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Analysis of in-Hospital Cardiac Arrests with a Functioning Early Warning System at the University Hospital, Poland

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Abstract

Objective: To investigate and evaluate the management of in-hospital cardiac arrests (IHCA) in accordance with selected elements of the Utstein protocol in a hospital with a functioning early warning system, with a particular focus on factors influencing the return of spontaneous circulation (ROSC).

Methods: Prospective cohort studies at the University Hospital in Krakow covering the year 2022.

Results: A total of 152 cardiac arrests occurred in hospital wards, excluding the Emergency Department, Operating Room, and Intensive Care Unit, resulting in 1.9 cardiac arrests per 1000 admissions. Return of spontaneous circulation was achieved in 40.8%, and discharge with a Cerebral Performance Category of 1-2 was attained in 5.3% of patients. Based on the obtained results, it can be inferred that the chances of achieving ROSC decreased with the patient's age and the duration of cardiopulmonary resuscitation. Factors such as cardiac arrest during the full staffing hours of the medical staff on the ward (7:00 am-3:00 pm) and airway management by medical personnel using a laryngeal mask airway before the arrival of the Rapid Response Team with the use of an i-Gel significantly increased the chances of achieving ROSC. Another factor positively influencing survival is the initial shockable rhythm.

Conclusions: Our study has demonstrated that, in addition to the factors described in previous research, the effective clearing of airways using a laryngeal mask airway such as i-Gel, coupled with ventilation prior to the arrival of the Rapid Response Team, can play a significant role. Future efforts aimed at improving in-hospital cardiac arrest outcomes should also focus on early patient identification. Hospitalized patients require regular assessment, especially within the first 24 hours of

admission, as our study found that cardiac arrests most frequently occurred in this patient group.

Keywords: Advanced Life Support**;** In-Hospital Cardiact Arrest; Rapid Response System; Rapid Response Team

Introduction

The average annual incidence of in-hospital cardiac arrest (IHCA) in Europe ranges from 1.5 to 2.8 per 1000 hospital admissions [1]. Individual country-specific studies reported rates of 1.6 in the United Kingdom [2], 1.7 in Sweden [3], 1.5 in Italy (Piedmont region) [4], and 2.8 in Poland [5]. The 30-day survival rate or survival until discharge varies between 15-34% [1,3]. Factors associated with survival that have been previously described include initial rhythm, the location of cardiac arrest, and the level of monitoring at the time of the event. Research and meta-analyses suggest that the implementation of early response systems reduces the frequency of in-hospital cardiac arrests and mortality in hospitals [6,7]. Based on this evidence, the International Liaison Committee on Resuscitation (ILCOR) recommends considering the introduction of such systems into hospitals. According to recommendations, hospital care systems should focus on recognizing cardiac arrest, initiating immediate cardiopulmonary resuscitation, calling for assistance and performing defibrillation. Following this principle, hospitals should have a resuscitation/early response team with an immediate response to IHCA, and resuscitation equipment on all hospital wards should be standardized. In 2019, the Utstein protocol for reporting IHCA cases was updated and published, emphasizing the importance of a standardized form for recording and collecting data for accurate analysis of these events. Another critical aspect is the assessment of neurological deficits in individuals who survived cardiac arrest. The Utstein guidelines recommend evaluating the neurological function of survivors using the Cerebral Performance Category (CPC) scale [8]. It should also be noted that there is a group of patients in whom resuscitation measures are not undertaken despite experiencing cardiac arrest. This approach aims to prevent futile therapy in patients during an irreversible disease process. In this study, we aim to present the characteristics of in-hospital cardiac arrests in a Polish University Hospital and to characterize the factors influencing the success of cardiopulmonary resuscitation by achieving sustained (over 20 minutes) return of spontaneous circulation (ROSC).

Objective

The aim of the study is to present the incidence, characteristics, and outcomes of in-hospital cardiac arrest in a hospital with a functioning early warning system. The study also evaluates actions taken by the medical staff before the arrival of the response team and actions taken by the team during cardiopulmonary resuscitation. The assessment includes selected single-factor elements influencing the return of spontaneous circulation and survival with a favorable neurological outcome on the CPC scale.

Methods

A prospective cohort study was conducted. Information regarding the patient's medical history before cardiac arrest and data on survival post-ROSC were obtained retrospectively. The presented data were collected by the SWIT Team (Early Therapeutic Intervention System) of the Clinical Department of Anesthesiology and Intensive Care at the University Hospital in Krakow, hereinafter referred to as RRT, based on intervention statistics, an OHCA form consistent with the Utstein protocol, and data retrieved from the Asseco Medical Management Solutions information system between January 1, 2022, and December 31, 2022. The RRT completed the form following in-hospital cardiopulmonary resuscitation. Subsequently, after a 30-day period, further medical documentation was analyzed to assess 30-day survival or discharge from the hospital. Data are presented as percentages with counts, means, or medians with Q1 and Q3 ranges. To select appropriate measures for group description, the Kolmogorov-Smirnov and Shapiro-Wilk tests were performed. Based on the results, the null hypothesis of normal distribution for age, patient length of stay, duration of cardiopulmonary resuscitation, and RRT response time was rejected. Therefore, the median was used as the measure to describe the group.

Selected factors related to IHCA considered significant were presented in a univariate model using logistic regression. Model fit was checked using the Hosmer-Lemeshow test, resulting in a Chi-square value of 11.795, with 8 degrees of freedom and $p = 0.161$, indicating a good model fit. Logistic regression was employed to identify factors influencing ROSC during CPR. ROSC lasting more than 20 minutes was taken as the dependent variable. In the group comparing airway management methods and ventilation, the effectiveness of using LMA (i-Gel) compared to bag-mask ventilation was examined. However, this division excluded approximately 30% of observations from the study, reducing the real value of such an analysis. Therefore, a comparison was made between the LMA (i-Gel) group and all other airway management and ventilation methods applied by medical personnel before the arrival of the RRT.

In the adopted model, no influence of the recorded rhythm on survival probability was demonstrated due to a significant disproportion between shockable and non-shockable rhythms. To assess the relationship between the first recorded rhythm and achieving ROSC, the Chi-square test of independence was used. Two observations were excluded due to lack of data. The following hypotheses were adopted: H0: The first recorded rhythm is independent of achieving ROSC. H1: The first recorded rhythm is not independent of achieving ROSC. IBM SPSS Statistics 29.0 software was used for statistical analysis.

Hospital

University Hospital in Krakow is one of the largest clinical hospitals in Poland. As a university center, it provides advanced care not only for the Małopolskie Voivodeship but also for the entire country. According to data from 2022, the University Hospital in Krakow has 40 inpatient units and 10 outpatient units. The hospital offers 1,256 beds. It houses one of the largest Clinical Departments of Anesthesiology and Intensive Care in Poland, equipped with 52 positions. Additionally, the hospital has a 24-hour cardiac catheterization laboratory, where 3,426 procedures were performed in 2022, including 2,231 in emergency settings. The total number of hospital admissions for the year 2022 was 80,424, with 1,885 recorded deaths. Since 2020, the hospital has been operating an Early Therapeutic Intervention System, modeled after hospital Rapid Response Teams (RRT).

Early Therapeutic Intervention System

Early Therapeutic Intervention System (SWIT) plays a crucial role in the early identification of patients experiencing sudden health deterioration during hospitalization across various hospital departments. The primary goal is to implement appropriate interventional and therapeutic measures promptly. This concept aligns with the "ICU without walls" idea, where experienced medical staff from the Department of Anesthesiology and Intensive Care are readily available and prepared to act throughout the entire hospital. This initiative enables the initiation of appropriate therapeutic measures for patients with sudden health deterioration on clinical wards before transferring them to the ICU or to prevent such deterioration. RRT also often perform tasks similar to the Resuscitation Team called in during in-hospital cardiac arrests [9,10]. SWIT's main objectives include improving the quality of patient care within the hospital by introducing standardized methods for clinical assessment in situations of sudden clinical deterioration. The team comprises a specialist in anesthesiology and intensive care, a resident physician, and two emergency medical technicians. The team is accessible through the standard hospital emergency number 2222 and constitutes a distinct organizational unit within the Anesthesiology and Intensive Care department. In 2021, standardized resuscitation carts were deployed throughout the entire University Hospital, available on every ward, kept locked, and used in cases of patient clinical deterioration or cardiac arrest. The RRT is equipped with a fully stocked resuscitation backpack, augmented with diagnostic and anesthesiologic modules, as well as a mechanical chest compression system.

Definition

In-hospital cardiac arrest refers to the cessation of the heart's activity in a hospitalized patient, requiring chest compressions and/or defibrillation to restore circulation. According to the recommendations of the IHCA Utstein Working Group, patients experiencing cardiac arrest in the Emergency Department are excluded from calculations of the in-hospital cardiac arrest rate per

1000 admissions and are treated as a separate group. Due to the distinct nature of cardiac arrest situations, cases within the Intensive Care Unit and within the Operating Room also constitute a separate category.

Exclusion Criteria

Patients were excluded from the study if they arrived at the hospital during cardiac arrest or if cardiac arrest occurred in the Emergency Department, Operating Room, or Intensive Care Unit. Only the initial call for cardiac arrest was considered in cases where patients experienced recurrent cardiac arrest.

Results

During the study period, the RRT participated in 2,673 interventions, of which 7.2% were in-hospital cardiopulmonary resuscitations (n=192). Detailed data are presented in Table 1.

The registered number of in-hospital cardiac arrests was 217, with 65 related to resuscitations conducted in the Emergency Department, Operating Room, and Anesthesiology and Intensive Therapy Department. For further analysis, 152 cardiac arrests that occurred in hospital wards were included. The calculated ratio of cardiac arrests per 1000 admissions was 1.9. During the study period, 57.9% of in-hospital cardiac arrests involved males, with a median age of 72 years. Upon admission to the hospital, 78.3% of individuals were assessed as CPC 1 or 2 on the CPC scale. In the admitted time intervals, the majority of cardiac arrests occurred after 7:00 PM and within the first day of hospital admission. Most patients (65.8%) were brought to the hospital by the Emergency Medical Services (EMS) on an emergency basis. Self-presenting patients and those admitted based on a planned referral constituted a smaller group, each accounting for 15.8%. A significant majority of IHCA patients were those hospitalized in internal medicine departments (79.6%). A detailed characterization of the study group is presented in Table 2.

The vast majority of IHCA occurred in the presence of witnesses, mainly in the presence of medical staff from the patient's home department (85.5%). At the time of RRT arrival, ventilation was being conducted in 91% of cases. Among the airway management methods, the most commonly used were facial mask ventilation with a self-inflating bag (36.2%), endotracheal intubation (24.3%), and LMA – i-Gel (23%). Most patients had cardiac electrical activity monitored using EKG electrodes or self-adhesive defibrillator electrodes (95.4%). The most common initial rhythm of cardiac arrest was a non-shockable rhythm (86.9%). Adrenaline was administered only in some cases until the arrival of the RRT (65.1%). The data are presented in Table 3.

The overall median duration of cardiopulmonary resuscitation (CPR) was 20 minutes, while among 62 patients who achieved sustained return of spontaneous circulation (ROSC), the median duration of CPR was 10 minutes. The median response time for the Rapid Response Team (RRT) was 2 minutes and 59 seconds. In 60.3% of cases, the RRT opted for the use of mechanical chest compression, and defibrillation during CPR was performed in 35 patients. The data is presented in table 4.

ROSC was achieved in 40.8% of patients. Those who survived until hospital discharge accounted for 13.2%, with a favorable neurological outcome (CPC 1,2) recorded in 5.3% of all patients with IHCA (Table 5).

Based on the obtained results, it can be inferred that the chances of achieving sustained spontaneous circulation decrease with the patient's age and the duration of CPR. To visualize the data, instead of survival odds, we can utilize the odds of non-survival by dividing 1 by the obtained odds ratio (OR). Consequently, it can be stated that for each year of the patient's life, the odds decrease by 1.04 times (1/0.953), while for each minute of CPR, the odds decrease by 1.15 times (1/0.868). Factors such as IHCA during daytime shifts or the use of LMA - i-Gel by the staff significantly increased the chances of survival. In the above analysis, no impact was demonstrated for the response team's arrival time and the first recorded rhythm on achieving ROSC. Detailed results are provided in table 6. To assess the relationship between the first recorded rhythm and achieving ROSC, the Chi-square test of independence was employed. The cross-tabulation. (Supplemental files for online publication only) clearly indicates a significant advan-

tage in cases where ROSC occurred in the shockable rhythm group (83.3% vs. 34.8%).

Table 1: Characteristics of the Study Group

Characteristics of Patients	Data Value	n (152)
Gender		
Female	42,1%	64
Male	**57,9%**	**88**
Age (Median, Q1, Q3)	72 (61, 79)	152
CPC at admission		
≤2	**78,3%**	**119**
>2	21,7%	33
Out-of Hospital Cardiac Arrest (OHCA)		
Tak	3,9%	6
Nie	**96,0%**	**146**
Time Interval od IHCA occurrence		
7:00-15:00	36,8%	56
15:00-19:00	19,1%	29
19:00-7:00	**44,1%**	**67**
Days of stay before IHCA (Median, Q1, Q3)	**1 (0,7)**	**152**
Mode of admission		
Planned referral	15,8%	24
Transfer from another hospital	2,6%	4
Emergency admission by EMS	**65,8%**	**100**
Emergency admission - patient presented independently to the Emergency Department	15,8%	24
Departments		
Internal Medicine	79,6%	121
Surgical*	20,4%	31
*The data are presented in percentages and numbers, with continuous variables expressed as medians with Q1, Q3. CPC-cerebral performance category. IHCA- in-hospital cardiac arrest. *The surgical category includes orthopedics.*		

Table 2: Management of cardiopulmonary resuscitation before the arrival of the Rapid Response Team (RRT)

Parameter	%	n
Manner in which cardiac arrest was observed		
IHCA during RRT intervention	8,6%	13
IHCA in the presence of medical staff from the home department	**85,5%**	**130**

IHCA in the presence of a third person (e.g., family, neighbor)		2,6%	4
Found - unknown time of cardiac arrest		0,7%	1
Data not available		2,6%	4
Conducting ventilation before RRT arrival			
Yes		91%	138
No		9%	14
Was the patient monitored with ECG before RRT arrival? (monitor and/or defibrillator)			
Yes	ECG Monitor	32,9%	50
	Defibrillator	62,5%	95
No		4,6%	7
First registered rhythm			
Non - shockable		**86,9%**	**132**
Asystole		32,9%	50
PEA (Pulseless Electrical Activity)		52,0%	79
Non-shockable AED		2,0%	3
Shockable		**11,8%**	**18**
VF		10,5%	16
VT		0,6%	1
Shockable AED		0,7%	1
Unknown		**1,3%**	**2**
Administration of adrenaline in non-shockable rhythm before RRT arrival (n=132)			
Yes		65,1%	86
Airway management before RRT arrival			
No ventilation performed		9,2%	14
Bag mask ventilation		36,2%	55
Oropharyngeal tube (OPA)		3,3%	5
LMA (i-Gel)		23,0%	35
Intubation		24,3%	37
Tracheostomy (patient with tracheostomy)		1,3%	2
Patient previously intubated		2,6%	4

The data is presented in percentages and numbers, and continuous variables as medians with Q1, Q3. IHCA- in-hospital cardiac arrest; CA- cardiac arrest; RRT- Rapid Response Team; LMA- Laryngeal Mask Airway; VF- Ventricular Fibrillation; pVT- Pulseless Ventricular Tachycardia; PEA- Pulseless Electrical Activity; AED- Automated External Defibrillator.

Table 3: Actions taken by the Rapid Response Team (RRT)

Parameter	Data Value	n (152)
Response Time (Median, Q1, Q3)	02:59 (01:59; 04:00)	**152**
Use of Mechanical Chest Compression		
Yes	60,3%	92
No	39,7%	60
Defibrillation at any point during CPR		
Yes	23,0%	35
No	77,0%	117
Medications used during CPR		
Epinephrine	94,7%	144
Amiodarone	6,6%	10
CPR Duration (Median, Q1, Q3)	**20 (10,30)**	**152**
CPR Duration in patients with ROSC (Median, Q1, Q3)	**10 (7,16)**	**62**
Cause of Cardiac Arrest		
Cardiologic	40,8%	62
Respiratory	33,5%	51
Other	25,7%	39

The data is presented in percentages and numbers, with continuous variables represented as medians with Q1 and Q3. IHCA stands for in-hospital cardiac arrest, CA for cardiac arrest, RRT for Rapid Response Team, and ROSC for return of spontaneous circulation.

Table 4: Outcome of in-hospital cardiopulmonary resuscitation (CPR)

CPR Outcome	%	n
Return of Spontaneous Circulation (ROSC)	40,8%	62
Survival to Hospital Discharge	13,2%	20
Death within 30 days of Cardiac Arrest (CA)	27,6%	42
Survival to Hospital Discharge (CPC 1,2)	**5,3%**	**8**
Survival to Hospital Discharge (CPC 3,4)	**7,9%**	**12**

Data presented in percentages and numbers. ROSC - Return of Spontaneous Circulation; CA - Cardiac Arrest; CPC - Cerebral Performance Category.

Table 5: Univariate regression analysis of factors influencing the likelihood of Return of Spontaneous Circulation (ROSC)

Factors	p-value	OR	95% CI	
Age (per year increase)	0.003	0.953	0.923	0.983
RRT Arrival Time	0.422	0.999	0.995	1.002
CPR Duration (per minute increase)	<0.001	0.868	0.822	0.918
Daytime Cardiac Arrest	0.009	3.622	1.372	9.560
Use of LMA (i-gel)	0.005	5.562	1.686	18.344
Initial Recorded Rhythm	0.089	5.042	0.781	32.541
RRT- Rapid Response Team, CPR- cardiopulmonary resuscitation, LMA- Laryngeal Mask Airway, OR-odds ratio, CI-confidence interval				

Supplemental Table: Distribution of interventions conducted by the RRT in 2022

Type of Interventions	n (2673)	%
Assessment of the patient for qualification for admission to the Intensive Care Unit	268	10%
Instrumental, advanced securing of airway patency	120	4,5%
Assistance with anesthetic procedures (including CVC, arterial line, tracheostomy, bronchoscopy, chest tube drainage)	96	3,6%
Intra-departmental interventions	140	5,2%
In-hospital cardiopulmonary resuscitation	**192**	**7,2%**
In-hospital transport of critically ill patients	1374	51,4%
Supervision of patients for 48-72 hours after discharge from the Intensive Care Unit	483	18,1%

Discussion

Despite being a single-center study, the discussed research is unique as, to the best of the authors' knowledge, it is the only work analyzing IHCA in Poland following the reporting guidelines of Utstein [11]. The frequency of IHCA in our study was 1.9 per 1000 hospitalizations. ROSC was achieved in 40.8%, survival until discharge day was 13.2%, with a favorable neurological outcome observed in 5.3% of patients. Factors positively influencing ROSC included the occurrence of cardiac arrest during daytime hours from 07:00 to 15:00 and the use of the i-Gel laryngeal mask before the arrival of the RRT. Age and the duration of CPR were identified as negative factors affecting ROSC. The initial shockable rhythm was identified as a factor increasing the chances of survival.

The frequency of IHCA in the described study is 1.9 per 1000 admissions, which is comparable to European data (1.51-1.8 per 1000 admissions) [4,12,13]. Demographic data of patients are also similar to other studies. The median age is 72 years, and IHCA more commonly occurred in males (57.9%). The pre-hospital functional status of patients was assessed using the CPC scale. The majority of patients (78.3%) were classified into CPC groups 1 or 2, indicating good functional status. Patients unable to work or live independently, assessed with a score of 3 or 4 on the scale, constituted a smaller group, accounting for 21.7%. This is still a larger proportion compared to other European centers, where this percentage was around 8% (Italy). This difference likely results from distinct legal and cultural conditions in Poland, where the decision to withhold futile therapy or a Do Not Attempt Resuscitation (DNAR) order is not made early enough or not made at all. The decision to refrain from resuscitation is often made by a doctor during a shift or is delegated to the consulting anesthesiologist who is part of the RRT.

The median length of hospital stay before the occurrence of IHCA was 1 day. This suggests that patients admitted to the hospital require regular assessment, especially during the first day of admission, to identify those at the highest risk of IHCA. Early identification will allow for the implementation of interventions such as increased monitoring, attempts to stabilize the condition, or identification of patients for whom intensification of treatment would be futile. These actions should involve a well-developed, mature RRT, resulting in a lower frequency of IHCA and higher survival rates for patients with a good neurological outcome.

The time it takes for the RRT to reach the location of cardiac arrest at the University Hospital is approximately 3 minutes (Q1 01:59, Q3 04:00). Until the arrival of the RRT, the personnel of the parent department, who undergoes regular CPR training is responsible for resuscitation. Depending on the rescuer's skills, the primary interventions included bag-mask ventilation (36.2%), followed by endotracheal intubation (24.3%), and the use of the i-Gel laryngeal mask airway (23%). Interestingly, the analysis of factors influencing the achievement of ROSC showed that one of the few interventions demonstrating statistical significance is the use of the i-Gel mask before the arrival of the RRT, with an odds ratio of 5.56. Other evaluated interventions, such as bag-mask ventilation, intubation, or the use of an oropharyngeal airway, did not show such a correlation.

ROSC occurred in 40.8% (n=62) of patients with IHCA. The survival rate until hospital discharge was 13.2% (n=20) and is comparable to data from European countries (Italy, England, Finland 15-29%) [11,13,14]. Unfortunately, the percentage of patients with a favorable neurological outcome in this group was only 5.3% of all IHCA cases (the aforementioned countries 16% - 28%) [11,13,14]. In our study, a poor neurological outcome with CPC 3-4 was observed in 60% of patients (n=12) who survived until hospital discharge. This result significantly deviates from countries where Withdrawal of Life-Sustaining Treatment (WLST) protocols are routinely used, with a percentage below 10% [11,13,14]. Such a significant difference likely stems from the previously mentioned distinct legal and cultural conditions in Poland. The consequence of these conditions is often the failure to refrain from futile therapy, its delay, or its selective application to only a few interventions such as renal replacement therapy. Undoubtedly, actions are needed to raise awareness among both medical personnel and society regarding the discontinuation of futile therapy and the culture of dying in Poland.

The study identified several interventions that have a positive impact on achieving ROSC. These include the previously described use of the supraglottic airway technique (i-Gel) by the parent department before the arrival of the RRT (OR 5.56) and the occurrence of cardiac arrest during daytime hours from 07:00 am to 3:00 pm (OR 3.6). The latter relationship has been described in earlier reports and is likely associated with a fully staffed medical team. Among interventions with a negative impact on achieving ROSC, associations were found for age (OR 0.95) and the duration of CPR exceeding 20 minutes (OR 0.86).

The only intervention that proved to have a statistically significant impact on increasing the survival of patients with IHCA is the initial shockable rhythm. Due to the small group of patients surviving until hospital discharge with a good neurological outcome, no independent factors influencing this parameter were identified.

Limitations

The primary limitation of the study is its single-center nature. Despite being a multi-profile hospital, the University Hospital does not include, for example, a chest surgery or cardiothoracic surgery department in its structure. Cardiac arrests in the intensive care unit, the hospital emergency department, and within the operating theatre were also excluded from the analysis due to the distinct characteristics of these events.

Another limitation of the study is the small group of patients with a favorable neurological outcome (CPC 1-2) at the time of hospital discharge. Expanding the data over subsequent years will provide results that help identify factors influencing the favorable neurological aspect in the management of IHCA.

Conclusions

Our study underscores the significant role of RRT in the context of IHCA. However, an equally crucial aspect is the effective response of the ward staff where the IHCA occurs, before calling for the RRT. A prompt and appropriate intervention before the arrival of the RRT can crucially impact the achievement of ROSC and the subsequent survival of the patient. In our study, it was observed that airway management using the LMA or i-Gel, along with ventilation before the arrival of the RRT, plays a significant role in achieving ROSC. The median duration of resuscitation until achieving ROSC was 10 minutes, indicating that the ward staff can conduct resuscitation for up to 4 minutes without RRT support. The conclusions suggest the need to focus on the early identification of patients, especially within the first day of admission, when IHCA most commonly occurs. The ward staff should be situationally aware and prepared for quick identification and initiation of cardiopulmonary resuscitation, particularly during afternoon and night shifts when these events often occur. Regular training for the staff to improve the quality of CPR before RRT arrival, including drug administration, is essential for enhancing IHCA outcomes.

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