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COMPARISON OF ENDOTRACHEAL INTUBATION WITH THE AIRTRAQ AVANT® AND THE MACINTOSH LARYNGOSCOPE DURING INTERMITTENT OR CONTINUOUS CHEST COMPRESSION: A RANDOMIZED, CROSSOVER STUDY IN MANIKINS

Michael Frass[1], Oliver Robak[1], Zenon Truszewski[2], Lukasz Czyzewski[3], Lukasz Szarpak[2]

[1]Department of Internal Medicine I, Medical University of Vienna, Vienna, Austria
[2]Department of Emergency Medicine, Medical University of Warsaw, Poland
[3]Department of Nephrologic Nursing, Medical University of Warsaw, Warsaw, Poland

ABSTRACT

BACKGROUND: Endotracheal intubation (ETI) currently is the gold standard of securing an airway during cardiopulmonary resuscitation.

PURPOSE: The aim of this study was to evaluate ETI with the Airtraq Avant (ATQ) compared to a conventional Macintosh laryngoscope when used by paramedics during resuscitation with and without chest compression (CC).

METHODS: Forty-seven paramedics were recruited into a randomized crossover trial in which each performed ETI with ATQ and MAC in both scenarios. The primary endpoint was time to successful intubation, while secondary endpoints included intubation success, laryngoscopic view on the glottis, dental compression, and rating of the given device.

RESULTS: In the manikin scenario without CC, nearly all participants performed ETI successfully both with ATQ and MAC, with a shorter intubation time using MAC 20.5 s [IQR, 17.5–22], compared to ATQ 24.5 s [IQR, 22–27.5] ($p = 0.002$). However, in the scenarios with continuous CC, the results with ATQ were significantly better than with MAC for all analyzed variables (success of first attempt at ETI, time to intubation (TTI) [MAC 27 s [IQR, 25.5–34.5], compared to ATQ 25.7 s [IQR, 21.5–28.5] ($p = 0.011$), Cormack-Lehane grade and rating). The success rate in scenarios with CC was 82.9% vs. 91.5% for MAC Laryngoscope vs. ATQ, respectively ($p = 0.021$).

CONCLUSIONS: The ATQ provides benefits in terms of ETI success rate, TTI, and glottic view when compared to MAC during ETI with continuous CC.

KEY WORDS: Cardiopulmonary resuscitation, simulation, videolaryngoscopy, paramedics

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INTRODUCTION

Both the European Resuscitation Council (ERC) and American Heart Association (AHA) 2015 cardiopulmonary resuscitation (CPR) guidelines emphasize the importance of minimalizing the interruption of chest compression (CC) in order to minimalize coronary and cerebral perfusion pressure [1, 2]. Several studies have shown that prolonged interruption of CC is associated with poor return of spontaneous circulation, reduced survival rates, and impaired post-resuscitation myocardial function [3, 4]. However, the same guidelines indicate endotracheal intubation (ETI) as

ADDRESS FOR CORRESPONDENCE:
Zenon Truszewski, Department of Emergency Medicine, Medical University of Warsaw, ul. Lindleya 4, 02–005 Warsaw, Poland
tel: +48 502 258 562, e-mail: ztruszewski@wum.edu.pl

the gold standard of airway management during CPR. The use of ETI during CPR brings a lot of benefits: securing the airway against aspiration, the possibility of conducting asynchronous resuscitation, the use of positive end-expiratory pressure (PEEP) monitoring, as well as continuous measurement of the concentration of carbon dioxide in exhaled air. However, there are potential complications: soft tissue damage, bleeding, dislocation of the arytenoid cartilage, damage to the glottis and vocal cords, rupture of the trachea, and the failure to recognize esophageal insertion.

In some situations, such as trauma or resuscitation, obtaining good visualization of the glottis can be difficult or even impossible [5–8]. According to recent research, the efficacy of endotracheal intubation in the pre-hospital setting, performed by paramedics using a standard laryngoscopy is insufficient and varies from 64% to 77% [9–12]. In order to increase the success rate of tracheal intubation, alternative airway devices are available on the market, including videolaryngoscopes, optical laryngoscopes, or intubation fiberoscopes. Direct laryngoscopy offers a possible solution by direct glottis visualization, which allows the introduction of the endotracheal tube into the trachea on sight via a monitor or optical conduct. One of these devices is the AirTraq Avant (ATQ; Prodol Meditec, Vizcaya, Spain) which, in its basic version, is an optical laryngoscope that can be coupled to a smartphone with special application thus providing videolaryngoscopy, providing better laryngeal and glottic view than when utilizing conventional direct laryngoscopy [13, 14].

The aim of this study was to evaluate the efficacy of the ATQ compared to a Macintosh laryngoscope (MAC) when used by paramedics during resuscitation in a manikin with and without CC. We hypothesized that ATQ could be an alternative to standard direct laryngoscopy (MAC) during ETI while performing CPR.

METHODS

Study design and participants

This prospective, randomized, crossover study was approved by the Institutional Review Board of the International Institute of Rescue Research and Education (Approval No. 15.01.2016.22) and was conducted in January 2016.

Forty-seven paramedics participated in this trial. All participants were informed of the purpose of the present study and gave their written informed consent to take part in this trial. Inclusion criteria comprised: professionally active paramedics, less than 2-years' experience in Emergency Medical Service (EMS) or Emergency Department (ED), more than 10 clinical ETI, no previous experience with videolaryngoscopes. Exclusion criteria comprised: wrist or low back diseases, or pregnancy.

Study protocol

To simulate the scenario of a sudden cardiac arrest patient, a SimMan 3G training manikin (Laerdal, Norway) was employed, while a LifeLine ARM device (DefibTech; Guilford, USA) was used for CC. The manikin was placed on the floor in a neutral, supine position in a bright room.

Two intubation devices were used in this trial: 1) the Macintosh laryngoscope with blade no. 3 (MAC; MERCURY MEDICAL, Clearwater, FL, USA); and 2) the ATQ with a universal phone adapter acting as a camera (Fig. 1). We used the Sony-Xperia Z3 smartphone (Sony Mobile Communications AB, Lund, Sweden) with the Airtraq Cam application (Prodol Meditec, Vizcaya, Spain). All ETI attempts were performed using a lubricated 7.0-mm internal diameter tracheal tube. A semi-rigid stylet was used during intubation with MAC. A self-inflating bag (AMBU, Copenhagen, Denmark) was readily available and within range of the participant.

Participants performed intubations in 2 airway scenarios:

Scenario A: normal airway without continuous CC.

Scenario B: normal airway with CC, where controlled continuous CC was applied using the LifeLine ARM mechanical CC system. Chest compression was provided according to current 2015 European Resuscitation Council (ERC) guidelines at a rate of 100 per minute to a depth of 4 to 5 cm.

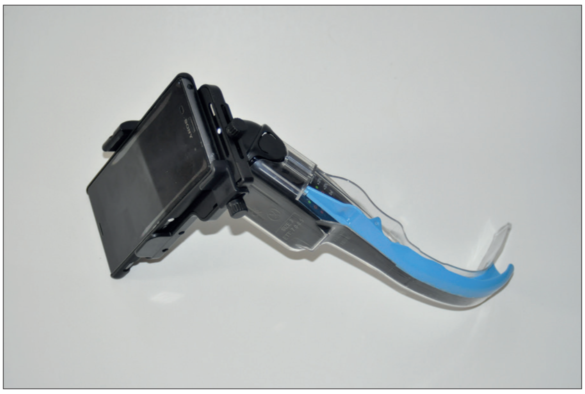

FIGURE 1. Airtraq Avant® videolaryngoscope

Prior to the study, all participants received a standardized audio-visual lecture lasting 20 minutes covering relevant aspects of anatomy and different techniques for securing an airway, including those using the MAC and the ATQ. Following the lecture, the participants took part in a practical demonstration, during which intubations with the respective devices were demonstrated by an independent anesthesiologist. After this session, participants were given 10 minutes to practice ETI with both of the laryngoscopes on the manikin in order to make sure they were familiar with their proper use. The same anesthesiologist was present during the practice session to give advice to the participants.

The Research Randomizer program [15] was used to split the volunteers into 6 groups and to determine the order of laryngoscope use (Fig. 2). The first group started intubation with MAC in scenario A; the second, using MAC in scenario B; the third, using ATQ in scenario A; and the fourth, using ATQ in scenario B. After completing this sequence, participants took a 10-minute break before performing an ETI attempt using another method. The participants were not allowed to watch each other during any of the intubation attempts to avoid any learning effects throughout the procedure. The participants had a maximum of one attempt of ETI in each method.

Outcomes

The primary endpoint was time to intubation (TTI), which was defined as the time from insertion of the laryngoscope between the teeth to the first manual ventilation of the manikin's lungs. The secondary endpoints were the success of the ETI attempt (i.e., intratracheal placement of the tube). ETI was deemed successful if the manikin's lungs were inflated, verified by the manikin's ventilation indicators. In accordance with the ERC guidelines, if ETI was not successfully achieved within 60s, the intubation attempt with the respective device was classified as failed, and no future attempts were allowed [8]. After each attempt, participants were asked to rate their best glottic view according to the

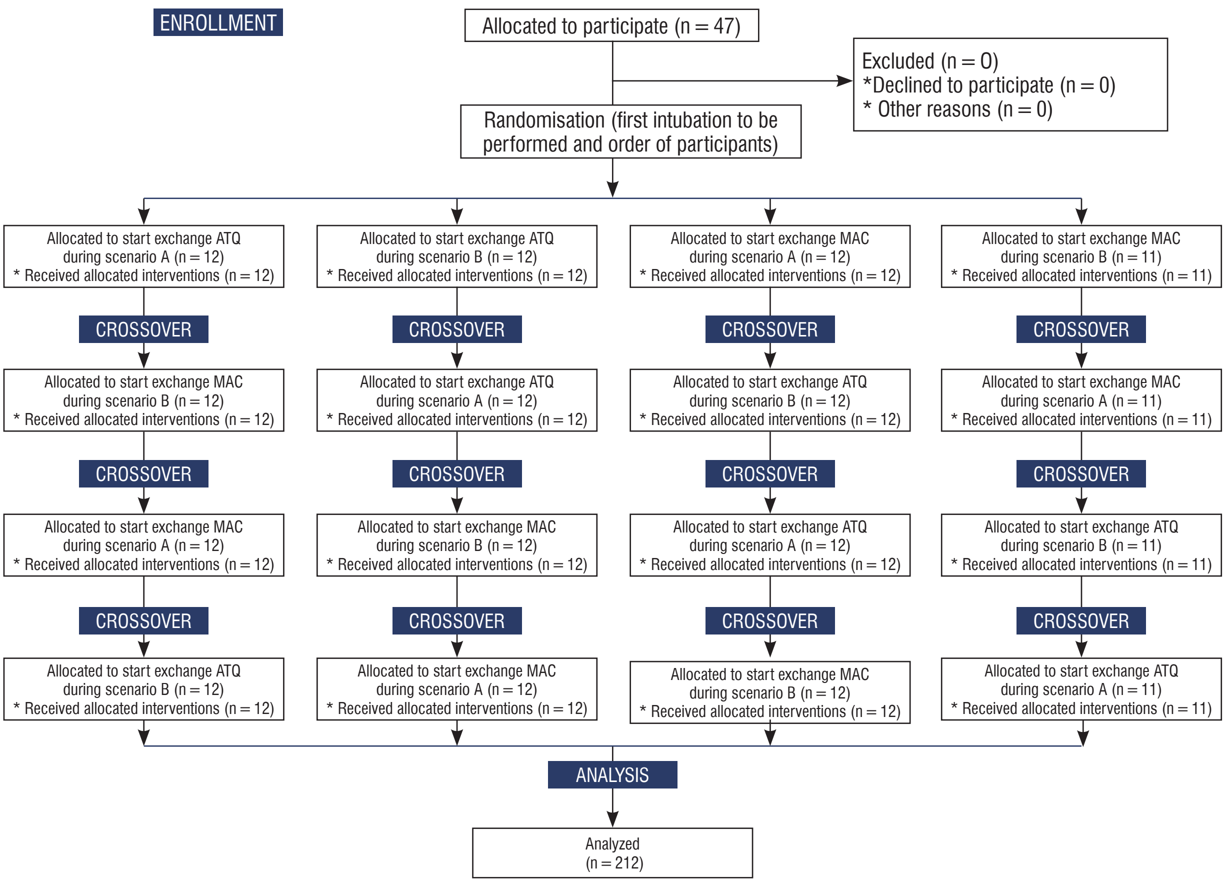

FIGURE 2. A flow chart presenting the study design and participants' recruitment according to CONSORT statement; ATQ — Airtaq Avant® videolaryngoscope, MAC — Macintosh laryngoscope, Scenario A — normal airway without continous CC, Scenario B — normal airway with continous CC

Cormack-Lehane grade [16].The severity of any potential dental trauma was calculated based on a previously described grading scale [8, 17]. All processes were video recorded, and such recordings was used to precisely identify each time variable.

In order to identify the subjective opinion about the difficulty of the each intubation method, participants were asked to rate it on an audio-visual scale (VAS) with a score ranging from 1 (extremely easy) to 10 (extremely difficult). In addition, participants were asked which method they would prefer in a real-life resuscitation.

Sample size and sequence generation

Based on pilot data, the following assumptions were made in order to calculate the number of participants to be included: we assumed an alpha risk of 0.05, a beta risk of 0.2. The success rate of the first ETI attempt (during uninterrupted CC) in the pilot data with the use of the distinct laryngoscopes varied and amounted to 90.7% vs. 76.2% (MAC and ATQ, respectively). We calculated that 38 participants would be required (paired, two-sided). Participants were randomized with a 1:1 ratio.

Statistical methods

Statistical analysis was performed using Statistica version 12.0 for Windows (StatSoft, Tulusa, USA). We described variables using percentages for qualitative variables and using a median with an interquartile range (IQR) for quantitative variables. If the data did not have a normal distribution, non-parametric tests were used. In order to compare the TTI between the groups, the Wilcoxon test for paired observations was used. The McNemar test was used to evaluate the differences in the effectiveness of the intubation, while Stuart-Maxwell test was used to compare the degree of dental compression, Cormack-Lehane grade and VAS score. All statistical tests were two-sided. We considered a p-value less than 0.05 as significant.

RESULTS

A total of forty-seven paramedics (18 female, 38.3%) participated in this study. All participants worked in emergency medical services (EMS) teams. Their mean age was 26.4 [IQR, 24.2–29.5] years, while their mean work time experience was 1.1 [IQR, 0.6–1.6] years. The participants' score on the clinical ETI was 15 [IQR, 11–17].

Primary endpoints

The primary study endpoint, namely TTI, during scenario A (without continuous CC), was achieved fastest when using MAC at 20.5 s [IQR, 17.5–22], and was significantly slower with ATQ at 24.5 s [IQR, 22–27.5] ($p = 0.002$). In scenario B (with continuous CC), the median time for intubation using ATQ was 25.7 s [IQR, 21.5–28.5], whereas in the case of MAC, this was 27 s [IQR, 25.5–34.5] ($p = 0.011$). The TTI scores using MAC and ATQ during scenario A and B are presented in Figure 3.

Secondary endpoints

The success rate after the first attempt using the distinct intubation methods varied and amounted to 97.9% vs. 100% (MAC vs. ATQ respectively) for scenario A, and 82.9% vs. 91.5%, respectively for scenario B. There was a statistically significant difference between the MAC Laryngoscope and ATQ ($p = 0.021$) in scenario B.

The Cormack-Lehane grade for each laryngoscopy method is shown in Table 1. During scenario A, the glottic view using Cormack-Lehane classification [16] was best with the ATQ, with 100% of participants reporting a quality of glottic view corresponding to a Cormack-Lehane grade classification of I. In scenario B, the glottis visibility was also better when using ATQ.

Dental compression was observed during intubation in scenario A and B, regardless of the method of intubation. Dental compression during ATQ intubation in scenario A was observed in 10.6% of

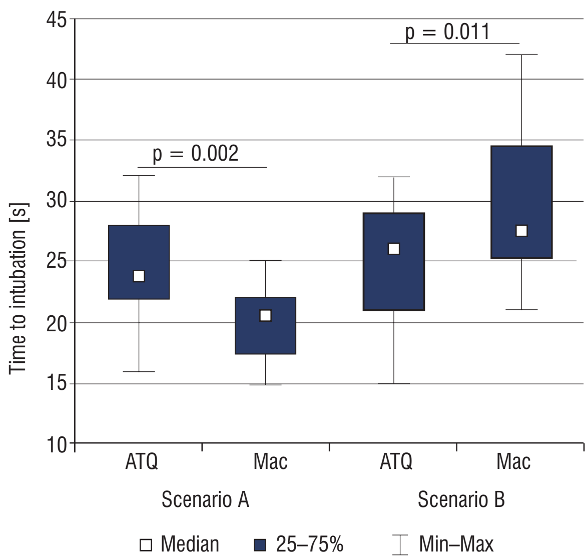

FIGURE 3. The time needed to perform the endotracheal intubation

Table 1. Grade of Glottic View According to the Cormack-Lehane Classification which was archived with the various devices. Data are given in absolute numbers

Scenario	Type of laryngoscope	Cormack-Lehane grade I/II/III/IV	p-value
Scenario A	MAC	42/5/0/0	= 0.032
	ATQ	47/0/0/0	
Scenario B	MAC	38/9/0/0	NS
	ATQ	40/7/0/0	

MAC — Macintosh laryngoscope, ATQ — Airtraq Avant laryngoscope, NS — not statistically significant

intubation attempts, whereas 9 of 47 participants (19.1%) caused dental compression during chest compression ($p < 0.001$). In the case of the use of MAC, dental compression was observed in 15.6% of intubation attempts in scenario A, and 23.4% in scenario B ($p = 0.037$).

Subjective assessment

Participants ratings of their subjective opinion about the ease-of-use of the intubation procedures using MAC and ATQ varied and amounted to: 2.5 vs. 2.9 points ($p = 0.056$) for scenario A, and 4.5 vs. 3.5 points (0.021) for scenario B.

When participants were asked which laryngoscope they would prefer in real-life ETI, thirty-five (74.5%) participants preferred the MAC laryngoscope versus the ATQ for intubation with interrupted CC. For intubated during continuous CC, users also preferred the ATQ laryngoscope (65.9%) more than the MAC (34.1%).

DISCUSSION

In our study, for the first time we compared the ATQ and MAC laryngoscopes during simulated CPR by paramedics, with and without CC. We hereby focused on a very common dilemma during CPR: how can the interruption of CC be minimized while keeping a high ETI success rate? Our study showed that at the first ETI attempt, the success rate with the MAC was higher than that with the ATQ in the scenario without CC. Moreover, ETI with the MAC was significantly faster. However, scenario B painted an opposite picture: the ATQ was superior in terms of success rate and TTI. This might be due to the fact that the glottic view quality was best with the ATQ during scenario B, as confirmed by assessment of the Cormack-Lehane grade. Overall, users preferred the ATQ over the MAC for scenario B.

Prolonged interruptions of CC are associated with a reduced return of spontaneous circulation, reduced survival rates, and reduced post-resuscitation myocardial function [3, 4]. It is, therefore, crucial to keep interruptions of CC to a minimum, with ongoing CPR during ETI as the ultimate goal. Although ETI utilizing MAC is considered as the gold standard for securing an airway under emergency conditions, on the other hand, the ERC guidelines recommend minimizing hands-off times, even if ventilation then has to be neglected [1]. Utilizing the ATQ for ETI might therefore pose a practical method of performing ETI without the need of interrupting CC. This might in turn then lead to better coronary and cerebral perfusion and, ultimately, a better outcome. With this regard, ATQ has to be recommended as it was superior in terms of success rate, TTI, glottic view quality, and subjective rating during ongoing CPR.

Although the success rates in both groups were acceptable, during continuous CC the ATQ showed a significantly higher success rate by nearly 10% compared to the MAC. Since during ETI it is crucial to get a good look at the glottis, we think that this is one of the major advantages of the ATQ.

Regarding TTI, the differences between the two devices in both conditions were significant, but minor and thus clinically not relevant, as has previously been reported elsewhere [18]. Moreover, these differences could probably be in part explained by the lack of experience of the participants with the ATQ. Dental compression occurred more often with the MAC. Although this is in accordance with many other studies, this issue should be considered insignificant during CPR. The rating of the devices was subjective; however, a large part of it might be attributed to the better glottic view with the ATQ that led to a better rating.

A major limitation of our study and of most other studies in this field is the use of manikins instead of real patients [19–21]. Although the SimMan 3G training manikin is generally acceptably realistic, it has significant limitations regarding the human airway anatomy [22]. Furthermore, the manikin's anatomy may favour a distinct ETI device [21, 23, 24], as has been shown for supraglottic airway devices. However, manikins allow for simulating the exact same airway situations for each participant and pose the only way to simulate standardized airway situations to date. While all participants in our study were experts in the field of emergency airway management, their mean work experience was 1.1 years, which is rather short. Thus, more experienced EMTs might be more comfortable, faster, and more successful with the MAC, most likely due to their everyday practice. Another limitation is that although every attempt lasting for more than 60 seconds was considered a failure, they may have been ultimately successful.

CONCLUSIONS

Conclusively, the ATQ provides benefits in terms of ETI success rate, TTI, and glottic view when compared to MAC during ETI with continuous chest compression. Although the results of the present investigation cannot be generalized to other medical professionals, we were able to provide evidence for choosing a device that enables uninterrupted CC during CPR, thereby possibly affecting the ultimate outcome.

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