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*Published in:*
Journal of the American Heart Association

*DOI (link to publication from Publisher):*
10.1161/JAHA.123.033913



*Publication date:*
2024

*Document Version*
Publisher's PDF, also known as Version of record

Journal of the American Heart Association

ORIGINAL RESEARCH

# Association Between Defibrillation Using LIFEPAK 15 or ZOLL X Series and Survival Outcomes in Out-of-Hospital Cardiac Arrest: A Nationwide Cohort Study

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**BACKGROUND:** Defibrillation is essential for achieving return of spontaneous circulation (ROSC) following out-of-hospital cardiac arrest (OHCA) with shockable rhythms. This study aimed to investigate if the type of defibrillator used was associated with ROSC in OHCA.

**METHODS AND RESULTS:** This study included adult patients with OHCA from the Danish Cardiac Arrest Registry from 2016 to 2021 with at least 1 defibrillation by the emergency medical services. We used multivariable logistic regression and a difference-in-difference analysis, including all patients with or without emergency medical services shock to assess the causal inference of using the different defibrillator models (LIFEPAK or ZOLL) for OHCA defibrillation. Among 6516 patients, 77% were male, the median age (quartile 1; quartile 3) was 70 (59; 79), and 57% achieved ROSC. In total, 5514 patients (85%) were defibrillated using LIFEPAK (ROSC: 56%) and 1002 patients (15%) were defibrillated using ZOLL (ROSC: 63%). Patients defibrillated using ZOLL had an increased adjusted odds ratio (aOR) for ROSC compared with LIFEPAK (aOR, 1.22 [95% CI, 1.04–1.43]). There was no significant difference in 30-day mortality (aOR, 1.11 [95% CI, 0.95–1.30]). Patients without emergency medical services defibrillation, but treated by ZOLL-equipped emergency medical services, had a nonsignificant aOR for ROSC compared with LIFEPAK (aOR, 1.10 [95% CI, 0.99–1.23]) and the difference-in-difference analysis was not statistically significant (OR, 1.10 [95% CI, 0.91–1.34]).

**CONCLUSIONS:** Defibrillation using ZOLL X Series was associated with increased odds for ROSC compared with defibrillation using LIFEPAK 15 for patients with OHCA. However, a difference-in-difference analysis suggested that other factors may be responsible for the observed association.

**Key Words:** cardiopulmonary resuscitation ■ defibrillation ■ emergency medical services ■ out-of-hospital cardiac arrest ■ shockable rhythm



Out-of-hospital cardiac arrest (OHCA) is a major threat to public health worldwide, affecting an estimated 4 million people annually of whom ≈5000 are in Denmark.[1–4] Survival is dismal with a 30-day survival rate of 14% in Denmark.[3]

For patients presenting with ventricular fibrillation or pulseless ventricular tachycardia, early defibrillation is crucial for achieving return of spontaneous circulation (ROSC).[5] In Denmark, the 30-day survival rate of patients with shockable rhythm has increased significantly

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This article was sent to Kori S. Zachrison, MD, MSc, Associate Editor, for review by expert referees, editorial decision, and final disposition.

This work was presented in part at the London Trauma Conference, December 6-8, 2022, in London, United Kingdom, the European Resuscitation Council Congress, November 02-04, 2023, in Barcelona, Spain, and at the Danish Emergency Medicine Conference, November 2-3, 2023, in Copenhagen, Denmark.

Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.123.033913

For Sources of Funding and Disclosures, see page 7.



*JAHA* is available at: www.ahajournals.org/journal/jaha

## CLINICAL PERSPECTIVE

### What Is New?

- We report real-world data comparing the effect of 2 commonly used defibrillators, LIFEPAK 15 and ZOLL X Series, on survival outcomes following defibrillation by emergency medical services in out-of-hospital cardiac arrest.
- We found that defibrillation using ZOLL was associated with a higher rate of return of spontaneous circulation with a concurrent nonsignificant association observed for patients without emergency medical services defibrillation.

### What Are the Clinical Implications?

- Our findings suggest the higher rate of return of spontaneous circulation for patients defibrillated using ZOLL compared with LIFEPAK was unlikely due to difference in defibrillation efficacy, but other factors such as chest compression feedback when using ZOLL or training when implementing new equipment may contribute to the association between defibrillator type and improved return of spontaneous circulation.

### Nonstandard Abbreviations and Acronyms

| | |
|---|---|
| **OHCA** | out-of-hospital cardiac arrest |
| **ROSC** | return of spontaneous circulation |

from 13% in 2001 to 49% in 2021, highlighting what can be achieved with a dedicated effort.[3,6,7] Efforts include enhanced public awareness regarding early recognition, cardiopulmonary resuscitation (CPR), and early defibrillation.[8–12]

Although it is evident that defibrillation holds a crucial role for cardiac arrest patients in shockable rhythm, various defibrillator models employing distinct approaches to shock delivery are available for the emergency medical services (EMS). Although contemporary defibrillators employ a transthoracic impedance-compensated biphasic waveform, the types of biphasic waveforms and maximal shock energy level differ.[13,14] The different types of defibrillators and biphasic waveforms are generally considered equivalent.[15,16] However, there is a paucity of real-world evidence on comparative effectiveness and impact on survival outcomes for the 2 defibrillators.

The 2 most commonly used waveforms in the Danish EMS are the biphasic truncated exponential used by LIFEPAK 15 and the rectilinear biphasic waveform used by ZOLL X Series. This study was initiated due to an observed trend of Danish EMS transitioning from using LIFEPAK 15 to ZOLL X Series.

Therefore, this study aimed to investigate whether the type of defibrillator used was associated with ROSC in adult patients with OHCA defibrillated at least once by the Danish EMS.

## METHODS

### Study Design

This was a nationwide, observational cohort study including adult patients with OHCA from 2016 to 2021. Data were obtained from the Danish Cardiac Arrest Registry and The National Patient Registry.[17,18] This study was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[19] The data that support the findings of this study are available from the corresponding author upon reasonable request.

### Setting

Denmark is divided into 5 regions responsible for the Danish health care system, including the prehospital service and hospitals.[20] The entire Danish health care system is publicly funded. Each region is responsible for their own EMS setup appropriate to their population density, geography and political position. This includes decisions on equipment and training. In general, Denmark operates a 2-tier EMS system. The first tier consists of an ambulance with either emergency medical technicians or paramedics and primarily provides basic life support, including manual rhythm analysis and defibrillation. The second tier consists of advanced life support units (rapid response vehicles or helicopters) usually operated by a paramedic at a minimum or an anesthesiologist.

The defibrillators used in the Danish EMS during the study period were the LIFEPAK 15 (Stryker, Redmond, WA) (hereafter LIFEPAK) and the ZOLL X Series (ZOLL Medical Corporation, Chelmsford, MA) (hereafter ZOLL). LIFEPAK uses a biphasic truncated exponential waveform and delivers up to 360 joules with duration and voltage adjusted to impedance.[21] ZOLL uses a rectilinear biphasic waveform with a fixed duration and maximal energy of 200 joules.[22] Furthermore, when using the ZOLL, EMS personnel can receive real-time CPR feedback (see Table S1 for further comparison). During the study period, 2 regions consistently employed LIFEPAK-equipped EMS, while 3 regions transitioned from LIFEPAK to ZOLL. The EMS followed the European Resuscitation Council guidelines using an escalating shock strategy according to manufacturer recommendations.[15] For LIFEPAK-defibrillators this corresponded to 200, 300, and 360 joules and for the ZOLL to 120, 150, and 200

joules, for the first, second, and subsequent shocks, respectively.[15]

## Study Population

We included adult patients with OHCA subjected to at least 1 defibrillation by the Danish EMS. Patients below 18 years of age, patients with nonindex events, patients with events occurring during the implementation period of a new defibrillator (washout period), patients with missing data on the primary outcome, and any missing or inconsistent (eg, EMS response time exceeding 24 hours) data on patient demographics and OHCA characteristics were excluded.

## Data Collection

Data regarding outcome and independent variables was defined according to the Utstein Resuscitation Registry Templates for OHCA[23] and extracted from the Danish Cardiac Arrest Registry.[17] A questionnaire was sent to the 5 prehospital EMS organizations obtaining information regarding the type of defibrillators and shock strategy (ie, energy used for first, second and subsequent shocks) used during the study period within their region (Table S2). Discharge diagnoses 10 years before index event were obtained from the National Patient Registry to derive the updated Charlson Comorbidity Index score (scores ranging from 0 to 24, with higher scores indicating more comorbidity) for each patient.[24,25] The Charlson Comorbidity Index score was then introduced into 4 categories (scores of 0, 1, 2, and ≥3).

## Exposure and Outcomes

The exposure of interest for the primary analysis was defibrillation by either LIFEPAK or ZOLL. The exposure of interest for the difference-in-difference analysis (including all patients with and without EMS shock) was defined as treatment by either a LIFEPAK-equipped or ZOLL-equipped EMS-unit.

The primary outcome was ROSC, defined as a clinical assessment that shows signs of life comprising a palpable pulse or generating a blood pressure.[23] This could be accomplished at any point during the resuscitation attempt. Secondary outcomes included ROSC at hospital arrival and 30-day survival.

## Statistical Analysis

Data distribution was examined using histograms and quantile-quantile plots. Descriptive results were presented as a number (percentage) for categorical data and median (interquartile range) for continuous data. Supplemental analyses compared baseline characteristics and outcomes of excluded and included patients. Categorical data were compared using the chi-square test and continuous data was compared using Wilcoxon rank sum test.

Our primary analysis of the association between the type of defibrillator used for defibrillation and patient outcomes was analyzed using multivariable logistic regression modeling adjusted for patient demographics (age, sex, and comorbidities) and OHCA characteristics (initial rhythm, bystander and EMS witnessed status, bystander CPR, bystander defibrillation before EMS arrival, EMS response time, public or private location of arrest, year of cardiac arrest, and prehospital physician involvement). We used directed acyclic graphs to identify relevant covariates for adjustment (Figure S1).

To explore whether other factors than the shock itself could have influenced the association between defibrillator models and outcomes, we conducted a sensitivity analysis on the association between the type of defibrillator used and survival outcomes for patients without EMS shock. We then conducted a difference-in-difference analysis to investigate whether the impact of the type of defibrillator was different for patients with EMS shock versus those without EMS shock. This would be the hypothesis if a benefit of using a specific defibrillator was due to the shock effectiveness itself, making patients without EMS shock *negative controls*.[26] This was analyzed using multivariable logistic regression modeling adjusted for the same variables as the primary analysis. Furthermore, another sensitivity analysis was made to account for missing variables. For this analysis, we used multiple imputations, where all missing variables were imputed 10 times through chained equations.[27] Lastly, as many of the ZOLL defibrillated patients originated from the Capital Region of Denmark, we performed a sensitivity analysis comparing the 2 defibrillators within this region only to further elucidate whether any regional differences could confound the results.

Adjusted odds ratios were reported with 95% CI, and a 2-sided $P$ value of <0.05 was considered statistically significant. Stata 18 (StataCorp LLC, College Station, TX) was used for the analyses.

## Ethics

Approval from the Committee on Health Research Ethics and informed consent were not required according to Danish legislation, as this was an observational registry-based study. The study was approved by both the data responsible unit in the Central Denmark Region (1-16-02-113-22) and the Danish Cardiac Arrest Registry committee.

# RESULTS

Complete data were available for 6516 of 7635 patients defibrillated at least once by the EMS

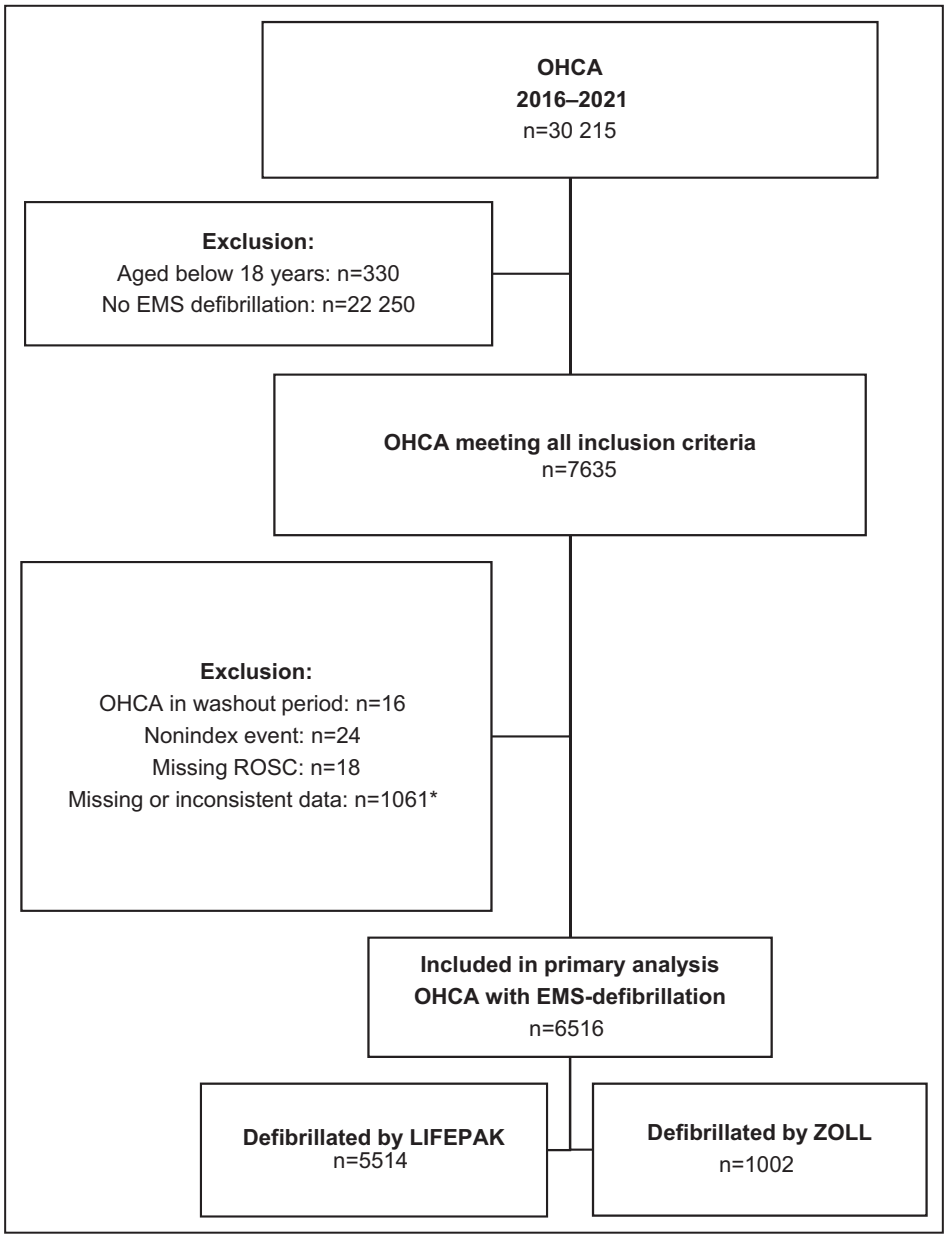


**Figure 1. Flow chart of the study population for OHCA in Denmark 2016–2021.**
For ROSC at hospital arrival: n=6470 as 46 patients were missing information on status at hospital arrival. *See Table S3. EMS indicates emergency medical services; OHCA, out-of-hospital cardiac arrest; and ROSC, return of spontaneous circulation.

(Figure 1; Table S3). Three regions changed defibrillators during the study period (Table S2) and there were no major differences in baseline characteristics; the majority were male and had an initial shockable rhythm (Table). In total, 5514 patients (85%) were defibrillated using LIFEPAK, with 3087 (56%) achieving ROSC and 1002 patients (15%) were defibrillated using ZOLL, with 630 (63%) achieving ROSC. Additional OHCA characteristics are provided in Table. The vast majority of all patients defibrillated by ZOLL originated from the Capital Region of Denmark (85% of patients defibrillated by ZOLL; Table S4).

Patients defibrillated by ZOLL had an increased unadjusted odds ratio (OR) for ROSC compared with LIFEPAK (OR, 1.33 [95% CI, 1.16–1.53]). The increased OR for ROSC for ZOLL compared with LIFEPAK was retained after confounder-adjustment (adjusted OR [aOR], 1.22 [95% CI, 1.04–1.43]). There was no statistically significant difference at hospital arrival (aOR, 1.11 [95% CI, 0.95–1.30]) or in 30-day survival (aOR, 1.11 [95% CI, 0.93–1.32]) (Figure 2A).

**Table. Patient Demographics and OHCA Characteristics Stratified According to Defibrillator Models for Patients Receiving EMS Defibrillation in Denmark 2016–2021**

| | LIFEPAK | ZOLL |
|---|---|---|
| | N=5514 | N=1002 |
| Patient demographics | | |
| Male sex | 4199 (76%) | 790 (79%) |
| Age, y, median (IQR) | 70 (59–79) | 69 (58–78) |
| Charlson Comorbidity Index score | | |
| 0 | 2888 (52%) | 554 (55%) |
| 1 | 542 (10%) | 109 (11%) |
| 2 | 1228 (22%) | 197 (20%) |
| ≥3 | 856 (16%) | 142 (14%) |
| OHCA characteristics | | |
| Location | | |
| Private | 3725 (68%) | 642 (64%) |
| Public | 1789 (32%) | 360 (36%) |
| Initial rhythm | | |
| Nonshockable | 2149 (39%) | 385 (38%) |
| Shockable | 3365 (61%) | 617 (62%) |
| Bystander witnessed | | |
| Yes | 3290 (60%) | 646 (64%) |
| EMS witnessed | | |
| Yes | 817 (15%) | 148 (15%) |
| Bystander cardiopulmonary resuscitation | | |
| Yes | 3821 (69%) | 691 (69%) |
| Automated external defibrillator defibrillation before emergency medical services | | |
| Yes | 766 (14%) | 158 (16%) |
| Prehospital physician involvement | | |
| Yes | 4678 (85%) | 986 (98%) |
| Time to scene arrival, median (IQR) | | |
| Minutes | 6 (4–10) | 6 (4–8) |

Categorical data are presented with a number (percentage) and continuous data with median (interquartile range). IQR indicates interquartile range; and OHCA, out-of-hospital cardiac arrest.

## Sensitivity Analysis

In the sensitivity analysis of patients not defibrillated (n=18 592), we found patients treated by ZOLL-equipped EMS had a nonsignificant, increased aOR for ROSC compared with LIFEPAK (aOR, 1.10 [95% CI, 0.99–1.23]; Figure 2B). There was no statistically significant difference for ROSC at hospital arrival (aOR, 0.98 [95% CI, 0.87–1.10]) or 30-day survival (aOR, 0.97 [95% CI, 0.81–1.16]).

To explore whether the higher rate of ROSC following defibrillation using ZOLL defibrillators was due to the defibrillation itself or other factors, we conducted a difference-in-difference analysis (n=25 108; see Figure S2 for cohort selection). We estimated the association between the defibrillator model (LIFEPAK or ZOLL) and outcomes in patients with EMS shock relative to the association in patients without EMS shock, and no statistical differences were found (Figure 2C). Difference-in-difference ORs for ROSC, ROSC at hospital arrival, and 30-day survival were 1.10 (95% CI, 0.91–1.34), 1.13 (95% CI, 0.93–1.38), and 1.14 (95% CI, 0.88–1.47), respectively.

To account for missing data, multiple imputations including the index event for adult patients with OHCA receiving at least 1 EMS defibrillation (n=7595) was performed. Similar associations with the primary analysis were found between the defibrillator used and ROSC (aOR, 1.24 [95% CI, 1.07–1.45]), ROSC at hospital arrival (aOR, 1.13 [95% CI, 0.98–1.32]), and 30-day survival (aOR, 1.10 [95% CI, 0.93–1.31]) in favor of ZOLL compared with LIFEPAK.

The sensitivity analysis comparing the 2 defibrillators in the Capital Region of Denmark yielded comparable results (Figure S3).

# DISCUSSION

In this nationwide, observational cohort study, we assessed the association between defibrillation using LIFEPAK or ZOLL in the EMS and survival outcomes following OHCA. We found defibrillation using ZOLL was associated with ROSC but not significantly associated with ROSC at hospital arrival or 30-day survival.

To the best of our knowledge, this is the first comparison of the efficacy of 2 commonly used defibrillators for OHCA. No trials have compared the 2 used biphasic waveforms in adult patients with OHCA. However, several studies compared the efficacy of different defibrillators, including LIFEPAK and ZOLL, in animal cardiac arrest studies and cardioversion for patients without OHCA with diverging results.[13,28–36]

In atrial fibrillation, trials found no significant differences in cardioversion success between LIFEPAK and ZOLL[28–30] although the biphasic truncated exponential waveform was more effective than the pulsed biphasic waveform, which uses a similar energy setting as ZOLL.[31] Maximum energy was more efficient compared with low-escalating energy shocks for cardioversion when using the same waveform.[37] Although data on delivered defibrillation energy were unavailable in this present study, we anticipated that the EMS adhered to the European Resuscitation Council's guidelines using an escalating shock strategy as per manufacturer recommendations.[15]

Two animal studies compared biphasic waveforms for cardiac arrest found the rectilinear waveform superior to the biphasic truncated exponential waveform.[35,36] Due to fewer shocks required, the rectilinear waveform was more effective in achieving ROSC, thus resulting in shorter total time before successful resuscitation than the biphasic truncated exponential

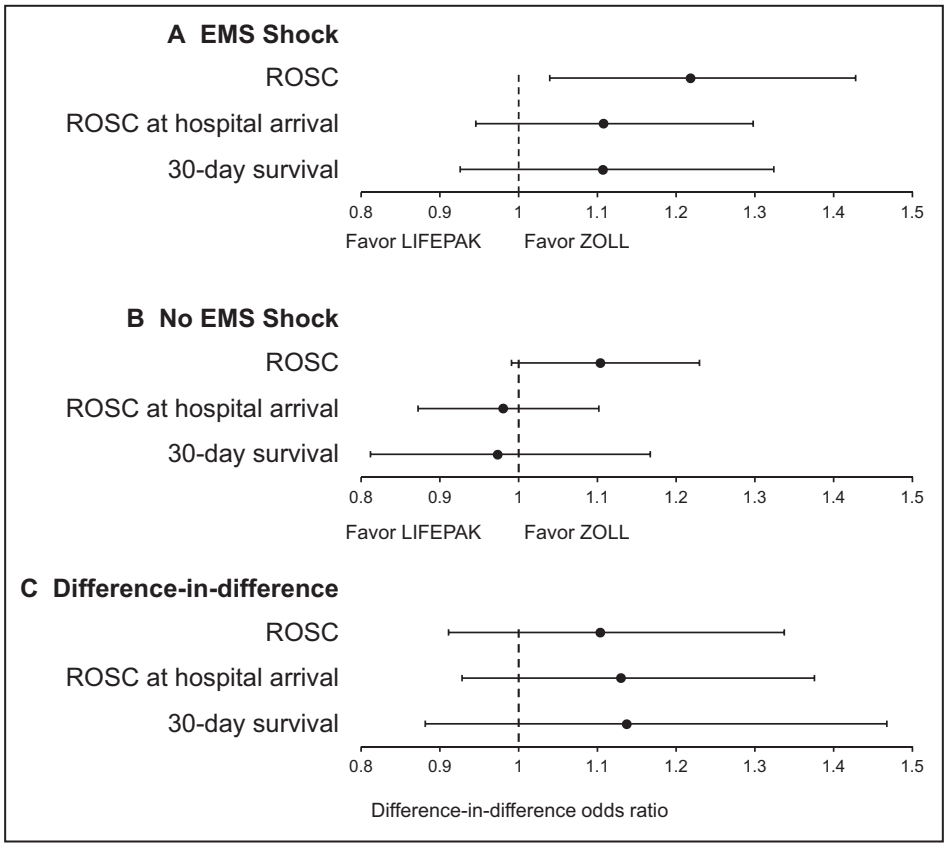


**Figure 2. Association between defibrillator models and patient outcomes.**
**A**, Adjusted odds ratios and 95% CIs for the association between defibrillator models (LIFEPAK or ZOLL) and outcomes for patients with EMS shock. **B**, Adjusted odds ratios and 95% CIs for the association between defibrillator models (LIFEPAK or ZOLL) and outcomes for patients without EMS shock. **C**, The difference-in-difference odds ratio and 95% CIs. The dashed line represents an odds ratio of 1 (no association). EMS indicates emergency medical services; and ROSC, return of spontaneous circulation.



waveform.[35] Furthermore, the rectilinear waveform required significantly less energy than the biphasic truncated exponential waveform for successful defibrillation in a piglet defibrillation model for young children.[36]

The defibrillation characteristics between LIFEPAK and ZOLL differ. LIFEPAK is capable of reaching a higher energy level (360 versus 200 joules) compared with ZOLL.[21,22] However, the rectilinear waveform delivers greater current for equivalent energy when compared with the biphasic truncated exponential waveform, which is supposed to enhance defibrillation efficacy.[33,34] Furthermore, the duration of the rectilinear biphasic waveform is fixed at 10 ms regardless of the patient's transthoracic impedance,[22] whereas the duration of the biphasic truncated exponential waveform is adjusted to transthoracic impedance (10–22 ms).[21] Some animal studies suggest waveforms over 10 to 12 ms are associated with a reduced efficacy[38] and an increase in the risk of myocardial dysfunction.[39] However, these studies are based on earlier investigations of monophasic versus biphasic waveforms.

If the observed differences in patient outcomes between ZOLL and LIFEPAK were primarily attributed to the defibrillation efficacy alone, it would be expected that these differences would not be observed in patients without EMS shock. Contrary to this assumption, we observed a nonstatistical difference in adjusted odds of ROSC for patients without EMS shock. However, in the difference-in-difference analysis, the estimated causal effect of receiving a shock from the ZOLL defibrillator was not statistically significant (Figure 2C), suggesting that other factors beyond the defibrillation efficacy contributed to the overall favorable patient outcomes associated with ZOLL compared with LIFEPAK.

Some notable differences exist between the LIFEPAK and ZOLL defibrillators not related to the defibrillation technology itself. The ZOLL defibrillators uses real-time feedback on chest compression depth

and rate when using the CPR puck.[22] Moreover, it uses a See-Thru CPR technology that filters out compression artifact so EMS personnel can see the patient's underlying rhythm during CPR, which may reduce pause durations for rhythm check. Real-time feedback has been associated with more guideline-compliant chest compression depth and rate and a higher chest compression fraction when compared with not using feedback.[40] Better chest compression quality could potentially improve physiologic parameters and affect patient outcomes although an association between CPR feedback and patient outcomes has yet to be proven.[40–42] The effectiveness of See-Thru CPR technology remains to be determined.[43]

Furthermore, the implementation of a new type of defibrillator in the EMS setting required additional training. This training in advanced life support could have led to improved adherence to guidelines[40,44] and an increased focus on correctly using the new defibrillators, including accurate pad placement, shorter chest compression pauses, and timely shock delivery.[43] This phenomenon was observed in the Central Denmark Region after a new defibrillation technique was introduced in 2018 resulting in increased guideline compliance, potentially associated with improved survival rate.[45,46]

## Limitations

The findings from this study should be interpreted with caution in the context of some important limitations. First, this was an observational cohort study based on registry data. Second, there were regional differences in the usage of the defibrillators and the ZOLL defibrillators were primarily used in the Capital Region of Denmark. Although we adjusted for covariates associated with cardiac arrests in an urban setting (eg, witnessed arrest, EMS response times, bystander CPR), residual confounding cannot be ruled out. Third, there was a significant proportion of patients excluded due to missing data. However, when using multiple imputation, a comparable association with the primary analysis was found. Fourth, the registries used did not have data on the energy used to defibrillate the patient; however, we anticipated the EMS followed the national guidelines as mentioned. Furthermore, as the registries did not include physiologic parameters and CPR quality data that may mediate the effect on the outcome through CPR feedback provided by the ZOLL defibrillators, we were unable to conduct any mediation analyses of for example, ventricular fibrillation amplitude spectral area or end-tidal carbon dioxide on survival outcomes. Finally, although a considerable number of covariates were included in our regression model, there is a risk of unmeasured confounding (ie, training of staff, guideline adherence).

# CONCLUSIONS

Defibrillation using ZOLL X Series was associated with increased odds for ROSC compared with defibrillation using LIFEPAK 15 for patients with OHCA. However, a nonsignificant increase was also observed for patients without EMS shock, and the difference-in-difference analysis suggested that other factors may be responsible for the observed association.

## ARTICLE INFORMATION

Received December 8, 2023; accepted March 5, 2024.

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### Acknowledgments

We are grateful to Bo Martin Bibby and Aparna Udupi, Department of Biostatistics at University of Aarhus, for their guidance and assistance with the statistical method and to the board of the Danish Cardiac Arrest Registry for facilitating the data collection and usage. Author Contributions: Carsten Meilandt: conceptualization, methodology, writing – original draft, writing – review and editing, project administration, funding acquisition, formal analysis, data curation. Mette Qvortrup: conceptualization, methodology, writing – original draft, writing – review and editing, project administration, formal analysis, data curation. Morten Thingemann Bøtker: conceptualization, methodology, writing - review and editing, funding acquisition, supervision. Fredrik Folke: writing – review and editing, resources. Lars Borup: writing – review and editing, resources. Helle Collatz Christensen: writing – review and editing, resources. Louise Milling: writing – review and editing, resources. Kasper Glerup Lauridsen: conceptualization, methodology, formal analysis, writing – review and editing, supervision. Bo Løfgren: conceptualization, methodology, formal analysis, writing – review and editing, supervision.

### Sources of Funding

This study was supported by the Central Denmark Region's Prehospital Research Fund.

### Disclosures

None.

### Supplemental Material

Tables S1–S4.
Figures S1–S3.

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