Resuscitation xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Resuscitation

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

Clinical paper

Outcomes and healthcare-associated costs one year after intensive care-treated cardiac arrest☆

Ilmar Efendijev[a,*], Daniel Folger[a], Rahul Raj[b], Matti Reinikainen[c], Pirkka T. Pekkarinen[a], Erik Litonius[a], Markus B. Skrifvars[a,d]

[a] University of Helsinki and Helsinki University Hospital, Division of Intensive Care Medicine, Department of Anaesthesiology, Intensive Care and Pain Medicine, Helsinki, Finland
[b] University of Helsinki and Helsinki University Hospital, Department of Neurosurgery, Helsinki, Finland
[c] North Karelia Central Hospital, Department of Intensive Care, Joensuu, Finland
[d] University of Helsinki and Helsinki University Hospital, Department of Emergency Care and Services, Helsinki, Finland

ARTICLE INFO

Keywords:
Cardiac arrest
Survival
Outcome
Long-term outcome
Neurological outcome
Healthcare costs
Cost-effectiveness

ABSTRACT

Background: Despite the significant socioeconomic burden associated with cardiac arrest (CA), data on CA patients' long-term outcome and healthcare-associated costs are limited. The aim of this study was to determine one-year survival, neurological outcome and healthcare-associated costs for ICU-treated CA patients.
Methods: This is a single-centre retrospective study on adult CA patients treated in Finnish tertiary hospital's ICUs between 2005 and 2013. Patients' personal identification number was used to crosslink data between several nationwide databases in order to obtain data on one-year survival, neurological outcome, and healthcare-associated costs. Healthcare-associated costs were calculated for every patient stratified by cardiac arrest location (OHCA = out-of-hospital cardiac arrest, IHCA = all in-hospital cardiac arrest, ICU-CA = in-ICU cardiac arrest) and initial cardiac rhythm. Cost-effectiveness was estimated by dividing total healthcare-associated costs for all patients from the respective group by the number of survivors and survivors with favourable neurological outcome.
Results: The study population included 1,024 ICU-treated CA patients. The sum of costs for all patients was €50,847,540. At one-year after CA, 58% of OHCAs, 44% of IHCAs, and 39% of ICU-CAs were alive. Of one-year survivors 97% of OHCAs, 88% of IHCAs, and 93% of ICU-CAs had favourable neurological outcome. Effective cost per one-year survivor was €76,212 for OHCAs, €144,168 for IHCAs, and €239,468 for ICU-CAs. Effective cost per one-year survivor with favourable neurological outcome was €81,196 for OHCAs, €164,442 for IHCAs, and €257,207 for ICU-CAs.
Conclusions: In-ICU CA patients had the lowest one-year survival with the effective cost per survivor three times higher than for OHCAs.

Introduction

Cardiac arrest (CA) remains an important cause of morbidity and mortality [1]. Despite numerous researches on CA, data on CA-related healthcare costs are still scarce [2]. However, with an estimated 350,000–700,000 sudden CA events yearly in Europe alone, no doubt exists that CA has significant socioeconomic consequences [3,4]. Accurate quantification of cardiac arrest-related healthcare costs is important, as it can facilitate management and allocation of available resources in order to improve post-CA outcomes through better prevention and treatment strategies.

In this study, we determined one-year healthcare-associated costs and outcomes in post-CA patients treated in intensive care units (ICU) of a tertiary hospital, focusing on the impact of CA location and initial cardiac rhythm on costs and outcomes.

Methods and materials

Setting and population

This retrospective study was conducted at Meilahti Hospital, Helsinki, Finland, which serves as the primary referral centre for CA

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at https://doi.org/10.1016/j.resuscitation.2018.06.028.

* Corresponding author at: Department of Anaesthesiology and Intensive Care Medicine, Helsinki University Hospital, Haartmaninkatu 4, PL 340, 00029 HUS, Helsinki, Finland.
E-mail address: ilmar.efendijev@hus.fi (I. Efendijev).

https://doi.org/10.1016/j.resuscitation.2018.06.028
Received 25 March 2018; Received in revised form 15 June 2018; Accepted 25 June 2018
0300-9572/

Please cite this article as: Efendijev, I., Resuscitation (2018), https://doi.org/10.1016/j.resuscitation.2018.06.028

patients in the Helsinki and Uusimaa region, with a population of approximately 1.6 million people (30% of the total Finnish population). Using the Finnish Intensive Care Consortium (FICC) database [5], we identified adult CA patients (age ≥18 years) treated in Meilahti Hospital's ICUs from January 1, 2005, to December 31, 2013. Only the first cardiac arrest event was considered. Electronic health records (EHR) of individual patients were reviewed for relevant data. Patients with missing or incomplete data were excluded from the analyses. The study was approved by the ethics committee of the Operative Division of Helsinki University Hospital (June 2014: 194/13/03/02/2014 TMK02 §97), the Finnish National Institute for Health and Welfare (May 2014: THL/713/5.05.01/2014), Statistics Finland (May 2014: TK-53-1047-14), the Social Insurance Institution (September 2015: Kela 55/522/2015) and the Office of the Data Protection Ombudsman (February 2016: 2794/204/2015).

Extracted variables and data sources

The FICC database provided data on hospital survival, preadmission physical status (a modified World Health Organisation/Eastern Cooperative Oncology Group [WHO/ECOG] classification implemented by FICC), mean daily Therapeutic Intervention Scoring System (TISS-76) score and its components for the whole ICU stay, Simplified Acute Physiology Score II (SAPS II) and Acute Physiology and Chronic Health Evaluation II (APACHE II) components and scores [6–10]. To obtain the confirmed date of death, we linked the patients' unique personal identification numbers with the Finnish Population Register Centre database, which registers all deaths of Finnish residents. From the hospital's EHR, we gathered detailed information regarding time of CA, time to return of spontaneous circulation (ROSC), initial cardiac rhythm, CA location and cerebral performance category (CPC) for survivors at one year after CA [11–13]. Good neurological outcome was defined as CPC scores 1–2, and poor neurological outcome as CPC scores 3–4 [12,14].

Healthcare-associated costs

Total one-year healthcare-associated costs included three parameters: hospital costs, rehabilitation costs and social security costs. Hospital costs were retrieved from the hospital's billing records. These costs were for the entire treatment period, including, e.g. personnel, surgery, diagnostics, ICU stay, and ward stay. Rehabilitation costs were calculated by multiplying the length of stay in the rehabilitation unit with the average price per day for the respective level of care unit [15]. Social security costs were obtained from the national Social Insurance Institution. All reimbursements made by the Social Insurance Institution, up to one-year after the admission, were obtained and summed. These costs covered disability allowances, sickness allowances, private physician and physiotherapist expenses, prescription drug expenses and medical transport expenses.

Cost data analysis included calculation of mean healthcare costs for hospital survivors, hospital non-survivors, one-year survivors and hospital survivors who failed to survive to one year after CA. Mean costs were calculated as the sum of total costs of the appropriate patient group divided by the number of individuals in the same group. To estimate cost-effectiveness, we calculated the effective cost per survivor (ECPS) and the effective cost per survivor with favourable neurological outcome (ECPFN). The ECPS and ECPFN were calculated as the sum of total costs for all patients divided by the number of survivors and by the number of survivors with favourable neurological outcome, respectively [16].

We adjusted all costs according to the consumer price index (CPI) in Finland to 2013 euros, using the following formula:

$$CPI\ adjusted\ cost = Cost * \frac{CPI\ in\ 2013}{Admission\ year\ CPI}$$

Statistical analyses

For the statistical analyses, we used SPSS statistics for MAC, version 24.0, released 2016 (IBM Corp, Armonk, NY, USA) and Stata Statistical Software for Mac OS (StataCorp LP, College Station, TX).

We used a chi-square test to compare categorical variables and a Mann-Whitney *U* test or Student's *t*-test for continuous data, as appropriate. To adjust for case-mix differences, we developed a severity-of-illness model based on age, admission year, simplified preadmission physical status (independent vs. non-independent), presence of a severe comorbidity (according to SAPS II and APACHE II), initial cardiac rhythm, time to ROSC and SAPS II score sum without age and comorbidity points. We used logistic regression to assess case-mix adjusted survival and neurological outcome stratified by CA location and multivariate linear regression with CA location as a separate additional variable to estimate the adjusted healthcare costs and treatment intensity for the whole study population and separately for hospital survivors.

Results

Study population

A total of 1,024 patients were eligible for the study (mean 114 patients per year): 66% out-of-hospital cardiac arrests (OHCA) and 34% in-hospital cardiac arrests (IHCA). Table 1 and Fig. 1 summarise the exclusion process and baseline characteristics of the study population. Compared to IHCA, OHCA patients were younger and had better

Table 1
Study population's baseline characteristics.

Variables	OHCA (n = 672)	IHCA (n = 352)	p-value
Age in years, *median (IQR)*	61 (53–69)	64 (56–74)	< 0.05
Male gender, *n (%)*	514 (77)	231 (66)	< 0.05
Simplified preadmission physical status[a]			
independent, *n (%)*	637 (95)	296 (84)	< 0.05
non-independent, *n (%)*	35 (5)	56 (16)	< 0.05
Severe comorbidity at the time of ICU admission, *n (%)*[b]	92 (14)	125 (36)	< 0.05
SAPS II, *median (IQR)*	43 (34–57)	52 (39–68)	< 0.05
APACHE II score, *median (IQR)*	21 (17–29)	27 (19–34)	< 0.05
SOFA score during the first 24 hours, *median (IQR)*	8 (6–10)	10 (8–13)	< 0.05
TISS-76 average daily score, *mean (SD)*	37 (8)	36 (9)	NS
Time to ROSC in minutes, *median (IQR)*	20 (14–25)	7 (3–12)	< 0.05
Initial cardiac rhythm			
ventricular fibrillation/ventricular tachycardia, *n (%)*	504 (75)	116 (33)	< 0.05
pulseless electrical activity	104 (15)	141 (40)	< 0.05
asystole	49 (7)	66 (19)	< 0.05
other/unknown	15 (2)	29 (8)	< 0.05
LOS ICU in days, *median (IQR)*	3 (2–4)	3 (1–6)	NS
LOS hospital in days, *median (IQR)*	10 (4–19)	10 (4–20)	NS
One-year survival, *n (%)*	391 (58)	146 (41)	–
One-year survivors with favourable neurological outcome, *n (%)*	367 (97)	128 (88)	–

OHCA = out-of-hospital cardiac arrest, IHCA = in-hospital cardiac arrest, IQR = interquartile range, ICU = intensive care unit, SD = standard deviation, SAPS = Simplified Acute Physiology Score, APACHE = Acute Physiology and Chronic Health Evaluation, SOFA = Sequential Organ Failure Assessment, TISS-76 = Therapeutic Intervention Scoring System 76, ROSC = return of spontaneous circulation, LOS = length of stay.

[a] A simplified World Health Organization/Eastern Cooperative Oncology Group classification.

[b] Any severe chronic comorbidity according to APACHE II or SAPSII.

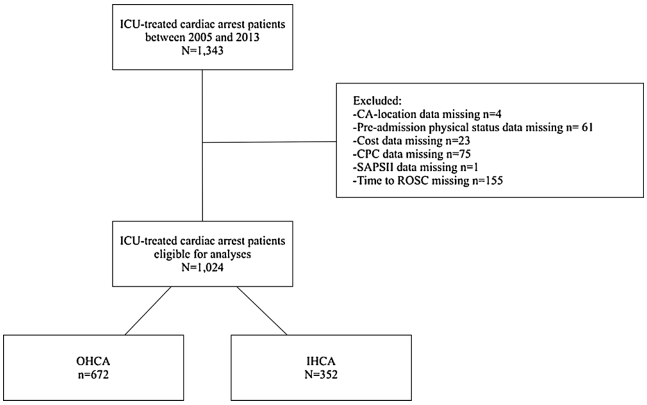

Fig. 1. Patient selection flowchart.
ICU = intensive care unit, CA = cardiac arrest, CPC = Cerebral Performance Category, SAPSII = Simplified Acute Physiology Score II, ROSC = return of spontaneous circulation, OHCA = out-of-hospital cardiac arrest, IHCA = in-hospital cardiac arrest.

physical status before ICU admission. Among IHCAs 67% experienced cardiac arrest during the first day of hospital admission. Compared to OHCAs, IHCA patients had more severe comorbidities and were more severely ill at the time of ICU admission. For the majority of OHCAs, the initial cardiac rhythm was shockable, whereas the initial cardiac rhythm was either pulseless electrical activity (PEA) or asystole (ASY) for most of the IHCA cases. Time to ROSC was considerably longer for OHCA patients (Table 1). Most of the excluded patients were from the IHCA group, otherwise baseline characteristics between excluded and included patients were similar (Supplementary material Table S1).

Outcomes

For OHCA patients, one-year survival was 58%; of these, 97% had favourable neurological outcome. At one year after CA, 44% of IHCA patients were alive, with favourable neurological outcome in 88% of survivors. Our initial severity-of-illness model demonstrated fair predictive ability for both one-year survival (area under the receiver operating characteristic curve [AUC], 0.78, 95% confidence interval [CI], 0.76-0.81) and for favourable neurological outcome (AUC 0.73 [95% CI, 0.65–0.82]).

Treatment intensity

Compared to OHCA, IHCA was associated with an increase in the daily TISS-76 score of 1.9 points (95% CI, 0.7–3.2, $p < 0.05$). Non-shockable rhythms and non-independent preadmission physical status were associated with significantly lower treatment intensity (Table S2).

Adjusted length of ICU stay was 1.2 days (95% CI 0.4–2.0) longer for IHCAs, but there was no difference in adjusted length of hospital stay between OHCA and IHCA. Neither initial cardiac rhythm nor time to ROSC influenced the length of ICU stay. However, non-shockable rhythms and prolonged time to ROSC were associated with significantly shorter length of hospital stay. Non-independent preadmission physical status was associated with shorter length of ICU and hospital stays (Tables S3 and S4). There was no significant change in length of ICU or hospital stay over the study period. For hospital survivors only, non-shockable rhythms and non-independent preadmission physical status were also associated with shorter length of hospital stay (Table S5).

Healthcare-associated costs

The sum of costs for all patients was €50,847,540. Of these, hospital costs comprised 74%, rehabilitation costs 14% and social security costs 12%. Approximately €32 million (64% of total costs) were used for one-year survivors with favourable neurological outcome. Mean total cost per one-year survivor was €62,535 (95% CI, €58,009–€67,060) for OHCA and €88,830 (95% CI, €73,108–€104,551) for IHCA. Mean total cost for patients with favourable neurological outcome at one year was €59,813 (95% CI, €55,514–€64,113) for OHCA and €81,796 (95% CI, €69,535–€94,057) for IHCA. Mean total costs were markedly higher for hospital and one-year survivors compared to non-survivors. Total costs were lower for survivors with favourable neurological outcome than for survivors with unfavourable outcome, irrespective of the location of CA or the initial cardiac rhythm (Figs. 2 and 3).

Factors influencing healthcare-associated costs

Multivariate linear regression indicated that increasing age and increased SAPS II score were associated with lower costs, although increased SAPS II score had the opposite effect on costs for hospital survivors (Tables 2 and S6). Severe preadmission comorbidity increased total costs, along with hospital and social security costs. Preadmission dependency on help in self-care did not influence healthcare costs.

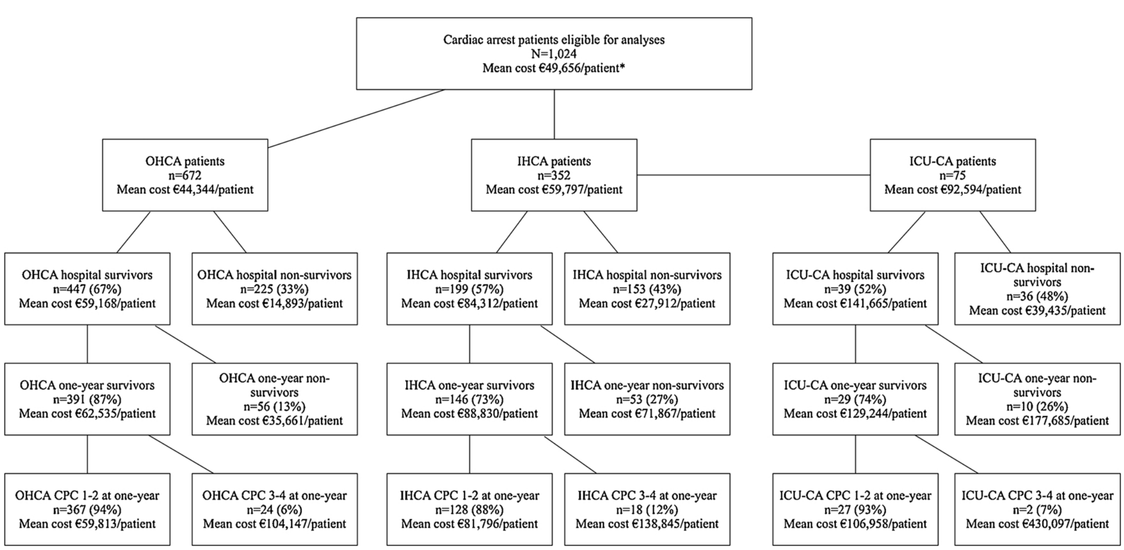

Fig. 2. Mean costs per patient stratified by cardiac arrest location.
OHCA = out-of-hospital cardiac arrest, IHCA = in-hospital cardiac arrest, ICU-CA = in-ICU cardiac arrest, CPC = Cerebral Performance Category. *Costs are adjusted to the consumer price index in Finland to 2013 euros.

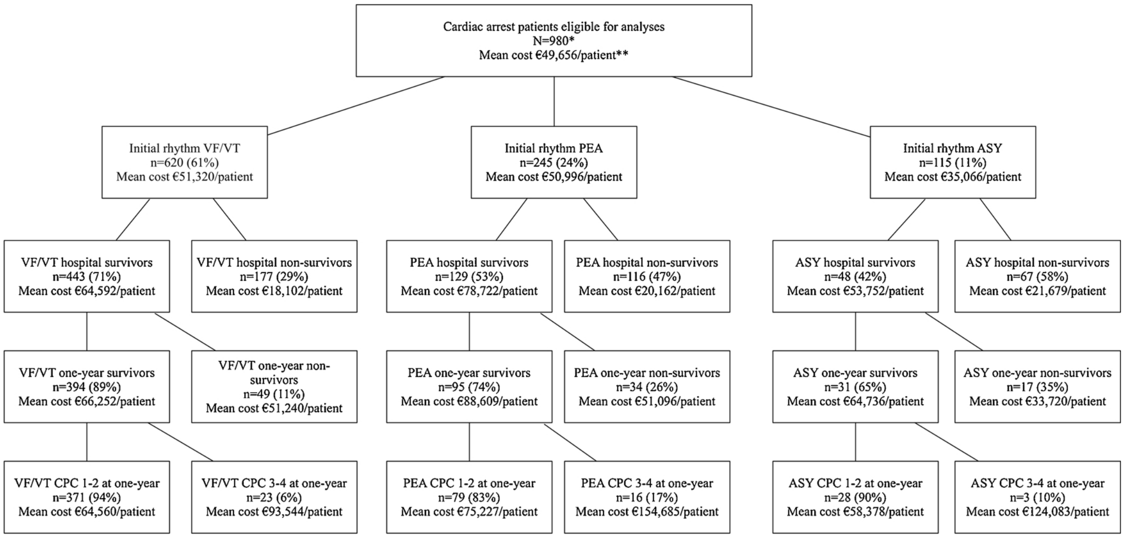

Fig. 3. Mean costs per patient stratified by initial cardiac rhythm.
VF/VT = ventricular fibrillation or ventricular tachycardia, PEA = pulseless electrical activity, ASY = asystole, CPC = Cerebral Performance Category. *Patients with other or unknown initial cardiac rhythm excluded n = 44 (4%). **Costs are adjusted to the consumer price index in Finland to 2013 euros.

Compared to shockable rhythms, PEA had no significant influence on total costs or any of the cost components. Asystole reduced total costs by a mean of €19,976 (95%CI €7,944–€32,008, $p < 0.05$) via reduction in hospital and social security costs, with a similar effect for hospital survivors (Tables 2 and S6). In comparison to OHCA, IHCA increased total costs by a mean of €17,974 (95% CI €9,004€–€26,944, $p < 0.05$). IHCA also increased hospital costs, but not rehabilitation or social security costs (Table 2). Admission year did not influence healthcare-associated costs.

Cost-effectiveness

The ECPS was €94,688 and the ECPFN was €102,722, for all patients. For OHCA, ECPS was €76,212, and ECPFN was €81,196. For IHCA, ECPS was €144,168, and ECPFN was €164,442. Both ECPS and ECPFN were the highest for patients with PEA as the initial cardiac rhythm (Fig. 4).

Subgroup analyses

Out of all IHCAs, 21% (75/352) had in-ICU cardiac arrest (ICU-CA) and achieved ROSC. At one year after CA, 39% (29/75) of ICU-CA patients were alive. Of these, 93% (27/29) had favourable neurological outcome.

Treatment intensity was significantly higher for ICU-CA patients than for OHCA patients (Table S2). Both case-mix adjusted length of ICU stay and case-mix adjusted length of hospital stay were significantly longer for ICU-CA patients than for OHCAs (Tables S3 and S4).

For ICU-CA patients, the mean cost per one-year survivor was €129,244 (95% CI €75,176–€183,311) and mean cost per one-year survivor with favourable neurological outcome was €106,958 (95% CI €74,863–€139,054). ICU-CA increased total costs significantly for the whole population and for hospital survivors (Tables 2 and S6). In the ICU-CA group ECPS was €239,468 and ECPFN was €257,207.

Discussion

Key results

We determined one-year survival and neurological outcome along with healthcare-associated costs for a tertiary hospital's ICU-treated CA patients. Patients with favourable neurological outcome consumed over half of all costs. Effective costs per survivor and per survivor with favourable neurological outcome were twice as high in the IHCA group compared to OHCA, with the highest costs seen in the ICU-CA subgroup. When stratified by the initial cardiac rhythm, the highest ECPS and ECPFN were in the PEA group. Compared to shockable rhythms, asystole was associated with a significant decrease in total healthcare costs, mainly due to reduction in hospital costs. Irrespective of the CA location and the initial cardiac rhythm, the majority of one-year survivors achieved favourable neurological outcome.

Survival and neurological outcome

Previous studies have reported one-year survival rates for hospital-treated OHCA between 27% and 55%, and for IHCA between 6% and 30% [17–23]. Over 80% of hospital survivors had favourable neurological outcome [24–30]. Compared to earlier publications, one-year survival was generally higher in our study. Several factors can possibly explain these differences in outcomes. Our study was conducted in a densely populated urban area with high by-stander cardiopulmonary resuscitation rates and efficient emergency medical services (EMS) with short CA-response times. Patients included in the study received post-CA treatment in the ICUs of a tertiary hospital that serves as the primary CA referral centre and has all established CA treatments and a wide set of diagnostic procedures available around the clock. Additionally, our study population consisted only of ICU-treated OHCA and IHCA patients, thus excluding patients who were denied ICU admission because of failure to achieve ROSC or presumed poor outcome.

Healthcare-associated costs

Several publications reported CA-related healthcare costs previously. One of the first studies on costs associated with the treatment of OHCA reported total costs, including pre-hospital and in-hospital costs, for a six-month survivor of €36,000 expressed in 2013 euros [17]. Several more recent studies reported hospital costs per patient between €50,000 and €60,000 in 2013 euros for OHCA and IHCA hospital survivors, with costs per hospital survivor with favourable neurological outcome between €17,000 and €80,000 in 2013 euros [2,19,31,32]. A study by van Alem et al. reported healthcare-associated costs during the first half-year after OHCA, including prehospital, in-hospital and post-hospital expenses, of €36,600 in 2013 euros [33]. Only one previous

Table 2
Factors associated with healthcare costs based on multivariate linear regression.

	Mean change in in costs per patient (€)	95%CI (€)		p-value
Total costs				
Age[a]	−420	−671	−168	< 0.05
Admission year[b]	589	−728	1,906	NS
SAPSII score[c]	−351	−582	−119	< 0.05
Severe comorbidity at the time of ICU admission[d]	10,825	1,942	19,707	< 0.05
Preadmission physical status				
Non-independent vs. independent	−10,227	−22,840	2,386	NS
Time to ROSC (min)[e]	−336	−723	51	NS
Initial cardiac rhythm, VF/VT as reference				
PEA	−4,808	−14,230	4,615	NS
Asystole	−19,976	−32,008	−7,944	< 0.05
Location of cardiac arrest, OHCA as reference				
all IHCA	17,974	9,005	26,944	< 0.05
ICU-CA	48,448	33,822	63,075	< 0.05
Hospital costs				
Age[a]	−164	−340	11	NS
Admission year[b]	859	−61	1,778	NS
SAPSII score[c]	−204	−365	−42	< 0.05
Severe comorbidity at the time of ICU admission[d]	7,139	940	13,338	< 0.05
Preadmission physical status				
Non-independent vs. independent	−7,736	−16,538	1,067	NS
Time to ROSC (min)[e]	−242	−512	28	NS
Initial cardiac rhythm, VF/VT as reference				
PEA	−5,297	−11,873	1,279	NS
Asystole	−15,493	−23,891	−7,097	< 0.05
Location of cardiac arrest, OHCA as reference				
all IHCA	14,320	8,060	20,581	< 0.05
ICU-CA	36,682	26,487	46,876	< 0.05
Rehabilitation costs				
Age[a]	−68	−174	39	NS
Admission year[b]	−315	−876	245	NS
SAPSII score[c]	−54	−152	44	NS
Severe comorbidity at the time of ICU admission[d]	36	−3,739	3,810	NS
Preadmission physical status				
Non-independent vs. independent	−1,015	−6,374	4,344	NS
Time to ROSC (min)[e]	−71	−235	94	NS
Initial cardiac rhythm, VF/VT as reference				
PEA	1,439	−2,565	5,442	NS
Asystole	−1,818	−6,930	3,295	NS
Location of cardiac arrest, OHCA as reference				
all IHCA	3,255	−557	7,066	NS
ICU-CA	10,926	4,658	17,193	< 0.05
Social security costs				
Age[a]	−188	−235	−140	< 0.05
Admission year[b]	45	−203	295	NS
SAPSII score[c]	−93	−137	−49	< 0.05
Severe comorbidity at the time of ICU admission[d]	3,650	1,967	5,333	< 0.05
Preadmission physical status				
Non-independent vs. independent	−1,476	−3,866	914	NS
Time to ROSC (min)[e]	−23	−97	50	NS
Initial cardiac rhythm, VF/VT as reference				
PEA	−949	−2,735	836	NS
Asystole	−2,664	−4,944	−385	< 0.05
Location of cardiac arrest, OHCA as reference				
all IHCA	399	−1,300	2,099	NS
ICU-CA	841	−1,966	3,649	NS

CI = confidence interval, OHCA = out-of-hospital cardiac arrest, IHCA = in-hospital cardiac arrest, ICU-CA = in-ICU cardiac arrest, ROSC = return of spontaneous circulation, NS = not significant, VF/VT = ventricular fibrillation or ventricular tachycardia, PEA = pulseless electrical activity.

[a] For each additional year.

[b] For each subsequent year.

[c] For each additional point.

[d] Any severe chronic comorbidity according to APACHE II or SAPSII.

[e] For every additional minute.

study reported cost data for ICU-CA patients with ICU-related expenses for hospital non-survivor of €54,000 in 2013 euros [34].

In comparison to previous studies, healthcare costs were higher in the present study. Data on post-discharge expenses were limited and only one of the previous studies reported healthcare-associated costs for ICU-CA patients, a subgroup of the IHCA population that, according to our study, consumes a considerable amount of resources for every gained life and especially for a survivor with good neurological outcome, suggesting a need to improve prevention and management strategies also for ICU-CA.

Indeed, IHCA, and especially ICU-CA, was associated with significantly higher total healthcare costs compared to OHCA.

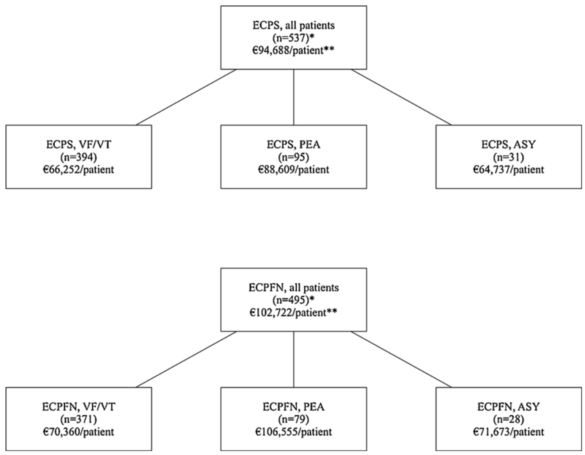

Fig. 4. Effective cost per one-year survivor (ECPS) and per one-year survivor with favorable neurological outcome (ECPFN) stratified by initial cardiac rhythm.
VF/VT = ventricular fibrillation or ventricular tachycardia, PEA = pulseless electrical activity, ASY = asystole. *Patients with other or unknown initial cardiac rhythm excluded (n = 17). **Costs are adjusted to the consumer price index in Finland to 2013 euros.

Interestingly, the observed increase in total costs for IHCA and ICU-CA patients was mostly due to increase in hospital costs. The design of our study does not allow for the establishment of any causative relationship between costs and CA location.

Asystole was associated with lower treatment intensity and shorter length of ICU and hospital stay, which possibly resulted in a significant reduction in total costs due to both reduced hospital and social security costs for the whole study population and for hospital survivors only. These findings suggest that CA patients with asystole as an initial rhythm are likely to consume fewer resources, possibly due to the higher risk of early mortality, different aetiology of arrest and, in some cases, an anticipated poor outcome and less active treatment approach. The connection between consumed resources and PEA is less clear. Increase in age and SAPS II score were associated with reduced total healthcare-associated costs, due mostly to the reduction in hospital and social security costs. One possible explanation could be the higher mortality in elderly and more acutely ill patients. This is supported by the inversed relationship between SAPS II score and healthcare-associated costs for hospital survivors. However, age did not influence treatment intensity or length of ICU and hospital stays, while an increase in SAPS II score slightly reduced the TISS-76 score and length of hospital stay but had no effect on length of ICU stay.

Costs associated with care after critically ill patients, and especially after comatose patients, are high and continue to increase [35–37]. In ICU patients treated for acute renal failure, the mean cost for one six-month survivor was €117,000 expressed in 2013 euros [38]. For critically ill cancer patients, costs per gained life were even higher [39]. For patients with traumatic brain injury, overall effective costs per one-year survivor and one-year independent survivor were €47,708 and €75,595 respectively expressed in 2013 euros [16]. Chin-Yee et al. reported ICU costs for very elderly (≥80 years) patients of €46,453 in 2013 euros [40]. Considering these results, the effective cost per one-year survivor with favourable neurological outcome of €102,722 in our study does not seem to be high and is lower than generally accepted incremental cost-effectiveness ratios [41].

Strengths and limitations

A major strength of the current study is that it was conducted in a setting of government-funded healthcare with no selection bias due to, e.g. socioeconomic factors and personal insurance. Thus, the study provides a comprehensive and detailed evaluation of one-year survival and healthcare-associated costs stratified by CA location with the case-mix adjustment for CA-specific variables. Yet, one should be careful to extrapolate our results to settings with very different healthcare systems. Further, as the study's population originates from a single tertiary hospital with a highly efficient local EMS, our results may not be generalisable on a global level.

Due to the retrospective nature of the study, the data are prone to common information and misclassification biases. We had to exclude 24% of patients from the analyses because of missing data. We were unable to separate pre-arrest expenses from cardiac arrest-inflicted expenses for IHCA and ICU-CA patients, which might lead to an overestimation of cardiac arrest-related costs. However, almost 70% of all IHCA (ICU-CA included) patients experienced cardiac arrest during the first day of hospital stay. Due to the design of the study and the limitations of the data sources, we also were unable to estimate CA-related indirect societal costs, such as loss of work days, loss of national taxes, and pension and life insurance pay-outs.

Conclusion

The lowest one-year survival of 39% was in ICU-CA patients. Irrespective of the CA location, the vast majority of one-year survivors had favourable neurological outcome, with ECPFN of €102,722. One-year healthcare-associated effective costs were twice as high for IHCA patients compared to OHCA patients, and markedly higher in the PEA group compared to other initial rhythms. Compared to OHCA, healthcare-associated costs were almost three times as high in ICU-CA patients. There is an undisputable need to improve prevention and management of IHCAs, especially those occurring in ICUs, to improve the overall cost-effectiveness of CA treatment.

Conflict of interest

None.

Acknowledgements

The study was supported by *Finska Läkaresällskapet*, *Viipurin tuberkuloosisäätiö*, *Svenska Kulturfonden*, *Medicinska Understödsföreningen Liv and Hälsa*, *Maud Kuistilan Säätiö*, *Eemil Aaltosen Säätiö*, *Ella and Georg Ehrnroothin Säätiö*, *Suomalais-Norjalainen Lääketieteen Säätiö*, *Suomen Lääketieteen Säätiö*, *Maire Taposen Säätiö*, Orion Research Foundation sr, and Helsinki University Hospital (state funding: VTR-TYH2014221). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2018.06.028.

References

[1] Bossaert LL, Perkins GD, Askitopoulou H, Raffay VI, Greif R, Haywood KL, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 11. The ethics of resuscitation and end-of-life decisions. Resuscitation 2015;95:302–11. http://dx.doi.org/10.1016/j.resuscitation.2015.07.033.

[2] Chan PS, Nallamothu BK, Krumholz HM, Curtis LH, Li Y, Hammill BG, et al. Readmission rates and long-term hospital costs among survivors of an in-hospital cardiac arrest. Circ Cardiovasc Qual Outcomes 2014;7:889–95. http://dx.doi.org/10.1161/CIRCOUTCOMES.114.000925.

[3] Berdowski J, Berg RA, Tijssen JGP, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: systematic review of 67 prospective studies. Resuscitation 2010;81:1479–87. http://dx.doi.org/10.1016/j.resuscitation.2010.08.006.

[4] Atwood C, Eisenberg MS, Herlitz J, Rea TD. Incidence of EMS-treated out-of-hospital cardiac arrest in Europe. Resuscitation 2005;67:75–80. http://dx.doi.org/10.1016/j.resuscitation.2005.03.021.

[5] Reinikainen M, Mussalo P, Hovilehto S, Uusaro A, Varpula T, Kari A, et al. Association of automated data collection and data completeness with outcomes of intensive care. A new customised model for outcome prediction. Acta Anaesthesiol Scand 2012;56:1114–22. http://dx.doi.org/10.1111/j.1399-6576.2012.02669.x.

[6] Oken MM, Creech RH, Tormey DC, Horton J, Davis TE, McFadden ET, et al. Toxicity and response criteria of the Eastern Cooperative Oncology Group. Am J Clin Oncol 1982;5:649–55.

[7] Le Gall JR, Lemeshow S, Saulnier F. A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicenter study. JAMA 1993;270:2957–63.

[8] Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. Crit Care Med 1985;13:818–29.

[9] Knaus WA, Wagner DP, Draper EA, Zimmerman JE, Bergner M, Bastos PG, et al. The APACHE III prognostic system. Risk prediction of hospital mortality for critically ill hospitalized adults. Chest 1991;100:1619–36.

[10] Keene AR, Cullen DJ. Therapeutic Intervention Scoring System: update 1983. Crit Care Med 1983;11:1–3.

[11] Jennett B, Bond M. Assessment of outcome after severe brain damage. Lancet 1975;1:480–4.

[12] Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Circulation 1991;84:960–75.

[13] Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). Circulation 2004;110:3385–97. http://dx.doi.org/10.1161/01.CIR.0000147236.85306.15.

[14] Morrison LJ, Neumar RW, Zimmerman JL, Link MS, Newby LK, McMullan PW, et al. Strategies for improving survival after in-hospital cardiac arrest in the United States: 2013 consensus recommendations: a consensus statement from the American Heart Association. Circulation 2013;127:1538–63. http://dx.doi.org/10.1161/CIR.0b013e31828b2770. American Heart Association, Inc.

[15] Kapiainen S, Väisänen A, Haula T. Terveyden- ja sosiaalihuollon yksikkökustannukset Suomessa vuonna 2011. THL; 2014.

[16] Raj R, Bendel S, Reinikainen M, Hoppu S, Luoto T, Ala-Kokko T, et al. Temporal trends in healthcare costs and outcome following ICU admission after traumatic brain injury. Crit Care Med 2018:1. http://dx.doi.org/10.1097/CCM.0000000000002959.

[17] Jakobsson J, Nyquist O, Rehnqvist N, Norberg KA. Cost of a saved life following out-of-hospital cardiac arrest resuscitated by specially trained ambulance personnel. Acta Anaesthesiol Scand 1987;31:426–9.

[18] Fischer M, Fischer NJ, Schüttler J. One-year survival after out-of-hospital cardiac arrest in Bonn city: outcome report according to the 'Utstein style'. Resuscitation 1997;33:233–43.

[19] Næss A-C, Steen PA. Long term survival and costs per life year gained after out-of-hospital cardiac arrest. Resuscitation 2004;60:57–64. http://dx.doi.org/10.1016/S0300-9572(03)00262-4.

[20] Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA 2013;310:1377–84. http://dx.doi.org/10.1001/jama.2013.278483.

[21] Wissenberg M, Folke F, Hansen CM, Lippert FK, Kragholm K, Risgaard B, et al. Survival after out-of-hospital cardiac arrest in relation to age and early identification of patients with minimal chance of long-term survival. Circulation 2015;131:1536–45. http://dx.doi.org/10.1161/CIRCULATIONAHA.114.013122.

[22] Bloom HL, Shukrullah I, Cuellar JR, Lloyd MS, Dudley Jr. SC, Zafari AM. Long-term survival after successful inhospital cardiac arrest resuscitation. Am Heart J 2007;153:831–6. http://dx.doi.org/10.1016/j.ahj.2007.02.011.

[23] Fredriksson M, Aune S, Thorén A-B, Herlitz J. In-hospital cardiac arrest—an utstein style report of seven years experience from the Sahlgrenska University Hospital. Resuscitation 2006;68:351–8. http://dx.doi.org/10.1016/j.resuscitation.2005.07.011.

[24] Grimaldi D, Dumas F, Perier M-C, Charpentier J, Varenne O, Zuber B, et al. Short- and long-term outcome in elderly patients after out-of-hospital cardiac arrest. Crit Care Med 2014;42:2350–7. http://dx.doi.org/10.1097/CCM.0000000000000512.

[25] Vaahersalo J, Hiltunen P, Tiainen M, Oksanen T, Kaukonen K-M, Kurola J, et al. Therapeutic hypothermia after out-of-hospital cardiac arrest in finnish intensive care units: the FINNRESUSCI study. Intensive Care Med 2013;39:826–37. http://dx.doi.org/10.1007/s00134-013-2868-1.

[26] Lindner TW, Søreide E, Nilsen OB, Torunn MW, Lossius HM. Good outcome in every fourth resuscitation attempt is achievable—an Utstein template report from the Stavanger region. Resuscitation 2011;82:1508–13. http://dx.doi.org/10.1016/j.resuscitation.2011.06.016.

[27] Lindner T, Vossius C, Mathiesen WT, Søreide E. Life years saved, standardised mortality rates and causes of death after hospital discharge in out-of-hospital cardiac arrest survivors. Resuscitation 2014;85:671–5. http://dx.doi.org/10.1016/j.resuscitation.2014.01.002.

[28] Meaney PA, Nadkarni VM, Kern KB, Indik JH, Halperin HR, Berg RA. Rhythms and outcomes of adult in-hospital cardiac arrest. Crit Care Med 2010;38:101–8. http://dx.doi.org/10.1097/CCM.0b013e3181b43282.

[29] Peberdy MA, Ornato JP, Larkin GL, Braithwaite RS, Kashner TM, Carey SM, et al. Survival from in-hospital cardiac arrest during nights and weekends. JAMA 2008;299:785–92. http://dx.doi.org/10.1001/jama.299.7.785.

[30] Tian J, Kaufman DA, Zarich S, Chan PS, Ong P, Amoateng-Adjepong Y, et al. Outcomes of critically ill patients who received cardiopulmonary resuscitation. Am J Respir Crit Care Med 2010;182:501–6. http://dx.doi.org/10.1164/rccm.200910-1639OC.

[31] Graf J, Mühlhoff C, Doig GS, Reinartz S, Bode K, Dujardin R, et al. Health care costs, long-term survival, and quality of life following intensive care unit admission after cardiac arrest. Crit Care 2008;12:R92. http://dx.doi.org/10.1186/cc6963.

[32] Petrie J, Easton S, Naik V, Lockie C, Brett SJ, Stumpfle R. Hospital costs of out-of-hospital cardiac arrest patients treated in intensive care; A single centre evaluation using the national tariff-based system. BMJ Open 2015;5. http://dx.doi.org/10.1136/bmjopen-2014-005797. e005797–7.

[33] van Alem AP, Dijkgraaf MGW, Tijssen JGP, Koster RW. Health system costs of out-of-hospital cardiac arrest in relation to time to shock. Circulation 2004;110:1967–73. http://dx.doi.org/10.1161/01.CIR.0000143150.13727.19.

[34] Wallace SK, Ewer MS, Price KJ, Feeley TW. Outcome and cost implications of cardiopulmonary resuscitation in the medical intensive care unit of a comprehensive cancer center. Support Care Cancer 2002;10:425–9. http://dx.doi.org/10.1007/s00520-002-0353-4.

[35] Halpern NA, Pastores SM. Critical care medicine in the United States 2000–2005: an analysis of bed numbers, occupancy rates, payer mix, and costs. Crit Care Med 2010;38:65–71. http://dx.doi.org/10.1097/CCM.0b013e3181b090d0.

[36] Hamel MB, Phillips R, Teno J, Davis RB, Goldman L, Lynn J, et al. Cost effectiveness of aggressive care for patients with nontraumatic coma. Crit Care Med 2002;30:1191–9.

[37] Damluji AA, Al-Damluji MS, Pomenti S, Zhang TJ, Cohen MG, Mitrani RD, et al. Health care costs after cardiac arrest in the United States. Circ Arrhythm Electrophysiol 2018;11:e005689http://dx.doi.org/10.1161/CIRCEP.117.005689.

[38] Korkeila M, Ruokonen E, Takala J. Costs of care, long-term prognosis and quality of life in patients requiring renal replacement therapy during intensive care. Intensive Care Med 2000;26:1824–31.

[39] Schapira DV, Studnicki J, Bradham DD, Wolff P, Jarrett A. Intensive care, survival, and expense of treating critically ill cancer patients. JAMA 1993;269:783–6.

[40] Chin-Yee N, D'Egidio G, Thavorn K, Heyland D, Kyeremanteng K. Cost analysis of the very elderly admitted to intensive care units. Crit Care 2017;21:109. http://dx.doi.org/10.1186/s13054-017-1689-y.

[41] Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of the $50,000-per-QALY threshold. N Engl J Med 2014;371:796–7. http://dx.doi.org/10.1056/NEJMp1405158.