

Comparison of Macintosh, McCoy and C-MAC D-Blade video laryngoscope intubation by prehospital emergency health workers: a simulation study

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Received: 7 December 2015 / Accepted: 9 March 2016 / Published online: 21 March 2016
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Abstract The aim of this study is to evaluate the intubation success rates of emergency medical technicians using a Macintosh laryngoscope (ML), McCoy laryngoscope (MCL), and C-MAC D-Blade (CMDB) video laryngoscope on manikin models with immobilized cervical spines. This randomized crossover study included 40 EMTs with at least 2 years' active service in ambulances. All participating technicians completed intubations in three scenarios—a normal airway model, a rigid cervical collar model, and a manual in-line cervical stabilization model—with three different laryngoscopes. The scenario and laryngoscope model were determined randomly. We recorded the scenario, laryngoscope method, intubation time in seconds, tooth pressure, and intubation on a previously prepared study form. We performed Friedman tests to determine whether there is a significant change in the intubation success rate, duration of tracheal intubation, tooth pressure, and visual analog scale scores due to violations of parametric test assumptions. We performed the Wilcoxon test to determine the significance of pairwise differences for multiple comparisons. An overall 5 % type I error level was used to infer statistical significance. We considered a *p* value of less than 0.05 statistically significant. The CMDB and MCL success rates were significantly higher than the ML rates in all scenario models (*p* < 0.05).

The CMDB intubation duration was significantly shorter when compared with ML and MCL in all models. CMDB and MCL may provide an easier, faster intubation by prehospital emergency health care workers in patients with immobilized cervical spines.

Keywords Intubation · Prehospital · Laryngoscope · Video · Manikin

Introduction

One of the tenets of prehospital patient stabilization after trauma is ensuring a reliable airway. For trauma cases requiring intubation, collars to protect the cervical spine or manual in-line cervical stabilization (MICS) significantly limit cervical extension to a degree that makes intubation difficult, lengthening the duration of intubation or causing repeated intubation interventions. Insufficient neck stabilization in trauma patients may cause damage to the cervical spine, which can lead to catastrophic neurological deficits [1, 2].

An evaluation of 35 clinical studies in the literature reported the incidence of difficulties with intubation for a variety of reasons as being from 1.5 to 20 % [3]. Intubation failure is generally due to not ensuring a straight line of sight along the oral, pharyngeal, and laryngeal axes for the direct laryngoscope as well as a lack of observation of the vocal cords [4]. After neck immobilization, intubation difficulties due to an inability to visualize the laryngeal structures with a traditional laryngoscope increase the morbidity and mortality of trauma patients requiring emergency intubation [5, 6]. Studies have reported that success levels for prehospital intubation of trauma cases with a standard laryngoscope are suboptimal, and the success rates of inexperienced users are even lower [7–9].

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Several methods that increase intubation success have been developed. Video laryngoscopes have improved, and have advantages compared to other methods. In classical laryngoscopes, a practitioner attempts to see vocal cords directly. Video laryngoscopes with micro-cameras transmit the indirect image of vocal cords to the monitor. Therefore, seeing vocal cords in a monitor facilitates the intubation process, reduces intubation time, and increases the intubation success rate [10, 11].

Our aim in this study is to evaluate the efficiency of emergency medical technicians (EMTs) working in ambulances and using a Macintosh laryngoscope (ML), a McCoy laryngoscope (MCL), and a C MAC D-Blade (CMDB) video laryngoscope on models with a normal airway, MICS without a cervical collar, and a cervical collar.

Methods

This randomized crossover manikin study began after obtaining permission from the ethics committee. The study included 40 EMTs who worked at least 2 years in ambulances in the Çanakkale province, in Turkey, after graduation. EMTs who had worked in the field less than 2 years after graduation, or refusing to participate in the study, were our exclusion criteria. Turkey uses the Anglo-American model of prehospital and hospital emergency services. In this model, mainly non-doctor personnel (EMTs or paramedics) work in ambulances, and patients are transferred to hospital in order to get definitive medical care. The EMTs begin emergency care at the scene, and transport patients to hospital emergency services.

In Çanakkale, 26 ambulance teams work in prehospital emergency situations, with only three doctors on these teams. EMTs comprise the majority of teams. The Ministry of Health grants the EMT title to people who graduate from the emergency medicine department of health vocational high school. EMT training and education is a four-year process. EMTs are responsible for several medical emergency procedures at the scene. One of these procedures is endotracheal intubation with a standard Macintosh laryngoscope; during training, EMTs perform both manikin and human intubations during their practice in emergency service and intensive care units.

After receiving consent from the participants, the study began. We divided the participants randomly into eight equal groups of five individuals, who intubated at different times. The technicians had no previous experience with CMDB or MCL. All technicians listened to 30-min lecture and a demonstration of the CMDB and MCL. Later participants practiced as much as desired with all laryngoscope types on normal models.

Laryngoscopes used (Fig. 1)

1. Macintosh laryngoscope, blade 3 (Heine Optotechnik, Munich, Germany).
2. McCoy laryngoscope, size 3 (Maxlite Flexitip F.O., InvoTech Excel Fzco, Dubai)
3. C-MAC D-Blade video laryngoscope (Karl Storz, Tuttlingen, Germany)

All intubations were completed on a SimMan brand manikin (Laerdal Medical, Kent, UK) in a training room on the table. Intubations used a cuffed endotracheal tube with 7.5 mm semi-rigid stylus attached. Before intubations, lubricant was applied to the cuff of the endotracheal tube

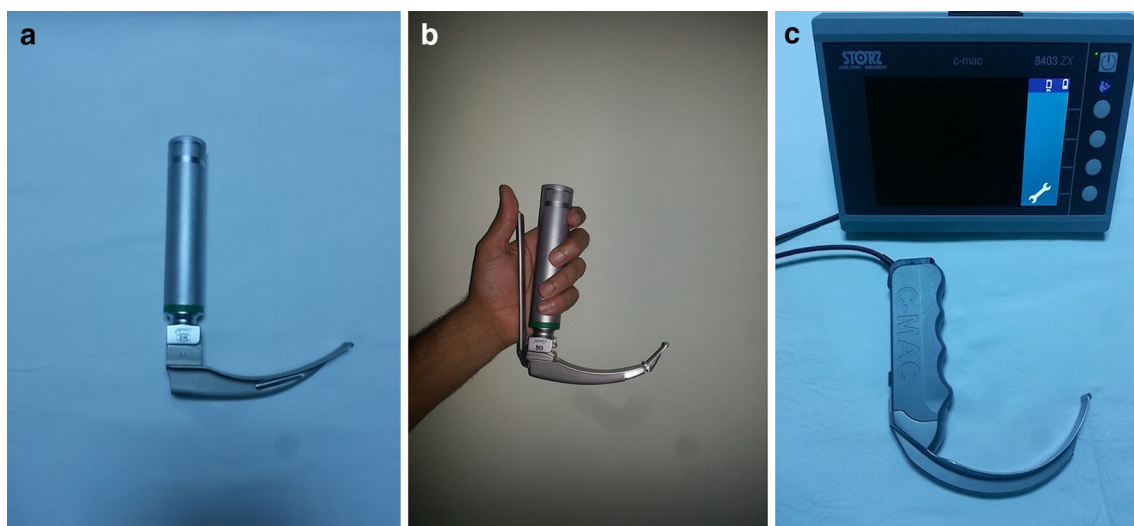


Fig. 1 a Macintosh laryngoscope; b McCoy laryngoscope; c C-MAC D-Blade videolaryngoscope

(Laerdal Medical). All participants were intubated with ML, MCL, and CMDDB laryngoscopes (Fig. 1).

Choice of scenario and technician

All technicians participating in the study completed intubations in three different scenarios; (1) a normal airway model, (2) a MICS without cervical collar model, and (3) a rigid cervical collar model without MICS (Fig. 2).

In the normal airway model, the manikin was put in a supine position and the normal airway anatomy. In the MICS without cervical collar model, a second person held both hands on the manikin's head to maintain cervical spine in a neutral position. In the rigid cervical collar model, a neck collar was attached to a manikin to limit cervical extension, but there was no manual stabilization.

We chose the method used for each model randomly—initially the participant, then the scenario, and finally the laryngoscope model was determined by a research randomizer program. After each intubation, participant, scenario, and laryngoscope type were randomly determined again. An emergency medicine specialist and an anesthesiologist recorded and evaluated intubation attempts.

We defined successful intubation as inserting the endotracheal tube and ventilating the manikin's lungs within 75 s. Unsuccessful intubation was defined as inserting the tube into the esophagus, removing and repositioning the endotracheal tube, or not completing intubation within 75 s. Participants had two attempts per scenario; if the first attempt was successful, a second attempt was not completed. If they did not complete intubation on the second attempt, it was also defined as unsuccessful. Participants were not informed about the criteria for successful intubation; however, they were requested to intubate in the shortest time. Measurement of the intubation duration began immediately after they inserted the laryngoscope blade between the model's teeth and ended with ventilation of the lungs. During intubation, the observer evaluated and recorded tooth pressure as 1, no pressure (upper teeth did not touch laryngoscope blade); 2, moderate pressure (no dental click sound but laryngoscope blade touches upper

teeth); and 3, severe pressure (audible dental click sound from laryngoscope blade touching upper teeth). After the procedure, each participant evaluated the intubation difficulty according to a visual analog scale (VAS) (between 0 and 10; 0 being easiest, 10 being most difficult).

The scenario, laryngoscope method, intubation time in seconds, tooth pressure, and intubation difficulty were recorded on a previously prepared study form.

Statistical analysis

We performed statistical analysis using the SPSS software version 19.0 (IBM, Armonk, NY). The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk test) to determine whether they were normally distributed. Descriptive analysis was presented using medians and interquartile ranges for the non-normally distributed and ordinal variables. We performed Friedman tests to determine whether there is a significant change in the intubation success rate, duration of tracheal intubation, tooth pressure, or visual analog scale score due to violations of parametric test assumptions. We performed the Wilcoxon test to determine the significance of pairwise differences using the Bonferroni correction to adjust for multiple comparisons. An overall 5 % type I error level was used to infer statistical significance. A *p* value of less than 0.05 was considered a statistically significant result.

Results

This study included 40 EMTs (27.5 ± 5.1 years old). Of participants, 60 % (24) were female, and all had worked in an ambulance for at least 2 years. The mean work experience was 5.87 ± 2.95 years.

Scenario 1: normal airway (Fig. 2)

Table 1 gives the success rate, intubation duration, tooth pressure, and degree of difficulty for the normal airway

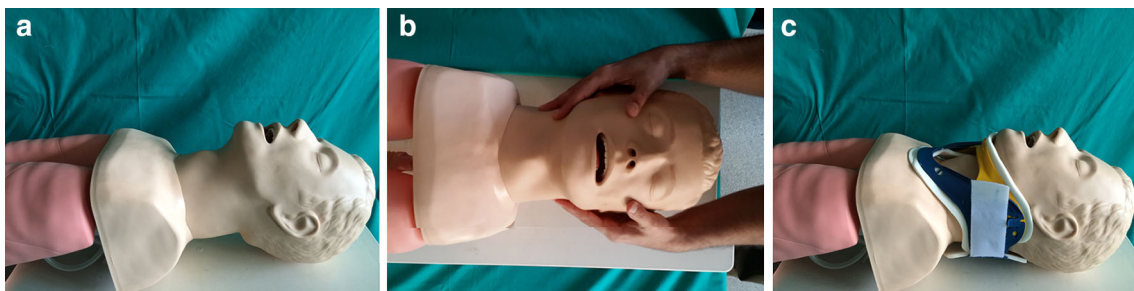


Fig. 2 a Normal airway model; b Manual in-line cervical stabilization model; c Normal airway with cervical collar model

Table 1 The success rate, intubation duration, tooth pressure and degree of difficulty of intubation for the normal airway scenario

Normal airway scenario	Macintosh	McCoy	C-MAC D-Blade	<i>p</i>
Success rate <i>N</i> (%)	36 (85)	40 (100) ^b	40 (100) ^c	0.002 ^a
Intubation duration (s)	22.57 ± 18.20 ^d	17.67 ± 10.06 ^e	14.62 ± 3.60	0.001 ^a
Tooth pressure				<0.001 ^a
1	1 (2.5) ^d	1 (2.5) ^c	17 (42.5)	
2	3 (7.5)	8 (20)	14 (35.0)	
3	36 (90)	31 (77.5)	9 (22.5)	
Degree of difficulty	5 (1–10) ^f	4 (1–7) ^f	1 (0–9) ^f	<0.001 ^a

^a Friedman test^b *p* < 0.05 compared with Macintosh, Wilcoxon test^c *p* < 0.05 compared with Macintosh, Wilcoxon test^d *p* < 0.05 compared with C-Mac D Blade, Wilcoxon test^e *p* < 0.05 compared with C-Mac D Blade, Wilcoxon test^f *p* < 0.05 for all two group comparisons, Wilcoxon test

scenario. All intubation attempts with CMDB and MCL were successful. ML intubation attempts were unsuccessful for four technicians. CMDB and MCL intubation success was statistically significant when compared to ML (*p* < 0.05). The CMDB intubation duration was 14.62 ± 3.60 s, which was significantly shorter compared to ML (22.57 ± 18.20 s) and MCL (17.67 ± 10.06 s) (*p* < 0.001). In the comparison of tooth pressure degrees between laryngoscopes, 1 (2.5 %) participant caused no pressure, 3 (7.5 %) participants caused moderate pressure and 36 (90 %) participants caused severe pressure with ML, these values were 1 (2.5 %), 8 (20 %) and 31 (77.5 %) with MCL and 17 (42.5 %), 14 (35 %) and 9 (22.5 %) with CMDB, respectively (*p* < 0.001). Degree of difficulty was the highest with ML [median VAS: 5 (1–10)] and the lowest with CMDB [median VAS: 1 (0–9)] (*p* < 0.001) (Table 1).

Scenario 2: manual in-line cervical stabilization (Fig. 2)

The success rates, intubation durations, tooth pressures, and degrees of difficulty for the MICS scenario are shown in Table 2. All intubation attempts with CMDB and MCL were successful. Six technicians were unsuccessful intubating with ML. The success rates of CMDB and MCL were significantly higher compared to ML (*p* < 0.05). The CMDB intubation duration was 14.92 ± 3.45 s, which was significantly shorter than the duration with ML (23.60 ± 17.88 s) and MCL (18.25 ± 4.97 s) (*p* < 0.05). In the comparison of tooth pressure degrees between laryngoscopes, 2 (5 %) participants caused no pressure, 5 (12.5 %) participants caused moderate pressure and 33 (82.5 %) participants caused severe pressure with ML, these values were 1 (2.5 %), 9 (22.5 %) and 30 (75 %) with MCL and 20 (50 %),

Table 2 The success rate, intubation duration, tooth pressure and degree of difficulty of intubation for the manual in-line cervical stabilization scenario

Manual in-line cervical stabilization	Macintosh	McCoy	C-MAC D-Blade	<i>p</i>
Success rate	34 (90)	40 (100) ^b	40 (100) ^c	0.018 ^a
Intubation duration (s)	23.60 ± 17.88 ^d	18.25 ± 4.97 ^e	14.92 ± 3.45	<0.001 ^a
Tooth pressure				<0.001 ^a
1	2 (5) ^d	1 (2.5) ^c	20 (50)	
2	5 (12.5)	9 (22.5)	13 (32.5)	
3	33 (82.5)	30 (75.0)	7 (17.5)	
Degree of difficulty	6 (2–10) ^f	5 (2–7) ^f	1 (0–9) ^f	<0.001 ^a

^a Friedman test^b *p* < 0.05 compared with Macintosh, Wilcoxon test^c *p* < 0.05 compared with Macintosh, Wilcoxon test^d *p* < 0.05 compared with C-Mac D Blade, Wilcoxon test^e *p* < 0.05 compared with C-Mac D Blade, Wilcoxon test^f *p* < 0.05 for all two group comparisons, Wilcoxon test

13(32.5 %) and 7(17.5 %) with CMDB, respectively ($p < 0.001$). Degree of intubation difficulty was the highest with ML [median VAS: 6 (2–10)] and the lowest with CMDB [median VAS: 1 (0–9)] ($p < 0.001$) (Table 2).

Scenario 3: normal airway with cervical collar (Fig. 2)

Table 3 gives the success rates, intubation durations, tooth pressures, and degrees of difficulty for the normal airway with cervical collar scenario. Intubation attempts with CMDB by all participants were successful. Six technicians had unsuccessful intubation with ML. For MCL only, one intubation attempted ended in failure; the same technician also was unsuccessful at intubation with ML. Intubation success for CMDB and MCL was statistically significant when compared to ML ($p < 0.05$). The intubation duration with CMDB was 15.25 ± 3.63 s, which was significantly shorter when compared with ML (28.12 ± 20.47 s) and MCL (18.60 ± 4.74 s) ($p < 0.05$). In the comparison of tooth pressure degrees between laryngoscopes, 2 (5 %) participants caused no pressure, 3 (7.5 %) participants caused moderate pressure and 35 (87.5 %) participants caused severe pressure with ML, these values were 1 (2.5 %), 10 (25 %) and 29 (72.5 %) with MCL and 23 (57.5 %), 10 (25 %) and 7 (17.5 %) with CMDB, respectively ($p < 0.001$). Degree of intubation difficulty was the highest with ML [median VAS: 6 (2–10)] and the lowest with CMDB [median VAS: 1 (0–9)] ($p < 0.001$) (Table 3).

Discussion

In this simulation study of EMTs working in ambulances, the CMDB intubation durations were shorter than intubation durations with ML and MCL on all models; the

CMDB intubation was shown to have less tooth pressure and degree of difficulty; and in all scenarios, intubation attempts with CMDB were successful and had the shortest intubation durations.

To see the vocal cords with a standard laryngoscope, it is necessary to bring the oral, pharyngeal, and laryngeal axes into the same line. The CMDB allows the possibility of indirectly observing the vocal cords, and as a result, it does not require extreme neck extension during intubation (Fig. 1). Images in CMDB are sent to a camera or color video unit mounted on the blade. The MCL is designed to visualize the vocal cords, with the flexible tip providing elevation of distal structures (Fig. 1).

Due to limited neck movements after cervical rigid collar and MICS administration, it is difficult to bring the oropharynx and laryngeal lines to the same level. This situation makes intubation difficult and lengthens intubation duration. The CMDB's major advantage is the blade structure (Fig. 1), which allows indirect observation of the vocal cords. The MCL's mobile tip requires less neck movement [12]. Recently, a simulation study using a cervical collar did not find any difference in intubation durations with CMDB and ML. Another study reports that the intubation duration with CMDB is longer than for ML [13, 14]. Bilgin and Bozkurt [15] created a cervical trauma simulation. They find the mean MCL intubation duration to be 30 s. Additionally, studies comparing normal airway intubation with ML and indirect video laryngoscopes emphasize that ML intubation is faster [16–18].

Our study contradicts all these findings. The CMDB intubation durations were shorter than those with ML and MCL were. Additionally, in all our scenarios, the shortest intubation duration was reached with CMDB. We think the reason for the difference in intubation duration in our study is that technicians had sufficient opportunity to practice intubation with MCL and CMDB. Video laryngoscopes

Table 3 The success rate, intubation duration, tooth pressure and degree of difficulty of intubation for the normal airway with cervical collar scenario

Normal airway with cervical collar	Macintosh	McCoy	C-MAC D-Blade	<i>p</i>
Success rate <i>N</i> (%)	34 (90) ^b	39 (97.5)	40 (100)	0.039 ^a
Intubation duration (s)	28.12 ± 20.47 ^c	18.60 ± 4.74 ^d	15.25 ± 3.63	<0.001 ^a
Tooth pressure				<0.001 ^a
1	2 (5) ^e	1 (2.5) ^d	23 (57.5)	
2	3 (7.5)	10 (25)	10 (25)	
3	35 (87.5)	29 (72.5)	7 (17.5)	
Degree of difficulty	6 (2–10) ^e	4 (1–7) ^e	1 (0–9) ^e	<0.001 ^a

^a Friedman test

^b $p < 0.05$ compared with C-Mac D Blade, Wilcoxon test

^c $p < 0.05$ compared with C-Mac D Blade, Wilcoxon test

^d $p < 0.05$ compared with C-Mac D Blade, Wilcoxon test

^e $p < 0.05$ for all two group comparisons, Wilcoxon test

allow technicians to see vocal cords indirectly; the technicians therefore do not need to displace tissues to create a visual axis, allowing them direct visualization of the vocal cords. Therefore, emphasizing the technical differences between direct and video laryngoscopes during training may increase the success rate with video laryngoscopes.

Another result obtained in our study is that CMDB causes the lowest tooth pressure in all simulation models, and reduces the degree of intubation difficulty. When MCL and ML are compared, there is no difference in tooth pressure; however, the MCL's degree of intubation difficulty is significantly reduced. The greater angle of the CMDB blade and the MCL's mobile head require less force to observe larynx structures and less neck extension [19, 20]. During intubation, maneuvers to observe the vocal cords use more force, and the resultant severe neck extension might cause spinal cord damage [1]. Intubation attempts with indirect laryngoscope require less neck extension and force, protecting the cervical vertebrae [21].

There were some limitations to our study; firstly, this was a simulation using manikins rather than real humans. There are some inevitable limitations in manikin studies—no live tissues, no airway fluids, and no anatomical damages from trauma. Additionally, study participants had less intubation practice compared to those working in emergency service and anesthesia units, which is a severe limitation. In our study, the subjective measurement of degree of intubation difficulty is a limitation. Also, there was no objective measure of tooth pressure, although we used dental click sounds to make standardization ideal. Lastly, success was defined as an intubation completed in 75 s, which is longer than the recommended time for real human intubation.

Conclusion

CMDB and MCL provide the possibility of faster, easier intubation by health workers with less intubation experience, such as EMTs working primarily in ambulances, for trauma cases with cervical immobilization.

Acknowledgments We would like to thank Dr. Şule Yıldırım for providing statistical analysis and Dr. Şükrü Kabaş for invaluable logistical support.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Funding source No external funding was secured for this study.

Financial disclosure The authors have no financial relationships relevant to this article to disclose.

Statement of human and animal rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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