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Impact of chest compression on endotracheal intubation efficacy: a randomized crossover trial

Wpływ uciskania klatki piersiowej na efektywność intubacji dotchawiczej: badanie randomizowane krzyżowe

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Keywords

endotracheal intubation, cardiopulmonary resuscitation, chest compression, efficacy, videolaryngoscopy

Słowa kluczowe

intubacja dotchawicza, resuscytacja krążeniowo-oddechowa, uciski klatki piersiowej, efektywność, wideolaryngoskopia

Summary

Introduction. Direct endotracheal intubation with a conventional laryngoscope such as Miller or Macintosh laryngoscopes may be problematic during cardiopulmonary resuscitation. A degree of the glottis visualization may affect the effectiveness of intubation.

Aim. Aim of this study was to compare intubation efficacy using direct and video-laryngoscopes during resuscitation with and without chest compression performed by medical students.

Material and methods. This was a randomized crossover trial. Fifty-seven last year medical students who have limited experience in direct laryngoscopy and none prior experience in videolaryngoscopy participated in this trial. The endotracheal intubation using C-MAC videolaryngoscope and standard Macintosh laryngoscope with and without chest compressions were compared.

Results. The median time of the MAC and C-MAC devices in the scenario without chest compressions were 21 (IQR: 20-27) vs. 18 sec (IQR: 16.5-24) respectively. During scenario with uninterrupted chest compressions, median intubation time using distinct devices varied and amounted to 39 (IQR: 24-47) vs. 22.5 sec (IQR: 17-25). The efficacy rate of first intubation attempt with MAC was 54.3% without chest compressions and 28.1% during chest compression conditions. For C-MAC the first intubation success rate was 100% for scenario without chest compressions and 96.5% for scenario with uninterrupted chest compressions.

Conclusions. Within limitations, we conclude that performing chest compressions during direct laryngoscopy prolongs the procedure and lowers the efficacy rate. C-MAC videolaryngoscope can be used by inexperienced intubators without interruptions in chest compressions. Additional studies are required to validate those results.

Conflict of interest
Konflikt interesów

None
Brak konfliktu interesów

Streszczenie

Wstęp. Laryngoskopia bezpośrednia z zastosowaniem standardowego laryngoskopu z łopatkami Millera bądź Macintosha może stanowić trudność w przypadku resuscytacji krążeniowo-oddechowej. Dobre uwidocznienie głośni może wpływać na skuteczność intubacji dotchawiczej.

Cel pracy. Celem badania było porównanie efektywności intubacji dotchawiczej wykonywanej przez studentów medycyny z zastosowaniem laryngoskopii bezpośredniej i wideolaryngoskopii podczas resuscytacji krążeniowo-oddechowej z uciskaniem i bez uciskania klatki piersiowej.

Materiał i metody. Badanie było badaniem randomizowanym, krzyżowym. Pięćdziesięciu siedmiu studentów ostatniego roku studiów medycznych, którzy mieli ograniczone

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doświadczenie w zakresie laryngoskopii bezpośredniej oraz brak doświadczenia w zakresie wideolaryngoskopii, uczestniczyło w badaniu. Intubacja dotchawicza była wykonywana z zastosowaniem wideolaryngoskopu C-MAC oraz standardowego laryngoskopu z łopatką Macintosha (MAC) z uciskaniem i bez uciskania klatki piersiowej.

Wyniki. Mediana czasu intubacji dla MAC i C-MAC podczas scenariusza bez uciskania klatki piersiowej wynosiła odpowiednio 21 (IQR: 20-27) i 18 s (IQR: 16,5-24). Podczas scenariusza z nieprzerwalnym uciskaniem klatki piersiowej mediana czasu intubacji wynosiła odpowiednio 39 s (IQR: 24-47) dla MAC oraz 22,5 s (IQR: 17-25) dla C-MAC. Skuteczność pierwszej próby intubacji w warunkach bez uciskania i z uciskaniem klatki piersiowej z wykorzystaniem MAC wynosiła odpowiedni 54,3 oraz 28,1%. W przypadku zastosowania C-MAC otrzymano skuteczność pierwszej próby intubacji na poziomie 100% dla scenariusza bez uciskania klatki piersiowej oraz 96,5% dla scenariusza z ciągłym uciskaniem klatki piersiowej.

Wnioski. Uciski klatki piersiowej wpływają na wydłużenie czasu procedury intubacji oraz skuteczność intubacji w przypadku wykorzystania laryngoskopii bezpośredniej. Wideolaryngoskop C-MAC może być wykorzystywany przez niedoświadczony w intubacji personel medyczny bez konieczności wykonywania przerw w uciskaniu klatki piersiowej na czas trwania intubacji. Dalsze badania są konieczne celem potwierdzenia uzyskanych wyników.

INTRODUCTION

Endotracheal intubation is commonly considered a life-saving procedure, especially in the emergency medicine (1, 2). Cardiopulmonary resuscitation is an example of one of many procedures where endotracheal intubation is considered the gold standard for maintaining the airway patency (3). Current American Heart Association guidelines recommend that the maintaining of the airway patency, endotracheal intubation included, should be performed with uninterrupted chest compressions (4). Performing the procedure in this way allows for minimizing the pauses during chest compressions and enables for the blood flow through the vital organs. The Resuscitation Guidelines recommend that the intubation should be performed with simultaneous chest compressions, preferably without a pause or with a short one to allow the insertion of the endotracheal tube between the vocal folds.

Performing the procedure with such prerequisites requires a lot of skill and experience from the person who performs it (5-7). What is worth noting is also that the efficacy of endotracheal intubation in anti-vital conditions is insufficient (8, 9). Additionally, intubation during chest compressions may result in an extended duration of the procedure when using direct laryngoscopy (10-12). The potential consequences to the patient of a failed endotracheal intubation are death or serious complications (13, 14).

We hypothesize that videolaryngoscope C-MAC reduce time of endotracheal intubation and increases intubation success rate compared to standard laryngoscope with Macintosh blade, when intubation is performed during cardiopulmonary resuscitation with uninterrupted chest compressions performed by inexperienced intubators.

AIM

The purpose of this study was to compare the endotracheal intubation using Macintosh laryngoscope and C-MAC videolaryngoscope with and without chest compressions by last year medical students in simulation setting.

MATERIAL AND METHODS

This is prospective, randomized, crossover, observational simulation study. After obtaining Institutional Review Board (Polish Society of Disaster Medicine; Approval number: 74.11.2017.IRB) approval and voluntary written informed consent, 57 last year medical students participated with this trial. All participants of the study had previously completed the anesthesiology and emergency medicine training modules and declared the ability to perform endotracheal intubation utilizing direct laryngoscopy. All participants watched a video demonstrating the correct intubation procedure with both the C-MAC videolaryngoscope and standard laryngoscope with Macintosh blade (fig. 1a, b), and instructor was giving verbal instructions regarding the correct use of each device. Subsequently, the correct use of both endotracheal intubation methods was demonstrated.

In order to demonstrate both the correct performance of intubation and for training Laerdal Airway Management Trainer (Laerdal, Stavanger, Norway) was used. After theoretical part, each of the

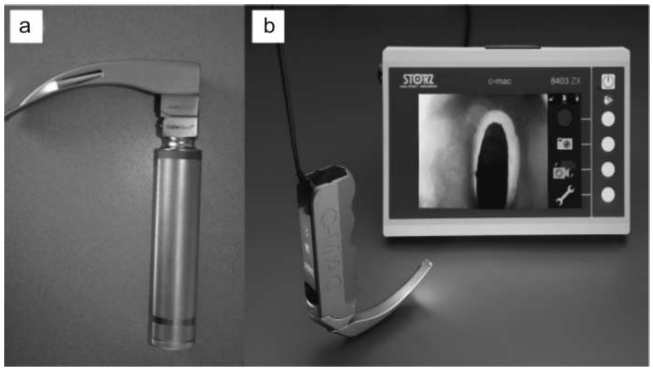

Fig. 1a, b. Laryngoscopes used in this trial: (a) Macintosh laryngoscope; (b) C-MAC laryngoscope

participants of the study had a maximum of 5 minutes to get acquainted with individual laryngoscopes and to perform training endotracheal intubation in normal airway conditions.

During the target study, the participants were asked to perform endotracheal intubation using the C-MAC and Macintosh laryngoscope during cardiopulmonary resuscitation. In order to assess the influence of chest compressions on the effectiveness of endotracheal intubation, participants performed intubation in two scenarios:

1. Scenario A – normal airways without chest compressions.
2. Scenario B – normal airways with constant chest compressions. In order to simulate the difficulties resulting from constant chest compressions, the LUCAS 3 system (Physio-Control, Lund, Sweden) was used.

The study participants were divided into four groups, the first of which performed endotracheal intubation utilizing C-MAC during scenario A, the second one used C-MAC during scenario B, the third one used MAC during scenario A, and the fourth one performed intubation using MAC during scenario B. A detailed randomization procedure for the study is presented on figure 2. All intubations were performed using a cuffed endotracheal tube with an internal diameter of 7.5 mm, and all intubations were facilitated with a malleable IVORY stylet (Smiths Medical; Minneapolis, MN, USA). The tip of the stylet was bent individually by participants.

The primary aim of this trial was the comparison of intubation times using direct and video-laryngoscopes during resuscitation with and without chest compression. Intubation time was defined as the time since laryngoscope entered the oral cavity until the first chest inflation using a self-inflating bag was performed. Intubation failure was defined as follows: intubation time longer than 60 seconds (10, 15), the insertion of the endotracheal tube into the esophagus of the manikin as well as removal of the endotracheal tube from the manikin's mouth before successful intubation. Secondary outcomes were: success rate of the first successful intubation attempt, overall intubation success rate, the best glottis view, and ease of intubation. The grading of the glottic view was based on the Cormack-Lehane system (16). To assess the subjective opinion about the easiness of using the intubation methods, participants were asked to rate the distinct device with a score from 1 (extremely easy) to 10 (extremely difficult).

The Statistica 13.3 EN software (StatSoft, Tulusa, OK, USA) was used for the analyses. The Kolmogorov-Smirnov test was utilized to analyze the parameters for normality. Categorical data are presented either as median and range or as frequencies and percentages. Data for the successful intubation attempt were analyzed using Chi^2 test, whereas time for successful intubation was analyzed using paired-samples T test. Data for the ease of intubation of each device was analyzed with paired-samples t-test. For all statistical analyses, $P < 0.05$ was considered statistically significant.

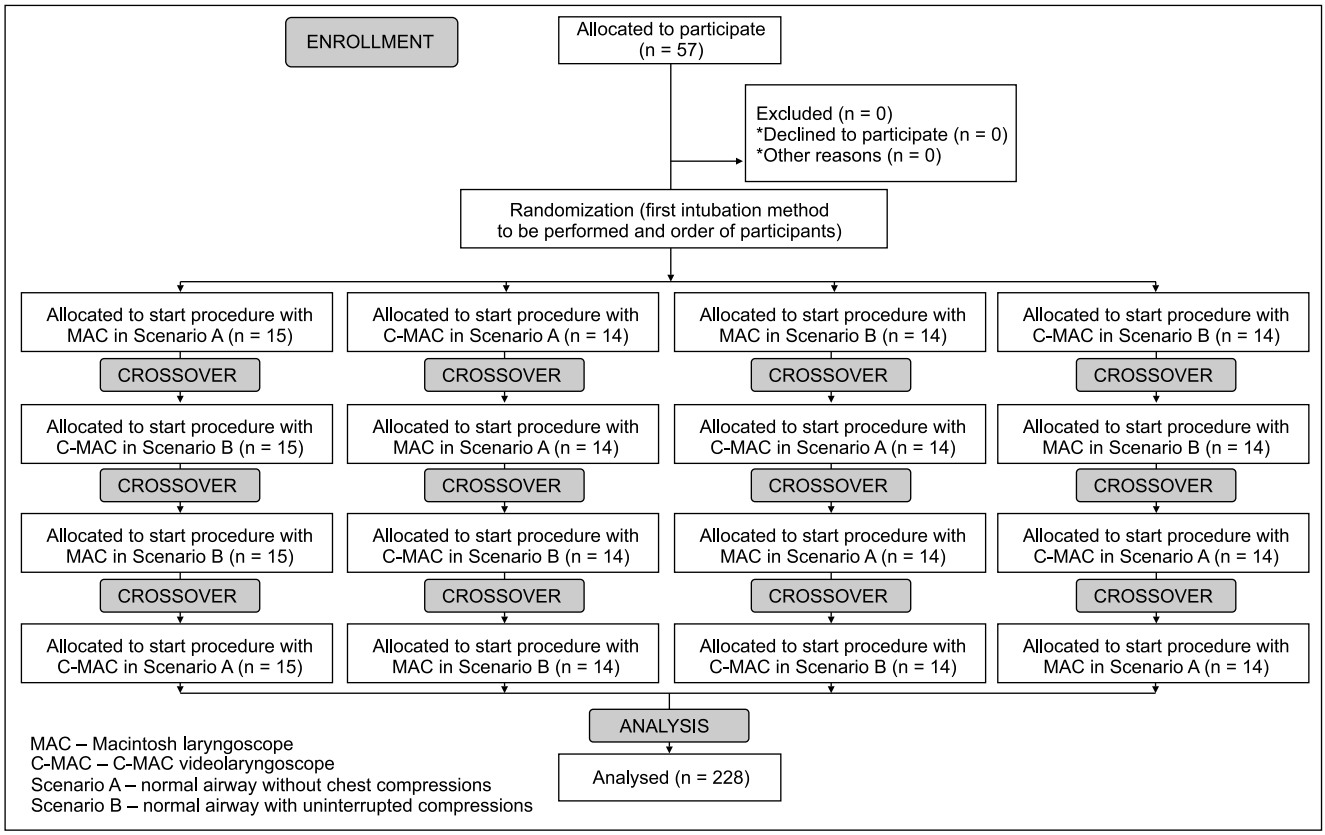

Fig. 2. Randomization flow chart

RESULTS

Fifty-seven last year medical students without prior experience in videolaryngoscopy were included in the study. All of the participants provided written informed consent prior to participation. Median age of participants was 24.5 (IQR: 24-25.5) years.

Time to intubation

Figure 3 describes the median times of the intubation with the use of researched techniques. Median intubation time using Macintosh laryngoscope with and without chest compression varied and amounted to 39 (IQR: 24-47) vs. 21 sec (IQR: 20-27) ($p = 0.002$), respectively. When using C-MAC videolaryngoscope the intubation time without chest compressions was 18 sec (IQR: 16.5-24) and for the uninterrupted chest compressions it was 22.5 sec (IQR: 17-25) ($p = 0.037$). Analysis of the study material also showed statistically significant differences between the intubation time using MAC and C-MAC during the scenario A ($p = 0.001$), as well as during the scenario B ($p < 0.001$).

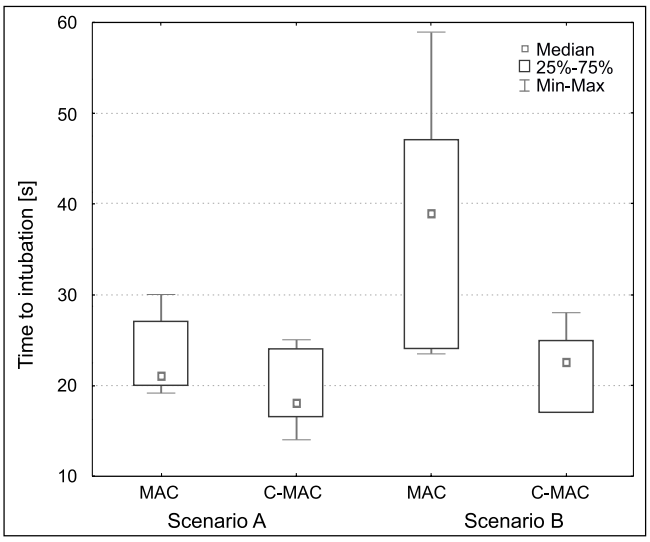

Fig. 3. Median intubation time using distinct laryngoscopes

Intubation success rate

The first intubation attempt success rate with the use of MAC without chest compression was 54.3%, and with chest compressions was 28.1% (tab. 1). And for the C-MAC the first intubation attempt success rate was 100% for scenario without chest compressions and 96.5% for the uninterrupted chest compressions scenario.

The total intubation success rate for MAC was 96.5 and 50.9% for the scenario A and scenario B respectively ($p < 0.001$). For C-MAC the total success rate for both scenarios was 100%.

Glottis view

During the scenario without chest compressions, the 1st degree of glottal visualization based on the Cormack-Lehane scale when using MAC was obtained in 50.9% of cases, and when using C-MAC it was obtained in 93% of cases ($p < 0.001$; tab. 2). During the scenario B the percentage of people who achieved the first degree of glottal visualization was 40.4 vs. 89.5% respectively ($p < 0.001$). A statistically significant reduction in the degree of glottal visualization between scenario A and B was proved when MAC was utilized ($p = 0.001$).

Tab. 1. Number of attempts for successful intubation with each technique

Number of attempts	Macintosh laryngoscope		C-MAC videolaryngoscope	
	without chest compressions	with chest compressions	without chest compressions	with chest compressions
1st	31 (54.3%)	16 (28.1%)	57 (100%)	55 (96.5%)
2nd	23 (40.4%)	9 (15.8%)	–	2 (3.5%)
3rd	1 (1.8%)	4 (7.0%)	–	–

Tab. 2. Glottic visualization using Cormack-Lehane grade

Cormack--Lehane grade	Macintosh laryngoscope		C-MAC videolaryngoscope	
	without chest compressions	with chest compressions	without chest compressions	with chest compressions
1st	29 (50.9%)	23 (40.4%)	53 (93.0%)	51 (89.5%)
2nd	28 (49.1%)	19 (33.3%)	4 (7.0%)	5 (10.5%)
3rd	–	11 (19.3%)	–	–
4th	–	4 (7.0%)	–	–

Ease of intubation

The ease of endotracheal intubation was evaluated by the participants and for MAC it was 3 points (IQR: 2-5) vs. 3 points for C-MAC (IQR: 2-4.5). In the scenario B, the intubation easiness amounted to 8 points (IQR: 5.5-8) when using MAC vs. 4 points (IQR: 2.5-5) for C-MAC. The degree of intubation difficulties was significantly influenced by performing chest compressions when using the Macintosh laryngoscope ($p < 0.001$).

DISCUSSION

The maintaining of airway patency is a crucial step when resuscitating a patient with sudden cardiac arrest. Although endotracheal intubation should not delay the inception of chest compressions or prolong the pauses in compressions – it is considered the gold standard for airway patency maintenance during resuscitation. The current American Heart Association guidelines recommend that intubation should be performed without interrupting chest compressions, or only with a short pause to allow for the insertion of endotracheal tube in between the vocal folds (4). However, as indicated by many studies, performing intubation during uninterrupted chest compressions

may be associated with a high risk of ineffectiveness of this procedure, including the migration of the intubation tube or the prolongation of the time when the patient is not being ventilated (17-19). At the same time, it is worth noting that the endotracheal intubation with direct laryngoscopy may be a challenge for emergency medical personnel, both in pre-hospital and hospital settings (20-22).

In this study we showed that performing chest compressions significantly reduces the effectiveness of endotracheal intubation and extends the duration of the procedure when performing the direct laryngoscopy with Macintosh laryngoscope. In order to insert the endotracheal tube between the vocal folds during direct laryngoscopy visualization of the glottis is required. In the conducted study, chest compressions significantly impeded the glottal visualization and thus increased the length of the intubation procedure, while simultaneously reducing the effectiveness of this procedure. On the other hand, videolaryngoscopes, including the C-MAC, are proven by many studies to provide better laryngeal visualization then conventional laryngoscopy and facilitate tracheal intubation in many emergency medicine settings i.e. cardiopulmonary resuscitation (23), or trauma patient intubation (24, 25).

In normal airways, when endotracheal intubation is performed without chest compressions the differences regarding the duration and the effectiveness of endotracheal intubation do not show such large discrepancies between direct and videolaryngoscopy as when the constant chest compressions are performed. Therefore, the benefits of videolaryngoscopy are more distinct in difficult airways.

Another interesting finding in the study was the improved performance with the C-MAC videolaryngoscope in the cardiopulmonary resuscitation. The study participants had no prior experience with video laryngoscopy. Therefore, this can be probably be attributed to the steep learning curve for the device. Konrad et al. (26) indicated that learning curve to reach an intubation success rate of 90% in direct laryngoscopy requires 47-56 patients and for videolaryngoscopy, Nouruzi-Sedeh et al. (27), indicated that only a few intubations were needed for the inexperienced users to archive proficiency with the GlideScope laryngoscope. The aforementioned findings are also confirmed by the studies of other authors (28, 29).

The study has several limitations. The first of one is that the research was carried out in the medical simulation environment, not in the real-life cardiopulmonary resuscitation. This way of conducting this study was chosen on purpose and was dictated by the fact that cross-randomized cross-over studies in cardiopulmonary resuscitation are unethical and can only be performed on medical simulation. The second limitation was the use of last year medical students for the study; however, they are the ones who will soon finish their medical studies and will perform cardiopulmonary resuscitation in their daily professional practice. In this study we included 57 participants, however Cho et al. (30) indicated that a minimum of 24 participants are needed to demonstrate the 20% difference in intubation time between intubation devices ($b = 0.3$; $a = 0.05$). Apart from the restrictions, the research has obvious advantages. These include: a randomized cross-study character, the use of a direct – and videolaryngoscopy in the study and also the use of a chest compression system to standardize the difficulties resulting from chest compressions.

CONCLUSIONS

Within limitations, we conclude that performing chest compressions during direct laryngoscopy prolongs the procedure and lowers the efficacy rate. C-MAC videolaryngoscope can be used by inexperienced intubators without interruptions in chest compressions. Additional studies are required to validate those results.

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