the likelihood of non-conveyance and subsequent re-contacts with a primary health care facility. This result is in line with the competence requests in the prehospital setting described above. Similarly, a rural area and longer distance to a health care facility were related to re-contacts. Although the geographic impact on adverse outcomes is not clear, it has been reported that geographic variation is high in the prehospital setting (Hanchate et al. 2017, Hegenberg et al. 2019), and the time spent at the destination has been long (Alanazy et al. 2019). Notably, individualized care and patient-centered solutions should be the goal in the prehospital setting. Consequently, night-time visits in the ED are not the most comfortable treatment for the patient if the problem can be safely treated in the next or following days. On the other hand, as noted, limited options for alternative pathways are available (Yeung et al. 2019, Blodgett et al. 2021). It is also noteworthy that all patients did not need any treatment or follow-up. This study indicates that a number of non-conveyed patients had minor symptoms, but the re-contacts were repeated; similar findings

have been seen in previous studies (Scott et al. 2014, Hoikka et al. 2017, Søvsø et al. 2019).

Non-specific complaints have been connected to adverse outcomes (Nielsen et al. 2020, Ivic et al. 2020, Magnusson et al. 2020a). In this study, there were some associations between non-specific complaints and subsequent events. However, a statistically non-specific reason for care predicted only the EMS re-contact within 24–48 h. Inadequate documentation in the prehospital setting has been seen as a risk for adverse outcomes (Hagiwara et al. 2019, Latten et al. 2020). Similarly, the current study indicates that among non-conveyance missions, 1 in 5 of the written texts in the ePCRs were short, and of these, 1 in 3 led to re-contacts in the follow-up period. This pattern might indicate an attitude problem on the part of EMS personnel. It also could demonstrate that the patient's complaints were minor, and subsequent events after these briefly written cases remain unclear. Nonetheless, it is possible that these patients were frequent callers without real need for treatment, and further studies are needed to fully understand the reasons for incomplete documentation. Having less than an hour to complete a shift was not related to non-conveyance decision making or the events in the follow-up period. This finding may suggest that the EMS personnel take patient needs into account even when the shift is coming to an end.

6.5 Strengths of the thesis and generalizability of the results

This thesis has some clear strengths. It relied on a prospective study design, which allowed for correction of errors and bugs based on several test data sets. The study design also made it possible to use the adjusted ICPC-2 classification and make further comparisons of how the subsequent event in the follow-up period was related to the initial non-conveyance mission. The large and recent dataset was collected from three different regions covering mixed rural and urban areas. Patient record review, which was used in this study, is considered to be a "gold standard" method in patient safety studies (Shojania et al. 2020), yielding a higher prevalence of reported incidents (O'Connor et al. 2021b). Patients in the study cohort were followed between different registries with a unique personal identification number. In Finland, the hospital districts and health care units have a statutory obligation to provide the data to the national health care registers (Finnish Institute for Health and Welfare 2018a, 2018b). Moreover, the Finnish Causes of Death registry covers 100% of deceased patients with manually checked and validated death certificates (Lahti et al. 2001). STROBE checklist was used as a guideline. Traditionally, patient safety studies are done inside the hospital (Fisher et al. 2015), but here a patient safety study was performed in the prehospital setting. Of note, a variety of methods

were used, and several variables were tested and reported. One of the main findings – that a subsequent event in a health care facility after an EMS non-conveyance decision was often planned with the patient and EMS on scene – is based on statistical analyses, as well as on text classification in the context of machine learning and further manual and content analyses.

The results of this thesis are possibly generalizable in western countries, where the EMS systems are more or less similar. However, as mentioned, in Finland, prehospital patient pathways are designed in collaboration with EMS and EDs. Also, university level, 4-year paramedic-nurse education with a dual degree has been successfully in place for more than 20 years (Dúason et al. 2021). Therefore, the generalizability of the findings of the thesis may be limited.

6.6 Limitations

Overall, this thesis has several limitations. The ePCRs and registries used were not originally designed for scientific research purposes. Therefore, a large number of EMS patients were excluded. Unknown patients with unclear or missing personal identity numbers have been reported before (Christensen et al. 2016, Tohira et al. 2016a), as have incomplete data (Yeung et al. 2019, Ilkka 2022).

Although the EMS personnel received training in the study area for using the adjusted ICPC-2 classification, it obviously was not implemented optimally. As mentioned, it is possible that a great number of patients with non-specific complaints pointed out inconsistency in the adjusted ICPC-2 classification. Notable, the adjusted classification has been intended for use in prehospital emergency care, but no validation has been done. There were also some other issues associated with the adjusted ICPC-2 codes. As a result of human error, two ICPC-2 codes (Z25 and Z29), which indicate social problems, were not available in one study area. Already considered earlier was that most often, the adjusted ICPC-2 codes were not mapped to the ICD-10 codes, but these re-contacts with a primary health care facility or ED were often planned beforehand. Finally, the actual rates of subsequent events with the same reason as in the initial non-conveyance case are probably higher than reported.

The NEWS2 scores were calculated so that the missing values were taken into account as normal. Clearly, the points obtained are lower than the actual values. A text mining method was used to find patients with COPD or whether oxygen was used. Spelling mistakes, for instance, were noted, but some information still may have been missed.

Even though health care units in Finland are obligated to report all the care periods with detailed information, there were some challenges in these registries. In case of subsequent contact with an ED, the initial non-conveyance mission was

judged to be first and the ED visit (0–24 h) was set to be on the same or on the following day, because the register included the visit date without information about the exact visit time. Also, the register for primary health care includes chronic disease monitoring. Thus, the real rate of subsequent contacts with a primary health care facility or ED might be lower. Conversely, it is possible that there were patients who sought help from private clinics. However, patients with significant deterioration would have been sent to an ED.

The sample size was large but could have been bigger. For example, 28-day mortality and hospitalization (within 24–48 h) had to be excluded from the multivariable logistic regression model as dependent variables because of the low number of events. Correspondingly, in the context of machine learning, where 90% of the data were used for model training, all subsequent events were forced to be set as equivalent. Therefore, the data were labeled in two groups, with (n=2550) or without a subsequent event (n=9296). Indeed, the numbers of subsequent events and correct model predictions in this experimental setup were limited. Of note, it was challenging to find predictors from the narrative texts of ePCRs because of their brevity and use of abbreviations, even if the performance of the FastText model was moderate (AUC 0.654), and predictors after manual and content analyses were also found. In general, Finnish, with its many cases and inflections, is challenging for such computational analyses. Similarly, machine learning models with predictions have many limitations (Chen & Asch 2017, Collins & Moons 2019, Spasic et al. 2020), and more studies are needed.

6.7 Future considerations

Further research on patient safety is needed to identify factual harmful events after a non-conveyance decision. Re-contacts without planned subsequent visits to a health care facility should be determined. Studies related to different patient groups and the main reasons for care are also required. Moreover, the benefits and safety of various pathways, alternative solutions, and the chain of emergency care should be evaluated. More studies also are needed on patients who have been conveyed unnecessarily.

The adjusted ICPC-2 classification should be validated, and studies need to evaluate its usefulness in prehospital emergency care. If the adjusted classification were to be introduced into primary health care facilities and EDs, prehospital patient follow-up and analyses would be easier. Machine learning was used in this thesis only to analyze the narrative texts from the ePCRs. In the future, the texts could be analyzed together with numerical variables in bigger data sets. Similarly, comparing prehospital texts and health care facility texts is important to obtain information about whether the subsequent event was related to the initial non-conveyance

mission, for instance. Machine learning will be a central part of health care, and evidence-based algorithms and implementation for EMS personnel decision making are needed.

7 Summary/Conclusions

Non-conveyance plays a vital role in EMS daily practice to provide appropriate care for patients and decrease unnecessary ED crowding. In this study, most non-conveyed patients did not have any re-contact with health care in the follow-up period. If there was a re-contact, most occurred within <24 hours after a non-conveyance decision, the reason differed from the initial main reason for care, the patients were in good condition, the need for intensive care was rare, and death was extremely uncommon. It is noteworthy that an event after non-conveyance did not automatically mean endangering patient safety, and this study indicates that most of the subsequent events were planned on the scene between the patient and EMS, demonstrating reasonable use of limited resources. Finally, EMS non-conveyance does not seem to compromise patient safety. More studies are needed to identify likely rare but real harmful events after a non-conveyance decision.

Kiitokset

Tämä väitöskirja tehtiin Turun yliopiston lääketieteellisen tiedekunnan anestesiologian, tehohoidon, ensihoidon ja kivunhoidon oppiaineessa vuosina 2016–2022.

Haluan kiittää väitöskirjan esitarkastajina toimineita dosentti Annika Takalaa ja dosentti Antti Kämäräistä hyvistä huomioista ja kommenteista. Teidän rakentava palaute auttoi väitöskirjan viimeistelyssä ja loppuun saattamisessa.

Suuret kiitokset väitöskirjan ohjaajille ylilääkäri Timo Iirolalle ja professori Jouni Kurolalle erittäin laadukkaasta ohjauksesta läpi projektin. Riippumatta kiireestä ja teidän monista velvoitteista, tuki oli aina saatavilla. Väitöskirjan aihe oli alun perin Timon idea, mitä ilman projekti ei olisi edes käynnistynyt. Timon asiantuntemus on laajaa, myös yksityiskohtiin menevä tarkkuus toimi hyvänä vastapainona omalle taipumukselle ”paketoida” asiat ennemmin kuin myöhemmin. Jounin laaja ymmärrys ja asiantuntemus ensihoidosta sekä tieteellisesti että kliinisesti on kiistatonta. Ei voi kuin ihailla Jounin tapaa työskennellä ja tässä tapauksessa tavasta auttaa väitöskirjan tekijää oikeaan suuntaan. Koen todella olevani etuoikeutettu pääsemisestä mukaan tähän kelkkaan.

Biostatistikko Mari Koivisto oli korvaamaton eri rekisteritietojen yhdistämisissä ja tilastollisissa analyyseissä. Eksploratiivinen kokonaisuus, missä datojen suhteen oli runsauden pula, tarkoitti käytännössä sitä, että analyyseja tehtiin todella paljon. Kiitos Mari. Professori Sanna Salanterä oli paljon enemmän kuin ohjausryhmän jäsen. Sannan laaja kokemus auttoi osaltaan hahmottamaan kokonaisuutta ja Sanna toimi myös tärkeänä linkkinä kliinisen käytännön ja itselle vieraan koneoppimisen välissä. Suuret kiitokset myös tekstin louhijoille. Hans Moen on tekstin louhinnan ja koneoppimisen guru, joka oman Akatemia-hankkeen kanssa samaan aikaan auttoi tämän projektin tekoälykuvioissa. Akseli Reunamolla oli suuri merkitys kolmannen osatyön algoritmin työstämisessä sekä koneoppimisen avaamisessa allekirjoittaneelle. Tero Vesanen auttoi merkittävästi datojen yhdistämisissä ja siivoamisissa. Kiitokset Heikki Riihimäelle, joka teki gradunsa tähän projektiin liittyen. Heikki toi tutkimusryhmään toiset ”ensihoitajan aivot”, mikä auttoi monen monta kertaa ratkaisuja mietittäessä. Kiitokset myös professori Niina Käyhkölle ja Venla Aaltoselle maantieteellisistä analyyseistä, teidän mukaan tulo tutkimusryhmään tuki

osaltaan poikkitieteellistä kokonaisuutta ja sitä, että maantieteelliset analyysit tulivat luotettavasti tehtyä.

Haluan kiittää apulaisylilääkäri Juhani Tavastia, sekä ylilääkäreitä Markku Grönroosia, Timo Jamaa, ja Janne Kuuselaa myötämielisestä suhtautumisesta ensihoidon uusien ICPC2-koodien käyttöönotolle tutkimusalueilla ja prospektiiviselle aineistonkeruulle. Kiitokset myös Kanta-Hämeen, Päijät-Hämeen ja Etelä-Savon ensihoito- ja lääkintäpäälliköille, sekä koko ensihoitohenkilöstölle asian edistämisestä. Kiitos Jari Rantanen (Etelä-Savo) ja Petri Pihlaja (Codea / Kanta- ja Päijät-Häme), teitä piinasin testidatojen ja aineistonkeruun osalta todella paljon.

THL:n ylilääkäri Jutta Järvelinin merkitys oli suuri, kun aineistonkeruun askelmerkkejä soviteltiin. Jutan vakuuttelut HILMO- ja avoHILMO-tietojen poimintojen onnistumisista oli projektin käynnistymisen kannalta ensiarvoisen tärkeitä. Raimo Mahkonen (THL) auttoi merkittävästi HILMO- ja avoHILMO -tietojen poiminnassa ja esimerkiksi ICPC2-koodien linkityksissä ICD10-koodeihin. Jenni Kauppinen (Tilastokeskus) auttoi keskeisesti kuolintietoaineistojen saamisissa. Kiitos myös Jukka Tennilälle (FinnHEMS) avusta ensihoitodatojen yhdistämisissä. Kiitokset Lasse Ilkka (STM) ja Viljami Lampilinna (THL), yhteinen tekoälyprojekti tuki väitöskirjan tekoälykokeiluja sekä datojen tietoturvallista poimintaa. Taloudellisesta tuesta iso kiitos Turun yliopistolle, FinnHEMS:lle, Ensihoidon tukisäätiölle ja Betania-säätiölle.

Suuret kiitokset Turun AMK:n esihenkilöille Anne Isotalolle ja Camilla Laaksoselle. Teidän varaukseton tuki oli välttämätöntä, että tämä väitöskirja valmistui. Kiitos dosentti Pirkko Routasalo ja Riitta-Liisa Lakanmaa, teidän mentorointi ja uskon luominen oli tärkeää erityisesti projektin alkuvaiheessa. Jari Säämäsen esimerkki sinnikkäästä tieteellisestä työskentelystä on viitoittanut myös tämän väitöskirjan valmistumista, kiitos Jari. Kiitos myös Tuija Leinonen. Tarpeeksi monta kertaa, kun kahviautomaatilla toistaa, että ”hyvältä näyttää” ja ”siitä tulee todella hyvä”, alkaa epäröivä väitöskirjan tekijä väkisinkin uskomaan, että ehkä tämä voi onnistua.

Iso kiitos oman väitöskirjansa kanssa painineelle Oulun AMK:n kollega Petri Roivaiselle, jonka kanssa käydyt pitkät puhelut olivat paitsi terapeuttisia, niin vertaistukea mitä suuremmassa määrin. Myös Petrin kyky nähdä tulevaa todentui jo väitöskirjan alkuvaiheessa, ”kyllä me ollaan Jani tämän kanssa vielä kusessa” (pahoittelut karkea ilmaisu, mutta kuvasi hyvin sen ajan tuntoja).

Edellä mainittujen lisäksi haluan lämpimästi kiittää ystäviä sekä nykyisiä ja aiempia kollegoita, jotka ovat vaikuttaneet allekirjoittaneen työuraan ja väitöskirjaan toisaalta tukien ja ymmärtäen, mutta ennen kaikkea siten, että elämässä on muutakin kuin projekti nimeltä väitöskirja.

Lämpimät kiitokset omille vanhemmille. Miten ikinä elämä onkaan heitellyt, jotenkin on aina sellainen olo, että minä pärjään. Urheilu oli nuorelle miehelle kaikki

kaikessa, mutta ehkä äidin väsymätön muistutus opiskelun tärkeydestä realisoitui viimeistään nyt väitöskirjan muodossa. Isän viesti on ollut aina selvä, kun tehdään, niin tehdään kunnolla. Olen sitä sitten noudattanut aina soveltuvin osin. Kiitokset myös isän puolisolle Tuulalle, sekä anopille Maisalle ja Ristolle kaikesta avusta ja tuesta vuosien varrella, sekä siitä, että aina olen ollut kelvannut juuri sellaisena kun olen.

Lopuksi tärkeimmät, eli suuret kiitokset rakkaalle vaimolle Johannalle, sekä rakkaille lapsille Nealle ja Oonalle. Ilman teitä tämä projekti ei olisi koskaan alkanut, saati valmistunut. Ei löydy sanoja. Teidän olemassaolo muistuttaa joka päivä mikä elämässä oikeasti olikaan tärkeää.

Liedossa elokuussa 2022
Jani Paulin

References

Abadi M, Barham P, Chen J, et al. TensorFlow: a system for large-scale machine learning. 2016 Nov, 12th USENIX Symposium on Operating Systems Design and Implementation, Savannah, GA, USA.

Abbott TEF, Cron N, Vaid N, et al. Pre-hospital National Early Warning Score (NEWS) is associated with in-hospital mortality and critical care unit admission: a cohort study. *Ann Medicine Surg.* 2018;27:17–21.

Act on the Status and Rights of Patients 785/1992. https://www.finlex.fi/en/laki/kaannokset/1992/en19920785. Accessed 18 Feb 2022.

Aitavaara-Anttila M, Liisanantti J, Ehrola A, et al. Use of prehospital emergency medical services according to income of residential area. *Emerg Med J.* 2020;0:1–5.

Al Amiry A, Maguire BJ. Emergency Medical Services (EMS) Calls During COVID-19: Early Lessons Learned for Systems Planning (A Narrative Review). *Open Access Emerg Med.* 2021;13:407-414.

Alanazy ARM, WarkS FJ, Nagle A. Factors Impacting Patient Outcomes Associated with Use of Emergency Medical Services Operating in Urban Versus Rural Areas: A Systematic Review. *Int J Environ Res Public Health*. 2019;16(10):1728.

Al-Dury N, Ravn-Fisher A, Hollenberg J, et al. Identifying the relative importance of predictors of survival in out of hospital cardiac arrest: a machine learning study. *Scand J Trauma Resusc Emerg Med*. 2020;28:60.

Al-Shaqsi SZK. Models of International Emergency Medical Service (EMS) Systems. *Oman Medical Journal.* 2010;25(4):320–3.

American College of Emergency Physicians. Emergency Medical Services Interfaces With Health Care Systems. *Ann Emerg Med.* 2018;71:e119-e120.

Andersson S, Høgskilde PD, Wetterslev J, et al. Appropriateness of leaving emergency medical service treated hypoglycemic patients at home: a retrospective study. *Acta Anaesthesiol Scand.* 2002;46(4):464–8.

Andersson U, Söderholm HM, Sundström BW, et al. Clinical reasoning in the emergency medical services: an integrative review. *Scand J Trauma Resusc Emerg Med*. 2019;27:76.

Andrew E, Nehme Z, Cameron P, et al. Drivers of Increasing Emergency Ambulance Demand. *Prehosp Emerg Care*. 2019;12:1.

Arbon P, et al. The reality of multiple casualty triage: putting triage theory into practice at the scene of multiple casualty vehicular accidents. *Emerg Med J.* 2008;25(4):230–4.

Bennett R, Mehmed D, Williams B. Non-technical skills in paramedicine: A scoping review. *Nurs Health Sci.* 2021;23:40–52.

Berg LM, Ehrenberg A, Florin J, et al. Associations Between Crowding and Ten-Day Mortality Among Patients Allocated Lower Triage Acuity Levels Without Need of Acute Hospital Care on Departure From the Emergency Department. *Ann Emerg Med.* 2019;74:345–56.

Bigham BL, Maher J, Brooks SC, et al. Patient Safety in Emergency Medical Services: Advancing and Aligning the Culture of Patient Safety in EMS. Edmonton, Canada: Canadian Patient Safety Institute, 2010.

Bigham B, Welsford M. Applying Hospital Evidence to Paramedicine: Issues of Indirectness, Validity and Knowledge Translation. *CJEM*. 2015;17(3):281-285.

Blaber AY, Harris G. Assessment Skills for Paramedics. Open University Press. McGraw-Hill Education.

Black JJM, Davies GD. International EMS Systems: United Kingdom. *Resuscitation.* 2005 Jan;64(1):21-9.

Blanchard IE, Kozicky R, Dalgarno D, et al. Community paramedic point of care testing: validity and usability of two commercially available devices. *BMC Emerg Med*. 2019;19(30):1.

Blodgett JM, Robertson DJ, Pennington E, et al. Alternatives to direct emergency department conveyance of ambulance patients: a scoping review of the evidence. *Scand J Trauma Resusc Emerg Med.* 2021;29(1):4.

Booker MJ, Shaw ARG, Purdy S. Why do patients with 'primary care sensitive' problems access ambulance services? A systematic mapping review of the literature. *BMJ Open.* 2015;5:e007726. doi:10.1136/bmjopen-2015-007726.

Booker MJ, Shaw ARG, Purdy S, et al. 'Primary care sensitive' situations that result in an ambulance attendance: a conversation analytic study of UK emergency '999' call recordings. *BMJ Open*. 2018;8:e023727.

Bos N, Krol M, Veenvliet C, Plass AM. 2015. Ambulance care in Europe—Organization and practices of ambulance services in 14 European countries. Available from: https://www.nivel.nl/sites/default/files/bestanden/Rapport_ambulance_care_europe.pdf. Accessed 17 Feb 2022.

Boyle A, Higginson I, Sarsfield K, et al. RCEM Acute Insight Series: Crowding and its Consequences. 2021.https://rcem.ac.uk/wpcontent/uploads/2021/11/RCEM_Why_Emergency_Department_Crowding_Matters.pdf. Accessed 10 Feb 2022.

Braithwaite SS. Ethics in Paramedic Practice: A Qualitative Case Study of Paramedic Perceptions of Ethical Decision Making in Practice (doctoral dissertation). 2014, North Carolina State University, USA.

Brandler ES, Sharma M, McCullough F, et al. Prehospital stroke identification: factors associated with diagnostic accuracy. *J Stroke Cerebrovasc Dis*. 2015;24:2161–6.

Breeman W, Poublon NA, Verhofstad MHJ, et al. Safety of on-scene medical care by EMS nurses in non transported patients: a prospective, observational study. *Scand J Trauma Resusc Emerg Med*. 2018;26:79.

Brooks IA, Cooke M, Spencer C, Archer F. A review of key national reports to describe the development of paramedic education in England (1966–2014). *Emerg Med J*. 2016;33:876–81.

CADTH-Canadian Agency of drugs and technologies in Health. Emergency Medical Service "Treat and Release" Protocols: A Review of Clinical and Cost-Effectiveness, Safety, and Guidelines. Emergency Medic Service "Treat and Release" Protocols: A Review of Clinical and Cost-Effectiveness, Safety, and Guidelines (cadth.ca). 2014. Accessed 20 Dec 2021.

Cain E, Ackroyd-Stolarz S, Alexiadis P, et al. Prehospital hypoglycemia: the safety of not transporting treated patients. *Prehosp Emerg Care.* 2003;7(4):458–65.

Campione J & Famolaro T. Promising Practices for Improving Hospital Patient Safety Culture. Jt Comm J Qual Patient Saf. 2018;44(1):23–32.

Carter AJE, Keane PS, Dreyer J. Transport refusal by hypoglycemic patients after on-scene intravenous dextrose. *Acad Emerg Med*. 2002;9(8):855–7.

Carter EJ, Pouch SM, Larson EL. The relationship between emergency department crowding and patient outcomes: a systematic review. *J Nurs Scholarsh*. 2014;46:106–15.

Chan J, Griffith L, Costa A, et al. 2019. Community paramedicine: A systematic review of program descriptions and training. *Canadian Journal of Emergency Medicine,* 21(6), 749–761.

Chen JH & Asch SM. Machine learning and prediction in medicine — beyond the peak of inflated expectations. *New England Journal of Medicine.* 2017;*376*:2507-2509.

Choi BY, Blumberg C, Williams K. Mobile integrated health care and community Paramedicine: an emerging emergency medical services concept. *Ann Emerg Med*. 2016;67:3.

Christensen EF, Larsen TM, Jensen FB, et al. Diagnosis and mortality in prehospital emergency patients transported to hospital: a population-based and registry-based cohort study. *BMJ Open*. 2016;6:e011558.

Christie A, Costa-Scorse B, Nicholls M, et al. Accuracy of working diagnosis by paramedics for patients presenting with dyspnoea. *Emerg Med Australas*. 2016;28(5):525–30.

Collins GS & Moons KGM. Reporting of artificial intelligence prediction models. *Lancet*. 2019; 393:1577-1579.

Coster JE, Turner JK, Bradbury D, et al. Why Do People Choose Emergency and Urgent Care Services? A Rapid Review Utilizing a Systematic Literature Search and Narrative Synthesis. *Acad Emerg Med.* 2017;24(9):1137-1149.

Coster JE, Irwing AD, Turner JK, et al. Prioritizing novel and existing ambulance performance measures through expert and lay consensus: A three-stage multimethod consensus study. *Health Expectations*. 2018;21:249–260.

Coster J, O'Cathain A, Jacques R, et al. Outcomes for Patients Who Contact the Emergency Ambulance Service and Are Not Transported to the Emergency Department: A Data Linkage Study. *Prehosp Emerg Care*. 2019;23(4):566–77.

Croskerry P. A universal model of diagnostic reasoning. *Acad Med*. 2009;84:1022–8.

Cummins NM, Dixon M, Garavan C, et al. Can advanced paramedics in the field diagnose patients and predict hospital admission? *Emerg Med J*. 2013;30(12):1043–7.

Dami F, Golay C, Pasquier M, et al. Prehospital triage accuracy in a criteria based dispatch centre. *BMC Emerg Med*. 2015;15:1–9.

Davis P, Howie G, Dicker B. New Zealand paramedics are ready for an autonomous pre-hospital thrombolysis protocol. *Aust J Paramed.* 2017;14(3):1.

Dick WF. Anglo-American vs. Franco-German Emergency Medical Services System. *Prehospital and Disaster Medicine.* 2003;18(1):29–37.

Dreyer NA, Garner S. Registries for Robust Evidence. *JAMA*. 2009;302(7):790–1.

Dúason S, Ericsson C , Jónsdóttir HL, et al. European paramedic curriculum—a call for unity in paramedic education on a European level. *Scand J Trauma Resusc Emerg Med*. 2021;29:72.

Dziadzko MA, Novotny PJ, Sloan J, et al. Multicenter derivation and validation of an early warning score for acute respiratory failure or death in the hospital. *Crit Care.* 2018;22:286.

Eastwood K, Morgans A, Smith K, et al. Secondary triage in prehospital emergency ambulance services: a systematic review. *Emerg Med J*. 2015;32:486–492.

Eastwood K, Morgans A, Smith K, et al. A novel approach for managing the growing demand for ambulance services by low-acuity patients. *Aust Health Review.* 2016;40:378–84.

Eastwood K, Morgans A, Stoelwinder J, et al. Patient and case characteristics associated with 'no paramedic treatment' for low-acuity cases referred for emergency ambulance dispatch following a secondary telephone triage: a retrospective cohort study. *Scand J Trauma Resusc Emerg Med.* 2018;26:8.

Ebben RHA, Vloet RF, Tönjes NW, Loef J, Pelgrin T, Hoogeveen M, Berben SAA. A patient-safety and professional perspective on non conveyance in ambulance care: a systematic review. *Scand J Trauma Resusc Emerg Med.* 2017;25:71.

Ebert JF, Huibers L, Lippert FK, et al. Development and evaluation of an "emergency access button" in Danish out-of-hours primary care: a study protocol of a randomized controlled trial. *BMC Health Serv Res.* 2017;17:379.

Endo T, Yoshida T, Shinozaki T, et al. Efficacy of prehospital National Early Warning Score to predict outpatient disposition at an emergency department of a Japanese tertiary hospital: A retrospective study. *BMJ Open*. 2020;10:1-7.

Finnish Environment Institute. YKR Urban-rural classification (2010). https://www.ymparisto.fi/enUS/Living_environment_and_planning/Community_structure/Information_about_the_community_structure/Urbanrural_classification. Accessed 7 Dec 2021.

Finnish Government. Finland's health and social services reform. https://soteuudistus.fi/en/frontpage. Accessed 3 Feb 2022.

Finnish Institute for Health and Welfare. Care Register for Health Care (2018a). https://www.julkari.fi/handle/10024/135620. Accessed 18 Feb 2022.

Finnish Institute for Health and Welfare. Register of Primary Health Care Visits (2018b). https://www.julkari.fi/handle/10024/135316. Accessed 26 Jan 2022.

Finnish Institute for Health and Welfare. The adjusted ICPC-2 classification for Emergency medical services. https://koodistopalvelu.kanta.fi/codeserver/pages/classification-view-page.xhtml?classificationKey=1283&versionKey=3625. Accessed 15 Jan 2022.

Fisher JD, Freeman K, Clarke A, et al. Patient safety in ambulance services: a scoping review. *Health Serv Deliv Res*. 2015;3:21.

Flin R, Patey R, Glavin R, et al. Anaesthetists' nontechnical skills. *Br J Anaesth.* 2010;105(1):38–44.

Forsell L, Forsberg A, Kisch A, et al. Inequalities and short-term outcome among patients assessed as non-urgent in a Swedish ambulance service setting. *Int Emerg Nurs.* 2021;57:101018.

Forsgärde ES, Elmqvist C, Fridlund B, et al. Patients' aged ≥65 years dispositions during ambulance assignments, including factors associated with non-conveyance to hospital: a longitudinal and comparative study. *BMJ Open*. 2020;10:e038885.

Friberg ML, Rognås L. Patient-tailored triage decisions by anaesthesiologist-staffed prehospital critical care teams: A retrospective descriptive study. *BMJ Open*. 2018;8(7).

Galvagno SM, Sikorski RA, Floccare DJ, et al. Prehospital point of care testing for the early detection of shock and prediction of lifesaving interventions. *Shock*. 2020;54:710–6.

Goldstein J, Jensen JL, Carter AJE, et al. The Epidemiology of Prehospital Emergency Responses for Older Adults in a Provincial EMS System. *CJEM*. 2015;17(5):491–496.

Greene JA, Deveau BJ, Dol JS, et al. Incidence of mortality due to rebound toxicity after 'treat and release' practices in prehospital opioid overdose care: a systematic review. *Emerg Med J.* 2018;0:1–6.

Green RS, Travers AH, Cain E, et al. Paramedic recognition of sepsis in the prehospital setting: a prospective observational study. *Emerg Med Int*. 2016;2016:6717261.

Gross B, Rusin L, Kiesewetter J, et al. Crew resource management training in healthcare: a systematic review of intervention design, training conditions and evaluation. *BMJ Open*. 2019;9:e025247.

Gupta AK, Savu A, Sheldon RS, et al. Ambulance Use, Health Outcomes, and Costs for Emergency Department Visits for Primary Diagnosis of Syncope in Canada. *CJC Open*. 2020;2(5):365–369.

Hagiwara MA, Suserud BO, Jonsson A, et al. Exclusion of context knowledge in the development of prehospital guidelines: results produced by realistic evaluation. *Scand J Trauma Resusc Emerg Med*. 2013;21:21–46.

Hagiwara MA, Magnusson C, Herlitz J, et al. Adverse events in prehospital emergency care: a trigger tool study. *BMC Emerg Med*. 2019;19:14.

Hanchate AD, Paasche-Orlow MK, Dyer KS, et al. Geographic Variation in Use of Ambulance Transport to the Emergency Department. *Ann Emerg Med.* 2017;70(4):533–543.e7.

Haines CJ, Lutes RE, Blaser M, et al. Paramedic initiated non-transport of pediatric patients. *Prehosp Emerg Care.* 2006;10:213–9.

Haniffa R, Isaam I, De Silva AP, et al. Performance of critical care prognostic scoring systems in low and middle-income countries: A systematic review. *Crit Care*. 2018;22(1).

Haupt TH, Petersen J, Ellekilde G, et al. Plasma suPAR levels are associated with mortality, admission time, and Charlson Comorbidity Index in the acutely admitted medical patient: a prospective observational study. *Crit Care.* 2012;16:130–9.

Hautz WE, Kämmer JE, Hautz SC, et al. Diagnostic error increases mortality and length of hospital stay in patients presenting through the emergency room. *Scand J Trauma Resusc Emerg Med*. 2020;27:54.

Health Care Act 1326/2010. https://www.finlex.fi/en/laki/kaannokset/2010/en20101326_20131293.pdf. Accessed 18 Feb 2022.

Hegenberg K, Trentzsch H, Gross S, et al. Use of pre-hospital emergency medical services in urban and rural municipalities over a 10 year period: an observational study based on routinely collected dispatch data. *Scand J Trauma Resusc Emerg Med.* 2019;27:35.

Heino A, Laukkanen-Nevala P, Raatiniemi L, et al. Reliability of prehospital patient classification in helicopter emergency medical service missions. *BMC Emerg Med*. 2020;20:42.

Heinonen K, Puolakka T, Salmi H, et al. Ambulance crew-initiated non-conveyance in the Helsinki EMS system—A retrospective cohort study. *Acta Anaesthesiol Scand.* 2022;00:1–9.

Hjälte L, Suserud BO, Herlitz J, et al. Why are people without medical needs transported by ambulance? A study of indications for pre-hospital care. *Eur J Emerg Med.* 2007;14(3):151-6.

Hochreiter S, Schmidhuber J. Long short-term memory. *Neural Comput.* 1997;9:1735–80.

Hoikka M, Länkimäki S, Silfvast T, et al. Medical priority dispatch codes—comparison with National Early Warning Score. *Scand J Trauma Resusc Emerg Med.* 2016;24:142.

Hoikka M, Silfvast T, Ala-Kokko TI. A high proportion of prehospital emergency patients are not transported by ambulance: a retrospective cohort study in northern Finland. *Acta Anaesthesiol Scand.* 2017;61(5):549–56.

Hoikka M, Silfvast T, Ala-Kokko TI. Does the prehospital National Early Warning Score predict the short-term mortality of unselected emergency patients? *Scand J Trauma Resusc Emerg Med*. 2018;26:48.

Højfeldt SL, Sørensen LP, Mikkelsen S. Emergency patients receiving anaesthesiologist-based pre-hospital treatment and subsequently released at the scene. *Acta Anaesthesiol Scand*. 2014;58:1025–1031.

Howard IL, Bowen JM, Al Shaikh LAH, et al. Development of a trigger tool to identify adverse events and harm in Emergency Medical Services. *Emerg Med J.* 2017;34:391–397.

Höglund E, Andersson-Hagiwara M, Schröder A, et al. Characteristics of non-conveyed patients in emergency medical services (EMS): a oneyear prospective descriptive and comparative study in a region of Sweden. *BMC Emerg Med*. 2020;20:61.

Höglund E, Schröder A, Andersson-Hagiwara M, et al. Outcomes in patients not conveyed by emergency medical services (EMS): a one-year prospective study. *Scand J Trauma Resusc Emerg Med*. 2022;30:40.

Ilkka L. Emergency Medical Services (EMS) in Finland: National data management as a path to better prehospital emergency care. Publications of the University of Eastern Finland. Dissertations in Health Sciences, 685. http://urn.fi/URN:ISBN:978-952-61-4543-3. Accessed 13 Jun 2022.

Ivic R, Kurland R, Vicente V, et al. Serious conditions among patients with non-specific chief complaints in the prehospital setting: a retrospective cohort study. *Scand J Trauma Resusc Emerg Med.* 2020;28:74.

Ivic R, Nurmi J, Kurland L, et al. Soluble urokinase plasminogen activator receptor and lactate as prognostic biomarkers in patients presenting with non-specific chief complaints in the pre-hospital setting – the PRIUS-study. *Scand J Trauma Resusc Emerg Med*. 2021;29:116.

Jensen JL, Croskerry P, Travers AH. Consensus on paramedic clinical decisions during high-acuity emergency calls: results of a Canadian Delphi study. *CJEM.* 2011;13(5):310–8.

Jensen JL, Carter AJE, Rose J, et al. Alternatives to Traditional EMS Dispatch and Transport: A Scoping Review of Reported Outcomes. *CJEM*. 2015;17(5):532-550.

Johansson H, Lundgren K, Hagiwara MA. Reasons for bias in ambulance clinicians' assessments of non-conveyed patients: a mixed-methods study. *BMC Emerg Med.* 2022;22:79.

Jones S, Moulton C, Swift S, et al. Association between delays to patient admission from the emergency department and all-cause 30-day mortality. *Emerg Med J.* 2022;39(3):168–173.

Joulin A, Grave E, Bojanowski P, et al. Bag of tricks for efficient text classification. In: Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics: Volume 2, Short Papers. Stroudsburg, PA, USA: Association for Computational Linguistics; 2017. p. 427–31.

Jousi M, Mäkinen M, Kaartinen J, et al. Pre-hospital suPAR, lactate and CRP measurements for decision-making: a prospective, observational study of patients presenting non-specific complaints. *Scand J Trauma Resusc Emerg Med.* 2021;29:150.

Kang DY, Cho KJ, Kwon O, et al. Artificial intelligence algorithm to predict the need for critical care in prehospital emergency medical services. *Scand J Trauma Resusc Emerg Med*. 2020;27:17.

Kannikeswaran N, Mahajan PV, Dunne RB, et al. Epidemiology of pediatric transports and non-transports in an urban Emergency Medical Services system. *Prehosp Emerg Care.* 2007;11(4):403–7.

Kemp K, Mertanen R, Lääperi M, et al. Nonspesific complaints in the emergency department – a systematic review. *Scand J Trauma Resusc Emerg Med.* 2020;28:6.

Kievlan DR, Martin-Gill C, Kahn JM, et al. External validation of a prehospital risk score for critical illness. *Crit Care.* 2016;20:255.

Knight S, Olson LM, Cook LJ, Mann NC, Corneli HM, Dean JM. Against all advice: an analysis of out-of-hospital refusals of care. *Ann Emerg Med.* 2003;42(5):689–96.

King R, Oprescu F, Lord B, et al. Patient experience of non-conveyance following emergency ambulance service response: A scoping review of the literature. *Australas Emerg Care*. 2021;24(3):210-223.

Kivipuro M, Tirkkonen J, Kontula, et al. National early warning score (NEWS) in a Finnish multidisciplinary emergency department and direct vs. late admission to intensive care. *Resuscitation*. 2018;128:164-169.

Khorram-Manesh A, Lennquist Montan K, Hedelin A, et al. Prehospital triage, discrepancy in priority-setting between emergency medical dispatch centre and ambulance crews. *Eur J Trauma Emerg Surg*. 2011;37:73–8.15.

Knowless E, Bishop-Edwards L, O'Cathain A. Exploring variation in how ambulance services address non- conveyance: a qualitative interview study. *BMJ Open*. 2018;8:e024228.

Koivulahti O, Tommila M, Haavisto E. The accuracy of preliminary diagnoses made by paramedics – a cross-sectional comparative study. *Scand J Trauma Resusc Emerg Med*. 2020;28:70.

Kohn LT, Corrigan JM, Donaldson MS. To Err Is Human: Building a Safer Health System. Washington, DC: Committee on Quality of Health Care in America, Institute of Medicine, 1999.

Krafft T, Castrillo-Riesgo LG, Edwards S, et al. European Emergency Data Project (EED Project): EMS databased Health Surveillance System. *Eur J Pub Health.* 2003;13(3).

Krumperman K, Weiss S, Fullerton L. Two types of prehospital systems interventions that triage low-acuity patients to alternative sites of care. *South Med J*. 2015;108:381–6.

Lahti RA, Penttila A. The validity of death certificates: routine validation of death certification and its effects on mortality statistics. *Forensic Sci Int.* 2001;115(1–2):15–32.

Langhelle A, Lossius HM, Silfvast T, et al. International EMS Systems: The Nordic countries. *Resuscitation.* 2004;61(1):9–21.

Larsson G, Dagerhem A, Wihlborg J, et al. Satisfaction among non-conveyed patients and signifcant others when discharged at the scene by the ambulance service: an exploratory cross-sectional survey. *BMC Emerg Med.* 2022;22:100.

Latten G, Hensgens K, de Bont EGPM, et al. How well are sepsis and a sense of urgency documented throughout the acute care chain in the Netherlands? A prospective, observational study. *BMJ Open.* 2020;10:e036276.

Laukkanen L, Lahtinen S, Raatiniemi L, et al. Emergency department admission and mortality of the non-transported emergency medical service patients: a cohort study from Northern Finland. *Emerg Med J.* 2021;0:1–8.

Lederman J, Löfvenmark C, Djärv T, et al. Assessing non-conveyed patients in the ambulance service: a phenomenological interview study with Swedish ambulance clinicians. *BMJ Open*. 2019;9:e030203.

Lederman J, Lindström V, Elmqvist C, et al. Non-conveyance of older adult patients and association with subsequent clinical and adverse events after initial assessment by ambulance clinicians: a cohort analysis. *BMC Emerg Med.* 2021;21:154. (1.article / 2020)

Lederman J, Lindström V, Elmqvist C, et al. Non-conveyance in the ambulance service: a population-based cohort study in Stockholm, Sweden. *BMJ Open*. 2020;10:e036659. (2.article / 2020)

Lederman J. Non-conveyed patients – a thesis on epidemiology, and patients' and ambulance clinicians' experiences. 2021. Thesis for doctoral degree. Department of Clinical Science and Education, Karolinska Institutet, Sweden.

Lee SE, Scott LD, Dahinten VS, et al. Safety Culture, Patient Safety, and Quality of Care Outcomes: A Literature Review. West J Nurs Res. 2019 Feb;41(2):279-304.

Leikkola PK, Mikkola RK, Salminen-Tuomaala MH, et al. Non-conveyance of patients: Challenges to decision-making in emergency care. *Clinical Nursing Studies.* 2016;4:4.

Lindskou TA, Mikkelsen S, Christensen EF, et al. The Danish prehospital emergency healthcare system and research possibilities. *Scand J Trauma Resusc Emerg Med*. 2019;27,100.

Lowthian JA, Cameron PA, Stoelwinder JU, et al. Increasing utilisation of emergency ambulances. *Aust Health Rev.* 2011;35:63–9.

Lyon RM, Bohm K, Christensen EF, et al. The inaugural European emergency medical dispatch conference – a synopsis of proceedings *Scand J Trauma Resusc Emerg Med.* 2013;21:73.

Magnusson C, Herlitz J, Karlsson T, et al. Initial assessment, level of care and outcome among children who were seen by emergency medical services: a prospective observational study. *Scand J Trauma Resusc Emerg Med.* 2018;26:88.

Magnusson C, Herlitz J, Axelsson C. Patient characteristics, triage utilisation, level of care, and outcomes in an unselected adult patient population seen by the emergency medical services: a prospective observational study. *BMC Emerg Med.* 2020;20:7. (1. Article / 2020)

Magnusson C, Herlitz J, Axelsson C. Pre-hospital triage performance and emergency medical services nurse's field assessment in an unselected patient population attended to by the emergency medical services: a prospective observational study. *Scand J Trauma Resusc Emerg Med.* 2020;28:81. (2. Article / 2020)

Magnusson C, Herlitz J, Höglind R, et al. Prehospital lactate levels in blood as a seizure biomarker: A multi-center observational study. *Epilepsia*. 2021;62(2):408-415. (1.article / 2021)

Magnusson C, Ryge H, Scott F, et al. Limited need for hospital resources among patients brought to hospital by the emergency medical services. *BMC Emerg Med*. 2021;21:156. (2. article / 2021)

Magnusson C, Hagiwara MA, Norberg-Boysen G, et al. Suboptimal prehospital decision- making for referral to alternative levels of care – frequency, measurement, acceptance rate and room for improvement. *BMC Emerg Med.* 2022;22:89.

Martín-Rodríguez F, López-Izquierdo R, del Pozo Vegas C, et al. A Multicenter Observational Prospective Cohort Study of Association of the Prehospital National Early Warning Score 2 and Hospital Triage with Early Mortality. *Emerg Medicine Int*. 2019;2019:5147808. (1. Article / 2019)

Martín-Rodríguez F, López-Izquidero R, del Pozo Vegas C, et al. Accuracy of National Early Warning Score 2 (NEWS2) in Prehospital Triage on In-Hospital Early Mortality: A Multi-Center Observational Prospective Cohort Study. *Prehosp Disaster Med.* 2019;34:610–618. (2. Article / 2019)

Martín-Rodríguez F, López-Izquierdo, Medina-Lozano, et al. Accuracy of prehospital point-of-care lactate in early in-hospital mortality. *Eur J Clin Invest.* 2020;50(12):e13341.

McLafferty S, Wong S. Spatial modeling place in health geography. In: Routledge handbook of health geography. New York: Routledge; 2018;338–46.

McLeod KE, Slaunwhite AK, Zhao B, et al. Comparing mortality and healthcare utilization in the year following a paramedic-attended non-fatal overdose among people who were and were not transported to hospital: A prospective cohort study using linked administrative health data. *Drug Alcohol Depend*. 2021;218:108381.

Mikolaizak AS, Simpson PM, Tiedemann A, et al. Systematic review of non-transportation rates and outcomes for older people who have fallen after ambulance service call-out. *Australas J Ageing*. 2013;32(3):147–57.

Mikolov T, Sutskever I, Chen K, et al. Distributed representations of words and phrases and their compositionality. *Adv Neural Inform Processing Syst.* 2013;26:3111–9.

Minaee S, Kalchbrenner N, Cambria E, et al. Deep Learning–based Text Classification: A Comprehensive Review. *ACM Comput. Surv.* 2021;54(3):62.

Ministry of Social Affairs and Health. Valtakunnallinen selvitys ensihoitopalvelun toiminnasta, loppuraportti. Sosiaali- ja terveysministeriön raportteja ja muistioita. –nimi englanniksi? 2016:67. http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79069/Rap_2016_67.pdf?sequence=1. Accessed 19 Feb 2022.

Ministry of Social Affairs and Health. Decree on the emergency medical services (585/2017). https://www.finlex.fi/fi/laki/alkup/2017/20170585?search%5Btype%5D=pika&search%5Bpika%5D=585%2F2017. Accessed 9 Jan 2022.

Ministry of Social Affairs and Health. Quality and patient safety in emergency medical services and hospital emergency department services – from planning to implementation and evaluation. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161737/STM_2019_23_Laatu_ja_potilasturvallisuus_ensihoidossa_ja_paivystyksessa.pdf. Accessed 20 Feb 2022.

Ministry of Social Affairs and Health and Ministry of the Interior. Selvitys ensihoitopalvelusta 2021. Loppuraportti. https://soteuudistus.fi/documents/16650278/90179099/2021+08+25+-+NHG+-+STM+-+Selvitys+ensihoitopalvelusta+2021+-+loppuraportti_valmis.pdf/0146fbd8-fde0-9032-99b5-6ca4da1789e3/2021+08+25+-+NHG+-+STM+-+Selvitys+ensihoitopalvelusta+2021+-+loppuraportti_valmis.pdf?t=1630929933558. Accessed 10 Jun 2022.

Ministry of Social Affairs and Health. Medical Helpline 116 117. https://stm.fi/en/116117en. Accessed 19 Feb 2022.

Moen H, Hakala K, Peltonen LM et al. Supporting the use of standardized nursing terminologies with automatic subject heading prediction: a comparison of sentence-level text classification methods. *J Am Med Inform Assoc.* 2020;27(1):81–8.

Moffet HH, Warton EM, Siegel L, et al. Hypoglycemia Patients and Transport by EMS in Alameda County, 2013-15. *Prehosp Emerg Care.* 2017;21(6):767–772.

Moll van Charante EP, van Steenwijk-Opdam PCE, Bindels PJE. Out-of-hours demand for GP care and emergency services: patients' choices and referrals by general practitioners and ambulance services. *BMC Family Practice*. 2007;8:46.

Morgans A, Burgess S. Judging a patient's decision to seek emergency healthcare: clues for managing increasing patient demand. *Australian Health Review,* 2012;36:110–114.

Myrstad M, Ihle-Hansen H, Tveita AA, et al. National Early Warning Score 2 (NEWS2) on admission predicts severe disease and inhospital mortality from Covid-19 – a prospective cohort study. *Scand J Trauma Resusc Emerg Med*. 2020;28:66.

Nannan Panday RS, Minderhoud TC, Alam N, et al. Prognostic value of early warning scores in the emergency department (ED) and acute medical unit (AMU): A narrative review. *Eur J Intern Med*. 2017;45:20–31.

National Audit Office of Finland. Tuloksellisuustarkastuskertomus. Ohjauksen vaikutus ensihoitopalvelun toimivuuteen. 2019. https://www.vtv.fi/app/uploads/2019/06/VTV-Tarkastuskertomus-9-2019-Ohjauksen-vaikutus-ensihoitopalvelun-toimivuuteen1.pdf. Accessed 17 Jan 2022.

Newgard CD, et al. Out-of-hospital decision-making and factors influencing the regional distribution of injured patients in a trauma system. *J Trauma.* 2011;70(6):1345–53.

Nielsen FV, Nielsen MR, Amstrup J, Lorenzen ID, Kløjgaard TA, Færk E, et al. Non-specific diagnoses are frequent in patients hospitalized after calling 112 and their mortality is high – a register-based Danish cohort study. *Scand J Trauma Resusc Emerg Med.* 2020;28(1):69.

Nordberg G, Sundström BW, Christensson L, et al. Swedish emergency medical services' identification of potential candidates for primary healthcare: Retrospective patient record study. *Scand J Prim Health Care*. 2015;33(4): 311–317.

O'Cathain A, Jacques J, Stone T, et al. Why do ambulance services have different non-transport rates? A national cross sectional study. *PLoS ONE*. 2018;13:e0204508.

O'Connor P, O'Malley R, Oglesby AM, et al. Measurement and monitoring patient safety in prehospital care: a systematic review. *International Journal for Quality in Health Care.* 2021;33(1):1–8. (1. Article / 2021)

O'Connor P, O'Malley R, Lambe K, et al. How safe is prehospital care? A systematic review. *International Journal for Quality in Health Care*. 2021;33(4):1–7. (2. Article / 2021)

Official Statistics of Finland (OSF): Causes of death [e-publication]. ISSN=1799–5078. Helsinki: Statistics Finland. https://www.stat.fi/til/ksyyt/2018/ksyyt_2018_2019-12-16_kat_001_en.html. Accessed 26 Jan 2022.

O'Hara R, Johnson M, Siriwardena AN, et al. A qualitative study of systemic influences on paramedic decision making: care transitions and patient safety. *J Health Serv Res Policy*. 2015;20:45–53.

Olsen S, Ilkka L, Berlac PA, et al. The Nordic Emergency Medical Services, project on data collection and benchmarking 2014–2018. Report Ordening NR IS-2750 2018. https://www.landlaeknir.is/servlet/file/store93/item36845/Nordic%20EMS%20benchmarking%20report%202014-2018.pdf. Accessed 6 Jan 2022.

Oosterwold J, Sagel D, Berben S, et al. Factors influencing the decision to convey or not to convey elderly people to the emergency department after emergency ambulance attendance: a systematic mixed studies review. *BMJ Open.* 2018;30(8):e021732.

Ornato JP: Science of emergency medical dispatch. *Circulation*. 2009;119:2023–2025.

Oulasvirta J, Salmi H, Kuisma M, et al. Outcomes in children evaluated but not transported by ambulance personnel: retrospective cohort study. *BMJ Paediatrics Open.* 2019;3:e000523.

Patel R, Nugawela D, Edwards HB, et al. Can early warning scores identify deteriorating patients in prehospital settings? A systematic review. *Resuscitation*. 2018;132:101–11.

Patton A, O'Donnel C, Keane O, et al. The Alternative Pre-hospital Pathway team: reducing conveyances to the emergency department through patient centered Community Emergency Medicine. *BMC Emerg Med.* 2021;21:138.

Pekanoja S, Hoikka M, Kyngäs H, Elo S. Non-transport emergency medical service missions – a retrospective study based on medical charts. *Acta Anaesthesiol Scand*. 2018;62:701–708.

Persse DE, Key CB, Baldwin JB. The effect of a quality improvement feedback loop on paramedic-initiated nontransport of elderly patients. *Prehosp Emerg Care.* 2002;6:31–5.

Pickering A, Turner J, Bradley P, et al. Emergency Service Review, A Comparative Review of International Ambulance Service Best Practice. NHS 2009. https://www.sheffield.ac.uk/polopoly_fs/1.43654!/file/OSHA-Report.pdf. Accessed 3 Jan 2022.

Pirneskoski J, Kuisma M, Olkkola KL, et al. Prehospital National Early Warning Score predicts early mortality. *Acta Anaesthesiol Scand.* 2019;63: 676–83.

Pirneskoski J, Tamminen J, Kallonen A, et al. Random forest machine learning method outperforms prehospital National Early Warning Score for predicting one-day mortality: A retrospective study. *Resuscitation Plus.* 2020;4:100046.

Porter A, Dale J, Foster T, et al. Implementation and use of computerized clinical decision support (CCDS) in emergency pre-hospital care: a qualitative study of paramedic views and experience using Strong Structuration Theory. *Implement Sci.* 2018;13:91.

Pozner CN, Zane R, Nelson SJ, et al. International EMS systems: the United States: past, present, and future. *Resuscitation.* 2004;60(3),239–244.

Raatiniemi L & Brattebø G. The challenge of ambulance missions to patients not in need of emergency medical care. Acta Anaesthesiol Scand. 2018;62(5):584–587.

Rajkomar A, Dean J, Kohane I. Machine learning in medicine. *New England Journal of Medicine*. 2019;380:1347-1358.

Rantala A, Ekvall A, Forsberg A. The meaning of being triaged to non-emergency ambulance care as experienced by patients. *Int Emerg Nurs.* 2016;25:65-70.

Rantala, A. Being taken seriously. Person-centredness and person-centred climate as experienced by patients and significant others when the patient is assessed as non-urgent by the Swedish Ambulance Service. Lund University: Faculty of Medicine. 2017. https://lucris.lub.lu.se/ws/portalfiles/portal/30050448/2017_Rantala_Kappa_170810.pdf.

Rasku T, Kaunonen M, Thyer E, et al. The core components of Community Paramedicine – integrated care in primary care setting: a scoping review. *Scand J Caring Sci.* 2019;33:508–521.

Rasku T. Community Paramedicine: An integrated care model in a Primary health care setting. Tampere University Dissertations 549. Tampere University, Faculty of Social Sciences. https://urn.fi/URN:ISBN:978-952-03-2286-1. Accessed 3 Jun 2022.

Rasmussen LJH, Ladelund S, Haupt TH, et al. Soluble urokinase plasminogen activator receptor (suPAR) in acute care: a strong marker of disease presence and severity, readmission and mortality. A retrospective cohort study. *Emerg Med J.* 2016;33(11):769–75.

Resuscitation Council UK. The ABCDE Approach. 2021. https://www.resus.org.uk/library/abcde-approach. Accessed 3 Jan 2022.

Reay G, Rankin JA, Smith-MacDonald L, et al. Creative adapting in a fluid environment: an explanatory model of paramedic decision making in the pre-hospital setting. *BMC Emerg Med.* 2018;18:42.

Rehn M, Hyldmo PK, Magnusson V, et al. Scandinavian SSAI clinical practice guideline on pre-hospital airway management. *Acta Anaesthesiol Scand.* 2016;60(7):852-64.

Robert N, 2019. How artificial intelligence is changing nursing. *Nurs. Manage.* 2019;50(9):30–39.

Roivainen P, Hoikka MJ, Raatiniemi L, et al. Telephone triage performed by nurses reduces non-urgent ambulance missions: a prospective observational pilot study in Finland. *Acta Anaesthesiol Scand*. 2020;64:556–63.

Roivainen, Petri, Care needs assessment of non-urgent ambulance missions performed by a telephone nurse. University of Oulu Graduate School; University of Oulu, Faculty of Medicine; Acta Univ. Oul. D 1666, 2022. http://jultika.oulu.fi/files/isbn9789526232652.pdf. Accessed 14 Jun 2022.

Roudsari BS, Nathens AB, Arreola-Risa C, et al. Emergency Medical Service (EMS) systems in developed and developing countries. *Injury.* 2007;38(9):1001-13.

Royal College of Physicians. National Early Warning Score (NEWS)2: Standardising the assessment of acute-illness severity in the NHS. Updated report of a working party. London: RCP; 2017. https://www.rcplondon.ac.uk/projects/outputs/national-early-warning-score-news-2. Accessed 2 Jan 2022.

Rudolph SS, Jehu G, Nielsen SL, et al. Prehospital treatment of opioid overdose in Copenhagen – Is it safe to discharge on-scene? *Resuscitation.* 2011;82(11):1414–8.

Runciman W, Hibbert P, Thomson RV, et al. Towards an international classification for patient safety: key concepts and terms. *Int J Qual Health Care*. 2009;21:18–26.

Saario EL, Mäkinen MT, Jämsen ERK, et al. Screening of community-dwelling older patients by the emergency medical services: An observational retrospective registry study. *Int Emerg Nurs.* 2021;59:101078.

Salminen-Tuomaala M, Mikkola R, Paavilainen E, et al. Emergency patients' and family members' experiences of encountering care providers and receiving care in nonconveyance situations. *Scand J Caring Sci*. 2018;32(4):1371–1378.

Satty T, Ramgopal S, Elmer J, et al. EMS responses and non-transports during the COVID-19 pandemic. *Am J Emerg Med*. 2021;42:1-8.

Schuster M, Paliwal KK. Bidirectional recurrent neural networks. *IEEE Trans Signal Process*. 1997;45:2673–81.

Scott J, Strickland AP, Warner K, et al. Frequent callers to and users of emergency medical systems: a systematic review. *Emerg Med J.* 2014;31:684–691.

Seymour CW, Kahn JM, Martin-Gill C, et al. Delays From First Medical Contact to Antibiotic Administration for Sepsis. *Crit Care Med*. 2017;45(5):759-765.

Shah, MN. The Formation of the Emergency Medical Services System. *American Journal of Public Health.* 2006;96(3),414–423.

Shaw D, Dyas JV, Middlemass J, et al. Are they really refusing to travel? A qualitative study of prehospital records. *BMC Emerg Med.* 2006;19;6:8.

Shaw J, Fothergill R, Clark S, et al. Can the prehospital National Early Warning Score identify patients most at risk from subsequent deterioration? *Emerg Med J.* 2017;34:533–7.

Shojania KG, Marang-van de Mheen PJ. Identifying adverse events: reflections on an imperfect gold standard after 20 years of patient safety research. *BMJ Qual Saf.* 2020;29:265–270.

Silcock DJ, Corfield AR, Govens PA, et al. Validation of the National Early Warning Score in the prehospital setting. *Resuscitation.* 2015;89:31–5.

Simpson PM, Bendall JC, Patterson J, et al. Epidemiology of ambulance responses to older people who have fallen in New South Wales, Australia. *Australas J Ageing.* 2013;32(3):171–6.

Simpson PM, Bendall JC, Toson B, et al. Predictors of Nontransport of Older Fallers Who Receive Ambulance Care. *Prehosp Emerg Care.* 2014;18(3):342–9.

Sinclair JE, Austin M, Froats M, et al. Characteristics, Prehospital Management, and Outcomes in Patients Assessed for Hypoglycemia: Repeat Access to Prehospital or Emergency Care. *Prehosp Emerg Care.* 2019;23(3):364-376.

Slawomirski L, Klazinga N. Economics of patient safety: from analysis to action. Paris: Organisation for Economic Cooperation and Development; 2020. http://www.oecd.org/ health/health-systems/Economics-of-Patient-Safety-October2020.pdf. Accessed 7 Jan 2022.

Smith GB, Prytherch DR, Meredith P, et al. The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. *Resuscitation.* 2013;84(4):465–470.

Snooks HA, Carter B, Dale J, et al. Support and Assessment for Fall Emergency Referrals (SAFER 1): Cluster Randomised Trial of Computerised Clinical Decision Support for Paramedics. *PLoS One*. 2014;12;9(9):e106436.

Søvsø MB, Kløjgaard TA, Hansen Pa, et al. Repeated ambulance use is associated with chronic diseases - a population-based historic cohort study of patients' symptoms and diagnoses. *Scand J Trauma Resusc Emerg Med.* 2019;27:46.

Spasic I, Nenadic G. Clinical Text Data in Machine Learning: Systematic Review. *JMIR Med Inform*. 2020;8(3):e17984.

Spangler D, Hermansson T, Smekal D, et al. A validation of machine learning-based risk scores in the prehospital setting. *PLoS One.* 2019;14:e0226518.

Stam NC, Pilgrim JL, Drummer OH, et al. Catch and release: evaluating the safety of non-fatal heroin overdose management in the out-of-hospital environment. *Clin Toxicol (Phila).* 2018;56(11):1135–1142.

Strote J, Simons R, Eisenberg M. Emergency medical technician treatment of hypoglycemia without transport. *Am J Emerg Med.* 2008;26(3):291–5.

Sun KM, Song KJ, Shin SD, et al. Comparison of Emergency Medical Services and Trauma Care Systems Among Pan-Asian Countries: An International, Multicenter, Population-Based Survey. *Prehosp Emerg Care.* 2017;21(2):242–251.

Sundström BW, Bremer A, Lindström V, et al. Caring science research in the ambulance services: an integrative systematic review. *Scand J Caring Sci.* 2019;33;3–33.

Tamminen J, Kallonen A, Hoppu S, et al. Machine learning model predicts short-term mortality among prehospital patients: A prospective development study from Finland. *Resuscitation Plus.* 2021;5:100089.

The Finnish Advisory Board on Research Integrity (TENK). Responsible conduct of research and procedures for handling allegations of misconduct in Finland. 2012. https://tenk.fi/sites/tenk.fi/files/HTK_ohje_2012.pdf. Accessed 18 Feb 2022.

The Finnish Transport Agency (FTA/Väylä). Digiroad – National Road and Street Database. 2019. https://vayla.fi/web/en/open data/digiroad#.XjJhmgzZPY. Accessed 20 Dec 2021.

The National Advisory Board on Social Welfare and Health Care Ethics, ETENE. Etiikan tila sosiaali- ja terveysalalla. 2012. ETENE-julkaisuja 35. https://etene.fi/documents/1429646/1559054/ETENE-julkaisuja+35+Etiikan+tila+sosiaali-+ja+terveysalalla.pdf/b02f3efc-c92b-456f-a97a-2a524ef3b2f9/ETENE-julkaisuja+35+Etiikan+tila+sosiaali-+ja+terveysalalla.pdf?t=1439805591000. Accessed 18 Jan 2022.

Tirkkonen J, Karlsson S, Skrifvars MB. National early warning score (NEWS) and the new alternative SpO_2 scale during rapid response team reviews: a prospective observational study. *Scand J Trauma Resusc Emerg Med.* 2019;27:111.

Tobias AZ, Guyette FX, Seymour CW, et al. Pre-resuscitation lactate and hospital mortality in prehospital patients. *Prehosp Emerg Care.* 2014;18:321–7.

Todd VF, Swain A, Howie G, et al. Factors associated with Emergency Medical Service reattendance in low acuity patients not transported by ambulance. *Prehosp Emerg Care.* 2021;25;1-17.

Tohira H, Fatowich D, Williams TA, et al. Is it Appropriate for Patients to be Discharged at the Scene by Paramedics? *Prehosp Emerg Care.* 2016;20(4):539-49. (1. Article / 2016)

Tohira H, Fatowich D, Williams TA, et al. Paramedic Checklists do not Accurately Identify Post-ictal or Hypoglycaemic Patients Suitable for Discharge at the Scene 2016b. *Prehosp Disaster Med.* 2016;31(3):282-93. (2. Article / 2016)

Topaz M, Murga L, Gaddis KM, et al. Mining fall-related information in clinical notes: comparison of rulebased and novel word embedding-based machine learning approaches. *J Biomed Inform.* 2019;90.

van Doorn SCM, Verhalle RC, Ebben RHA, et al. The experience of non-conveyance following emergency medical service triage from the perspective of patients and their relatives: A qualitative study. *Int Emerg Nurs.* 2021;54:100952.

Van Gelder CM, Frantz R, Bogucki S. Emergency medical services in Connecticut. *Prehospital Emerg Care.* 2005;9(2):219–226.

Van Schuppen H, Bierens J. Understanding the prehospital physician controversy. Step 1: Comparing competencies of ambulance nurses and prehospital physicians. *Eur J Emerg Med.* 2011;18(6):322–327.

Veldhuis L, Ridderikhof ML, Schinkel M, et al. Early warning scores to assess the probability of critical illness in patients with COVID-19. *Emerg Med J.* 2021;38:901–905.

Venesoja A, Castren M, Tella S, et al. Patients' perceptions of safety in emergency medical services: an interview study. *BMJ Open.* 2020;10:e037488.

Vihonen H, Lääperi M, Kuisma M, et al. Glucose as an additional parameter to National Early Warning Score (NEWS) in prehospital setting enhances identification of patients at risk of death: an observational cohort study. *Emerg Medicine J.* 2020;37:286–292.

Vincent C. Patient Safety. 2nd Edition, 2010. Wiley Blackwell, BMJ Books.

Vloet LCM, de Kreek A, van der Linden WMC, van Spijk A, et al. A retrospective comparison between non-conveyed and conveyed patients in ambulance care. *Scand J Trauma Resusc Emerg Med.* 2018;26:91.

von Gerich H, Moen H, Block LJ, et al. Artificial Intelligence -based technologies in nursing: A scoping literature review of the evidence. *Int J Nurs Stud.* 2021;127:104153.

Wang F. Quantitative methods on socio-economic applications in GIS. 2nd ed. Boca Raton: Taylor & Francis group; 2014a. p. 27–40.

Wang F. Quantitative methods on socio-economic applications in GIS. 2nd ed. Boca Raton: Taylor & Francis group; 2014b. p. 82–3.

WHO. International Classification of Primary Care, Second edition (ICPC-2). 2003. https://www.who.int/standards/classifications/other-classifications/ international-classification-of-primary-care. Accessed 15 Sept 2021.

WHO. Global patient safety action plan 2021–2030: towards eliminating avoidable harm in health care. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO.

WHO. Prehospital trauma care systems. 2005. https://www.who.int/violence_injury_prevention/publications/services/39162_oms_new.pdf. Accessed 3 Dec 2021.

Wichmann S, Nielsen SL, Siersma VD, et al. Risk factors for 48-hours mortality after prehospital treatment of opioid overdose. *Emerg Med J.* 2013;30:223–225.

Williams TA, Tohira H, Finn J, et al. The ability of early warning scores (EWS) to detect critical illness in the prehospital setting: a systematic review. *Resuscitation.* 2016;102:35–43.

Wilson C, Harley C, Steels S. Systematic review and meta-analysis of pre-hospital diagnostic accuracy studies. *Emerg Med J.* 2018;35:757–764.

World Organization of Family Doctors (WONCA). International Classification of Primary Care. 2016. https://www.globalfamilydoctor.com/site/DefaultSite/filesystem/documents/Groups/WICC/International%20Classification%20of%20Primary%20Care%20Dec16.pdf. Accessed 29 Dec 2021.

Yeung T, Shannon B, Perillo S, Nehme Z, Jennings P, Olauseen A. Review article: outcomes of patients who are not transported following ambulance attendance: A systematic review and meta-analysis. *Emerg Med Australas.* 2019;31(3):321–31.

TURUN
YLIOPISTO
UNIVERSITY
OF TURKU

Painosalama, Turku, Finland 2022

ISBN 978-951-29-8959-1 (PRINT)
ISBN 978-951-29-8960-7 (PDF)
ISSN 0355-9483 (Print)
ISSN 2343-3213 (Online)