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Clinical paper

Does endotracheal intubation increase chest compression fraction in out of hospital cardiac arrest: A substudy of the CAAM trial



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Abstract

Background: Optimal out of hospital cardiac arrest (OHCA) airway management strategies remain unclear. We compared chest compression fraction (CCF) between patients receiving endotracheal intubation (ETI) versus bag mask ventilation (BMV).

Methods: We studied adult OHCA enrolled from our center in the CAAM trial. Primary exposures were ETI or BMV. Primary outcome was whole intervention CCF, adjusted for Utstein confounders. Secondary outcomes were per cycle CCF, no flow time associated (NFT) with ventilation, rhythms checks and mechanical chest compression device placement.

Results: Of 2040 OHCA enrolled in the CAAM trial we analyzed 112 cases recruited by our center. Unadjusted CCF was 0.89 for ETI and 0.88 for BMV ($p = 0.19$). Compared with BMV, ETI achieved lower NFT associated with ventilations (32 vs 127 s; $p < 0.001$). ETI cases experienced higher NFT associated with rhythm checks (69.5 vs 42.5 s; $p = 0.02$) and with mechanical chest compression placement (29 vs 20 s; $p = 0.04$). CCF was higher during the first cycle in BMV than in ETI patients (0.81 vs 0.74; $p = 0.02$). After correction for confounders we observed no difference in global intervention CCF between the ETI and BMV (Δ CCF [ETI-BMV] 0.301; [95%CI: -1.9 to 2.51]; $p = 0.79$).

Conclusion: In our substudy whole intervention CCF among OHCA was not modified by ETI compared to BMV. In the ETI group we observed lower NFT associated with ventilations and higher NFT associated with mechanical chest compression devices placement. CCF was lower in the ETI group during the first cycle.

Keywords: Adult cardiac arrest, Airway management, Endotracheal intubation, Chest compression fraction, Bag mask ventilation

Introduction

Minimally interrupted high quality chest compressions are critical to achieve return of spontaneous circulation (ROSC) and improve the likelihood of survival to hospital discharge as emphasized by both European resuscitation council and American heart association.^{1,2} Brief interruptions of chest compressions adversely affect hemodynamic and are associated with prolonged decreases in both cerebral and coronary perfusion pressure.³ Even when delivered according to

guidelines CPR is inherently inefficient as it provides only 10%–30% of normal blood flow to the heart and 30%–40% of baseline blood flow to the brain.^{4,5} Quality indicators of CPR such as chest compression fraction (CCF), chest compression rate, chest compression depth and peri-shock pauses have all been associated with improved outcome in out-of-hospital cardiac arrest (OHCA).^{6–9} Despite widespread emphasis put on minimally interrupted high quality chest compressions, and the evidence supporting their association with good neurological outcome^{6,10} these quality benchmarks remain difficult to achieve in out-of-hospital cardiac arrest.^{11,12} While a substantial bulk of evidence on

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optimal chest compression supports high quality chest compressions during CPR weaker levels of evidence supports current advanced airway management recommendations.¹ Endotracheal tube placement theoretically protects the airway and allows uninterrupted chest compressions.¹³ In-hospital endotracheal intubation has been associated with improved CCF when compared to bag-valve-mask ventilation.¹⁴ Nevertheless ETI has been associated in OHCA with prolonged interruptions in chest compressions and reduced CCF. One study in OHCA showed median of CPR interruptions associated with endotracheal tube placement as high as 109.5 s (IQR 54–198), representing 22.1% of all CPR pauses, therefore reducing whole-intervention CCF.¹⁵ Recent literature shows no evidence in support of routine endotracheal tube placement in terms of intact neurological outcome at 28 days for both in-hospital¹⁶ and out-of-hospital cardiac arrest.^{17,18,19} The objective of this study was to evaluate whether endotracheal tube placement was associated with a reduction in CCF compared to bag-valve-mask ventilation during episodes of resuscitation.

Methods

Study design

This study was a secondary analysis of data prospectively collected as part of the Cardiac arrest airway management (CAAM) trial. The CAAM study was conducted under European regulations. In accordance to these regulations the boards waived the requirement for obtaining informed consent because of the emergency setting of the research. However, deferred consent from the patient or relatives was required. The population, design, and results of the primary analyses of the CAAM trial have been reported elsewhere.¹⁹ CPR process data prospectively collected from our centre detailing second by second thoracic impedance were cleaned and error checked prior to consolidation with the CAAM dataset. The study protocol was reviewed and approved by the Institutional Review Board for Human Research at our institution. Our ethical committee waived the requirement for obtaining informed consent from patients because of the retrospective and observational setting of the research.

Study setting

CAAM was a multicentre trial involving 15 centres in France and five in Belgium. The Centre Hospitalier Universitaire Saint Pierre included 115 patients in the trial and prospectively recorded CPR quality indicators for 112 patients constituting the cohort of this secondary analysis. CPR process data was collected by either changes in thoracic impedance recorded from external defibrillation electrodes or via an accelerometer interface depending on provider discretion or local medical direction and not dictated by study protocol. The defibrillator used was a Corpuls 3 (GS Elektromedizinische Geräte G. Stemple, Kaufering, Germany) allowing for continuous ambient voice recording during CPR.

Methods of measurement

The CAAM study followed uniform data collection and reporting guidelines according to Utstein standards. Prehospital care provided was described on electronic care reports, including details of airway and resuscitation management. Digital process recordings of the

whole duration of the resuscitation after the arrival of the ALS team, or the first 40 min of CPR, whichever was the shortest, were evaluated for the presence and frequency of chest compressions. Continuous ambient voice recording were used to characterize identified pauses in CPR from digital process recordings. CPR cycle duration was considered to be 2 min long and counting started at the moment when the ALS team applied the defibrillation pads on the patient.

Outcome measures

The primary outcome of this analysis was chest compression fraction (CCF), defined as the proportion of each elapsed minute of treatment with active chest compressions. The method of CPR performance (i.e., manual or mechanically assisted) was left to the providing physician. Active chest compressions were defined as any detectable attempt to compress the chest, regardless of quality. Any pause of greater than two seconds was considered an interruption for the purposes of calculating CCF and categorized according to pre-specified categories based on the vocal ambient recording. CCF was measured during the entire resuscitation up to a maximum of 40 min. We limited the analysis at 40 min in order to avoid a drift of the results due to few very long resuscitation attempts hindering the generalizability of the results. CCF was measured after the application of the defibrillation pads on the patient, allowing for impedance measurement. All pauses were included in the analysis regardless of their appropriateness or whether the cause could be identified.

The key exposure was the type of ventilation strategy applied to the patient defined as endotracheal intubation (ETI) or bag mask ventilation (BMV). The BMV strategy allowed for rescue ET placement in cases when standard BMV was impossible, or in case of massive regurgitation of gastric contents during ventilation.¹⁹ Covariates used for risk adjustment included age, sex, BMI, presence of a shockable rhythm, duration of the resuscitation attempt and utilization of a mechanical compression devices.

Statistical analysis

Based on a previous out-of-hospital CPR study²⁰ (average CCF 0.71, standard deviation 0.14) we calculated we would have required 42 patients in each arm to detect a 0.1 difference in CCF with a 90% power. We therefore proceeded to the analysis of our sample of 112 patients given its relevance. Quality of CPR was analysed comparing CCF during the whole resuscitation manoeuvre. A subsequent analysis comparing CCF cycle by cycle was performed. We compared the average no flow time associated with a mechanical chest compression device placement, the per minute average of no flow associated with rhythm checks and the per minute average of no flow associated with ventilations. Data were assessed for normality using a Shapiro-Wilk test. Whenever analysing normally distributed data were compared by unpaired t-tests, non-parametric data were analysed by unpaired Mann-Whitney U-test. Finally we fit a linear multivariable model testing the association between CCF and airway strategy and adjusted the estimates for other measured confounding factors such as such as age, sex, BMI, bystander CPR, presence of a shockable rhythm, duration of the resuscitation attempt and utilization of mechanical compression devices. To analyse temporal differences in CPR quality over time, we included a 'before and after insertion' effects for BMV group. The median time of insertion of ETI (360 s, IQR range 210–560) was used as the cut point for before and after insertion in BMV group. Analysis was conducted using Stata 13.0 (Stata Corp Lakeway Dr, College Station, TX, USA).

Results

Our study enrolled a population of 112 adult patients. 54 were randomised by the original study to BMV and 58 to ETI. There was no significant difference in baseline characteristics between the two groups (Table 1).

The mean duration of the ALS CPR was 18.2 (± 10.5) min for the BMV group and 19.4 (± 10.7) min for the ETI group. The CCF of the whole intervention was not significantly different between the 2 groups (BMV vs ETI: 0.880 vs 0.890) (Table 2). When analysing CCF cycle by cycle we observed a lower CCF in the group randomized to a ETI strategy during the first cycle compared to the group randomized to a BMV strategy (0.81 vs 0.74; $p = 0.02$). During the 4th, 5th, 6th, 8th, 9th, 10th and 15th cycle CCF was significantly higher in the ETI than in the BMV group (Fig. 1).

The no flow time (NFT) associated with ventilation was higher in the BMV group compared to the ETI group (127.5 vs 32 s; $p < 0.001$). Accordingly the per-minute of ALS no flow time associated with ventilations was also higher in the BMV group (8.2 vs 1.9 s; $p < 0.001$) (Table 2). The no flow time associated with mechanical chest compression device (LUCAS[®]) placement was higher in the ETI group (29 vs 20 s; $p = 0.04$). Finally the no flow time associated with rhythm checks was higher in the ETI group (69.5 vs 42.5 s; $p = 0.02$) but this difference was not anymore significant when comparing the ratio between no flow time associated with rhythm checks and duration of ALS (3.8 vs 2.7 s; $p = 0.05$).

When comparing before and after ETI, ETI led to a significant increase in CCF (Δ CCF [after–before] 0.12; $p < 0.001$) (Fig. 2) while no differences were observed in the BMV group (Δ CCF [after–before]

0.02; $p = 0.717$). This difference persisted after adjustment for measured confounders (Table 3). Nevertheless the group randomized to ETI placement had a lower CCF compared to BMV before the insertion of the ET (Δ CCF [ETI–BMV] -0.033; $p = 0.02$) (Table 3).

After adjusting for all measured confounders such as age, sex, BMI, presence of a witness, presence of a shockable rhythm, ALS duration and use of a mechanical chest device no differences in terms of CCF for the entire resuscitation were detected between the two groups ($p = 0.79$) (Table 3).

No significant differences were observed between the two groups in terms of ROSC (BMV vs ETI: 19 (35.2%) vs 29 (50%)), being alive at hospital arrival (BMV vs ETI: 22 (40.7%) vs 28 (48.3%)) and survival at 28 days (BMV vs ETI: 8 (14.8%) vs 5 (8.6%)). Within survivors 3 patients from the BMV group and 5 from the ETI group had a good cerebral performance at 28 days (CPC 1 and 2; $p = 0.529$). (Table 4 Supplementary material).

Discussion

In this single centre substudy of the CAAM trial, a large randomized trial specifically designed to evaluate the impact of ETI versus BMV on survival, we observed that patients who were intubated did not have an associated increase in CCF over the entire duration of resuscitation when compared to patients managed with a BVM. As expected ETI was associated with a significant reduction in no flow time associated with ventilations. The per-minute no flow time associated with ventilations dramatically dropped from 8.2 s in the BMV group to 1.9 in the ETI. Nevertheless this did not result in the expected increase in CCF.

Table 1 – Characteristics of patients included in the ITT analysis.

	Bag mask ventilation	Endotracheal intubation	p Value
Number of observations	54	58	
Age, mean (SD), y	63.2 (16.4)	63.3 (16.8)	0.976
Female, No. (%)	14 (25.9)	19 (32.8)	0.428
BMI, median (IQR)	27.8 (23.5–31.2)	27.8 (24.2–32.9)	0.792
Etiology of arrest, No. (%)			
Cardiac	46 (90.2)	50 (86.2)	
Traumatic	1 (2)	3 (5.2)	
Overdose	4 (7.8)	3 (5.2)	
Drowning	0 (0)	1 (1.7)	
Asphyxial	0 (0)	1 (1.7)	0.579
Bystander witnessed cardiac arrest, No. (%)	38 (70.4)	44 (75.8)	0.512
Bystander initiated CPR, No. (%)	15 (27.8)	19 (32.8)	0.567
Bystander initiated ventilation, No. (%)	5 (9.3)	9 (15.5)	0.317
No flow duration, median (IQR), min	6 (3–10)	5 (1–8)	0.285
Time from collapse to initiation of advanced life support, median (IQR), min	13 (11–18)	12 (11–15)	0.189
Shockable first rhythm, No. (%)	10 (18.5)	11 (19)	0.952
Use of mechanical chest compression device, No. (%)	23 (42.6)	27 (46.6)	0.674
Initial cardiac rhythm, No. (%)			
Ventricular tachycardia	0 (0)	0 (0)	
Ventricular fibrillation	10 (18.5)	11 (19)	
Pulseless electrical activity	9 (16.6)	9 (15.5)	
Asystole	35 (64.8)	38 (65.5)	0.986
Number of defibrillation events, median (IQR)	0 (0–1)	0 (0–1)	0.724

Abbreviations: BMI, body mass index; CPR, cardiopulmonary resuscitation; IQR, interquartile range; SD, standard deviation; ITT, intention-to-treat.

Table 2 – CRP metrics during ALS.

Number of observations	Bag mask ventilation 54	Endotracheal intubation 58	p Value
ALS CPR duration, mean (SD), min	18.2 (10.5)	19.4 (10.7)	0.35
Chest compression fraction, median (IQR)	0.880 (0.836–0.902)	0.890 (0.850–0.920)	0.19
No flow time associated with ventilation, median (IQR), sec	127.5 (52–171)	32 (18–55)	<0.001
No flow time associated with rhythm checks, median (IQR), sec	42.5 (17–89)	69.5 (36–111)	0.02
No flow time associated with endotracheal intubation, median (IQR), sec	27.5 (9.5–42)	0 (0–20)	0.07
No flow time associated with MCCD placement, median (IQR), sec	20 (11–28)	29 (18–40)	0.04
ET placement attempts, median (IQR)	1 (1–1)	1 (1–1)	0.89
Per minute of ALS no flow time associated with ventilation, median (IQR)	8.2 (5.2–9)	1.9 (1–4)	<0.001
Per minute of ALS no flow time associated with rhythm checks, median (IQR)	2.7 (1.7–5)	3.8 (2.7–6.2)	0.05

Abbreviations: ALS, advanced life support; CPR, cardiopulmonary resuscitation; SD, standard deviation; IQR, interquartile range; MCCD, mechanical chest compression device; ET, endotracheal tube.

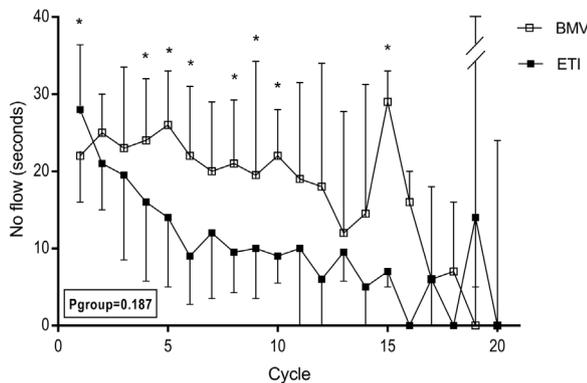


Fig. 1 – The effect of ETI on no flow time. Repeated-measures multivariate model on the effect of ETI placement on per cycle no flow time. Squares represent median including error bars for 95% confidence limits. Asterisks indicate a significant interaction between groups at each time point. Pgroup represents the overall difference between ETI and BMV. Abbreviations: BMV bag mask ventilation, ETI endotracheal tube placement.

We formulated multiple hypotheses based on our observations to explain this unexpected result. First we observed a significantly higher no flow time in the ETI group associated with mechanical chest compression device placement. This might suggest that ET and eventually the connected ventilator might obstruct or complicate the placement of a mechanical chest compression device.

Second we observed that ETI is associated with a significant increase in total NFT associated with rhythm checks. This result might be due to the fact that experienced clinicians use the pauses associated with bag-mask ventilations to perform rhythm checks. This practice in bag-mask ventilated patients virtually suppresses the need for additional pauses associated with rhythm and pulse checks as long as the patient is in asystole. Despite this difference observed when analysing total NFT associated with rhythm checks there was no significant difference when comparing the per-minute of ALS NFT associated with rhythm checks suggesting that part of the difference between the two groups might be driven by differences in the length of ALS.

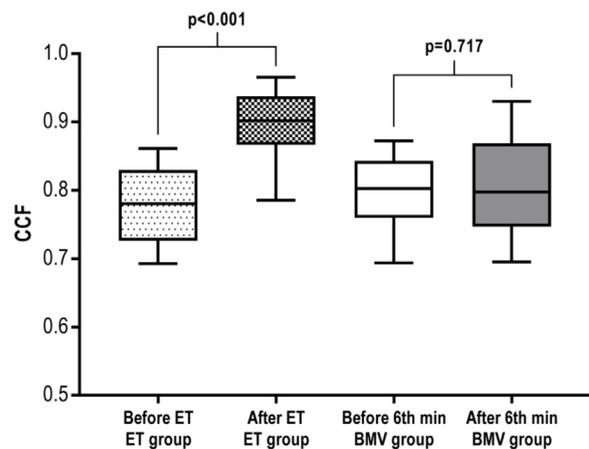


Fig. 2 – The effect of ETI on CCF. Before/after model on the effect of ETI placement on CCF. Boxes represent median and 2th–75th percentile including error bars for 10th–90th percentile. p values for Mann-Whitney U test are shown. The median time of insertion of ETI (360 s) was used as the cut point for before and after insertion in BVM group. Abbreviations: BMV bag mask ventilation, ETI endotracheal tube, CCF chest compression fraction.

Finally ETI was associated with an additional no flow time due to the placement of the ET. Performing direct laryngoscopy for ETI without interrupting CPR requires a high level of operator skill and might be associated with significant no flow even in highly experienced doctors.²¹ Despite observing a median no flow time of 0 s meaning that at least half of the ETI placements were done without any pause in CPR our study showed a mean time for ETI of 12 s, higher than recommended from guidelines.¹ Moreover CCF was significantly lower in the ETI group before ET insertion compared to the same period in the BMV group. This could suggest that the preparation of the material for ETI as well as the environmental preparation for ETI placement such as patient positioning and clearance of sufficient space at the head of the patient for the doctor performing the ETI is associated with a reduction in CCF.

When analysing the data on a before–after ET insertion basis we observed a lower CCF in the ETI group by 3.3% compared to BMV during

Table 3 – Multivariable analysis on ETI impact on CCF adjusted chest compression fraction and out of hospital cardiac arrest airway management. Coefficient estimates are adjusted for age (continuous), BMI (continuous), ALS duration (continuous) bystander CPR (bystander attempted vs. not attempted), initial shockable rhythm (VF/VT vs PEA/asystole), mechanical chest compression device (mechanical chest compression device placement vs hands only CPR).

	Before ETI	p Value	After ETI	p Value	Global ALS intervention	p Value
Δ CCF (ETI-BMV); (95%CI)	–0.033 (–0.06, –0.005)	0.02	0.072 (0.043, 0.101)	<0.001	0.003 (–0.019–0.025)	0.787

Abbreviations: ETI endotracheal tube insertion, CCF chest compression fraction, BMI body mass index, ALS advanced life support, CPR cardio pulmonary resuscitation, VT ventricular tachycardia, VF ventricular fibrillation, PEA pulseless electrical activity, CI confidence interval, BMV bag mask ventilation.

the period before ET insertion. Meanwhile, after ET insertion we observed a significant increase of CCF by 7.2% in the ETI group compared to BMV. As previously reported in the literature we observed that ETI was associated with an improvement in CCF when comparing CCF before and after ET insertion.¹⁴ Nevertheless this was not associated with an increase in CCF when evaluating the whole ALS intervention.

Finally, when comparing the no flow time from the two groups over subsequent cycles we observed a higher no flow time during the first cycle in the ETI group. Given that the median time for ET insertion was 360 s (IQR 210–564) during the first cycle of ALS most of the patients randomized to ETI were actually receiving BMV. The difference in terms of CCF might be driven by the difficulty in initially providing a high quality CPR while preparing the material and the patient for an early ET placement. Benefits in terms of NFT were apparent in the ETI group starting from the 4th cycle. This result deserves a special attention as it suggests that preparation for ET placement may reduce CCF during the very early phases of CPR.

Altogether our study shows that patients who were intubated did not have lower CCF when evaluated over the entire duration of CPR. This is in line with the results from the CAAM study showing no differences in terms of survival between the BMV and ETI groups. Given that the chances of survival to hospital discharge with a good neurological outcome decline rapidly with the duration of CPR²² it should be recommended to implement airways management strategies achieving a significantly higher CCF during the initial period of ALS. Given the lower CCF observed in the ETI group during the initial minutes of the ALS our data recommend against a strategy promoting a systematic ETI during early CPR.

Our study has both strengths and weaknesses. We performed a post-hoc analysis of a randomized trial specifically designed to evaluate the impact of ETI on survival. Although being a subgroup analysis of the original study, and therefore exposed to a potential selection bias, our study population was randomly allocated to the two groups therefore minimising biases and confounding factors. Second, CCF data were prospectively collected throughout the original trial minimising recall error and selection bias. All patients included in the trial had at least impedance and audio recording of the whole CPR event therefore eliminating a possible bias of non-randomly missing data. Its main weakness is the monocentric design and limited number of observations which potentially reduces the generalisability of our findings. Furthermore another weakness of our study is the limited generalizability to EMS systems that do not staff ambulances with physicians.

Conclusion

In our substudy from the CAAM trial an advanced airway strategy based on ETI did not increase CCF in OHCA when compared to a strategy based on BMV. While being associated with a reduction in pauses associated with ventilation, ETI was associated with an increase in pauses associated with rhythm checks and mechanical chest compression device placement.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resuscitation.2019.01.032>.

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