Comparison of two strategies for managing in-hospital cardiac arrest

Jafer Haschemi1,3, Ralf Erkens1,3, Robert Orzech1, Jean Marc Haurand1, Christian Jung1, Malte Kelm1,2, Ralf Westenfeld1 & Patrick Horn1*

In-hospital cardiac arrest (IHCA) is associated with poor outcomes. There are currently no standards for cardiac arrest teams in terms of member composition and task allocation. Here we aimed to compare two different cardiac arrest team concepts to cover IHCA management in terms of survival and neurological outcomes. This prospective study enrolled 412 patients with IHCA from general medical wards. From May 2014 to April 2016, 228 patients were directly transferred to the intensive care unit (ICU) for ongoing resuscitation. In the ICU, resuscitation was extended to advanced cardiac life support (ACLS) (Load-and-Go [LaG] group). By May 2016, a dedicated cardiac arrest team provided by the ICU provided ACLS in the ward. After return of spontaneous circulation (ROSC), the patients (n = 184) were transferred to the ICU (Stay-and-Treat [SaT] group). Overall, baseline characteristics, aetiologies, and characteristics of cardiac arrest were similar between groups. The time to endotracheal intubation was longer in the LaG group than in the SaT group (6 [5, 8] min versus 4 [2, 5] min, p = 0.001). In the LaG group, 96% of the patients were transferred to the ICU regardless of ROSC achievement. In the SaT group, 83% of patients were transferred to the ICU (p = 0.001). Survival to discharge did not differ between the LaG (33%) and the SaT (35%) groups (p = 0.758). Ultimately, 22% of patients in the LaG group versus 21% in the SaT group were discharged with good neurological outcomes (p = 0.857). In conclusion, we demonstrated that the cardiac arrest team concepts for the management of IHCA did not differ in terms of survival and neurological outcomes. However, a dedicated (intensive care) cardiac arrest team could take some load off the ICU.

In-hospital cardiac arrest (IHCA) is a major adverse event with an incidence of 1–6/1000 hospital admissions1. Mortality after IHCA is high, and the neurological outcome after the return of spontaneous circulation (ROSC) remains dismal3,4. Approximately every fourth IHCA patient survives to discharge4,5. Strategies to manage out-of-hospital cardiac arrest (OHCA) have been widely researched6,7, but little is known about the best management of IHCA to improve outcomes. Outcomes might be affected by patient characteristics3,8–10, cardiac arrest timepoint and location11, and cardiac arrest team performance. Ensuring adequate basic life support (BLS) and subsequently employing advanced cardiac life support (ACLS) according to the current resuscitation guidelines are of critical importance12,13.

Improving cardiac arrest team performance may increase survival. However, team compositions vary among hospitals and countries14. Currently, there are no international standards for IHCA teams in member composition and task allocation. It remains unclear how hospitals should assemble cardiac arrest teams to guarantee the optimal management of patients suffering from IHCA. Should IHCA management be organised based on OHCA strategies with a dedicated team that comes to the patient and continues ACLS on-site (Stay-and-Treat [SaT])? Alternatively, might it be advantageous when the patient is transferred as soon as possible (with ongoing cardiopulmonary resuscitation [CPR]) to an intensive care unit (ICU) where CPR can be continued and extended with higher levels of staff and equipment resources (Load-and-Go [LaG])? The latter concept could mean poorer chest compressions during transportation, but that effect might be compensated for by higher competency at ICU arrival and a higher possibility of treating reversible causes in the ICU.

This study aimed to compare the two different IHCA team concepts, CPR survival and neurological outcomes, at a single university hospital.

1Department of Cardiology, Pulmonology and Vascular Medicine, Medical Faculty of the Heinrich Heine University, Moorstr. 5, 40225 Duesseldorf, Germany. 2Cardiovascular Research Institute, Medical Faculty of the Heinrich-Heine University, Düsseldorf, Germany. 3These authors contributed equally: Jafer Haschemi and Ralf Erkens. *email: patrick.horn@med.uni-duesseldorf.de
Methods

In this before-and-after study, we prospectively enrolled all comers with IHCA between May 2014 and April 2018 in an internal medicine or neurological general ward at the university hospital. The patients were grouped according to cardiac arrest team concept. Patient characteristics, baseline data, and event data were assessed using medical records and event protocols. This study was conducted in accordance with the guidelines of the Declaration of Helsinki and received approval from the University of Düsseldorf Committee on Human Research (study number 2018-112-RetroDEuA), which waived the requirement for informed patient consent due to our use of anonymised data collected during critical care hospitalisation.

Cardiac arrest team concepts (LaG versus SaT). From May 2014 to April 2016, IHCA patients were treated by a cardiac arrest team with various staff compositions (LaG group) (Fig. 1), while the rapid initiation of CPR and early defibrillation were performed by nurses and physicians in the wards (non-intensive care specialists from the internal medicine or neurology department). During nights and weekends, the nurses, house officers on duty, and senior house officers on duty (from the internal medicine department) performed BLS and early defibrillation. Staff members are trained once a year for BLS. The patients were directly transferred to the ICU (after the achievement of early return of spontaneous circulation [ROSC] or with ongoing manual CPR. The airway was secured with a laryngeal mask or a single bag mask valve ventilation. In the ICU, the resuscitation was continued and extended to ACLS.
The primary endpoint of this study was survival to discharge. The secondary endpoints were the proportion of patients who achieved ROSC, time to achieve ROSC, and neurological outcome. Neurological outcomes were assessed according to peak neuron-specific enolase (NSE) levels and the cerebral performance category (CPC) scale. The CPC scale was determined by chart review of the neurological assessment performed by a physician at the time of discharge. In cases of missing chart reviews, a structured interview was conducted. The five-point CPC scale assesses brain recovery by assessing the functional and cognitive aspects of brain function. CPC 1 was defined as good cerebral performance (conscious, alert, able to be aroused). CPC 2, moderate cerebral disability (conscious, sufficient cerebral performance for independent activities of daily life, able to work, mild neurologic or psychologic deficit); CPC 3, severe cerebral disability (conscious, dependent on others for daily support because of impaired brain function/progression from ambulatory state to severe dementia or paralysis; CPC 4, coma or vegetative state (any degree of coma with fixed task assignments (Fig. 1) (SaT group): The team supported and extended CPR to ACLS on-site. CPR measures were continued or terminated according to the cardiac arrest team’s assessment, and cases of death were recorded. After ROSC achievement, the patient was transferred to the ICU.

Statistics. Categorical variables are reported as absolute values and percentages, whereas continuous data are expressed as median with interquartile range. The χ² test or Fisher’s exact test was used to assess the distribution of the continuous variables. In cases of normal distribution, Student’s unpaired t-test was performed to compare the means between the two groups. Continuous variables that did not follow a normal distribution were compared using the Mann–Whitney U test. Cox regression analysis was used to identify whether variables associated with hospital mortality after IHCA differed between the LaG and SaT groups. Variables with a p-value < 0.1 in the univariate analysis and variables known or thought to be associated with mortality after IHCA were included in the multivariable model. Statistical significance was set at P < 0.05. The statistical analyses were performed using SPSS® Statistics 25 (IBM, Armonk, NY, USA) and Prism® (GraphPad, San Diego, CA, USA).

Results

Patients’ characteristics. From May 2014 to April 2016, 24,590 patients were admitted to the internal medicine or neurology departments of the university hospital. During this period, 228 patients had IHCA (LaG group). Between May 2016 and April 2018, 25,251 patients were admitted, and 184 cases of IHCA occurred (SaT group). This means that the occurrence of IHCA decreased from 0.9 per 1000 patient admissions in the period of the LaG concept to 0.7 per 1000 patients (p = 0.014) in the period of the SaT concept.

Overall, the baseline characteristics were similar between the two groups (Table 1). The median age was 75 (64, 81) years in the LaG group versus 75 (64, 82) years in the SaT group (p = 0.730). The LaG and SaT groups included 62% and 64% male patients, respectively (p = 0.716). The aetiology of cardiac arrest did not differ between groups: IHCA had a cardiac aetiology in 120 patients (53%) versus 82 patients (46%), respectively (p = 0.103). The primary rhythm was shockable in 69 patients (30%) in the LaG group versus 63 patients (34%) in the SaT group (p = 0.390).

Table 1. Baseline characteristics of the study population. Categorical variables are reported as absolute values and percentages, whereas continuous data are expressed as median with interquartile range. IHCA, in-hospital cardiac arrest; LaG, Load-and-Go; SaT, Stay-and-Treat; CAD, coronary artery disease; PAD, peripheral arterial disease; GFR, glomerular filtration rate.
Main results. The time from team arrival to first shock (if indicated) and the first administration of epinephrine did not differ between groups: 1 (0.5, 1) min versus 1 (0.5, 1) min, \((p = 0.422)\), and 3 (2, 5) min versus 3 (3, 4) min \((p = 0.143)\) (Table 2). The time to endotracheal intubation was longer in the LaG group than in the SaT group 6 [5, 8] min versus 4 [2, 5] min, \(p = 0.001\).

ROSC was achieved in 168 patients (74%) in the LaG group versus 143 patients (78%) in the SaT group \((p = 0.344)\) (Table 2). The time to achieve ROSC did not differ between the LaG and SaT groups \((15 [5, 30] \text{ min versus } 10 [2, 20] \text{ min}, p = 0.173)\). In the LaG group, 220 of 228 patients (96%) were transferred to the ICU regardless of ROSC achievement; in 44 (20% of the transferred patients), ROSC could not be achieved and the CPR was promptly terminated after ICU arrival. In the SaT group, 153 of 184 patients (83%) were transferred to the ICU; ROSC could not be achieved in 10 patients (6.5% of the transferred patients) \((p = 0.001 \text{ vs. the LG group})\).

Survival to discharge did not differ between the LaG (75 patients, 32.9%) and (64 patients [34.8%]) group \((p = 0.687)\). Kaplan–Meier curves and the log-rank (Mantel-Cox) test confirmed similar survival rates in the LaG and SaT groups (Fig. 2A).

To identify predictors of hospital mortality after IHCA, we performed a logistic regression analysis. In the multivariate analysis, a longer time to achieve ROSC, a higher first lactate level, and (in the SaT group) advanced age were independent predictors of poor survival to discharge (Tables 3, 4).

Neurological outcomes did not differ between the LaG and SaT group. The peak NSE levels did not differ between the groups at 41 (25, 68) µg/L in the LaG group versus 37 (24, 57) µg/L in the SaT group \((p = 0.315)\). Fifty of 228 patients (21.9%) in the LaG group versus 39 of 184 patients (21.2%) in the SaT group \((p = 0.857)\) were discharged with good neurological outcome according to CPC scale score (Fig. 2B).

Discussion

Here we compared for the first time two different cardiac arrest team concepts used in the management of IHCA. Switching between the two different team strategies of IHCA management at one centre made it possible to compare their survival and neurological outcomes data. We reported that the two cardiac arrest team strategies for the management of IHCA had similar survival and neurological outcomes.

The different strategies of both cardiac arrest team concepts did not impact survival (36% in the LaG versus 35% in the SaT group). In particular, the transfer of patients under ongoing CPR in the LG group; together with this finding, the delay in endotracheal intubation did not worsen the outcome. Airway management and ventilation are essential components of CPR to achieve oxygen delivery and prevent hypoxic injury. Endotracheal intubation may have adverse effects on outcomes by interrupting cardiopulmonary resuscitation and delaying timely defibrillation and epinephrine administration. Bag-mask ventilation is a less complex technique than endotracheal intubation for airway management during the ACLS phase of cardiopulmonary resuscitation in patients. In a previous study, IHCA patients without preceding respiratory failure were more likely to survive IHCA at hospitals with lower rates of tracheal intubation use compared to hospitals with higher rates. In contrast, in a large observational cohort study, delayed (> 15 min) endotracheal intubation during resuscitation was associated with decreased survival after IHCA. In our study, intubation time was longer in the LG group, but it remained under 15 min. In both groups, adherence to guidelines was high, and the rapid initiation of CPR and early defibrillation after the recognition of IHCA were ensured. Our findings emphasise that, regardless of where the cardiac arrest occurs, early CPR initiation and early defibrillation of a shockable rhythm is more crucial for patient prognosis than ACLS measures since every minute of a delay increases the risk of patient mortality.

Nevertheless, the use of a dedicated intensive care cardiac arrest team and resuscitation performance, such as the presented SaT concept might have some advantages in terms of process consistency. Team composition, team leader, and task allocation are constant irrespective of the time point and location at which IHCA occurs. The transfer of patients with ongoing CPR to an ICU can potentially hamper the efficacy of chest compressions and impair circulatory flow time, especially when the distance to the ICU is too long. In addition, an experienced team is more inclined to terminate CPR and declare death after prolonged and unsuccessful CPR without ICU.

Table 2. IHCA characteristics. Categorical variables are reported as absolute values and percentages, whereas continuous data are expressed as median with interquartile range. * indicates \(p \leq 0.05\) between LaG group and SaT group. Significant values are in bold. IHCA In-hospital cardiac arrest, LaG Load-and-Go, SaT Stay-and-Treat, ICU Intensive care unit, ROSC return of spontaneous circulation.

| IHCA characteristics | Complete cohort n = 412 | LaG-group n = 228 | SaT-group n = 184 | p-value |
|---------------------|------------------------|------------------|------------------|---------|
| Cardiac arrest etiology, n (%) | 202 (49) | 120 (53) | 82 (46) | 0.103 |
| Primary shockable rhythm, n (%) | 132 (32) | 69 (30) | 63 (34) | 0.390 |
| Time to first shock (min) | 1.0 (0.5, 1.0) | 1.0 (0.5, 1.0) | 1.0 (0.5, 1.0) | 0.422 |
| Time to first epinephrine administration (min) | 3 (2, 4) | 3 (2, 5) | 3 (3, 4) | 0.143 |
| Time to endotracheal intubation (min) | 5 (3, 7) | 6 (5, 8) | 4 (2, 5) | *0.001 |
| Patients with ROSC, n (%) | 311 (75) | 168 (74) | 143 (78) | 0.344 |
| Time to ROSC (min) | 10 (3, 29) | 15 (5, 30) | 10 (2, 20) | 0.114 |
| Phosphat after ROSC (mmol/l) | 1.9 (1.1, 2.5) | 1.8 (1.2, 2.5) | 2.0 (1.0, 2.4) | 0.921 |
| Lactate after ROSC (mg/l) | 8.7 (3.6, 12.7) | 9.4 (4.5, 12.5) | 6.7 (2.7, 13.0) | 0.281 |
| Transfer to ICU n, (%) | 373 (91) | 220 (96) | 153 (83) | *0.001 |
Figure 2. Outcome after IHCA. (A) Survival was similar between the two different cardiac arrest team concepts, the Load-and-Go group and the Stay-and-Treat group. (B) Neurological outcome was determined at the time of discharge according to the Cerebral Performance Category (CPC) scale after IHCA. CPC scale of 1 and 2 indicates good neurological outcome. Neurological outcome was similar between the two different cardiac arrest team concepts, the Load-and-Go and the Stay-and-Treat groups. IHCA in-hospital cardiac arrest, CPC cerebral performance category.

Table 3. LaG group: Regression analysis for hospital mortality after IHCA. Significant values are in bold. IHCA in-hospital cardiac arrest, LaG load-and-go, SaT stay-and-treat, IHCA intra-hospital cardiac arrest, OR odds ratio, CI confidence interval, GFR glomerular fraction rate, CPR cardiopulmonary resuscitation, CAD coronary artery disease, PAD peripheral arterial disease, ROSC return of spontaneous circulation.
transferred patients in the LaG group than in 6.5% of the patients in the SaT group. Therefore, a dedicated ICU cardiac arrest team can take some load off the ICU as demonstrated in the present study.

Patient characteristics such as malignancy, sepsis, low functional status prior to IHCA, and renal or hepatic dysfunction have been identified as significant predictors of poor survival. It was previously demonstrated that patients who are witnessed or monitored at the time of cardiac arrest demonstrate a significantly higher survival rate to hospital discharge than those who are neither monitored nor witnessed. In the present study, higher patient age, longer time to achieving ROSC, and higher lactate levels were independent predictors of poor survival after IHCA. This observation is in line with previous studies demonstrating that patients with a non-shockable rhythm have poorer survival to hospital discharge rates than patients with a shockable rhythm. The presence of a non-shockable rhythm may reflect the delayed detection of initial shockable rhythms that progress to non-shockable rhythms. In this context, the rapid recognition of IHCA and quick initiation of resuscitation are more crucial for outcomes than details in the organisation of cardiac arrest teams.

There are several limitations to this study. The present single-centre study included patients on an internal medicine or neurology non-ICU ward; therefore, the interpretation of the results may not be generalised and transferred to other hospitals. Furthermore, the variability among countries in incidence and survival after IHCA likely reflects differences in the definitions used to identify IHCA, the proportion of cardiac arrests captured by various registries, patient populations, and country-specific factors such as do-not-resuscitate orders, and withdrawal of care. Comparisons of IHCA rates between countries or registries should be performed carefully.

In conclusion, here we demonstrated that both cardiac arrest team concepts for the management of IHCA did not differ in terms of survival and neurological outcomes. However, a dedicated (intensive care) cardiac arrest team can help unburden the ICU.

Received: 29 June 2021; Accepted: 8 November 2021
Published online: 18 November 2021

References
1. Schluep, M., Gravesteijn, B. Y., Stolker, R. J., Endeman, H. & Hoeks, S. E. One-year survival after in-hospital cardiac arrest: A systematic review and meta-analysis. Resuscitation 132, 90–100 (2018).
2. Starks, M. A. et al. The Association of Duration of participation in get with the guidelines-resuscitation with quality of Care for in-Hospital Cardiac Arrest. Am. Heart J. 204, 156–162 (2018).
3. Andersen, L. W., Holmberg, M. J., Berg, K. M., Donnino, M. W. & Granfeldt, A. In-hospital cardiac arrest: A review. JAMA 321, 1200–1210 (2019).
4. Benjamin, E. J. et al. Heart disease and stroke statistics-2019 update: A report from the American Heart Association. Circulation 139, e56–e528 (2019).
5. Hessulf, F. et al. Adherence to guidelines is associated with improved survival following in-hospital cardiac arrest. Resuscitation 155, 13–21 (2020).
6. Ong, M. E. H., Perkins, G. D. & Cariou, A. Out-of-hospital cardiac arrest: Prehospital management. Lancet 391, 980–988 (2018).

|                          | Univariate |             |             | Multivariate |             |             |
|--------------------------|------------|-------------|-------------|--------------|-------------|-------------|
|                          | OR  | 95% CI     | p-value     | OR  | 95% CI     | p-value     |
| Age                      | 1.031 | 1.006–1.057 | 0.014       | 1.047 | 1.001–1.095 | 0.046       |
| Gender                   | 1.273 | 0.672–2.410 | 0.459       |              |             |             |
| Diabetes                 | 0.922 | 0.461–1.840 | 0.817       |              |             |             |
| CAD                      | 0.951 | 0.516–1.751 | 0.871       |              |             |             |
| PAD                      | 0.925 | 0.366–2.336 | 0.868       |              |             |             |
| GFR                      | 0.981 | 0.963–1.000 | 0.052       |              |             |             |
| Hemoglobin               | 0.920 | 0.769–1.101 | 0.361       |              |             |             |
| Non-cardiac arrest etiology | 1.810 | 0.981–3.341 | 0.058       | 1.4887 | 0.501–4.419 | 0.474       |
| Arrest time off-hours    | 2.072 | 1.087–3.950 | 0.027       | 1.006 | 0.358–2.831 | 0.991       |
| Non-shockable primary rhythm | 1.889 | 1.004–3.552 | 0.048       | 1.394 | 0.464–4.196 | 0.554       |
| Time to ROSC             | 1.102 | 1.052–1.154 | 0.001       | 1.118 | 1.039–1.204 | 0.003       |
| Lactate                  | 1.152 | 1.067–1.244 | 0.001       | 1.113 | 1.004–1.233 | 0.042       |

Table 4. SaT group: Regression analysis for hospital mortality after IHCA. Significant values are in bold. IHCA in-hospital cardiac arrest, LaG load-and-go, SaT stay-and-treat, IHCA intra-hospital cardiac arrest, OR odds ratio, CI confidence interval, GFR glomerular fraction rate, CPR cardiopulmonary resuscitation, CAD coronary artery disease, PAD peripheral arterial disease, ROSC return of spontaneous circulation.
Author contributions

J.H. and R.E. performed data curation, validation, formal analysis, investigation, and writing of the original draft. R.O. and J.M.H. performed data curation, validation, investigation, and writing (review & editing). M.K. and R.W. performed supervision, writing (review & editing), and visualization. P.H. conceived the study, performed formal analysis, conceptualization, project administration, writing (review & editing). All authors revised the manuscript and approved the final version.

Funding

Open Access funding enabled and organized by Projekt DEAL.

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to P.H.

Publisher’s note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access

This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2021