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Original Article

How a system saves lives: Results of Luxembourg's nationwide cardiac arrest project

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Abstract

Background: In 2018 the prehospital Emergency Medical System (EMS) in Luxembourg underwent a major reorganization by the creation of a single EMS structure. We aimed to study the impact of this reorganization on outcome after out-of-hospital cardiac arrest (OHCA).

Methods study design: We conducted a before-and-after study on outcome after OHCA in Luxembourg taking advantage of the existing EuReCa studies protocols and case report forms. The first period extended from October 2017 to September 2018, and the second from September 2021 to August 2022.

Setting: Nationwide observational database on OHCA.

Participants: All OHCA patients within the territory of the Grand Duchy of Luxembourg reported through an emergency call.

Intervention: None.

Main outcomes and measures: The primary outcome was the survival rate after OHCA. Secondary outcomes were rates of bystander and phone cardio-pulmonary resuscitation (CPR), return of spontaneous circulation (ROSC) rates and arrival times of EMS.

Results: Over the 2 time periods, the incidence of OHCA emergency calls remained stable, whereas the confirmed OHCA increased from 236 to 375 cases per year. Bystander and phone CPR rates significantly increased, by 1.5 and 5-fold, respectively. EMS response time was significantly reduced (16:19 min vs 11:03 min, $p < 0.001$) and associated with significantly improved survival (OR per minute 0.83, 95 % CI 0.73–0.95). Hospital admission with ROSC increased non-significantly from 19 % to 24 % ($p = 0.08$) and 1-month survival increased significantly from 9 (3.8 %) to 37 survivors (9.8 %) ($p = 0.006$), corresponding to 28 additional lives saved within one year. No statistically significant difference could be shown on 1-month survival or ROSC rate when phone CPR or bystander CPR were performed.

Conclusion: Over 4 years, major structural and organizational EMS changes led to significantly shorter EMS response times and were accompanied by a significant increase of survival after OHCA. Whether other factors also have contributed to better survival remains unclear.

Keywords: Bystander cardiopulmonary resuscitation, Phone assisted cardiopulmonary resuscitation, Prehospital, Resuscitation, Quality of care, Emergency medical system, Out-of-hospital cardiac arrest

Introduction

Outcome after out-of-hospital cardiac arrest (OHCA) is closely linked to the rapidity of initiation of cardio-pulmonary resuscitation (CPR).[1,2] Besides bystanders, emergency medical services (EMS) organization plays a crucial role, especially for the detection of a cardiac arrest (CA) already during the emergency call, guiding lay people to perform cardio-pulmonary resuscitation (CPR) via phone assistance and, rapidly dispatching first responders and EMS teams to the scene of the CA.[3]

In Luxembourg, favorable outcome after OHCA remains sparse[4,5] and the awareness that society and the system should evolve, sparked the Luxembourg Resuscitation Council (LRC) and the government to take action to improve outcome after cardiac arrest.

Back in 2015 the LRC started the "Réagis au Lycée!" ("react at high school!") campaign aiming at teaching compression only CPR

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during their school curriculum at high school.[6] Starting as a pilot project, the interest and the number of pupils trained has steadily increased. Each year more than 10 000 students are trained. Since June 2023, this training has become mandatory, hopefully boosting the number of school children being instructed for CPR and eventually increasing the number of lay bystanders.

Mid 2018, the Luxembourg national fire and rescue corps ("Corps Grand-ducal d'incendie et de secours" CGDIS) was created (https://112.public.lu/). This new entity groups all prehospital emergency actors (like ambulance services, physician and nurse staffed emergency medical vehicles ("service d'aide médicale urgente" (SAMU") and firefighters) within one single organization, including a single national emergency dispatch center. Since 2021, additionally a nurse officer is on duty 24/7 at this dispatch center thriving steady efforts to implement and improve detection for cardiac arrests[7] and to routinely instruct phone CPR.

Prior to 2018, the ambulance service was primarily managed by the Civil Protection, heavily relying on volunteers coming from home to arm the ambulances and depending on the Ministry of Interior. Only in Luxembourg City the ambulance service was operated by a professional fire brigade. The physician and nurse staffed "SAMU" depended on the Ministry of Health and was run by different hospitals. The creation of a single entity allowed for a nationwide fourfold increase of professional firefighters and paramedics. Ambulances stations have increased by numbers and now run exclusively from their base with onsite personnel, the means of the "SAMU" have also increased and organizational measures have been taken to lower the response times of all means.

The major organizational changes in EMS are depicted in Fig. 1.

We took advantage of the EuReCa-TWO study (run from October to December 2017)[8] and the EuReCa-THREE study (run from September to November 2022)[9] to extend the data collection period from 3 months to a whole year (CARDLUX). As such, we were able to cover the period before the creation of CGDIS (or at least before all the structural and personnel changes came to effect) and the period where CGDIS was fully operational with structural and personnel changes in place. Using the EuReCa/CARDLUX data we aimed to analyze the impact of the prehospital management of OHCA on patient survival in Luxembourg, after the creation of a new and more effective prehospital care system and a lay bystander training program in secondary school kids. As secondary endpoints we analyzed bystander CPR rates, phone CPR rates, EMS response times and return of spontaneous circulation (ROSC) rates.

Methods

Study design

We performed a prospective observational registry study over 2 periods. We used our national data of the EuReCa-TWO study[8] and the EuReCa-THREE study[9] and extended the data collection from 3 months to a full one year period. The extension projects were called CARDLUX 1 and CARDLUX 2 ("**C**ardiac **AR**rest and **D**efibrillation in **Lux**embourg") respectively. CARDLUX1, including EuReCa-TWO, ran from October 2017 to September 2018 and CARDLUX2, including EuReCA-THREE, ran from September 2021 to August 2022. For both studies we used the same electronic case report form (eCRF). All cases of OHCA on the whole territory of Luxembourg were included in the database. Confirmed OHCA was defined as CPR performed by EMS or AED shocks delivered, in the absence of signs of irreversible death and absence of "do not resuscitate" orders. To reduce the risk of missed cases, data originated from 2 distinct sources, the call center and the ambulance files, to allow a double check. All patients recognized as having a cardiac arrest were listed at the emergency call center and were cross-checked with a specific file for OHCA reporting originating from the EMS staff. All relevant information was extracted from the EMS chart and call center data. All incoming emergency phone calls of the CARDLUX2 period were audited *post hoc* by a designated EMS nurse to extract data and gain important information for quality improvement. Outcome data were obtained via the treating physicians or hospitals.

Both studies received ethical approval from the national ethics board (CNER 201709/04 and 202208/02, respectively). Informed consent was waived for deceased patients, patients regaining consciousness were asked for informed consent *post hoc*. As the first study period covered the last period before the creation of CGDIS, and the second period corresponded to CGDIS already being set up for 3 years, this study allowed us to study the impact of an important EMS organizational change on the initial care and the outcome of OHCA.

Statistical analysis

Continuous variables are presented with mean and standard deviation (SD), and categorical data are presented as numbers and percentages. We compared baseline demographic and clinical characteristics between groups using Chi-square test, Fisher exact test, *t*-test, or Wilcoxon rank sum tests for categorical and continuous variables, as appropriate. We performed multivariable logistic regression to assess independent predictors of 1-month survival, including dispatcher-assisted CPR, bystander CPR, first AED shock, and EMS response time. An interaction term between response time and study period (CARDLUX1 vs CARDLUX2) was added to formally test whether the effect of response time differed between periods. P values lower than 0.05 are considered statistically significant. All statistics were performed on IBM SPSS, Version 29. Data was complete for the primary endpoint (survival) and missing values for secondary endpoints were lower than 5 %. We did not correct for missing data.

Results

In total, 611 patients presented a confirmed OHCA, 236 in CARDLUX1 and 375 in CARDLUX2, respectively. Over the two study periods, the incidence of emergency calls for presumed cardiac arrest, in relation to a steadily growing population, remained stable with a slight tendency to drop, while the number of confirmed OHCA where CPR has been started, markedly increased by nearly 40 %. We noticed an increase in the ROSC rate resulting in an overall improvement in the admission rate to the hospital, as well as a significant increase of 1-month survival rate from 3.8 % to 9.8 % (p = 0.006), corresponding to additional 28 lives per year saved (Table 1).

A 1.5-fold increase of bystander CPR rate was noticed, while the rate of phone CPR increased nearly 5-fold. EMS intervention times from call to scene were also significantly reduced by more than 5 min. In adjusted analysis using multivariable logistic regression including an interaction term between EMS response time and study period, a significant effect modification was observed (OR 1.17, 95 % CI 1.05–1.30, p = 0.004). In CARDLUX 2, shorter EMS response time was independently associated with higher 1-month survival,

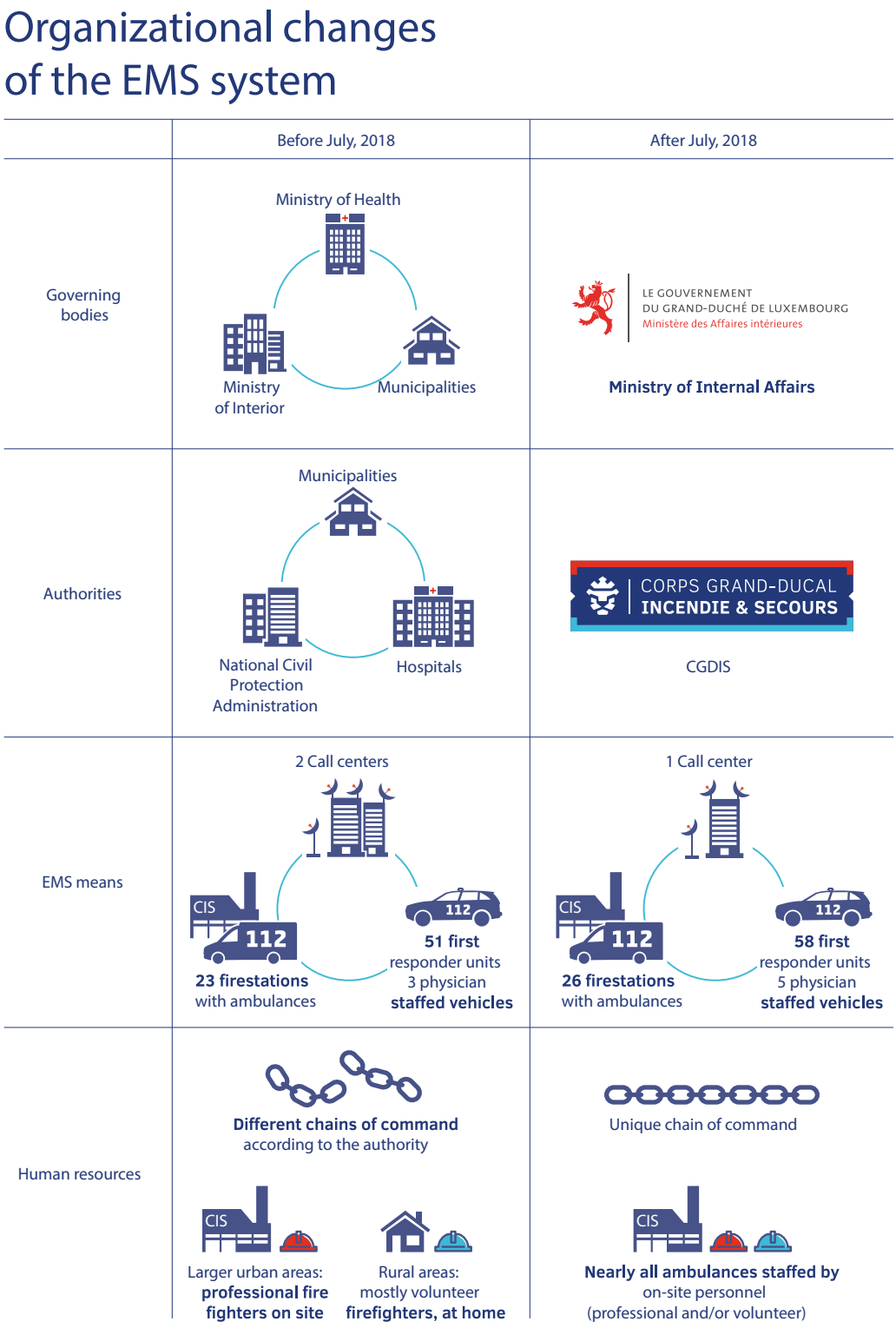

Fig. 1 – Major organizational changes following implementation of a unique Emergency Medical System in Luxembourg. Legend: CGDIS = û Corps Grand-ducal d'incendie et de secours ý (National fire and rescue corps); EMS = emergency medical services; CIS = û Centre d'incendie et de secours ý (Fire and rescue/ambulance station).

with each additional minute of delay reducing the odds of survival by approximately 17 % (OR 0.83 per minute, 95 % CI 0.73–0.95, p = 0.006). In contrast, EMS response time was not significantly related to survival in CARDLUX1 (OR ~ 0.97, p = n.s.). Phone CPR showed a non-significant trend toward improved survival (OR 1.45, 95 % CI 0.96–2.20, p = 0.08), whereas bystander CPR and first shock by an AED were not independently associated with outcome after adjustment (Table 2).

Table 1 – Comparative results between CARDLUX1 and CARDLUX2.

	CARDLUX1	CARDLUX2	p value
Population covered (x 1000)	549.7	660.8	
Incidence OHCA calls per 100 000 population	83.1	78.2	
Emergency calls for OHCA (n)	457	517	
CA confirmed with CPR attempts (n)	236	375	
Patient age (years)	68.9 95 % CI 66.6–71.2	68.8 95 % CI 66.9–70.7	0.95
Male (%)	63.1	66.8	0.559
Bystander CPR (n,%)	73 (31 %)	186 (49.6 %)	0.065
Phone CPR (n,%)	15 (6.3 %)	113 (30 %)	<0.001
Time to scene (min:sec)	16:19 95 % CI 15:00–17:38	11:03 95 % CI 10:33–11:34	<0.001
First recorded rhythm shockable (n,%)	77 (34 %)	87 (24 %)	0.037
AED connected before EMS arrival (n,%)	32 (14 %)	63 (17 %)	0.49
First shock AED (n,%)	21 (8.9 %)	22 (5.8 %)	0.056
Causes of cardiac arrest			0.1
Medical (n,%)	186 (79 %)	264 (70 %)	
Traumatic (n,%)	10 (4.2 %)	25 (6.7 %)	
Drug overdose (n,%)	1 (0.4 %	3 (0.8 %)	
Asphyxial (n,%)	10 (4.2 %)	18 (4.8 %)	
Unknown (n,%)	29 (12 %)	65 (17 %)	
Outcome			
Any ROSC (n,%)	62 (26 %)	123 (33 %)	0.13
Admission with ROSC to hospital (n,%)	44 (19 %)	90 (24 %)	0.08
Admission with ongoing CPR to hospital(n,%)	16 (6.8 %)	19 (5.1 %)	0.16
1 month-survival (n,%)	9 (3.8 %)	37 (9.8 %)	0.006
Bystander CPR	*n* = 73	*n* = 186	
ROSC if bystander CPR (n,%)	25 (34.2 %)	60 (32.2 %)	0.6
Survival if bystander CPR (n,%)	3 (4.1 %)	20 (10.8 %)	0.11
Phone CPR	*n* = 15	*n* = 113	
ROSC if phone CPR (n,%)	6(40 %)	37(33 %)	0.46
Survival if phone CPR (n,%)	1(6.7 %)	11 (9.7 %)	0.7

Table 2 – Multivariable analysis for survival.

	OR	95 % CI	p value
CARDLUX 1	0.95	0.37–2.44	0.91
Phone CPR	1.45	0.96–2.20	0.08
Bystander CPR	1.03	0.95–1.11	0.51
First shock AED	1.75	0.98–3.11	0.06
Time to scene	0.83	0.73–0.95	0.006
Time to scene * CARDLUX 1	1.17	1.05–1.30	0.004

The ROSC rate (any ROSC after CPR, including transient unstable ROSC) also increased by one quarter from 26 % to 33 %. The initial rhythm was less frequently shockable in the second study period (34 % vs 24 % respectively).

No statistically significant differences could be shown on ROSC rate or 1-month survival when phone CPR or bystander CPR were performed.

Discussion

Major structural changes in the organization of the EMS system resulted in significantly shorter response times and we showed a nearly 3-fold increase in OHCA survivors. Other outcomes like “any ROSC” and “admission to hospital with ROSC” also improved, although not significantly.

Over the 2 study periods we noticed an increase in the number of confirmed OHCA exceeding the mere increase of population. This finding might be related to the fact that more bystanders performed CPR, phone assisted CPR increased, and ambulances arrived earlier on scene.

Nearly all recorded variables that could be linked to better outcomes have improved over time. In multivariable analysis, only EMS response times were significantly different between the study periods. In CARDLUX2, each additional minute resulted in a 17 % reduction of the chance of survival.

The increase in bystander CPR rates may have contributed the improved outcome, even though we could not demonstrate statistical significance. With only close to 50 % of bystander CPR rate, there is still a huge margin of improvement compared to other high performing countries.[8,10]

Adaptations at the emergency call center also contributed to a close to 5-fold increase in phone-assisted CPR. Unfortunately, we were not able to discern whether our bystander CPR-rate also comprises phone CPR. Still, with the projected measures to further refine dispatchers' capacities to detect cardiac arrest on the phone and targeting "gasping" that is mistakenly taken for breathing, we expect further improvements in upcoming analysis over the next years.[7]

Notably, the rate of AED's attached prior to the arrival of the EMS did not increase markedly although the availability of public AEDs is steadily increasing. Rather than questioning the utility of public AEDs, our findings might well be related to the faster EMS arrival on scene and the inherent lack of time to apply a public AED.

Current scientific evidence indicates a decline over time in the proportion of OHCA cases presenting with initial shockable rhythms.[11,12] Given the fact that non-shockable rhythms generally have a less favorable outcome than shockable rhythms, the improvement of overall survival rates in our study must be regarded as even more relevant.

The decreasing need for transporting patients under ongoing CPR might be explained by a higher ROSC rate favored by the preceding improvements, be it the higher bystander CPR/phone CPR rate, or earlier arrival of the ambulance teams providing high quality CPR. The physician staffed "SAMU" system in Luxembourg favors physician led decisions on scene and this might have influenced the decision not to transport the patient whereas in some countries with paramedics only on scene, the decisions to transport under CPR might be more systematic.

We were not able to show a statistically significant impact of phone CPR and bystander CPR on patient outcome, which might be linked to the small number of patients (type 2 error). Although the rate of phone CPR increased, the lack of control or live feedback on the CPR quality from the lay rescuers might result in overall low-quality CPR and thus only confer a marginal benefit for the patient. Whereas trained bystanders are perhaps more prone to deliver high quality CPR compared to completely untrained people only being instructed over a phone. These findings are in line with recent findings from Korea.[13]

With a thorough and well thought reorganization of the EMS, many interventions, aiming at enhancing OHCA care and outcome, can be improved, although in our study only response time was found to be independently associated with better survival. We were not able to demonstrate significant associations between the other studied interventions and survival, nevertheless our results indicate that some 28 additional lives were saved in the final year of the study compared to the first period. Efforts should continue to further enhance the detection and rapidity of delivering high quality CPR. As we are currently running the CARDLUX-R registry, using the same methodology, over a five-year period (from October 2023 until September 2028), we will be able to follow the evolution of the care provided to OHCA victims. Especially, efforts are being undertaken to reduce the undetected cardiac arrests and the implementation of the "hands-on belly" technique[7] as well as some recent additional improvements in the timely alert of EMS and first responders are expected to further positively influence patient outcome.

Due to the design of the study, we were only able to collect data that influenced survival after OHCA from the EMS records. Thus, it was not possible to conclude on the impact of other measures, like our school training initiative "Réagis au Lycée!". It might still be that such campaigns have contributed to increasing the overall bystander CPR rate, but this remains speculative.

Limitations and strengths

Our study has several limitations. The data set is limited, both in terms of size, as Luxembourg is a small country, but also in terms of granularity of data available. Ethical considerations as well as limited resources made us decide to continue with the existing and approved eCRF of the EuReCa trials without changing them. We acknowledge, that 1-month survival is not equivalent to good outcome and death due to neurologic impairment may also occur after the 1-month follow-up period. We also are unable to provide long-term follow-up. Another limitation is the before and after design within a real-life evolution of the EMS system and the society. As such we are unable to directly link the results observed to the changes in the system or the impact of our training campaigns on bystander CPR rates. Another unknown variable is the quality of CPR, especially for lay and phone CPR bystanders, that could not be assessed in our study. Finally, given the low number of overall survivors, we must emphasize that the robustness of the multivariable analysis remains limited.

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Still, our study has some strengths. It is a nationwide allcomers analysis of 2 time periods reflecting 2 different ways of EMS functioning. Given the similar incidence and a coherent increase in cases in parallel to an increase in the population, we can consider the data complete with very few, if any, missing cases. Due to the single contact point and the centralized data collection, the missing cases can be considered very low.

Conclusions

Over two 1-year observation periods we were able to show a marked increase in survival after OHCA in Luxembourg. In the 4 in-between years, major structural and organizational changes of the EMS have taken place and resulted in a significant reduction of response times associated with increased survival. Whether other factors also have contributed to better survival remains unclear. Further observational registry data is required to follow-up step-by-step improvements of

detection and care of OHCA, by educating the general population and refining internal EMS procedures.

CRediT authorship contribution statement

Pascal Stammet: Writing – original draft, Validation, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Valentin Hajek:** Writing – review & editing, Investigation, Data curation. **Nicolas Rinaldis:** Writing – review & editing, Investigation, Data curation. **Olivier Pierrard:** Writing – review & editing. **Carlo Clarens:** Writing – review & editing, Project administration, Investigation, Funding acquisition. **Philippe Degrell:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

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Declaration of competing interest

None of the authors declare a conflict of interest.

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