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Clinical Paper

The clinical significance of a failed initial intubation attempt during emergency department resuscitation of out-of-hospital cardiac arrest patients

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ABSTRACT

Objective: Advanced airway management is one of the fundamental skills of advanced cardiac life support (ACLS). A failed initial intubation attempt (FIIA) is common and has shown to be associated with adverse events. We analysed the association between FIIA and the overall effectiveness of ACLS.
Methods: Using emergency department (ED) out-of-hospital cardiac arrest (OHCA) registry data from 2008 to 2012, non-traumatic ED-resuscitated adult OHCA patients on whom endotracheal intubation was initially tried were identified. Prehospital and demographic factors and patient outcomes were retrieved from the registry. The presence of a FIIA was determined by reviewing nurse-documented CPR records. The primary outcome was achieving a return of spontaneous circulation (ROSC). The secondary outcomes were time to ROSC and the ROSC rate during the first 30 min of ED resuscitation.
Results: The study population ($n = 512$) was divided into two groups based on the presence of a FIIA ($N = 77$). Both groups were comparable without significant differences in demographic or prehospital factors. In the FIIA group, the unadjusted and adjusted odds ratios (ORs) for achieving a ROSC were 0.50 (95% confidence interval [CI], 0.31–0.81) and 0.40 (95% CI, 0.23–0.71), respectively. Multivariable median regression analysis revealed that FIIA was associated with an average delay of 3 min in the time to ROSC (3.08; 95% CI, 0.08–5.80). Competing risk regression analysis revealed a significantly slower ROSC rate during the first 15 min (adjusted subhazard ratio, 0.52; 95% CI, 0.35–0.79) in the FIIA group.
Conclusion: FIIA is an independent risk factor for the decreased effectiveness of ACLS.

1. Introduction

Advanced airway management is one of the fundamental skills of advanced cardiac life support (ACLS).[1,2] Endotracheal intubation is commonly employed to secure an airway during the emergency department (ED) resuscitation of out-of-hospital cardiac arrest (OHCA) patients. However, intubation is difficult to master and requires frequent repetition to maintain the skill.[3–7] The failure rate of first ED or first inhospital emergency intubation attempts varies from 20% to 32%,[8–10] and repeated intubation attempts are associated with various adverse events.[8–11] Similar findings might be expected in ED OHCA patients undergoing ACLS; however, information about the incidence and its association with outcomes in ED OHCA patients is currently unavailable.

The purpose of this study was to analyse the association between a failed initial intubation attempt (FIIA) event and the incidence of ROSC during CPR. We hypothesised that a FIIA may impair the overall effectiveness of ACLS, thus causing significant delay in ROSC as well as slower ROSC rate.

2. Materials and methods

This is a retrospective study of all OHCA patients from 2008 to 2012 on whom an endotracheal intubation was attempted as the initial choice of advanced airway during ED ACLS. The OHCA ED registry was the primary source of data for this study. The institutional review board at the study site approved the analysis and provided a waiver of informed consent.

2.1. Study setting

The study was conducted at a 950-bed tertiary hospital that was located in a city with an estimated population of 1,000,000.

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Prehospital emergency care in the city is provided by government-run fire service.[12] The level of prehospital care is primarily basic life support, and ED transfer is required for ACLS in most cases. Upon arrival to the ED, ACLS commences: chest compressions are immediately provided by duty EMTs, and airway management is provided by ED physicians. ED nurses primarily take care of inserting lines, administering drugs and logging CPR events. We follow the most up-to-date American Heart Association CPR guidelines, which were last updated in 2010.[2] Therefore, any interruption of chest compressions for advanced airway management is not allowed unless absolutely required. Any supraglottic airway placed during the prehospital course is routinely changed to an endotracheal tube at the beginning of ED resuscitation.

2.2. Participants, data collection and outcome measures

Using ED OHCA registry data[13,14] from 2008 to 2012, adult (aged ≥ 18) patients presenting with a non-traumatic OHCA who were resuscitated upon ED arrival because of prehospital resuscitation failure were identified. Patients without an initial intubation attempt in ED were excluded. Prehospital and demographic factors and patient outcomes were retrieved from the registry. The detailed definitions of the prehospital variables and the patient outcome measures are described in supplementary Table 1 (available online at the RESUSCITATION journal website). The presence of a FIIA was determined by reviewing nurse-documented CPR log sheets. The review process was done by a resuscitation researcher who was blinded to the patient long-term outcomes. The criteria for a FIIA were (1) any extubation after the first pass of the endotracheal tube during resuscitation, (2) any repeated advanced airway attempt regardless of its method after first intubation attempt or (3) any first intubation attempt described as "failure" in the CPR log sheets. The primary outcome was the overall chance of achieving a ROSC. Secondary outcomes were the time to ROSC and the ROSC rate during the first 30 min of ED resuscitation.

2.3. Statistical analysis

Student's *t*-test, Mann–Whitney test, Chi-square test and Fisher's exact test were performed, as appropriate, for comparisons between patient groups with and without a FIIA. Univariable and multivariable logistic regression analyses were performed to assess the unadjusted and adjusted associations between a FIIA and attaining a ROSC. Multivariable quantile regression analyses at 25th, 50th and 75th percentiles were conducted to determine the possible association between FIIA and time to ROSC during ED resuscitation. An analysis of the Fine and Gray regression models, accounting for the competing risk of resuscitation termination, was conducted to assess the association between a FIIA and the ROSC rate during the first and second 15 min of ED resuscitation.[15] The proportional hazards assumptions of the models were confirmed by examining plots of Schoenfeld residuals. The results of the logistic regression, quantile regression and Fine and Gray regression analyses were presented as odd ratios (ORs), regression coefficients (min/unit) and subhazard ratios (SHR), respectively, and their 95% confidence intervals (CIs) were also presented. *P*-values < 0.05 were considered significant. All analyses were performed using STATA 12 (StataCorp 113 LP, TX, USA).

3. Results

Among the 636 adult ED OHCA patients during the study period, 608 patients without a prehospital ROSC underwent ACLS upon ED arrival. After excluding patients with a traumatic cardiac arrest (n = 69, 11.3%) and cases without an initial intubation attempt (n = 31, 5.1%), 512 adult patients with a non-traumatic OHCA and an initial ED intubation attempt were included as the study population (Supplementary Fig. 1, available online at the RESUSCITATION journal website). Among the study population, 293 (57.23%, Table 1) patients had a ROSC. A total of 50 (9.8%) patients survived until discharge to home or a nursing care facility, and 24 (4.7%) patients had a favourable neurologic outcome (based on 6-month cerebral performance criteria 1 or 2).

Table 1
Patient characteristics of study population.

Age, years, median (IQR)	70 (54–79)
Sex, male, no. (%)	311 (60.7)
Witnessed, no. (%)	343 (67.0)
Public place, no. (%)	75 (14.6)
Shockable rhythm, no. (%)	63 (12.4)
Presumed cardiac aetiology, no. (%)	238 (46.5)
Bystander CPR, no. (%)	177 (34.6)
No-flow time, minutes, median (IQR)	6 (0–12)
Prehospital low-flow time, minutes, median (IQR)	16 (9–23)
Prehospital advanced airway[a]	
No advanced airway, no. (%)	498 (97.3)
LMA, no. (%)	8 (1.6)
E-tube, no. (%)	1 (0.2)
Unknown, no. (%)	5 (1.0)
Return of spontaneous circulation, no. (%)	293 (57.23)
Survival discharge, no. (%)	50 (9.8)
Good neurologic outcome[b], no. (%)	24 (4.7)

IQR, interquartile range; CPR, cardiopulmonary resuscitation; LMA, laryngeal mask airway; E-tube, endotracheal tube.
[a] Among the eight patients with prehospital LMA, seven patients were successfully changed to E-tube without any failed attempt at the beginning of ED resuscitation. The patient with prehospital E-tube was first intubated in a private clinic before his cardiac arrest which occurred during his transfer to study ED. He was successfully reintubated after one failed attempt.
[b] Cerebral performance criteria score 1 or 2.

Patients were divided into two groups according to whether a FIIA was present (FIIA group, n = 77, 15.0%; non-FIIA group, n = 435, 85.0%). The groups were comparable in their baseline characteristics, with no significant differences in their demographic and prehospital factors (Table 2). There was an absolute difference of 16.9% between the groups in achieving a ROSC (42.9% for the FIIA group vs. 59.8% for the non-FIIA group, p = 0.006). The difference between the groups in time to ROSC was almost significant (12 min for the FIIA group vs. 10 min for the non-FIIA group, p = 0.053), and there was no significant difference in the duration of ED resuscitation until CPR was terminated (30 min for the FIIA group vs. 30 min for the non-FIIA group, p = 0.981). There was no significant difference in the long-term outcomes, including patient survival to discharge (7.8% for FIIA group vs. 10.1% for non-FIIA group, p = 0.527) and the proportion of patients with good neurologic outcomes (6.5% for FIIA group vs. 4.4% for non-FIIA group, p = 0.416).

We conducted univariable and multivariable logistic regression analysis to investigate the association between a FIIA and attaining a ROSC (Table 3). With a FIIA, the unadjusted OR for a ROSC was 0.50 (95% CI, 0.31–0.81; p = 0.006). Multivariable logistic regression analysis revealed that a FIIA was independently associated with a decreased chance of a ROSC, with an OR of 0.40 (95% CI, 0.23–0.71; p = 0.002). Other significantly associated variables in the model were witnessed cardiac arrest (OR, 3.78; 95% CI, 2.46–5.79; p < 0.001), shockable initial rhythm (OR, 1.91; 95% CI, 1.01–3.63; p = 0.047), presumed cardiac aetiology (OR, 0.38; 95% CI, 0.25–0.58; p < 0.001), no-flow time (OR, 0.98 per 1 min; 95% CI, 0.96–1.00; p = 0.023) and prehospital low-flow time (OR, 0.97 per 1 min; 95% CI, 0.94–0.98; p < 0.001).

Fig. 1 depicts the incidence of ROSC in both groups during the first 30 min of ED resuscitation. In the figure, the divergence of the two incidence curves is observed during earlier ACLS period which rather suddenly decreases by the midpoint of this 30-min period. However, competing events of resuscitation termination

Table 2
Comparisons between the groups with and without FIIA.

	FIIA (N = 77)	No FIIA (N = 435)	p
Demographic and prehospital factors			
Age, years, median (IQR)	71 (54–78)	70 (54–79)	0.840
Sex, male, no. (%)	48 (62.3)	263 (60.5)	0.756
Witnessed, no. (%)	49 (63.6)	294 (67.6)	0.497
Public place, no. (%)	11 (14.3)	64 (14.7)	0.922
Shockable rhythm, no. (%)	10 (13.0)	53 (12.2)	0.823
Presumed cardiac aetiology, no. (%)	32 (41.6)	206 (47.4)	0.347
Bystander CPR, no. (%)	28 (36.4)	149 (34.3)	0.720
No-flow time, minutes, median (IQR)	7 (0–16)	6 (0–12)	0.586
Prehospital low-flow time, minutes, median (IQR)	16 (10–22)	16 (9–23)	0.921
Number of failed advanced airway attempt including FIAA			
One failed attempt, no. (%)	62 (80.5)		
Two or more failed attempts, no. (%)	15 (19.5)		
Resuscitation outcomes			
ROSC, no. (%)	33 (42.9)	260 (59.8)	0.006
Time to ROSC in ED, minutes, median (IQR)	12 (10–18)	10 (6–15)	0.053
Time to CPR termination, minutes, median (IQR)	30 (17–34)	30 (22–32)	0.981
Survival discharge, no. (%)	6 (7.8)	44 (10.1)	0.527
Good neurologic outcome, no. (%)	5 (6.5)	19 (4.4)	0.416

FIIA, failed initial intubation attempt; IQR, interquartile range; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; ED, emergency department.

Table 3
Multivariable logistic regression model of ED ROSC achievement.

	Odds ratio (95% CI)	p
Failed initial intubation attempt	0.40 (0.23–0.71)	0.002
Age, per 1 year	1.00 (0.99–1.02)	0.547
Sex, male	0.89 (0.59–1.35)	0.591
Witnessed cardiac arrest	3.78 (2.46–5.79)	<0.001
Public place	1.79 (0.99–3.24)	0.054
Shockable initial rhythm	1.91 (1.01–3.63)	0.047
Presumed cardiac aetiology	0.38 (0.25–0.58)	<0.001
Bystander CPR	1.43 (0.86–2.37)	0.168
No-flow time, per 1 min	0.98 (0.96–1.00)	0.023
Prehospital low-flow time, per 1 min	0.96 (0.94–0.98)	<0.001

ED, emergency department; ROSC, return of spontaneous circulation; OR, odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.

without ROSC prohibited a direct comparison between the groups using a log-rank test or Cox regression analysis. Therefore, we compared the duration of resuscitation until a ROSC using a multivariable quantile regression analysis and the incidence rate of ROSC using a Fine and Gray regression analysis which accounts for the risk of a competing event to prove that the presence of a FIIA is associated with both an increased time to ROSC and a decreased incidence rate of ROSC during the early resuscitation period. The multivariable quantile regression analysis (Supplementary Table 2, available online at the RESUSCITATION journal website) revealed a significant overall delay in the time until ROSC in the FIIA group (2.94 min at the 50th percentile; 95% CI, 0.08–5.80; p = 0.044). However, this difference was only significant in patients with a relatively short time to ROSC (3.08 min at the 25th percentile; p = 0.011). For a direct comparison of incidence rate of ROSC between the groups, we constructed univariable and multivariable Fine and Gray regression models for the first and second 15 min of ED resuscitation (Table 4 and Fig. 2). An analysis of the models showed that the presence of a FIIA was associated with a slower ROSC rate during the first 15 min of ED resuscitation, with an unadjusted SHR of 0.56 (95% CI, 0.37–0.85; p = 0.006) and an adjusted SHR of 0.52 (95% CI, 0.35–0.79; p = 0.002) for a ROSC event. However, during the second 15 min, no significant association between a FIIA and the ROSC rate was observed (unadjusted SHR: 0.95; 95% CI, 0.47–1.90; p = 0.876; adjusted SHR: 0.80; 95% CI, 0.39–1.65; p = 0.545; number of patients analysed = 272), as might be intuitively expected from examining Fig. 1.

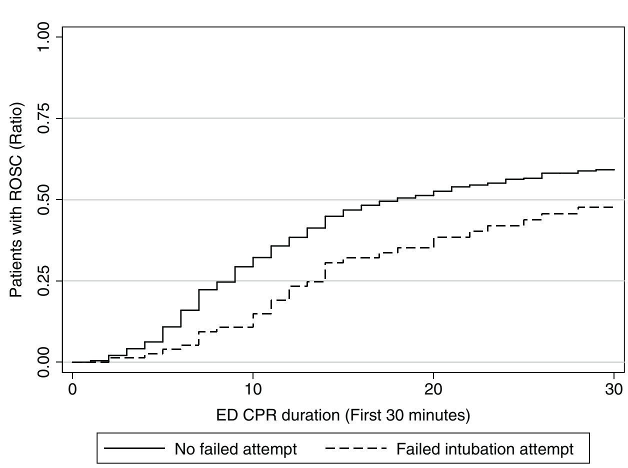

Fig. 1. The unadjusted cumulative incidence of ROSC during the first 30 min of resuscitation in the FIIA group (solid line) and the non-FIIA group (dashed line).

4. Discussion

In this study, a FIIA was independently associated with a decreased chance of a ROSC in ED patients with an OHCA. FIIA was also independently associated with a significant increase in the time to ROSC and a slower ROSC rate during the first 15 min of ED resuscitation. Overall, it seems that FIIAs by ED physicians significantly decrease the efficacy of ACLS, especially during early phase of ED resuscitation.

Over the past few years, the role of advanced airway management in resuscitation for cardiac arrest has been de-emphasised. Previous retrospective studies have indicated that advanced airway management during the prehospital course do more harm than good.[16–19] This lack of benefit might arise due to the risks incurred by the EMTs' relatively poor airway management skills, interruptions of chest compression and overzealous ventilatory efforts after a successful intubation exceed the benefit provided by the improved gas exchange achieved with functioning advanced airways. Therefore, it is reasonable to defer advanced airway

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Table 4
Multivariable competing risk regression models for ROSC incidence rate during first and second 15 min of ED resuscitation.

	First 15 min		Second 15 min	
	Subhazard ratio (95% CI)	*p*	Subhazard ratio (95% CI)	*p*
Failed initial intubation attempt	0.52 (0.35–0.79)	0.002	0.80 (0.39–1.65)	0.545
Age, per 1 year	0.99 (0.99–1.00)	0.157	1.01 (0.99–1.02)	0.341
Sex, male	0.87 (0.66–1.14)	0.307	1.09 (0.60–1.96)	0.782
Witnessed cardiac arrest	1.85 (1.32–2.61)	<0.001	3.71 (1.67–8.20)	0.001
Public place	1.55 (1.09–2.21)	0.015	0.94 (0.38–2.30)	0.889
Shockable initial rhythm	1.35 (0.89–2.04)	0.164	1.60 (0.70–3.65)	0.263
Presumed cardiac aetiology	0.57 (0.43–0.76)	<0.001	0.50 (0.27–0.92)	0.026
Bystander CPR	1.16 (0.84–1.61)	0.359	0.99 (0.46–2.13)	0.982
No-flow time, per 1 min	0.98 (0.97–1.00)	0.010	1.00 (0.97–1.02)	0.724
Prehospital low-flow time, per 1 min	0.98 (0.97–0.99)	0.004	0.96 (0.92–1.00)	0.031

ROSC, return of spontaneous circulation; ED, emergency department; CI, confidence interval; CPR, cardiopulmonary resuscitation

management during prehospital resuscitation unless it is absolutely necessary.

However, advanced airway management remains a key component of ACLS.[20] During ACLS in the ED, the benefit of advanced airway management might exceed its potential harm for the following reasons. First, prolonged prehospital CPR can lead to significant pulmonary and skeletal injuries, including pulmonary oedema, lung contusions and fractures of the ribs and sternum;[21–26] these injuries most likely impair both oxygenation and ventilation during subsequent resuscitation in the ED. Indeed, even in recent preclinical studies advocating compression-only CPR over standard 30:2 CPR, a progressive increase in the arterial pCO_2 levels and a decrease in the pulmonary ventilation/perfusion ratios were observed during the first 12–14 min, regardless of the CPR method.[27,28] Considering the prehospital low-flow time in this study (16 min; IQR, 9–23 min), we believe that a significant proportion of ED OHCA patients might be subjected to significantly impaired oxygenation and ventilation to a critical point where a ROSC is difficult[29–31] unless ventilation is assisted using an advanced airway. Second, there is usually a wider variety and greater number of staff in an ED compared to the prehospital field. Trained physicians are usually available in most EDs, and intubating physicians can focus on the procedure, while the other ED staffs such as registered EMTs or nurses focus on performing chest compressions, placing lines and administering medications. Third, multiple tools that can facilitate and confirm safe endotracheal intubation such as video laryngoscopes and $EtCO_2$ monitors are frequently available in EDs.

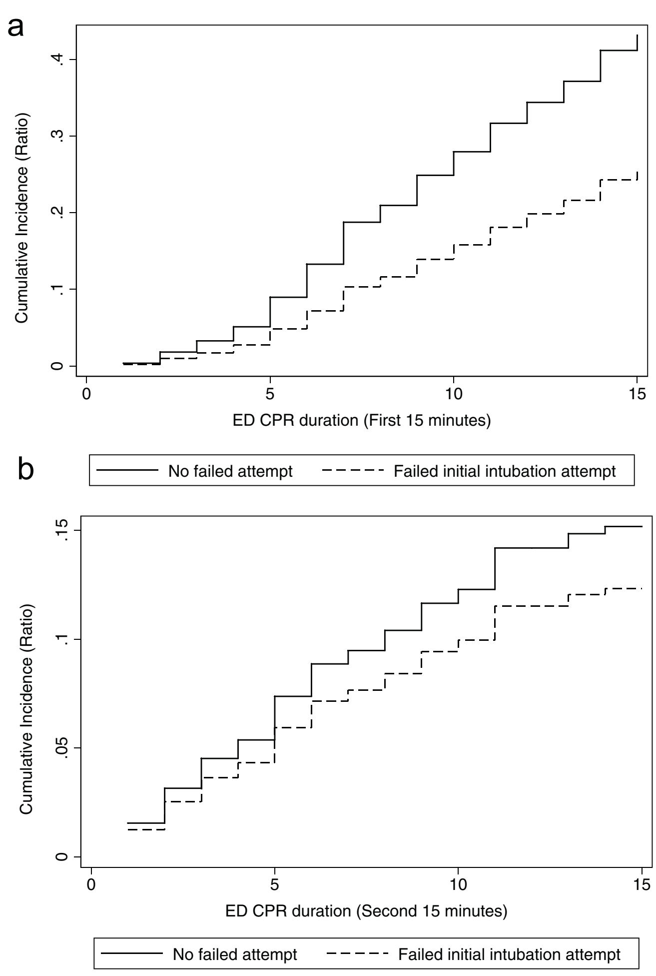

Fig. 2. The cumulative incidence of ROSC in the FIIA group and the non-FIIA group during the first (A) and second (B) 15 min of resuscitation, after adjusting for the competing risk of resuscitation termination and other potential confounding variables. The ROSC rate in the FIIA group was significantly slower during the earlier resuscitation period (first 15 min: adjusted SHR, 0.52; 95% CI, 0.35–0.79; $p = 0.002$; second 15 min: adjusted SHR, 0.80; 95% CI, 0.39–1.65; $p = 0.545$).

Our study only suggests that a FIIA is significantly associated with the decreased efficacy of ACLS in the ED; it does not address whether advanced airway management is a net benefit in such a situation. The prolonged intubation attempt in the FIIA group could have caused significant interruption of CPR with reduced hands-on chest time. However, our results do indicate that once advanced airway management is attempted during CPR, a successful clean first-pass intubation is important for a ROSC. We think that a successful clean first-pass intubation, particularly during chest compression, should be emphasised in emergency medicine education.

In this study, the slower ROSC rate in the FIIA group was significant only during the early ED resuscitation period (within the first 15 min), which might be due to the eventual success in placing an advanced airway after a FIIA. Similarly, the improved proportion of patients with a ROSC in the first-pass success group did not correspond to improved long-term outcomes, e.g., survival to discharge or a good CPC, possibly because the beneficial effect of first-pass intubation success is important only in patients with gas exchange abnormalities so severe that irreversible ischaemic brain damage has most likely occurred by the time of arrival to the ED. Another possible explanation is that the sample size of this study was too small to detect a real long-term difference. Because a ROSC is a prerequisite for long-term survival and good neurologic outcome, it is possible that a larger study could detect a harmful effect of a FIIA on long-term patient outcomes.

This study has several limitations. First, the results of this study are based on a retrospective analysis of an OHCA registry and the medical records of a single ED; the study is thus limited by the possible biases that are intrinsic to such a design. Second, the presence of a FIIA was determined by reviewing the CPR log sheets recorded by ED nurses rather than a review of airway management-oriented records. Third, it is impossible to determine whether the harmful effects associated with a FIIA are due to insufficient gas exchange. A FIIA could distract the whole CPR team and delay important management or decisions. Fourth, a detailed analysis of the association between failed intubation attempts and long-term outcomes was not possible because the number of cases with a good outcome in FIIA group was too small.[32]

5. Conclusion

A failed initial intubation attempt in the ED was an independent risk factor for the decreased effectiveness of ACLS in OHCA patients resuscitated in the ED.

Conflict of interest statement

The authors have no conflict of interest.

Source of funding

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2014.01.017.

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