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Research Article

When Time is of the Essence: Comparison of the Resuscitation Time Frame Recommended by the Advanced Life Support Guidelines and Daily Practice

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Abstract

Objective: Advanced Life Support (ALS) providers are guided through several time-specific critical actions during Cardiac Arrest (CA) by universally adopted guidelines. The objective of this study was to evaluate whether the advised timings of these critical interventions are met in practice. **Subject and methods:** This single centre, prospective observational study analyzed data derived from Out-Of-Hospital Cardiac Arrest (OHCA) video recordings by a team member. Real life timings of critical actions were compared to recommendations. **Results and conclusion**: The first dose of epinephrine was administered at a median time of 3 min 10s in the non-shockable patient group and 3 min 27s in the shockable group. In 27.8% of all non-shockable OHCAs, epinephrine was administered in the first cycle. Placement of an Advanced Airway (AA) took place in the advised cycle in less than 20% of cases. Initial endotracheal intubation success rate was 69.5%. In 20.3% of the resuscitations, more than two attempts were needed for endotracheal intubation. Medical mobile teams failed in starting treatment on time, taking up to twice the recommended time. The first shock was administered at a median time of 25.5s after the first rhythm check. The second and third shock were administered after respectively 3 min 44s, and 5 min 21s, respectively. With more than 75% of all OHCA deviating from the guidelines, it is necessary to make prehospital healthcare workers aware of time loss during critical actions. Training in a time-sensitive manner might help increase awareness and optimize daily practice.

Keywords: Advanced Life Support, Timing, ALS Algorithm, Video recording

Introduction

Cardiac Arrest (CA) carries a significant disease burden worldwide with an incidence of 81.6 Out-Of-Hospital Cardiac Arrest (OHCA) per 100,000 adult inhabitants in Europe [1]. Given the survival rate of approximately 10% for OHCA, efforts are continuously being made to improve outcomes, with research focusing on the timely and effective delivery of several critical interventions (such as administration of epinephrine, defibrillation, and advanced airway placement) during Advanced Life Support (ALS) next to Basic Life Support (BLS) in Cardiopulmonary Resuscitation (CPR) [2,3]. Outcome seems to be influenced by the intervals between collapse and the delivery of basic and advanced interventions, thus suggesting that the passage of time is an important factor in the survival of CA patients. The ideal timing and sequence of every critical step, however, seems to be rather unclear. The International Liaison Committee on

Resuscitation (ILCOR) recommendations for adult ALS advise giving an intravenous push dose of epinephrine as soon as feasible in case of a non-shockable rhythm, whereas early defibrillation is advised in case of a shockable rhythm, keeping interruptions of chest compressions to a minimum and placing an advanced airway in time, using a stepwise approach [4–11]. Consequently, different key interventions must take place in a timely fashion, leading to questions regarding priority and sequence. To lead healthcare professionals through this process in an evidence-based manner, the European Resuscitation Council (ERC) provides updated guidelines every five years based on recommendations by ILCOR [12]. Adherence to these guidelines implies good quality of resuscitation, which is presumed to lead to better survival [13]. The evidence-base supporting this thesis, however, is not extensive nor unequivocal. Studies concerning In-Hospital Cardiac Arrest (IHCA) found a positive correlation between guideline adherence and Return of Spontaneous Circulation (ROSC), whereas other investigations were Inconclusive [14–17]. Studies investigating regional variability in outcomes of CA patients suggest, however, that these guidelines are not always met in real life [2,18-21]. When addressing CPR quality, many investigators have divided the adult CA algorithm into key components [22-24]. To our knowledge, no study has tried to investigate the compliance to the recommended timings for the critical actions visualized in the CA algorithm diagram in a prospective video recording-based manner. The main objective of this study was to evaluate the timings of each critical intervention during ALS. Prospective data derived from OHCA video recordings were analyzed and real-life timings were compared with the 2015 ERC guidelines for Resuscitation algorithm [12].

Materials and Methods

Setting

This prospective observational study was conducted by the Emergency Medical Services (EMS) connected to the Emergency Department (ED) of the University Hospital UZ Leuven, a tertiary referral center in Belgium. Mobile Medical Teams (MMT), consisting of at least an emergency physician and an emergency nurse, accompanied by an intern, manages patients sustaining an OHCA. At least two paramedics, trained in intermediate life support, reinforce the out-of-hospital team. All emergency medicine attending physicians and residents (minimum 3years of clinical experience) in this study have an ALS certificate and regular experience in handling CAs. During the study period, the MMTs used the 2015 ERC guideline algorithms for CA resuscitation efforts. A defibrillator (Philips Heart Start MRx) was available for rhythm analysis and defibrillation, if needed. There was no 'point of care'-ultrasound or -testing available prehospital.

Study population

All adult patients (≥ 18years) who sustained an OHCA and were treated by a MMT from July 1, 2016 to June 31, 2018, were eligible for inclusion in the study. The MMT had to consist of at least three resuscitation members (including an emergency physician) (Figure 1). Patients were excluded if

1. The video recording of the CA was not complete,
2. The quality of video recording did not allow for reliable data collection or
3. The patient was found with rigor mortis or other obvious signs of irreversible death.

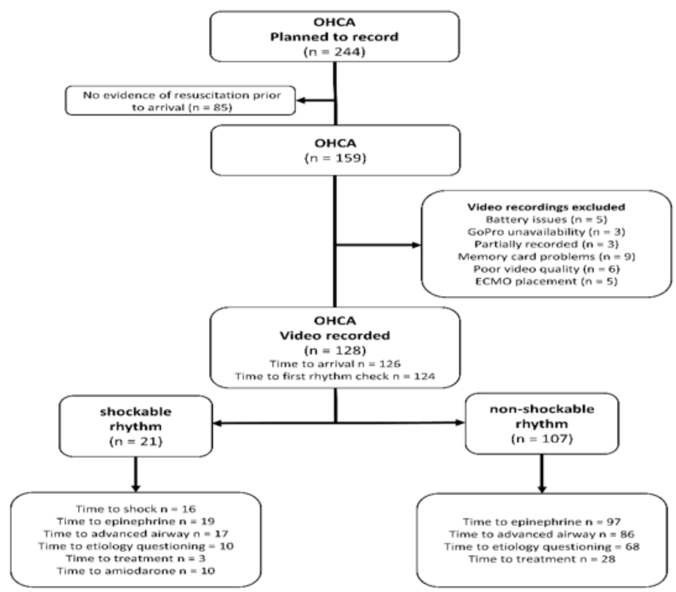

Figure 1: Flow diagram of video-recorded resuscitations. Abbreviations: OHCA: Out-Of-Hospital Cardiac Arrest. ECMO: Extracorporeal Membrane Oxygenation.

Data collection

A mobile digital real-time video recording GoPro HERO 4 device (black edition) was used. The GoPro was body-mounted on the team leader with a chest harness (Chesty) or on a participating emergency medicine intern who then oriented the camera to the team leader's perspective. The team leader was responsible for recording the resuscitation process and the security of the videotape afterwards. The recording was started upon arrival at the scene.

Two physicians, who were not involved in prehospital care, independently reviewed video recordings of all included resuscitations. For privacy reasons, video recordings were erased within two weeks after the CA event. All study data were stored on a secure, hospital-based protected server.

The following demographic characteristics and CA event data were collected: age, gender, witnessed arrest (yes/no), bystander CPR (yes/no), arrival time of the MMT, time to first rhythm, initially detected cardiac rhythm, time to first defibrillation, time to first epinephrine administration, time to advanced airway placement, time to etiology questioning and treatment, CA event duration and patient outcome according to the Utstein criteria (Return of spontaneous circulation (ROSC)) [25]. Additionally time to subsequent doses of epinephrine and subsequent timings of rhythm checks, defibrillations and time to amiodarone where gathered. The absolute timings of critical actions were recorded and adjusted to set the first rhythm check as Time point zero (T_0).

Overview of guidelines	Shockable guidelines (s)	Non-shockable guidelines (s)
Time to first shock	0 - 10	not applicable
Time to second rhythm check	130 - 140	120 - 130
Time to second shock	130 - 140	not applicable
Time to third rhythm check	260 - 270	250 - 260
Time to third shock	260 - 270	not applicable
First dose of epinephrine	270 - 300	0 - 120
Second dose of epinephrine	450 - 600	180 - 420
Third dose of epinephrine	630 - 900	360 - 720
Time to advanced airway	140 - 260	0-120
Time to cordarone	270 - 300	not applicable
Time to treatment of reversible causes	270 - 390	130-250

Table 1: Overview of 2015 guidelines.

Data analysis

All data were imported into Microsoft Excel for Mac OS, version 16.8 (Microsoft Corp., Redmond, Washington, USA). Data were described as percentage and frequency of occurrence for categorical variables and as central tendency measures for continuous data. Median times were calculated for all time critical actions. Based on the 2015 ERC guidelines, a guidance table was created including the recommended timings for each time critical action (Shown in **Table 1**) [26]. For each of them, the percentage of critical actions taking place within the proposed time interval was calculated. For airway management and treatment of reversible causes, the ERC does not make clear timing recommendations, so we looked at the timings proposed by ILCOR.

Results

From July 1, 2016, to June 31, 2018, the MMTs from UZ Leuven were dispatched 244 times for patients experiencing an OHCA. Of these, 85 resuscitations were not video recorded since there was no evidence of a need of resuscitation prior to arrival on scene. From the 159 cases where the prehospital teams planned to film, 31 video recordings were excluded due to poor video quality, memory card problems, battery issues, unavailability of the GoPro, irreversible death, or Extracorporeal Membrane Oxygenation (ECMO) placement (shown in Figure 1). In total 128 recordings were deemed valid for evaluation, but not all recordings gave clear and concise audio or video proof regarding all data, so each intervention was assessed individually. Figure 1 shows the number of resuscitations for which a timing was obtained for each intervention.

Resuscitation characteristics

The mean age of patients sustaining an OHCA was 69.4 years (range 25 to 95 years). The large majority was male (87 out of 128). Return of Spontaneous Circulation (ROSC) occurred in 53 patients. In 60.2% of all OHCAs, the arrest was witnessed and in 68.8%, patients received bystander CPR. The initial rhythm on arrival was in 18.0% shockable (shown in Table 2). Of all included patients, 27.3% survived one day. The one-month and one year survival rates were 10.2%, and 5.5%, respectively.

Variables	All OHCA (n=128)	No ROSC (n=75)	ROSC (n=53)
Age (years, median (IQR))	73.5 (62 – 81)	74 (65 – 81)	71 (59 – 82)
Gender (% male)	68.0	68.0	68.0
Witnessed (%)	60.2	42.7	84.9
Bystander CPR (%)	68.8	61.3	79.2
Initial shockable rhythm (%)	18.0	12.0	26.4
CPR duration (min, median (IQR))	14.4 (10.5 – 22.9)	19 (12.2 – 27.6)	10.9 (7.5 – 15.5)

Table 2: Resuscitation characteristics.

Continuous variables are expressed as medians with their interquartile ranges. Categorical variables are expressed as frequencies with percentages.

Resuscitation time frame

The median time from call to EMS to arrival at the patient's side was 877s (15min 24s). A first rhythm check occurred at a median time of 64 s after arrival at the patient's side. After the first rhythm check (T_0-Time 0s), a distinction was made between patients with an initial shockable (n=21) and non-shockable rhythm (n=107).

Defibrillation

In the shockable group, the first shock was administered at a median time of 26s after the first rhythm check (T_0). The second and third shock were administered after 224s (3min 44s), and 321s (5min 21s), respectively.

Epinephrine administration

The first dose of epinephrine was administered at a median time of 190s (3min 10s) after the first rhythm check (T_0) in the non-shockable patient group and 207s (3min 27s) in the shockable group. In 27.8% of all non-shockable OHCAs, the MMT was able to administer epinephrine in the first cycle, as advised in the ALS guidelines. In 73.74% of shockable OHCA's, epinephrine was administered before the third cycle. Subsequent doses in the non-shockable group followed at a median time of 578 s (2^{nd} cycle) (9 min 38 s), and a median time of 1,139s (3^{rd} cycle) (18 min 59s) after the first rhythm check. In the shockable group subsequent doses of epinephrine followed at a median time of 551s (9min 11s) and 989s (16min 29s) in the 2^{nd}, and 3^{rd} cycle, respectively.

Advanced Airway Placement

The elapsed median time from first rhythm check to successful placement of an advanced airway was 265s (4min 25s) for shockable rhythms, and 240s (4min) for non-shockable rhythms, respectively. The percentages of correct AA placement in relation to the suggested CPR-cycles can be found in Figures 3 and 4. Initial Endotracheal Intubation (ETI) success rate was 69.5%. In 20.3% of the resuscitations, the physician needed more than two attempts for ETI. All attempts are summarized in Table 2. In two cases, it was unclear whether an attempt for an Advanced Airway was made due to unclear video footage. In 7 cases, it was clear no attempt to placement of an AA was made. Reasons reported for Bag Valve Mask (BVM) usage only included death prior to airway insertion attempt (1x) and adequate ventilation with BVM (4x). In 2 cases, the reason was unclear. During five OHCAs, a Laryngeal Tube (LT) was used, one time after 1 ETI attempt, one after 2 attempts, 1 time after 3 attempts and 2 times after 5 attempts.

All other advanced airway placement attempts ended with an ETI. In total 190 attempts were made during 119 OHCAs. In 31.6% (60 out of 190) of the ETI attempts, chest compressions were interrupted for more than 10 s (median: 31s-IQR: 14-32). In 41 resuscitations one prolonged attempt (>10s) was made, in 6 cases two prolonged attempts were needed, in one resuscitation 3 prolonged attempts and in one resuscitation 4 attempts were made. In 63% (75 out of 119) of all ETIs capnography was used.

Attempts ETT placement	ALL OHCAs (n=128)	Shockable (n=21)	Non shockable (n=107)
0	07/128 (2%)	0	7
1	89/128 (69.5%)	16	73
2	11/128 (9%)	2	9
3	09/128 (6%)	0	9
4	04/128 (3%)	1	3
5	01/128 (1%)	1	0
6	04/128 (3%)	1	3
7	01/128 (1%)	0	1
Unknown	02/128 (5%)	0	2

Table 3: Attempts for Endotracheal Tube (ETT) placement.

Etiologic evaluation and treatment of reversible causes

In 85 resuscitations, a clear timing for etiology questioning could be discerned. Therefore, only 85 were included in the final analysis. The median times to etiology questioning for the non-shockable and shockable groups were 242s (4min 2s), and 240s (4min) after T_0, respectively. The median time to treatment of a reversible etiology (without the standard treatment with shock or ETI) after finding the first rhythm was 492s (8min 12s) for the non-shockable group and 422s (7min 2s) for the shockable group. More than 60% of treatment of reversible causes took place after the recommended cycle in the non-shockable group. For obvious reasons, time to first shock was omitted from treatment of reversible causes.

All gathered date were visualized using an adapted flowchart, based on the 2015 ERC Adult CA algorithm, with median timings from daily practice based on the OHCA video recordings (shown in Figure 2).

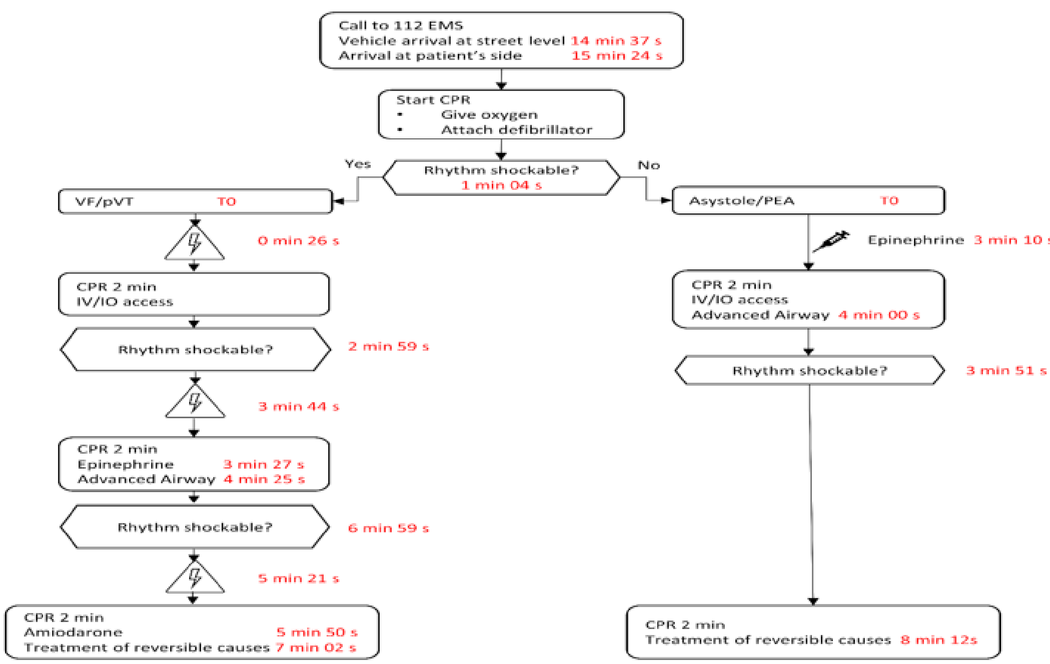

Figure 2: Resuscitation time frame, including median timings from daily practice based on the OHCA video recordings.

Comparison of the resuscitation guidelines with daily practice

Based on the 2015 ERC and ILCOR recommendations a guidance table was created including the recommended timings for each time critical action (shown in Table 1) [26]. In Figures 3 and 4, the percentages of critical actions taking place within the proposed time intervals are reported.

For resuscitations with an initial shockable rhythm, the percentages of resuscitations for which the critical actions were performed within the recommended time frames were the following:

1. Time to second rhythm check: 11.1% (2 out of 1),
2. Time to second shock 0% (0 out of 10),
3. Time to first dose of epinephrine: 0% (0 out of 19),
4. Time to advanced airway: 17.6% (3 out of 17),
5. Time to amiodarone: 0% (0 out of 10).

For resuscitations with an initial non-shockable rhythm, the percentages of resuscitations for which the critical actions were performed within the recommended time frames were the following:

1. Time to second rhythm check: 7.9% (8 out of 101),
2. Time to first dose of epinephrine: 24.7% (24 out of 97),
3. Time to advanced airway: 17.6% (13 out of 74),
4. Time to treatment of reversible causes: 10.7% (3 out of 28).

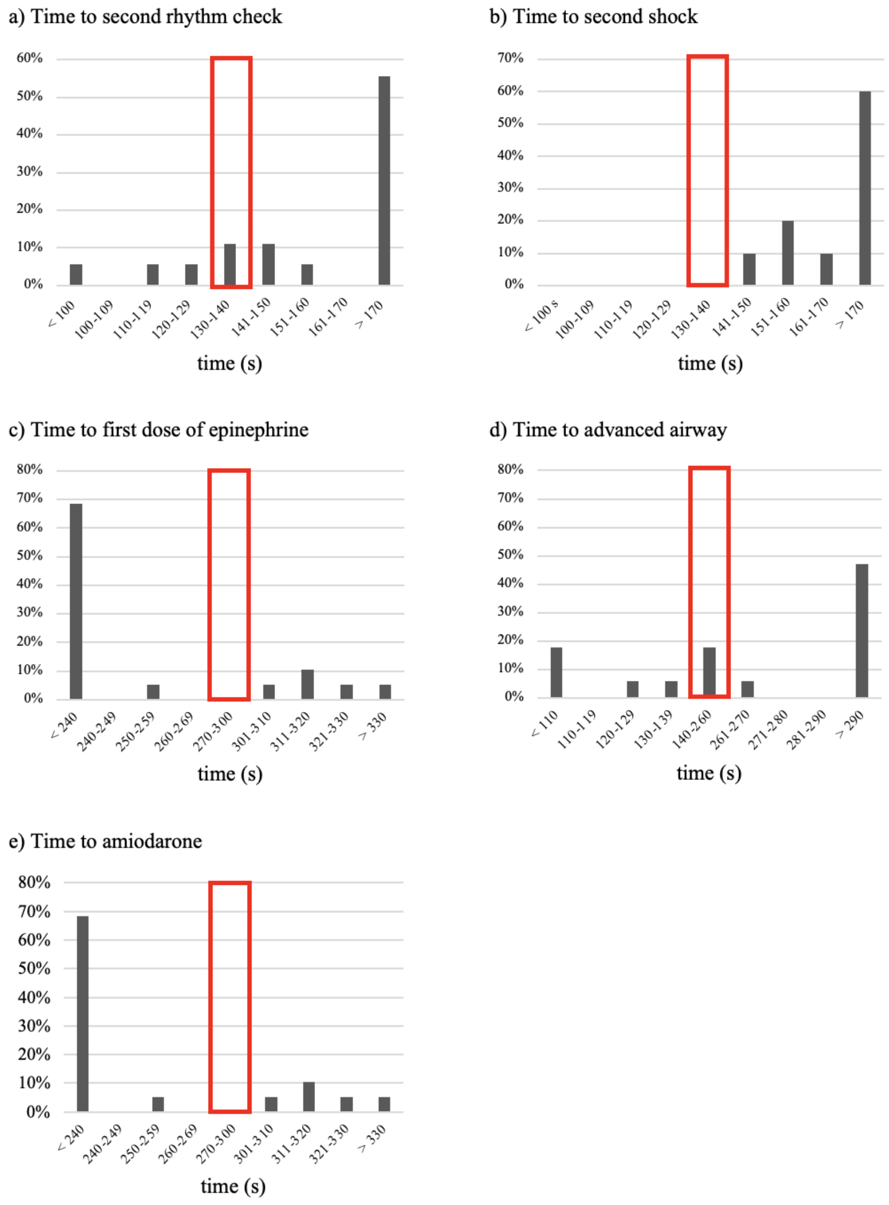

Figure 3: Guidelines versus reality for patients with an initial shockable rhythm. The red frame indicates the advised timing according to the guidelines. For each time critical action, the percentage of resuscitations following and deviating from the guidelines is shown. A) Time to second rhythm check; B) Time to second shock; C) Time to first dose of epinephrine; D) Time to advanced airway and E) Time to amiodarone.

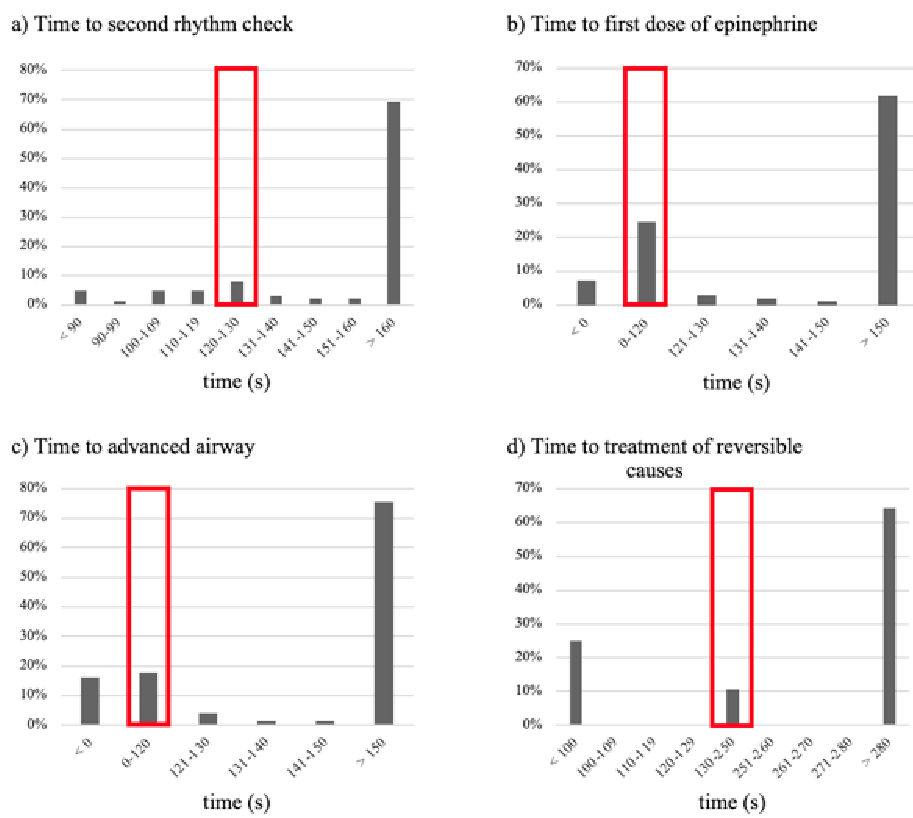

Figure 4: Guidelines versus reality for patients with an initial non-shockable rhythm. The red frame indicates the advised timing according to the guidelines. For each time critical action, the percentage of resuscitations following and deviating from the guidelines is shown. A) Time to second rhythm check; B) Time to first dose of epinephrine; C) Time to advanced airway; D) Time to treatment of reversible causes.

Discussion

Time is crucial during resuscitation where chances of good clinical outcome decrease with every fading second without perfusion. Successful outcomes rely on the coordination of the “chain of survival” [26]. Research has shown that the time it takes to initiate CPR has the greatest impact on survival [27]. It therefore falls to the community to start CPR and maintain viability of the patient until emergency medical services arrive. This study focused on all time critical actions that occur once the MMT has arrived. Our aim was to measure time lapses in real-life during ALS (and compare them to the theory). Particularly, the goal of this study was to investigate in a prospective manner whether the timings of critical actions as advised by the guidelines, are met in clinical practice.

The arrival time of MMTs in case of an OHCA seems to be dependent on the prehospital care system. Comparison of the times to arrival in this study with international data shows that the median arrival time of 15min 24s in this study is in sharp contrast with the very short ± 5 min arrival interval found in the ROC PRIMED registry or the German resuscitation registry, but corresponds more to the registries of Northern-Italy and Switzerland [28-31]. Belgium has a dual EMS system, where a paramedic’s team and a medical prehospital team are simultaneously dispatched, but the latter covers a larger area than the former, which explains the longer arrival time.

Despite the ongoing debate regarding the place of epinephrine in CPR, it has an important place in the ALS guidelines [12]. Our MMTs administered a first dose of epinephrine in a median time of 268s (non-shockable) and 234.5s (shockable) after the first rhythm check, comparable to previously published data sets [32]. Only in 24.7% of all non-shockable OHCAs, the MMT was able to administer epinephrine in the first cycle, as advised in the ALS guidelines. The 0% adherence in the shockable group, where the administration of epinephrine follows later in the algorithm, is remarkable. Both amiodarone and epinephrine are administered sooner than the guidelines recommend (shown in Figure 3c and d). The reasoning behind this early administration was not investigated.

ILCOR recommends starting with basic airway techniques during CPR and progressing stepwise according to the skills of the rescuer until effective ventilation is achieved. If an advanced airway is required, rescuers with a high tracheal intubation success rate should use tracheal intubation.

The expert consensus is that a high success rate is over 95% within two intubation attempts [12]. With more than 20% of AA placements requiring more than 2 attempts and a 69.5% overall success-rate, our findings clearly do not match the recommendations made by ILCOR. Whether this is due to inadequate skillset, an excessive urge to intubate, or inadequate knowledge of the protocols cannot be ascertained from our data. Nevertheless, this offers perspectives for training with an emphasis on quickly turning to a plan B when first attempts are unsuccessful. The ideal time for advanced airway insertion, however, is unclear. ILCOR evaluated the scientific evidence of advanced airway management during CA. However, the ERC ALS guidelines do not specify the time of placement of an AA. Therefore, we used the ILCOR recommendations advising an AA before the second rhythm check in non-shockable and the third in shockable CA. Adherence to these timings seems to be poor in our dataset with a great disparity in advanced airway placement in both groups and less than one fifth of all AA placements taking place in the allotted cycle. This, despite comparable median timings when compared to the ROC PRIMED trial, where they noted a median time of 10 min to advanced airway placement after arrival at the patient's side and only 12% of the patient cohort (shockable and non-shockable) received their advanced airway within the first 5min [31]. Taking a closer look at our data, we noted similarities in the distribution of advanced airway maneuvers in both groups. This seems to be contradictory to guidelines suggesting not to emphasize on AA placement in shockable rhythms, in contrast with non-shockable rhythms, which perhaps indicates a wrong focus during CA advanced airway management.

In the shockable group, there was a notable difference between the median time to third rhythm check and the third shock. However, since in each resuscitation a rhythm check should be performed every two minutes, much more data concerning rhythm checks versus shock deliveries was available, explaining this discrepancy.

Remarkably, time differences were larger in the shockable group compared to the non-shockable group. A possible explanation might be that for patients with an initial shockable rhythm more interventions need to be performed in the proposed time frame resulting in a smaller time window for each action.

The goal of this study was to evaluate whether these guidelines are achieved in daily practice and to make prehospital healthcare providers aware of the timing of critical actions and to use the available time optimally. Overall, it is remarkable that adherence to the suggested timings falls short in a high percentage of cases, even though our survival rate and median timings seems to be in line with previously published data [34]. A previously published paper concerning Chest Compression Fraction (CFF) in this population also indicated good quality CPR with CFF of more than 86% [35]. When looking into the available literature there are conflicting data concerning guideline adherence and survival rates [14-17]. This raises the question whether these protocols are too strict and suggests that a more lenient timing approach is obviously more feasible in practice. It seems that prioritizing could be key, suggesting that further investigating the sequences and timings of critical actions could be useful in the future. Special attention should be given to the team lead. It is his/her job to focus on the timely implementation of all critical actions. Therefore, the team lead should be made aware of every possible loss of time.

Our dataset also suggests time lost performing a critical action to be a contributing factor to poor guideline adherence. Therefore, attention should be paid to the timely completion of critical actions during CA in simulation education. Simulation should thus not only focus on the quality of CPR, but also on the time spent by each member of the resuscitation team for each critical action. In simulation, each action should take the same amount of time as in real life. Time limits should be set for actions like changing compressors, rhythm checks and epinephrine administration. This can help to increase time awareness and optimize team organization.

To reach the goals described by the ERC guidelines, we need to practice with our resuscitation teams to improve and retain our skills. A promising initiative is the formation of a CPR pit-crew. Pit-crew CPR focuses on high-quality CPR performed by a highly organized and cooperative team with preassigned roles, just like the pit crew in a car race. The focused components of high-quality CPR are minimal interruptions in chest compressions, providing compressions of adequate depth and rate, avoiding leaning between compressions, allowing full chest recoil, avoiding excessive ventilations, and minimizing peri shock pauses [26]. With adequate training, teamwork and the use of CPR feedback devices, high-quality CPR with minimal interruptions in chest compressions can be achieved by prehospital providers [36]. However, next to these focused components there is an absolute necessity to add a time sensitive approach in training.

Limitations

There were several limitations in this study. First, due to the rather small sample size, this study was underpowered to evaluate the impact of time-adherence on ROSC or clinical outcomes.

Rather, our intent was to evaluate whether guidelines are followed in real life. Furthermore, similar to other studies that use video recording in CPR studies, one of the major advantages of this set-up is also a disadvantage. Data retrieved by filming is less biased than data reported in medical charts retrospectively [20]. However, video recording in a non-controlled environment causes a degree of data loss due to poor video quality, battery issues, and data storage issues. Previous studies report data loss of up to 6-39% [27]. Time to IV/IO access was not retained in our data but time to first epinephrine administration was obtained. This can serve as a surrogate in non-shockable rhythm. Finally, we are aware that analysis of the data using time frames may result in a rigid evaluation of time adherence. To correct for small time differences inherent to real life, a 10s error margin was included.

Conclusion

In this prospective study conducted at a single center, we assessed the adherence of our Mobile Medical Teams (MMTs) to the 2015 ERC ALS guidelines regarding the recommended timings in 128 cases of out-of-hospital cardiac arrests (OHCAs). Notably, over 75% of the OHCAs exhibited deviations from the prescribed guidelines. Despite the median timings for critical actions aligning with previously published data, this discrepancy prompts consideration of the appropriateness of the current protocol stringency, suggesting a potential need for a more practical and flexible timing approach. An intriguing observation is the uniform distribution of Advanced Airway (AA) placement timings across shockable and non-shockable groups, indicating a possible misalignment of priorities. Additionally, the underutilization of capnography in only 63% of endotracheal intubations and the delayed administration of epinephrine in non-shockable CPR, coupled with premature Amiodarone administration before the third shock, underscore challenges in adhering to the ALS algorithm. Of concern is the delayed response to reversible causes, as per resuscitation guidelines, highlighting a suboptimal compliance with the algorithm despite adequate training. These findings emphasize the crucial need to enhance awareness among prehospital healthcare workers regarding time-critical actions. Addressing this issue through targeted, time-sensitive training during simulations may serve as a valuable strategy to augment awareness and optimize daily practice.

Acknowledgments

We thank all healthcare providers for their professional care and contribution to this study.

Statement of Ethics

This study is part of the Pro Rea Study, a quality study approved by the UZ Leuven Institutional Ethical Review Board (identification number withheld for review). The videotapes could only be viewed by the team members taking part in a particular resuscitation and by the study investigators. All team members were informed of the recording before the start of the project and prior to resuscitation and had the option to not participate in the study. Patients and relatives were not informed of the video recording. All data were processed within two weeks after the research team started reviewing the record the recordings. After this time frame, the video recordings were deleted, and patient tracing was no longer possible.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Data Availability Statement

The data that support the findings of this study are available on the servers of the institution where this study was performed and are available upon request from author 1.

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