

The suction-assisted laryngoscopy assisted decontamination technique toward successful intubation during massive vomiting simulation

A pilot before–after study

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Abstract

This study demonstrated a training program of the suction-assisted laryngoscopy assisted decontamination (S.A.L.A.D.) technique for emergency medical technician paramedic (EMT-P). The effectiveness of the training program on the improvements of skills and confidence in managing soiled airway was evaluated.

In this pilot before–after study, 41 EMT-P participated in a training program which consisted of 1 training course and 3 evaluation scenarios. The training course included lectures, demonstration, and practice and focused on how to perform endotracheal intubation in soiled airway with the S.A.L.A.D technique. The first scenario was performed on standard airway mannequin head with clean airway (control scenario). The second scenario (pre-training scenario) and the third scenario (post-training scenario) were performed in airway with simulated massive vomiting. The post-training scenario was applied immediately after the training course. All trainees were requested to perform endotracheal intubation for 3 times in each scenario. The “pass” of a scenario was defined as more than twice successful intubation in a scenario. The intubation time, count of successful intubation, pass rate, and the confidence in endotracheal intubation were evaluated.

The intubation time in the post-training scenario was significantly shorter than that in the pre-training scenario ($P = .031$). The pass rate of the control, pre-training, and post-training scenario was 100%, 82.9%, and 92.7%, respectively. The proportion of trainees reporting confident or very confident in endotracheal intubation in soiled airway increased from 22.0% to 97.6% after the training program. Kaplan–Meier analysis revealed that the adjusted hazard ratio of successful intubation for post-training versus pre-training scenario was 2.13 (95% confidence interval of 1.57–2.91).

The S.A.L.A.D. technique training could efficiently help EMT-P performing endotracheal intubation during massive vomiting simulation.

Abbreviations: BMV = bag-mask ventilation, EMS = emergency medical services, EMT = emergency medical technician, EMT-P = emergency medical technician paramedic, IQR = interquartile range, OHCA = out-of-hospital cardiac arrest, S.A.L.A.D. = suction-assisted laryngoscopy assisted decontamination.

Keywords: emergency airway management, emergency medical technicians, endotracheal intubation, suction-assisted airway management

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1. Introduction

Establishment of a secure airway as soon as possible during resuscitation is recommended by the European Resuscitation Council and the American Heart Association.^[1,2] Although endotracheal intubation is associated with better outcomes compared with the use of supra-glottic airway devices,^[3] endotracheal intubation is a challenging technique.

Many factors are related to the failure of endotracheal intubation in pre-hospital resuscitation. Some of these factors are vomitus, blood or secretions in the pharynx, forming a soiled airway which may not be managed well by the assistance of bag-valve-mask or supra-glottic airway devices.^[4] Gaither et al.^[5] reported that the failure rate was 11.8% in a total of 1137 prehospital endotracheal intubation over 3 years. In this study, of the 161 failures, 57.8% were due to blood in airway and 23.0% were from vomitus in airway. The presence of vomitus is also associated with decreased survival to hospital discharge^[6] and worsened long-term outcomes, due to possible aspiration pneumonia and aspiration pneumonia.^[7] It has been reported that 25% of out-hospital cardiac arrest (OHCA) victims had regurgitation, and 10% of regurgitation occurred before emergency medical services (EMS) arrival, 7% during chest compression by EMS personnel, and 8% during intubation.^[8]

However, traditional training in airway management cannot simulate the challenging conditions of soiled airway. Several training barriers for emergency medical technicians (EMTs) have been reported: didactic teaching cannot reflect the physical nuances of the procedure, few opportunities of clinical application, mannequins for endotracheal intubation training do not reflect the feel of live airway structure and the real-world difficulties EMTs might face in clinical practice.^[9]

To improve the capability of soiled airway management, some training systems have been developed.^[10,11] In 2017, DuCanto et al.^[10] described the suction-assisted laryngoscopy assisted decontamination (S.A.L.A.D.) simulation system. The S.A.L.A.D. simulation system adds a pump on a standard airway mannequin head to simulate the dynamic challenges of emergency airway, which were frequently contaminated with vomitus and blood. The trainees can practice on the simulation system and learn how to perform endotracheal intubation via laryngoscopy and suction technique in soiled airways. DuCanto et al.^[10] proved that the training session of the S.A.L.A.D. simulation system can significantly improve trainees' confidence in managing soiled airway.

In the present study, we aimed to demonstrate that a training program using the S.A.L.A.D. simulation system can be used to train emergency medical technician paramedic (EMT-P) how to manage soiled airways, the effectiveness of the S.A.L.A.D. technique training on the improvements of performance and confidence in endotracheal intubation in soiled airway were assessed by analyzing the intubation time, the pass rate of the control, pre-training, and post-training scenario, in addition to the trainees' confidence.

2. Materials and methods

2.1. Subjects

A pilot before–after study with observational before–after study design was reviewed and proven by the Institutional Review Board of Shin Kong Wu Ho-Su Memorial Hospital. The EMS system in New Taipei City has 7 EMS divisions responding to

>135,000 dispatches annually. In this study, EMT-paramedics (EMT-Ps) were invited to be the volunteers from 2 EMS divisions which were supervised by EMS medical directors of Shin Kong Wu Ho-Su Memorial Hospital. One division consisted of urban and suburban EMS services and the other division consisted of rural EMS services. All 41 participants provided written informed consents when agreed to participate this training program after being explained the objects and study design.

2.2. Simulation setting and training program

The training program was held from September 2017 to November 2017. The program included 3 scenarios and 1 training course. All trainees were requested to perform endotracheal intubation for 3 times in each scenario. The first scenario was the standard airway mannequin head with clean airway (the control scenario). The second and the third scenarios simulated massive vomiting using the S.A.L.A.D. simulation system. The second scenario was before the training course (the pre-training scenario) and the third one was immediately after the training course (the post-training scenario).

The S.A.L.A.D. simulation system was set up according to the description by DuCanto et al.^[10] Briefly, a standard airway mannequin head (Airway Larry, Nasco, Ft. Atkinson, WI) was modified by adding a clear vinyl tube to the existed esophagus of the mannequin and the tube was connected with a drill-powered fluid pump for pumping the simulated contaminant into the airway. The simulated contaminant was made by mixing xanthan gum powder and water, with a ratio of 5 g power to 1-liter water. Green food color was added to the mixture to simulate gastric contents. The flow rate of the drill-powered pump was 225 gallon per hour, equal to 237 mL per second. Initially, the simulated contaminant was filled in the airway for 15 seconds, and then the pump was turned on to add new contaminant for 1 second every 5 seconds for simulating massive vomiting.

After the control and the pre-training scenarios, all trainees participated in a 1-hour training course. The course given by an emergency physician consisted of lectures, demonstration, and practice of endotracheal intubation in soiled airway on the S.A.L.A.D. simulation system. The lecture included anatomic structures, appropriate head position for airway management, and correct steps of suction and intubation technique. The physician demonstrated the S.A.L.A.D. technique and intubation technique on the S.A.L.A.D. simulation system, and all trainees practiced. After the training course, the post-training scenario was performed immediately. In all scenarios, the trainees were requested to perform endotracheal intubation for 3 times. A video laryngoscope (TVI-8000, Biotronic instrument enterprise Ltd., Kaohsiung, Taiwan) with standard Macintosh blade number 4 was used. The monitor on the video laryngoscope handle was removed. Participants used this video laryngoscope as the direct laryngoscope and the images were sent to a monitor through a video-out cable for confirming successful intubation.

2.3. S.A.L.A.D. technique training

The first step was to insert a Yankauer suction catheter through the right mouth angle to lift up the tongue and to suction the contaminant. The next was to insert the laryngoscope and to keep the Yankauer suction catheters suctioning from mouth to hypopharynx. After correct positioning the laryngoscope, the third step was to pull out the Yankauer suction catheter

and to re-insert it through left mouth angle (also at the left side of the laryngoscope) for continuous suctioning until the tip of the suction catheter was in the hypopharynx. Finally, the endotracheal intubation was inserted through the right side of the laryngoscope and was correctly positioned.

2.4. Evaluation

The intubation time of each attempt was recorded. Successful endotracheal intubation was defined as intubation within 120 seconds and with correct placement of the endotracheal tube which was confirmed by the observers according to the images on the monitor. Failed intubation referred to that intubation attempt took longer than 120 seconds or the endotracheal tube was placed in the esophagus. The “pass” of a scenario was defined as more than twice successful intubation in a scenario. If a trainee did not pass a certain scenario, the intubation time in this scenario of the trainee was excluded from analysis. The intubation time of a scenario was calculated by averaging the 2 shortest intubation time. The demographic data and previous experience of all trainees were collected. The confidence in the management of soiled airway were surveyed before and after the training program by a questionnaire using 4-point Likert scales with items as “Very Unconfident,” “Unconfident,” “Confident,” and “Very Confident.” Satisfaction of the training program was also investigated.

2.5. Statistical analysis

Continuous data were presented as median with interquartile range (IQR) and categorical data were presented as count with percentage. The comparison of categorical variables between the control scenario and the pre-training scenario as well as between the pre-training scenario and the post-training scenario were performed by the Wilcoxon signed-rank test. Friedman repeated measures ANOVA on ranks was used to compare the intubation time among the 3 scenarios. Post hoc analysis was performed by Wilcoxon signed-rank test with Bonferroni adjustment. Mann-Whitney *U* test was used for comparing the intubation time in the post-training scenario between the trainees who passed and those who did not pass the pre-training scenario. A 2-tailed *P*-value of <0.05 indicated statistical significance. Kaplan-Meier analysis was used to plot each intubations in pre-training and post-training scenario. Cox regression model stratified by proportional hazard types was applied to cope the repeated intubation attempts by the same participants. IBM SPSS Statistics version 24.0 (Armonk, NY) and STATA version 11.2 (Stata Corp, College Station, TX) were used for data analysis.

3. Results

A total of 41 EMT-P participated this study. They had a median EMT experience of 8 years (IQR = 7–11 years), and mainly were men ($n=39$, 95.1%). The real-world experiences of advance airways indicated the great success rate of the participants when all kinds of methods were count, 87.8% and 82.9% for whole EMT service period and within 6 months, respectively. However, when only endotracheal intubation was count, the success rate dropped to 57.5% and 61% of whole EMT service period and within 6 months, respectively. The most frequently used advanced airway by these EMT-P was endotracheal intubation ($n=35$, 85.4%) which was achieved with direct laryngoscope

Table 1

Demographic characteristics and baseline information.

Variables	N = 41 (%)
Age, y	32.7 (30.7–4.7)*
Gender	
Male	39 (95.1)
Female	2 (4.9)
EMT experience, y	8 (7–11)*
Major reason of failed endotracheal intubation	
Too much vomitus	19 (46.3)
Restricted mouth opening	11 (26.8)
Unseen vocal cord	11 (26.8)
The most used advanced airway	
Endotracheal intubation	35 (85.4)
I-gel	5 (12.2)
Laryngeal mask airway	1 (2.4)
Combitube	0 (0)
Instruments for endotracheal intubation at workplace	
Direct laryngoscope	39 (95.1)
Video laryngoscope	21 (51.2)
Laryngeal mask airway (supraglottic)	13 (31.7)
Suction instruments at workplace	
Oxygen resuscitator kit	39 (95.1)
Portable suction pump	4 (9.8)
Vehicle mounted type suction pump	2 (4.9)
None	1 (2.4)
Using suction instruments while endotracheal intubation	
Yes	16 (39)
No	25 (61)

* Data were presented in count (percentage) or median (interquartile range).

($n=39$, 95.1%). The major reason of failed airway management was vomitus contamination ($n=19$, 46.3%). The most available suction instrument at their workplace was oxygen resuscitator kit ($n=39$, 95.1%), but more than half of the participated EMT-P never applied suction instruments to manage soiled airway ($n=25$, 61%) (Table 1).

The intubation time significantly differed among the 3 scenarios. As shown in Fig. 1A, the intubation time in the post-training scenario (26.9 seconds, IQR = 21.2–33.3) was significantly shorter than that in the pre-training scenario (37.1 seconds, IQR = 20.5–59.8, $P=.031$). Both the intubation time of pre-training and the post-training scenario were significantly longer than that of the control scenario (12.0 seconds, IQR = 8.6–15.8, both $P < .001$). The count of successful intubation also significantly differed between the control and the pre-training scenario ($P < .001$) and between the pre-training and the post-training scenario ($P = .001$) (Table 2). In the control scenario, 92.7% of trainees had successful intubation for 3 times. The proportion decreased to 36.6% in the pre-training scenario and then increased to 80.5% in the post-training scenario. The pass rate of the control, pre-training, and post-training scenario was 100% (41/41), 82.9% (34/41), and 92.7% (38/41), respectively. The rate of esophageal intubation was 0.8%, 13.8%, and 6.5% in the control, pre-training, and post-training scenario, respectively. The rate of intubation time longer than 120 seconds was 16.2%, 13.8%, and 2.4% in the control, pre-training, and post-training scenario, respectively.

To further understand the effect of the training program, we compared the intubation time in the post-training scenario according to the results of the pre-training scenario. In the pre-training scenario, 7 trainees did not pass. After training, all the 7 trainees passed the post-training scenario. As shown in Fig. 1B,

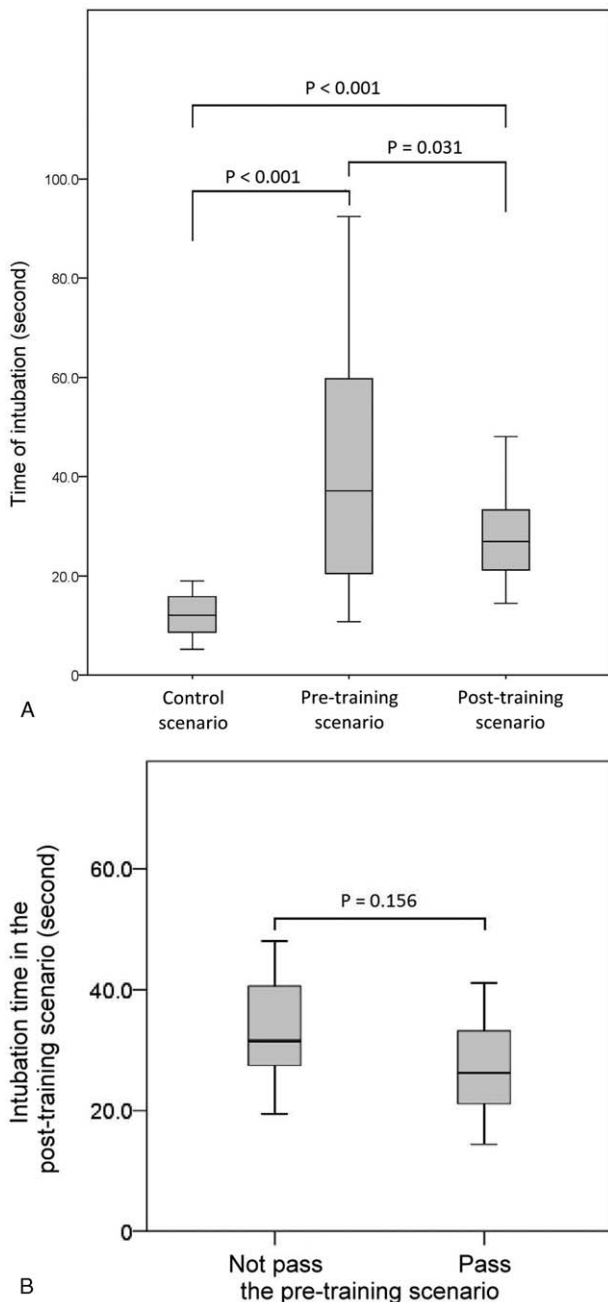


Figure 1. (A) The intubation time in each scenario. (B) The intubation time in the post-training scenario by the results of the pre-training scenario.

these 7 trainees had a median intubation time of 31.5 seconds (IQR=25.4–47.9), which was not significantly different from those who passed the pre-training scenario had in the post-training scenario (26.3 seconds, IQR=21.0–33.2, $P=.156$). In the Kaplan–Meier analysis (Fig. 2), the hazard ratio of successful intubation for the post-training scenario versus the pre-training scenario after adjusting the repeated measurements was 2.13 (95% confidence interval of 1.57–2.91).

As presented in Table 3, the training program significantly improved the confidence of the trainees in airway management, including endotracheal intubation, endotracheal intubation in soiled airway, and using suction instruments. The proportion of the trainees reporting confident or very confident in endotracheal intubation significantly increased from 82.9% before the training program to 100% after the training program. The trainees reporting confident or very confident in endotracheal intubation in patients having soiled airway also increased from 22.0% to 97.6%. The increased proportion of the trainees reporting confident or very confident in using suction instruments was also observed (before vs after the training program, 46.3% vs 92.7%). All trainees felt this training program was helpful, and most of them gave the highest grade (75.6%) and had willingness to apply the learned techniques to manage soiled airways.

4. Discussion

Our results indicated that the S.A.L.A.D. simulation system can be used for EMT-P training. The training program with the S.A.L.A.D. technique could significantly improve the performance of soiled airway tracheal intubation by EMT-P, including shorter intubation time, increased successful intubation rate, improved confidence in endotracheal intubation, and the willingness of using suction instruments to manage soiled airways. The pass rate was increased significantly from 82.9% of the pre-training scenario to 92.7% of post-training scenario. The confidence in endotracheal intubation in soiled airway increased more, from 22.0% to 97.6% after the training program. A simulation system like S.A.L.A.D. system is very helpful to mimic the real-world difficult airway, not only the static containing emesis, blood, and secretions contaminating the glottic view, but also the continuous vomiting condition which was more complicated to manage. The flow rate of contaminants can be altered easily by controlling the pump,^[10] providing the dynamic technical challenges to further improvement of the skill. Of note, EMT-P trainees who did not pass the pre-training scenario improved their technique immediately in the post-training scenario, with a similar level to the trainees who had already passed the pre-training scenario. This indicated the great capability and efficacy of the training program with the S.A.L.A.D. simulation system. However, the S.A.L.A.D. technique is a complex procedure. Inadequate placement of rigid

Table 2

Count of successful intubation in each scenario.

Count	Control scenario	Pre-training scenario	Post-training scenario	<i>P</i>
3	38 (92.7)	15 (36.6)	33 (80.5)	$<.001^*$
2	3 (7.3)	19 (46.3)	5 (12.2)	
1	0 (0)	6 (14.6)	3 (7.3)	
0	0 (0)	1 (2.4)	0 (0)	

* Comparison between the control and pre-training scenarios.

† Comparison between the pre-training and post-training scenarios.

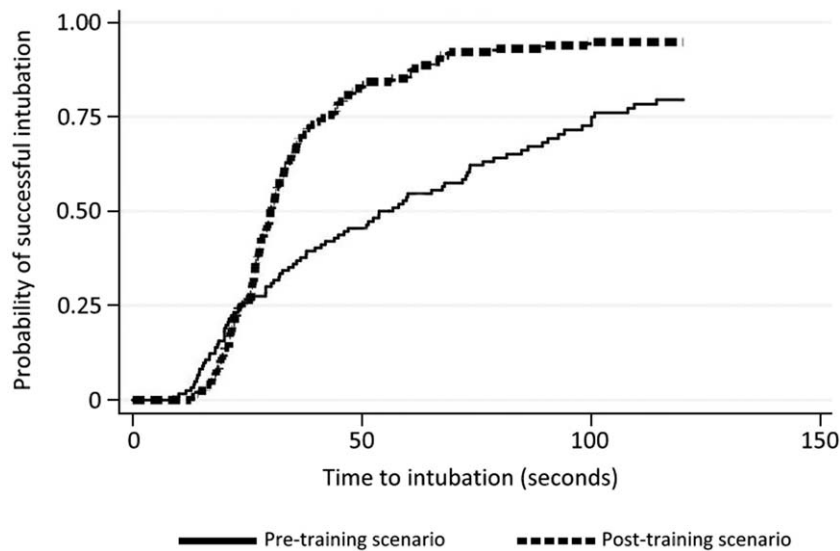


Figure 2. Kaplan-Meier curve of successful intubation in the pre-training and post-training scenario.

suction catheter into the hypopharynx may decrease the capability of suction for overwhelming vomitus. The oropharyngeal space is limited after placing a rigid suction catheter to the left of laryngoscope. To place the tip of laryngoscope blade into the vallecula is more difficult. In addition, the limited space also impacts endotracheal tube insertion. These were reasons that esophageal intubation and intubation attempt longer than 120 seconds still happened after the S.A.L.A.D. technique training.

Several studies proved that the failed first attempt was associated with increased adverse events, indicating the importance of the first pass success.^[12-14] Pre-hospital airway management is usually done by EMTs. A study conducted by Australian helicopter EMS found that the associated factors with >1 attempts in prehospital rapid sequence intubation included paramedic laryngoscopist.^[15] Furthermore, patients who need emergency intubation often have soiled airway, which may impair visualization during intubation and reduce intubation rate success.^[15] These results suggested the importance of enhancing the capability of endotracheal intubation in soiled airway for

EMTs. However, EMTs are rarely trained for suction techniques or told its critical importance of patient outcomes in prehospital setting.^[16] In addition, many EMS agencies don't routinely take their portable suction units, and this was also noticed in our surveys. This probably increased the failure rate when managing soiled airway.^[16]

Most airway training programs still use traditional airway mannequins in the controlled setting, such as surgical room. Trainees are then expected to apply these basic skills to manage more complicated airways in clinical emergencies just after a brief training program. Therefore, EMS personnel could not care patients efficiently and improve patient outcomes without high fidelity simulation training. Performing endotracheal intubation requires high levels of skills and experience as well as regular training and practice. The major difference between the S.A.L.A.D. technique and intermittent Yankauer suction technique is the stabilization of a rigid suction catheter to the left of the laryngoscope and the placement of the rigid catheter tip in the hypopharynx. This core step of the S.A.L.A.D. technique can

Table 3

The comparison of confidence in endotracheal intubation in pre-training scenario and post-training scenario.

Level of confidence	Pre-training scenario	Post-training scenario	P
Confidence in endotracheal intubation			
Very confident	6 (14.6)	18 (43.9)	<.001
Confident	28 (68.3)	23 (56.1)	
Unconfident	7 (17.1)	0 (0)	
Very unconfident	0 (0)	0 (0)	
Confidence in endotracheal intubation in vomiting patients			
Very confident	0 (0)	11 (26.8)	<.001
Confident	9 (22.0)	29 (70.7)	
Unconfident	22 (53.6)	1 (2.4)	
Very unconfident	10 (24.4)	0 (0)	
Confidence in using suction instruments			
Very confident	1 (2.4)	12 (29.3)	<.001
Confident	18 (43.9)	26 (63.4)	
Unconfident	18 (43.9)	2 (4.9)	
Very unconfident	4 (9.8)	1 (2.4)	

continually divert contaminants and avoid glottis obscured by additional contaminants during intubation with intermittent suction technique. When the amount of vomitus or blood exceeds the capability of the suction equipment, another rigid catheter may be placed to the right of the laryngoscope and into the oropharynx and hypopharynx for continuous or intermittent suction, based on needs. When the amount of vomitus or blood exceed the capability of the suction equipment again or the suction equipment is obstructed by large food particles or blood clots, usually a surgical airway approach should be considered.^[4]

In Taiwan, EMTs can perform endotracheal intubation only for OHCA patients. However, OHCA airway management strategies are still controversial. Endotracheal intubation is the most common airway management in the United States, but in most Asian countries, less than 10% of OHCA patients receive endotracheal intubation by EMTs in prehospital setting.^[17–19] Although previous studies have identified that endotracheal intubation was associated with worse survival and neurological function comparing with bag-mask ventilation (BMV),^[20,21] conflicting results are reported^[3,22] and both sides are supported by population-based study and meta-analysis. A multicenter randomized clinical trial was conducted with the aim to solve this conflict. The results indicated that the use of BMV comparing with endotracheal intubation failed to demonstrate non-inferiority or inferiority for survival with favorable 28-day neurological function.^[23] Another important results should be noted; complications including airway management difficulty, failure, and regurgitation were significantly more frequent when BMV was used comparing with endotracheal intubation.^[23] Regurgitation or sequential aspiration might be present in almost 25% of all dead OHCA patients.^[24] To avoid regurgitation, endotracheal intubation may still the best choice when compared with other devices either BMV or supra-glottic airway devices during cardiopulmonary resuscitation.^[25]

Our study had a number of limitations that have to be acknowledged. The first was the relatively small sample size and all participants were volunteers from 2 EMS divisions and were not selected by a random sampling method. Secondly, this study only included EMT-P. Future studies including the other health personnel (e.g., emergency residents, emergency physicians, or anesthesiologists) are warranted. The third limitation was non-randomized cross-over design and repeated intubation attempts may potentially increase success rate and shorten intubation time. However, the hazard ratio after adjusting repeated measurements was 2.13, indicating the improvement may not be fully explained by the learning effect from repeat intubations. Finally, this study was based on the simulated vomiting setting. The clinical effectiveness of the S.A.L.A.D. technique training in the soiled airway should be confirmed by further clinical study.

In conclusion, we observed that the S.A.L.A.D. technique training on the S.A.L.A.D. simulation system could efficiently train the EMT-P performing endotracheal intubation in soiled airway and could significantly increase success rate, shorten intubation time, and improve confidence in endotracheal intubation and suction in soiled airway. Portable suction instrument should be prepared and encouraged to be used more frequently for better prehospital airway management.

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