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Clinical paper

Endotracheal intubation versus supraglottic procedure in paediatric out-of-hospital cardiac arrest: a registry-based study

Quentin Le Bastard[a], *Jade Rouzioux*[b], *Emmanuel Montassier*[a], *Valentine Baert*[c,d], *Morgan Recher*[c,d], *Hervé Hubert*[d,e], *Stéphane Leteurtre*[c,d], *François Javaudin*[a,*], *on behalf of the GR-RéAC*

[a] CHU Nantes, Department of Emergency Medicine, Nantes University Hospital, F-44000 Nantes, France
[b] Department of Emergency Medicine, CH La Roche Sur Yon, F-85000 La Roche Sur Yon, France
[c] CHU Lille, Department of Paediatric Intensive Care, Jeanne de Flandre Hospital, F-59000 Lille, France
[d] University of Lille, CHU Lille, EA 2694 - Santé Publique: épidémiologie et qualité des soins, F-59000 Lille, France
[e] French National Out-of-Hospital Cardiac Arrest Registry Research Group – Registre électronique des Arrêts Cardiaques, F-59000 Lille, France

Abstract

Background: Out-of-hospital cardiac arrest (OHCA) in children is associated with a low survival rate. Conclusions in the literature are conflicting regarding the best way to handle ventilation. The purpose of this study was to assess the impact of two airway management strategies, endotracheal intubation (ETI) vs. supraglottic procedure, during cardiopulmonary resuscitation (CPR) on 30-day survival in paediatric OHCA.

Methods: This was a retrospective, observational, multicentre, registry-based study conducted from July 2011 to March 2018. All paediatric OHCA patients under 18 years of age and managed by a mobile intensive care unit were included. The primary endpoint was 30-day survival in a weighted population (based on propensity scores).

Results: Of 1579 children, 1355 (85.8%) received ETI and 224 (14.2%) received supraglottic ventilation during CPR. We observe a lower 30-day survival in the ETI group compared to the supraglottic group (7.7% vs. 14.3%, absolute dierence, 6.6 percentage points; 95% confidence interval [CI], 2.3–12.0; propensity-adjusted odds ratio [paOR], 0.39; 95% CI, 0.25–0.62; p < 0.001), and also a poorer neurological outcome (paOR, 0.32; 95% CI, 0.19–0.54; p < 0.001). However, we did not identify any significant association between airway management strategy and return of spontaneous circulation (paOR, 1.15; 95% CI, 0.80–1.65; p = 0.46).

Conclusions: The findings of this large cohort study suggest that ETI in paediatric OHCA, although performed by trained physicians, is associated with a worse outcome, regardless of traumatic or non-traumatic aetiology.

Keywords: Paediatric out-of-hospital cardiac arrest, Airway management, Endotracheal intubation, Supraglottic ventilation

Background

Out-of-hospital cardiac arrest (OHCA) in children remains a rare event representing around 8 events versus 62.3 events per 100,000 people in the adult population.[1–4] Despite medical progress in post-cardiac arrest care, paediatric OHCA still carries a low likelihood of survival.[5] Evidence on practices in the management of paediatric cardiac arrest remains weak and guidelines are partly based on extrapolations from adult data.[6,7] Aetiologies of OHCA differ strongly between adults and children; hypoxic OHCA represents up to 42% of OHCA in the paediatric population.[8] Thus, airway manage-

Abbreviations: OHCA, out-of-hospital cardiac arrest, CPR, cardiopulmonary resuscitation, ETI, endotracheal intubation, IPTW, inverse probability of treatment weighting, PS, propensity score, ROSC, return of spontaneous circulation, BVM, bag-valve mask, MICU, mobile intensive care unit, EMS, emergency medical system, AED, automated external defibrillator, SGA, supraglottic, CPC, Cerebral Performance Category, MICE, multiple imputation using chained equations, ATE, average treatment eect, SMD, standardised mean dierences

* Corresponding author at: Department of Emergency Medicine, CHU Nantes, University Hospital of Nantes, Nantes, France.
E-mail address: francois.javaudin@chu-nantes.fr (F. Javaudin).

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ment is a key issue in paediatric OHCA. Most up-to-date guidelines on paediatric cardiopulmonary resuscitation (CPR) recommend positive pressure ventilation combined with thoracic compressions and still consider tracheal intubation as the most secure and effective procedure to maintain the airway and provide efficient oxygenation.[6]

Although endotracheal intubation (ETI) remains the standard procedure in France during CPR, it is now subject to debate, and data from the most recent literature are conflicting.[9,10] Several studies have found an association between ETI and increased mortality in OHCA in children, whether it occurs inside or outside of the hospital.[11–14] The most recent results are provided by a prospective and randomised study comparing bag-valve mask (BVM) ventilation and ETI in adult OHCA, and were not able to conclude that ETI was not inferior, but highlighted a lower rate of adverse effects in the ETI group.[15] Performing an ETI on a child during CPR is challenging and can result in significant interruptions in chest compressions, especially since it takes place out of the hospital.[16–18] These conflicting data call into question the best way to handle ventilation in paediatric OHCA.

The purpose of this study was to assess the impact of airway management strategies during CPR (ETI vs supraglottic procedure) on 30-day survival in paediatric OHCA, in a large cohort involving physician-staffed mobile intensive care units.

Methods

Study design

We performed a retrospective, observational, multicentre cohort study analysis using the data from the French National OHCA Registry (RéAC) collected from July 2011 to July 2018. This cohort includes all OHCA patients managed by a physician-staffed mobile intensive care unit (MICU) in France. MICUs consist of an ambulance driver, a nurse and a trained emergency physician experienced in airway management and tracheal intubation as a minimum team. A detailed description of the French emergency medical system (EMS) has been previously published.[19] Briefly, it is a two-tiered system with a fire department ambulance or private ambulance available for prompt intervention and basic life support (BLS), and MICU for advanced life support (ALS) on scene.[20] Importantly, BLS providers are not able to provide advanced airway management (supraglottic airway [SGA] or ETI). The choice of airway management strategy is made by the physician. The database includes patients managed by 94 MICUs representing 90% of French MICUs. The RéAC form meets the requirements of the French Emergency Medical Service organisations and is structured according to the Utstein universal style.[21] Data are collected in the secured RéAC database (www.registreреac.org).

The present study was approved by the French Advisory Committee on Information Processing in Health Research (CCTIRS) and the French National Data Protection Commission (CNIL, authorisation no. 910946). As it was approved as a medical assessment registry study, informed consent was waived.[22]

Study sample

We included all RéAC patients under 18 years of age for whom resuscitation was attempted by a first response team and a MICU was called to the scene. Patients were included regardless of the suspected aetiology of OHCA. Subjects with obvious signs of death such as rigor mortis or an instruction not to resuscitate were not included in the study.

Variables of interest and study outcomes

Patient characteristics obtained from the database included sex, age, CPR initiated by bystander witness, arrest location, on-scene time of first response team and MICU, aetiology of OHCA, initial rhythm, automated external defibrillator (AED) use, no-flow duration (time between collapse and initiation of basic life support), low-flow duration (time between initiation of basic life support and return of spontaneous circulation), airway management strategies, drug administration route (intraosseous, peripheral vein, central vein or endotracheal access) and adrenaline administration. Patients were classified in two groups depending on airway management strategy during CPR: those for whom an ETI was performed and those for whom ventilation was performed by a supraglottic procedure (SGA or BVM). The supraglottic group is a combination of subjects who received either BVM or SGA ventilation during CPR, whereas the ETI group only included subjects who benefited from orotracheal intubation. The primary outcome of interest was 30-day survival, irrespective of Glasgow-Pittsburgh Cerebral Performance Category (CPC). The secondary endpoints were the return of spontaneous circulation (ROSC) and a good neurological outcome, defined as a CPC score of 1 (no neurologic disability) or 2 (moderate disability).

Statistical analysis

The study population was characterised using descriptive analysis. Categorical variables are reported as counts and percentages and continuous variables as means and standard deviations (SD), or median and first and third quartiles for non-normally distributed variables. Categorical variables were compared using the χ^2 test, with Yates' continuity correction when relevant, or Fisher's exact test. Continuous variables were compared using Student's t-test or the Wilcoxon rank sum test when relevant. Analyses were performed using an intention to treat strategy, which means that in cases of ETI failure and subsequent BVM ventilation, the patients were analysed in the ETI group.

In order to minimise the impact of missing data, we performed multiple imputation using chained equations (MICE) with predictive mean matching for continuous data and logistic regression for binary data.[23] The list of variables used for imputation are available in the *Data Supplement* (Table S2), including characteristics of CPR and outcomes.

Because of the retrospective design of this study, we used the inverse probability of treatment weighting (IPTW) to obtain unbiased estimations of the average treatment effect.[24,25] The goal of this strategy is to simulate random assignment of the treatment. We firstly estimated the propensity score (PS) of treatment (ETI during CPR), which is defined as the probability of being assigned to the treatment group (ETI) given all relevant covariates. The PS was estimated using a generalised boosted logistic regression model that incorporated all relevant variables listed above. The average treatment effect (ATE) was used to generate balanced groups. After PS was generated, weights were applied to the patients, corresponding to 1/PS for patients in the ETI group and [1/(1 − PS)] for patients in the supraglottic group. Then, we checked weighted data for covariate balance using standardised mean differences (SMD). SMD exceeding ±0.1 were considered to be significantly unbalanced. There is no consensus on the cut-off point for SMD in the literature, but several authors have proposed that a value above 0.1 could

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denote meaningful imbalance in the baseline covariate.[26] This conservative strategy was preferred to PS matching because it limits the loss of data.[24] The limited number of events in this cohort forced us to carefully select the variables to be included in the PS estimation. Including variables not or weakly correlated to the outcome could indeed have increased the variance of the effect and resulted in a low reduction of bias.[27] Covariates included in the model were selected using a univariate analysis of their impact on treatment assignation and on 30-day survival.

The primary endpoint was adjusted according to the IPTW method. Then, the impact of airway management on good neurological outcome and ROSC were assessed using the same strategy. Results are expressed as odds ratios and standardised marginal probabilities with 95% CIs. The threshold of significance was set at $P < 0.05$ and all associations were determined using two-sided testing. Statistical analyses were performed using the R environment (version 3.4.4) in Rstudio software (version 1.2.1335) using the packages mice (version 3.6.0), survey (version 3.35–1) and twang (version 1.5).

Results

Characteristics of the patient population

Overall, we included 1641 children under 18 years of age with OHCA (Fig. 1). Sixty-two patients were excluded from the analysis because of missing data about airway management procedure by MICU ($n = 58$) or vital status on day 30 ($n = 4$, all receiving ETI).

The final population consisted of 1579 children with a median age of 3 years (0–13) (Table 1). Cardiac arrests mostly occurred in boys (62.0%, 979 of 1579), at their home/residence (58.7%, 927 of 1579) and were witnessed by a bystander (62.6%, 988 of 1579). Often, CPR was not initiated immediately by a witness (37.8%, 597 of 1579). Bystander CPR included chest compressions in most cases (54.4%, 859 of 1579) but often did not include ventilation (25.8%, 407 of 1579). Cardiac arrest mostly occurred in a non-traumatic context (73.3%, 1157 of 1579).

The first response team was on the scene within a mean time of 10.9 (SD 9.5) minutes and the MICU within a mean time of 20.2 (SD 13.5) minutes. The initial rhythm was mostly unshockable (88.4%, 1396 of 1579). After MICU arrival, most patients underwent ETI (85.8%, 1355 of 1579) and received adrenaline during CPR (79.7%, 1259 of 1579) via a peripheral vein (53.5%, 844 of 1579). Most of the patients in the supraglottic procedure group ($n = 224$) received BVM ventilation (92.9%, 208 of 224) and some received ventilation through SGA (7.1%, 16 of 224). MICU teams reported a failure in ETI procedure for 31 patients (2.0%).

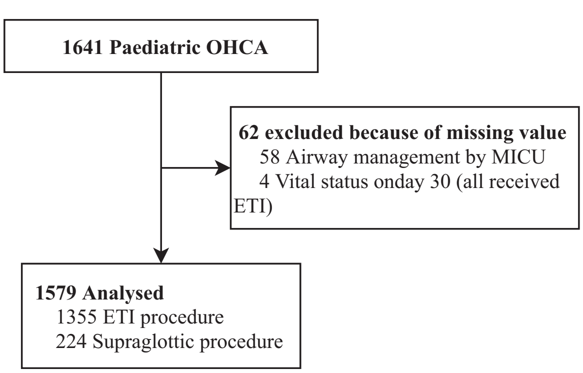

Fig. 1 – Flow chart of patient inclusion.

The most important characteristics associated with 30-day survival are detailed in Table S1 in the *Data Supplement*. Only the covariates that were the most significantly associated with outcome were included in our PS calculation and are detailed in Table 2.

Overall outcomes and unadjusted analysis

The overall 30-day survival was 8.6% (136 of 1579). In unadjusted univariate analysis, ETI during CPR was associated with a lower 30-day survival (7.7% [104 of 1355] vs. 14.3% [32 of 224]; absolute difference, 6.6 percentage points; 95% CI, 2.3–12.0; OR, 0.50; 95% CI, 0.33–0.76, $P = 0.001$) (Table 1). ROSC occurred in 29.4% of children (465 of 1579). A good neurological outcome was observed for 5.6% of all children (88 of 1579). In unadjusted univariate analysis, ETI during CPR was associated with increased ROSC (30.5% [413 of 1355] vs. 23.2% [52 of 224], absolute difference, 7.3 percentage points; 95% CI, 0.8–12.9; OR, 1.45; 95% CI, 1.04–2.02) and decreased favourable neurological outcome (4.6% [63 of 1355] vs. 11.1% [25 of 224], absolute difference, 6.5 percentage points; 95% CI, 2.8–11.4; OR, 0.39; 95% CI, 0.24–0.63).

Inverse probability of treatment-adjusted analysis

The baseline characteristics of the weighted population and comparisons between groups are presented in Table 2. We observed 346 missing items of data for immediate CPR by bystander, 599 for first response team time on site, 13 for bystander-witnessed OHCA, six for CPR by MICU and four for ROSC. All were managed using the previously described multiple imputation strategy. After IPTW, the population was well matched for all included variables as shown in Fig. 2 and Table 2 and univariate comparisons were non-significant after IPTW (all $P > 0.15$ and standardised mean differences between -0.1 and $+0.1$, except for shockable rhythm with $SMD = 0.102$). In the weighted population, survival at day 30 was lower in patients intubated during CPR (propensity-adjusted odds ratio [paOR], 0.39; 95% CI, 0.25–0.62; $P < 0.001$).

Secondary adjusted analysis showed that children in the ETI group did not show a significant difference in the frequency of ROSC (paOR, 1.15; 95% CI, 0.80–1.65; $P = 0.46$) compared to those in the supraglottic group. However, we identified a worse neurological outcome at 30 days in the ETI group (paOR, 0.32; 95% CI, 0.19–0.54; $P < 0.001$).

Discussion

In our work, we assessed the impact of airway management strategies during CPR on 30-day survival in paediatric OHCA by comparing ETI to supraglottic procedures in a large prospective cohort. The main findings were that 30-day survival and neurological outcomes were worse in the ETI group.

Airway management during CPR in children remains a thorny issue and the optimal strategy is still unclear. Current guidelines recommend BVM ventilation as the first-line method for managing the airways during cardiac arrest, but also consider ETI as the most secure and effective procedure for maintaining the airway.[6]

OHCA in children is a rare event with a low survival rate of 8.6% in our cohort. These results are consistent with previous studies that found a survival rate of between 10.9% and 11.3%.[12,13,28] Our data confirm that ETI remains the standard of care in France for airway

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Table 1 – Characteristics of patients and cardiac arrest management.

Characteristics	No. of Patients (%)			*P* Value
	Overall Population *n* = 1579)	ETI (*n* = 1355)	Supraglottic Procedure (*n* = 224)	
Age, med, (Q1;Q3), years	3 (0;13)	3 (0;13)	2 (2;11.3)	0.1
Gender (male)	979 (62.0)	849 (62.7)	130 (58.0)	0.05
Witness and bystander				
Bystander-witnessed	996 (63.1)	849 (62.7)	147 (62.5)	0.4
First response team- or MICU-witnessed	102 (6.5)	85 (6.3)	17 (7.6)	0.6
Location of arrest				0.1
Home	927 (58.7)	806 (59.5)	121 (54.0)	
Street/highway	273 (17.3)	237 (17.5)	36 (16.1)	
Public building	98 (6.2)	84 (6.2)	14 (6.3)	
Other or non-specified	281 (17.8)	228 (16.8)	53 (23.7)	
Bystander CPR				
Immediate CPR by bystander	606 (38.4)	530 (39.1)	76 (33.9)	0.08
Bystander compression only	859 (54.4)	767 (56.6)	92 (41.1)	<0.001
Bystander compression and ventilation	407 (25.8)	358 (26.4)	49 (21.9)	0.2
Bystander defibrillation	115 (7.3)	108 (8.0)	7 (3.1)	0.007
Time from first call to contact to patient in minutes, mean (SD)				
First response team time on scene	11.4 (10.3)	11.0 (10.4)	13.6 (9.1)	0.02
MICU time on scene	20.2 (13.5)	19.9 (12.6)	22.3 (17.9)	0.06
Cardiac arrest baseline characteristics				
Non-traumatic cardiac arrest	1157 (73.3)	991 (73.1)	166 (74.1)	0.8
First documented rhythm by MICU				<0.001
Shockable	58 (3.7)	57 (4.2)	1 (0.4)	
Non-shockable	1396 (88.4)	1210 (89.3)	186 (83.0)	
ROSC	125 (7.9)	88 (6.5)	37 (16.5)	
No-flow duration, mean (SD), min[a]	10.2 (11.0)	9.8 (11.0)	12.6 (15.6)	0.01
Low-flow duration, mean (SD), min[b]	37.7 (27.3)	40.3 (26.0)	22.3 (29.8)	<0.0001
Basic life support				
Basic life support by first response team	1298 (82.2)	1176 (86.8)	122 (54.5)	<0.001
Use of AED	829 (52.5)	760 (56.1)	69 (30.8)	0.2
Defibrillation	94 (6.0)	89 (6.6)	5 (2.2)	0.09
Advanced life support				
Intubation failure[c]	31 (2.0)	31 (2.3)	0 (0)	<0.001
Pulmonary aspiration	449 (28.4)	441 (32.5)	8 (3.6)	<0.001
$EtCO_2$ max during CPR, mean (SD), mmHg	30.7 (23.2)	30.8 (23.2)	25.5 (21.4)	0.29
Defibrillation	141 (8.9)	139 (10.3)	2 (0.9)	<0.001
Number of shocks delivered, med, (Q1;Q3), (*n* = 141)	2 (1;4)	2 (1;4)	3 (2.5;3.5)	0.54
Intraosseous vascular access	607 (38.4)	577 (42.6)	30 (13.4)	<0.001
Peripheral venous vascular access	844 (53.5)	811 (59.8)	33 (14.7)	<0.001
Central venous vascular access	21 (1.3)	19 (1.4)	2 (0.9)	0.75
Endotracheal access	56 (3.5)	56 (4.1)	0 (0)	<0.001
No vascular access	20 (1.3)	9 (0.7)	11 (4.9)	<0.001
Adrenaline administration	1259 (79.7)	1209 (89.2)	50 (22.3)	<0.001
Outcomes				
ROSC after advanced life support	465 (29.4)	413 (30.5)	52 (23.2)	0.03
Vital status on hospital admission (*n* = 566)				0.04
ROSC	407 (25.8)	355 (26.2)	52 (23.2)	
Dead on admission	73 (4.6)	70 (5.2)	3 (1.3)	
Manual chest compressions	65 (4.1)	64 (4.7)	1 (0.4)	
Automatic chest compressions	20 (1.3)	19 (1.4)	1 (0.4)	
Alive on day 30	136 (8.6)	104 (7.7)	32 (14.3)	0.002
Neurologically favourable survival (CPC 1 & 2)	88 (5.6)	63 (4.6)	25 (11.1)	<0.001

Abbreviations: ETI: endotracheal intubation; MICU: mobile intensive care unit; CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; AED: automated external defibrillator; $EtCO_2$: end-tidal capnography; SD: standard deviation; Q1:Q3: first and third quartiles. *P* values were calculated using Student's *T*-test, χ^2 test with Yates' continuity correction, Wilcoxon rank sum test or Fisher's exact test.

[a] No-flow duration: time between collapse and initiation of basic life support.

[b] Low-flow duration: time between initiation of basic life support and return of spontaneous circulation.

[c] The intubation failure rate for the "supraglottic procedure" group represents patients for whom intubation failed and management was pursued using a supraglottic device.

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Table 2 – Patients, arrest and intervention characteristics included in primary analysis before and after Inverse Probability of Treatment Weighting (IPTW).

	Before IPTW			After IPTW		
Baseline Characteristic, mean (SD)	Supraglottic Procedure	ETI	*P* value	Supraglottic Procedure	ETI	*P* value
Age (years)	5.49 (6.41)	6.24 (6.48)	0.10	5.60 (6.23)	6.15 (6.47)	0.22
Gender (male)	0.58 (0.49)	0.63 (0.48)	0.19	0.64 (0.48)	0.62 (0.49)	0.57
Witnessed OHCA	0.65 (0.48)	0.63 (0.48)	0.38	0.63 (0.48)	0.63 (0.48)	0.93
No-flow time <5 min	0.29 (0.45)	0.36 (0.48)	0.039	0.38 (0.49)	0.35 (0.48)	0.42
CPR immediately initiated by bystander	0.33 (0.47)	0.39 (0.49)	0.037	0.36 (0.48)	0.39 (0.49)	0.47
First response team arrival time	13.59 (9.07)	10.98 (10.4)	<0.001	10.86 (7.70)	11.31 (10.41)	0.45
Non-traumatic cardiac arrest	0.74 (0.44)	0.73 (0.44)	0.75	0.74 (0.44)	0.73 (0.44)	0.84
Shockable rhythm on MICU arrival	0.004 (0.07)	0.04 (0.2)	<0.001	0.02 (0.14)	0.04 (0.19)	0.11

Abbreviations: CPR: cardiopulmonary resuscitation; SD: standard deviation. *P* values were calculated using Student's *T*-test, χ^2 test or Fisher's exact test.

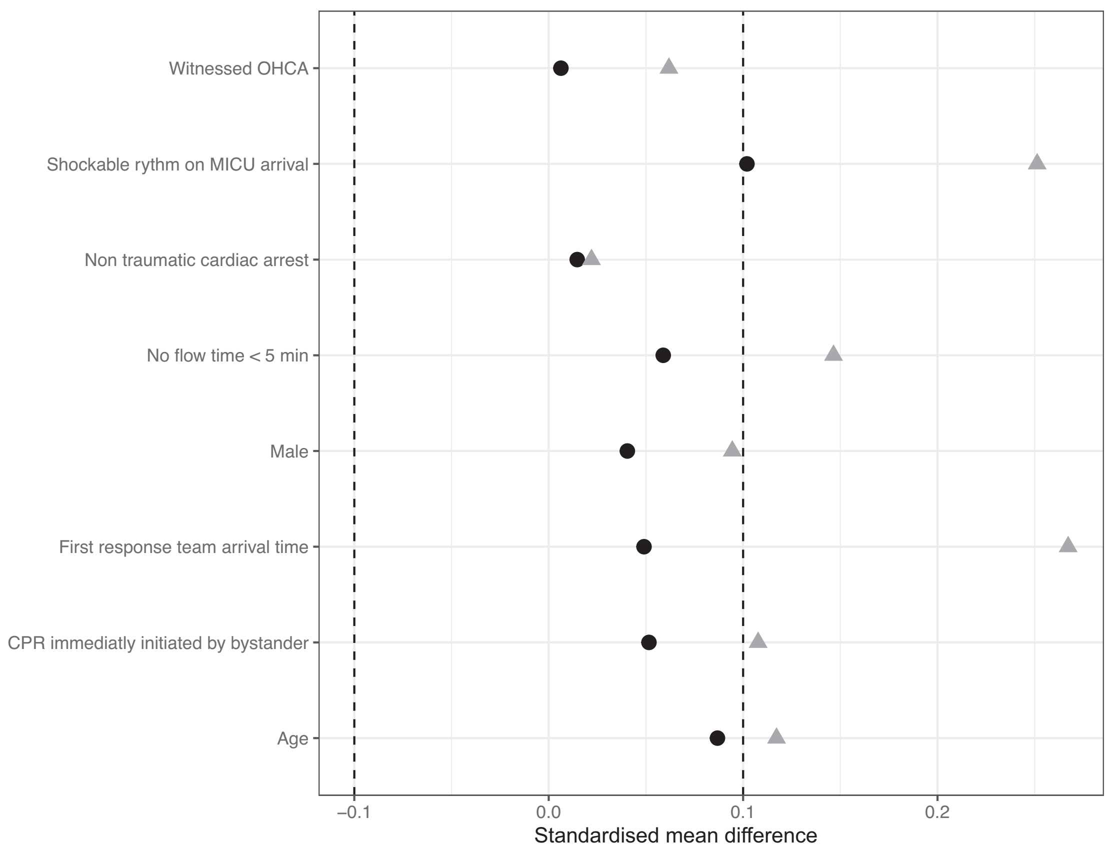

Fig. 2 – Standardised mean differences (SMD) before and after population weighting Vertical broken lines represent absolute standardised mean differences of −0.1 and +0.1, above which covariates are considered significantly unbalanced. Grey triangles represent the standard mean difference before IPTW and black circles represent the standard mean deviation after IPTW. Abbreviations: OHCA: out-of-hospital cardiac arrest; CPR: cardiopulmonary resuscitation.

management in OHCA, as 85% of children were intubated during CPR. In this work, the rate of children undergoing intubation was higher than in previously published studies.[12,13,29] As the aetiology of cardiac arrest may strongly influence outcomes, our model was weighted according to the reported aetiology (medical or traumatic). Indeed, traumatic cardiac arrest is associated with a lower survival rate.[30] Importantly, we found that, in paediatric patients who suffered OHCA, ETI was significantly associated with a lower 30-day survival after accounting for the probability of receiving this treatment, regardless of aetiology. These results did not differ from previous, lower-powered retrospective studies, which found an association between ETI during CPR and lower survival rates, with risk ratios of 0.89 and 0.39, respectively.[11,12] We also observed a non-significantly different proportion of ROSC in children who were intubated during CPR, where previous in-hospital and out-of-hospital studies reported a decreased or non-significantly modified rate of ROSC.[11,12,14] As found in previous cohort studies, we identified an association between airway management strategy and neurological outcome.[12]

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Cardiac arrest in children is mainly caused by hypoxia, and providing efficient and secured oxygenation could be a key element in CPR.[8] Previous studies have reported higher survival rates with chest compressions in association with ventilation in children.[17] However, a major concern about ETI is that rapid and successful intubation depends on the experience and skill of the operator and that delayed intubation could increase interruptions in chest compressions during CPR.[31–33] Indeed, interruption of chest compressions has been shown to negatively impact favourable functional survival.[34] This is especially true for children because intubation is reported to be more difficult than in adults.[18] However, in a randomised trial in adult OHCA, BVM ventilation was associated with a greater number of pauses longer than 2 seconds in chest compressions.[15] In our cohort, we report that intubation was not possible in only 2.0% of cases, which is similar to the results of a previously cited study in adults, with a corresponding rate of 2.1%.[15] However, we were not able to record the time of interruption of chest compressions caused by the ETI procedure. The literature reports that BVM may have several advantages over ETI because it is easier to use and ventilation may be achieved more quickly and efficiently, limiting adverse events.[31,32] However, a higher rate of ventilation failure and adverse events such as pulmonary aspiration and gastric distension have been observed in patients undergoing BVM ventilation, supporting that ETI may provide more secure access to the airways.[15]

Limitations

This was an observational study using a registry, although we performed IPTW survival analysis and adjusted for selection bias to balance the groups and control for confounding factors. However, under these conditions, some authors consider the measured effect to be comparable to randomised trials.[35] As airway management strategy was not randomly assigned to children, we can assume that some confounding factors that may have affected assignment to SGA or ETI or the outcomes were not controlled in our study. We were also unable to consider the time-to-intubation, weight-related adrenaline dose administered, or the time of interruption of chest compressions in our analysis because we could not obtain these data. An inherent limitation of this type of registry analysis is the incompleteness of the data, which may have resulted in a limited quality of the adjustment of the groups. To account for this and limit their impact on the calculation of PS, we used a multiple imputation strategy (MICE) for the covariates included in the model.

Ultimately, the generalisability of our findings is limited by the organisation of the EMS which includes here a trained emergency physician in the MICU, in contrast with paramedic teams from other European and non-European countries. Indeed, we report a lower rate of ETI failure than in previously published studies for emergency departments.[18]

Conclusions

The findings of this nationwide population-based study of paediatric OHCA suggest that ETI was associated with a worse outcome regardless of its traumatic or non-traumatic aetiology compared to supraglottic procedure. These results are in agreement with previous registry-based studies, which found an association between ETI and lower survival rates in the paediatric population. Even with a high rate of successful intubation by a trained emergency physician in our study, the ETI procedure during CPR was deleterious. This work questions the optimal airway management strategies for OHCA in children. A large, randomised, multicentre trial is warranted. Also, further data are needed to establish if and when intubation should be performed: during CPR or in comatose post-cardiac arrest patients.

Members of the GR-RéAC

Jacob Line, Ricard-Hibon Agnes, Dall acqua David, Watrelot Olivier, Narcisse Sophie, Sadoune Sonia, Guillaumee Frederic, Courcoux Hubert, Dhers marion, Gonzalez Geraldine, Capel Olivier, Ta Trung hung, Megy-Michoux Isabelle, Masson Caroline, Pernot Thomas, Poher Fabien, Joly Marc, Bages-Limoges Florence, Tentillier Eric, Blottiaux Emmanuel, Bohler Clio, Thibaut Klein, Coletta Mauro, Agostinucci Jean marc, Goument Melanie, Le pimpec Philippe, Letarnec Jean yves, Robart Jean-Christophe, Branche Fabienne, Kindle Carine, Dagoret Elodie, Lefevre Nathalie, Jardel Benoit, Prineau Stevens, Segard Julien, Beharelle Julien, Bernadet Patricia, Vial Michael, Bertrand Philippe, Simonnet Bruno, Jonquet Sebastien, Ursat Cecile, Vergne Muriel, Kernaleguen Cecile, Longo Celine, Boucard Severine, Thiriez Sylvain, Clementine Bonnet, Gay Julien, Pes Philippe, Puchois Aurelien, Besnier Sylvie, Arnaud Gaelle, Robert Helene, Boussarie Catherine, Heydel Virginie, Kamga Cyrille, Hullin Thomas, Meyran Daniel, Roudiak Nathalie, Kaliszczak Isabelle, Fuster Patrick, Peguet Olivier, Bouilleau Guillem, Begaudeau Aurelie, Forel Alban, Jenvrin Joel, Laot Melanie, Lacroix Arnaud, Wassong Corinne, Abarrategui Diego, Grua David, David Serrano, du Besset Marc, Hollecker Eric, David Olivier, Tellier Robin, Herkelmann Laurent, Champenois Anne, Leroy Antoine, Vignaud Frederic, Martinage Arnaud, Moine Linda, Andre Antoine, Cabanne Laurent, Lancon Virgine, Pavageau Laure, Spriet Audrey, Lespiaucq Christine, Benenati Sylvain, Bernigaud Emmanuel, Fournier Marc, Tabary Romain, Myriam Van tricht, Raconnat Julien, Campagne Guillaume, San miguel Marie, Salaun Beatrice, Frances Herve, Morel Jean-Charles, Jammes Guillaume, Lagadec Steven, Garay Emilie, Robert Frederique, Sanchez Oriana, Benguigui Yony, Dumouchel Julie, Paula palma Serge, Peyrat Sylvie, Dissait Francois , Cornuault Mathieu, Robert Damien, Vassor Isabelle, Deleu Stephanie, Chesneau Anne sophie, Fiani Nasri, Khiter Mounir, Rakotonirina Jean-Louis, Laborne Francois xavier, Girault Fabrice, Legeard Estelle, Resplandy Emilie, Gauclere Vincent, Fritsch Emmanuelle, Marchi Jacques, Hourdin Nicolas, Cohen Rudy, Legay Lea, Viallard Marie-Sophie, Chauveau Celine, Polini Stephanie, Cornaglia Carole, Sanjuan Chantal, Paringaux Xavier, Guinard Sollweig, Arnaudet Idriss, Heleniak Karina, Gaillard Florence, Maugein Laure, Guerin Thomas, Cys Alain, Hamdan David, Fillatre Olivier, Carle Olivier, Kadji Roger, Kuczer Vincent, Thivellier Agnes, Sapir David, Le jan Arnaud, Escutnaire Josephine, Benard Amandine, Bazzoli Cyril, Delattre Catherine, Saada Laure, Roucaud Nicolas, Sussat Myriam, Babet Thierry, Vasseur Laurene, Guillot Philippe, Line Sebastien, Roze Guillaume, Devillard Arnaud, Orhon Frederic, Lougnon Jean-Paul, Menot Pascal, Bredel Stephanie, Ruellan Gautier, Soulat Marie, Chassery Carine, Guiot Olivier, Gonet-Dubois Corinne, Benaziz Imane, Ayllon-Milla Sonia, Mariage Julien, Barthelemy Francois-Xavier, Versmee Gregoire, El abdi Mounir, Men ay Marion, Rungsawad Phloy, Rousselon Charlotte, Delbos Marc, Quibel Thomas, Gaillard Nancy, Lalande Jessica, Yali Matthieu, Desclefs Jean-

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Ethics and patient consent

The present study was approved by the French Advisory Committee on Information Processing in Health Research and the French National Data Protection Commission (authorisation no. 910946). It was approved as a medical assessment registry study without a requirement for patient consent.

Availability of data and materials

The datasets used and/or analysed in the current study are available from the corresponding author on reasonable request.

Conflicts of interests

The authors declare that they have no competing interests.

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Authors' contributions

QLB and FJ conceptualised the study, conducted the analysis, drafted the initial manuscript, and reviewed and revised the manuscript; JR conceptualised the study, conducted the initial analysis and drafted the initial manuscript; EM conceptualised the study and reviewed and revised the manuscript; VB collected data and reviewed and revised the manuscript; MR reviewed and revised the manuscript; HH collected data and reviewed and revised the manuscript; SL reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Appendix A. Supplementary material

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REFERENCES

1. Luc G, Baert V, Escutnaire J, Genin M, Vilhelm C, Di Pompéo C, et al. Epidemiology of out-of-hospital cardiac arrest: A French national incidence and mid-term survival rate study. Anaesth Crit Care Pain Med 2019;38(2):131–5.
2. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, et al. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. Circulation 2009;119(11):1484–91.
3. Fink EL, Prince DK, Kaltman JR, Atkins DL, Austin M, Warden C, et al. Unchanged pediatric out-of-hospital cardiac arrest incidence and survival rates with regional variation in North America. Resuscitation 2016;107:121–8.

4. Berdowski J, Berg RA, Tijssen JGP, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. Resuscitation 2010;81(11):1479–87.
5. Donoghue AJ, Nadkarni V, Berg RA, Osmond MH, Wells G, Nesbitt L, et al. Out-of-hospital pediatric cardiac arrest: an epidemiologic review and assessment of current knowledge. Ann Emerg Med 2005;46(6):512–22.
6. Maconochie IK, Bingham R, Eich C, López-Herce J, Rodríguez-Núñez A, Rajka T, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 6. Paediatric life support. Resuscitation 2015;95:223–48.
7. Topjian AA, Raymond TT, Atkins D, Chan M, Duff JP, Joyner BL, et al. Part 4: Pediatric basic and advanced life support: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2020;142:S469–523.
8. Moler FW, Meert K, Donaldson AE, Nadkarni V, Brilli RJ, Dalton HJ, et al. In-hospital versus out-of-hospital pediatric cardiac arrest: A multicenter cohort study. Crit Care Med 2009;37(7):2259–67.
9. deCaen AR, Garcia Guerra G, Maconochie I. Intubation during pediatric CPR: Early, late, or not at all? JAMA 2016;316:1772–4.
10. Lavonas EJ, Ohshimo S, Nation K, Van de Voorde P, Nuthall G, Maconochie I, et al. Advanced airway interventions for paediatric cardiac arrest: A systematic review and meta-analysis. Resuscitation 2019;138:114–28.
11. Andersen LW, Raymond TT, Berg RA, Nadkarni VM, Grossestreuer AV, Kurth T, et al. Association between tracheal intubation during pediatric in-hospital cardiac arrest and survival. JAMA 2016;316(17):1786–97.
12. Hansen ML, Lin A, Eriksson C, Daya M, McNally B, Fu R, et al. A comparison of pediatric airway management techniques during out-of-hospital cardiac arrest using the CARES database. Resuscitation 2017;120:51–6.
13. Ohashi-Fukuda N, Fukuda T, Doi K, Morimura N. Effect of prehospital advanced airway management for pediatric out-of-hospital cardiac arrest. Resuscitation 2017;114:66–72.
14. Gausche M. Effet of Out of hospital pediatric endotracheal intubation on survival and neurological outcome. JAMA 2000;283:783–91.
15. Jabre P, Penaloza A, Pinero D, Duchateau F-X, Borron SW, Javaudin F, et al. Effect of bag-mask ventilation vs endotracheal intubation during cardiopulmonary resuscitation on neurological outcome after out-of-hospital cardiorespiratory arrest. JAMA 2018;319:779–87.
16. Donoghue A, Hsieh T-C, Nishisaki A, Myers S. Tracheal intubation during pediatric cardiopulmonary resuscitation: A videography-based assessment in an emergency department resuscitation room. Resuscitation 2016;99:38–43.
17. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, et al. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. The Lancet 2010;375(9723):1347–54.
18. Sagarin MJ, Chiang V, Sakles JC, Barton ED, Wolfe RE, Vissers RJ, et al. Rapid sequence intubation for pediatric emergency airway management. Pediatr Emerg Care 2002;18(6):417–23.
19. Adnet F, Lapostolle F. International EMS systems: France. Resuscitation 2004;63(1):7–9.
20. Javaudin F, Penverne Y, Montassier E. Organisation of prehospital care: the French experience. Eur J Emerg Med 2020;27:404–5.
21. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa). Resuscitation 2004;63(3):233–49.
22. Hubert H, Tazarourte K, Wiel E, Zitouni D, Vilhelm C, Escutnaire J, et al. Rationale, methodology, implementation, and first results of the French out-of-hospital cardiac arrest registry. Prehospital Emerg Care 2014;18(4):511–9.
23. van Buuren S. Multiple imputation of discrete and continuous data by fully conditional specification. Stat Methods Med Res 2007;16(3):219–42.
24. Elze MC, Gregson J, Baber U, Williamson E, Sartori S, Mehran R, et al. Comparison of propensity score methods and covariate adjustment: Evaluation in 4 cardiovascular studies. J Am Coll Cardiol 2017;69(3):345–57.
25. Javaudin F, Lascarrou J-B, Le Bastard Q, Bourry Q, Latour C, De Carvalho H, et al. Thrombolysis during resuscitation for out-of-hospital cardiac arrest caused by pulmonary embolism increases 30-day survival: Findings from the French National Cardiac Arrest Registry. Chest 2019;156(6):1167–75.
26. Mamdani M, Sykora K, Li P, Normand S-L, Streiner DL, Austin PC, Rochon PA, Anderson GM. Reader's guide to critical appraisal of cohort studies: 2. Assessing potential for confounding. BMJ 2005;330(7497):960–2.
27. Brookhart MA, Schneeweiss S, Rothman KJ, Glynn RJ, Avorn J, Stürmer T. Variable selection for propensity score models. Am J Epidemiol 2006;163:1149–56.
28. Naim MY, Burke RV, McNally BF, Song L, Griffis HM, Berg RA, et al. Association of bystander cardiopulmonary resuscitation with overall and neurologically favorable survival after pediatric out-of-hospital cardiac arrest in the United States: A report from the cardiac arrest registry to enhance survival surveillance registry. JAMA Pediatr 2017;171:133–41.
29. Fukuda T, Sekiguchi H, Taira T, Hashizume N, Kitamura Y, Terada T, et al. Type of advanced airway and survival after pediatric out-of-hospital cardiac arrest. Resuscitation 2020;150:145–53.
30. Escutnaire J, Genin M, Babykina E, Dumont C, Javaudin F, Baert V, et al. Traumatic cardiac arrest is associated with lower survival rate vs. medical cardiac arrest – Results from the French national registry. Resuscitation 2018;131:48–54.
31. Wang HE, Simeone SJ, Weaver MD, Callaway CW. Interruptions in cardiopulmonary resuscitation from paramedic endotracheal intubation. Ann Emerg Med 2009;54(5):645–652.e1.
32. Andersen LW, Berg KM, Saindon BZ, Massaro JM, Raymond TT, Berg RA, et al. Time to epinephrine and survival after pediatric in-hospital cardiac arrest. JAMA 2015;314:802–10.
33. Zhan L, Yang LJ, Huang Y, He Q, Liu GJ. Continuous chest compression versus interrupted chest compression for cardiopulmonary resuscitation of non-asphyxial out-of-hospital cardiac arrest. Cochrane Database Syst Rev 2017;3:CD10134.
34. Brouwer TF, Walker RG, Chapman FW, Koster RW. Association between chest compression interruptions and clinical outcomes of ventricular fibrillation out-of-hospital cardiac arrest. Circulation 2015;132(11):1030–7.
35. Austin PC. The use of propensity score methods with survival or time-to-event outcomes: reporting measures of effect similar to those used in randomized experiments. Stat Med 2014;33(7):1242–58.

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