

# Aspects of cardiac arrest in Sweden – studies based on the Swedish Registry for CPR

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**Fredrik Hessulf**

Fakultetsopponent

Professor **Markus Skrifvars**

Medicinska Fakulteten

Helsingfors Universitet, Finland

Avhandlingen baseras på följande delarbeten:

- I. **Factors of importance to 30-day survival following in-hospital cardiac arrest in Sweden – A population based study of more than 18000 cases.** Hessulf F, Karlsson T, Lundgren P, Aune S, Strömsöe A, Södersved-Källested ML, Djärv T, Herlitz J, Engdahl J. *Int J Cardiol.* 2018 Mar 15;255:237-242
- II. **Adherence to guidelines is associated with improved survival following in-hospital cardiac arrest.** Hessulf F, Herlitz J, Rawshani A, Aune S, Israelsson J, Södersved-Källested ML, Nordberg , Lundgren P, Engdahl J. *Resuscitation.* 2020;155:13-21.
- III. **Temporal variation in survival following in-hospital cardiac arrest in Sweden.** Hessulf F, Herlitz J, Lundgren P, Aune S, Myredal A, Engdahl J, Rawshani A. *Submitted.*
- IV. **Predicting Survival and Neurological Outcome in Out-of-Hospital Cardiac Arrest Using Machine Learning: The SCARS Model.** Hessulf F, Bhatt DL, Engdahl J, Lundgren P, Omerovic E, Rawshani Ai, Helleryd E, Dworeck C, Friberg H, Nielsen N, Myredal A, Frigyesi A, Herlitz J, Rawshani A. *eBioMedicine.* 2023 Feb 9;89
- V. **Characteristics, survival and neurological outcome in out-of-hospital cardiac arrest: A nationwide study of 56,203 cases with emphasis on cardiovascular comorbidities.** Rawshani A, Hessulf F, Völz S, Dworeck C, Odenstedt J, Råmunddal T, Hirlekar G, Petursson P, Angerås O, Ioanes D, Myredal A. *Resuscitation Plus.* 2022 Aug 24;11:100294.

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Fredrik Hessulf

## ABSTRACT

**Background:** Since the introduction of modern cardiopulmonary resuscitation (CPR) by Peter Safar in the late 1950s, a tremendous amount of work and scientific discovery has expanded our knowledge of cardiac arrest (CA), made resuscitation a core skill of health care providers and improved survival substantially. Despite the many advances, the core elements of resuscitation have remained largely intact: immediate recognition and initiation of CPR and swift defibrillation. The importance of doing the basics well and evaluating the effect of guidelines and recommendations have only increased considering the rapid growth of cardiac arrest research.

**Aims:** The aims of the thesis were: to investigate factors associated with 30-day survival following IHCA (paper I); to evaluate the importance of adherence to resuscitation guidelines on survival following IHCA (paper II); to explore the impact of time day and day of week on 30-day survival following IHCA and investigate if hospital and ward characteristics modify the importance of time of CA (III); to build a prediction model for 30-day survival and neurological outcome following OHCA(IV), and to evaluate the impact of cardiovascular comorbidities on survival following OHCA (V).

**Methods:** Data from the Swedish Cardiopulmonary Resuscitation Registry (SCRR) was used through-out the thesis. IHCA data from the registry was used in papers I-III, and OHCA data was used in papers IV-V. In paper IV-V we merged the SCRR with the Swedish Patient Registry, the Swedish Prescribed Drug Registry and the Longitudinal Integrated Database for health insurance and labour market studies (LISA). Papers I-III and V were registry-based observational cohort studies. Paper IV was a registry-based machine learning study.

**Results:** Multiple factors (modifiable, partly modifiable and non-modifiable) were associated with 30-day survival following IHCA. Notably, several factors that relate to how resources are allocated (ECG-monitoring, ward type, witnessed status, time to treatment, time of day) were independently associated with the chance of 30-day survival (paper I). In paper II we show that adherence to resuscitation guidelines was high (70-80%) and increased marginally during the time period 2008-2017. Adherence to guidelines was associated with a higher odds ratio (OR) for 30-day survival for both shockable and non-shockable rhythms. Adherence was higher on high-resource wards including the ICU and CCU compared to general wards. In paper III we further evaluated the importance of time and location of IHCA and found that IHCAs that took place during the day had the highest rates of 30-day survival and that survival decreased during the evening and night. The decrease in survival from day to evening to night was associated with lower rates of witnessed CAs, lower rates of ventricular fibrillation or tachycardia as the initial recorded rhythm and greater delays from detection of a shockable rhythm to defibrillation. Survival decreased more from day to night in small hospitals, non-academic hospitals and on non-monitored wards.

In paper IV we built a machine learning model (SCARS-1) to predict the chance of 30-day survival following OHCA in the emergency department. At a sensitivity level of 95%, the AUC-ROC was 0.97, with excellent calibration across survival probabilities. We developed a web application, the SCARS-1 app, that enabled a survival prediction to be made with readily available variables within 30 seconds in the emergency department.

In paper V we show that hypertension and associated cardiovascular conditions were prevalent in the population affected by OHCA and that hypertension and heart failure in combination had the lowest rates of survival. Early onset hypertension was associated with shorter time to OHCA compared to later onset hypertension.

**Conclusions:** The chance of survival following IHCA is dependent on rapid detection and treatment, and by selecting patients at high risk of CA and prioritizing these patients to wards with high resources (ICU, CCU) or ECG-monitoring, survival rates could potentially be improved. Adherence to current resuscitation guidelines is high and associated with increased survival rates in IHCA. Time of in-hospital cardiac arrest is associated with the chance of survival: IHCA during the day showed the highest survival rates followed by IHCA during the evening and during the night. Survival rates decreased disproportionately more from day to night in small hospitals, non-academic hospitals and on general wards indicating that IHCA care is not of equal quality around the clock. Prediction of OHCA survival is possible in the emergency department during ongoing CPR using the SCARS-1 prediction model and can be a valuable tool during ongoing resuscitation in adjunct to other sources of information. Finally, hypertension in combination with heart failure has the lowest survival rates of all cardiovascular conditions among patients with OHCA and should be considered a major risk factor. The earlier the onset of hypertension, the shorter the time from hypertension diagnosis to OHCA.

**Keywords:** Cardiac arrest, resuscitation, comorbidity, prediction

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