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COMPARISON OF VARIOUS INTUBATION DEVICED DURING RESUSCITATION OF COVID-19-SUSPECTED PATIENTS BY PARAMEDICS WEARING PERSONAL PROTECTIVE EQUIPMENT

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Background: Endotracheal intubation is one of the basic methods for airway control during cardiopulmonary resuscitation. In the era of the prevailing pandemic of SARS-CoV-2, medical personnel may face a necessity of resuscitating aninfected patient.

Objective: The objective was to compare three intubation methods for suspected/confirmed COVID-19 adult patient resuscitation performed by paramedics wearing personal protective equipment (PPE) for aerosol generating procedures (AGP).

Material and Methods: The multicentre, single-blind, prospective, randomized, crossover simulation trial involved 32 paramedics. The participants wearing PPE AGP performed tracheal intubations with the Macintosh, Airtraq, and McGrath MAC laryngoscopes in a patient with suspected COVID-19 in two resuscitation scenarios: scenario A – without chest compressions; scenario B – with continuous chest compressions. The primary outcome was time to intubation.

Results: In scenario A, the intubation time for the respective devices equalled 35 s (IQR: 29–46) vs. 44s (IQR: 35–67) vs. 49 (IQR: 34–72) (p = 0.003). The total efficacy of each intubation method was 100%; however, the efficacy of the first intubation attempt was highest for McGrath MAC (90.6%), followed by Macintosh (68.1%) and Airtraq 62.5%) (p<0.001). In scenario B, the results with McGrath MAC were significantly better than those with Macintosh and Airtraq(p<0.05) for all the analysed variables.

Conclusions: In conclusion, the McGrath MAC videolaryngoscope offers better intubation conditions as compared with the Macintosh laryngoscope or Airtraq in the resuscitation COVID-19.

***Keywords**: endotracheal intubation; personal protective equipment; COVID-19; paramedic; cardiopulmonary resuscitation.*

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According to the World Health Organization, the SARS-CoV-2 coronavirus is a serious concern to public health [1] and has taken the form of a global pandemic. Since the first reported cases in December 2019 in China, there have been 622,450 confirmed infections (as of March 28, 2020); the death rate is 4.5%. On the basis of research conducted by Li et al. [2], the population most at risk are people with a compromised immune function such as the elderly and those with renal or hepatic dysfunction. COVID-19, caused by SARS-CoV-2, is classified as an airborne high consequence infectious disease. Personal protective equipment PPE must be worn by healthcare professionals, comprising, as a minimum, a correctly fitted FFP3 respirator, gown, gloves, and eye protection [3, 4].

In the case of cardiac arrest, the immediate start of resuscitation procedures improves survival [5]. High-quality chest compressions are also of paramount importance for survival and good neurological outcome. Unfortunately, even medical personnel often perform chest compressions without achieving the appropriate parameters specified by the European Resuscitation Council [6] or the American Heart Association [7]. Numerous simulation studies often indicate too shallow chest compressions, too fast compression rate, and incomplete chest recoil [8]. In patients with suspected/confirmed COVID-19, no chest compressions or airway procedures should be performed without full PPE for aerosol generating procedures (AGP) [9]. However, the use of PPE AGP may make it difficult to perform cardiopulmonary resuscitation. Therefore, it is advisable to look for alternative methods of chest compressions that will increase its effectiveness in such patients.

Aim of the study. The objective of this randomized crossover study was to determine which of the three intubation methods – standard Macintosh laryngoscope, Airtraq optical laryngoscope, or McGrath MAC videolaryngoscope – was associated with shorter times for successful intubation by paramedics wearing PPE AGP in a suspected/confirmed COVID-19 adult patient resuscitation scenario.

Material and methods

The study was designed as a single-blind, multicentre, prospective, randomized, crossover

simulation study and was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (approval No. 12.01.2020.IRB). The investigation was carried out at the Medical Simulation Centre of Poznan University of Medical Sciences and Lazarski University in February 2020. Paramedics with at least one year of experience were invited to take part in the study, and voluntary written informed consent was obtained from all participants. The inclusion criteria involved at least one year of work experience, a minimum of 10 clinical intubations, as well as no experience with videolaryngoscopy.

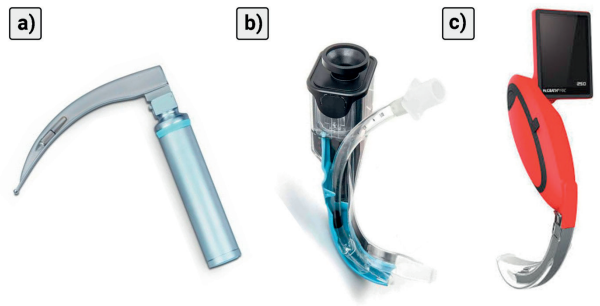

Figure 1. – Devices included in the study: a) standard Macintosh laryngoscope; b) Air traq optical laryngoscope; c) video laryngoscope Mc Grath MAC

Рисунок 1. – Устройства, включенные в исследование: а) стандартный ларингоскоп Макинтоша; б) оптический ларингоскоп Air traq; в) видеоларингоскоп Mc Grath MAC

Devices. The following devices were included in the study (Figure 1):

a) standard Macintosh laryngoscope, size #3 (MAC; HEINE Optotechnik GmbH & Co. KG, Herrsching, Germany);

b) Airtraqoptical laryngoscope with a size #3 channelled blade (Prodol, Vizcaya, Spain);

c) McGrath MAC (Aircraft Medical Ltd., Edinburgh, UK).

Each endotracheal intubation was performed with a standard 7.5 mm internal diameter, cuffed, plastic endotracheal tube (SUMI, Sulejowek, Poland). For MAC and McGrath MAC intubation, a single-use intubation stylet was applied. Before each intubation attempt, both the guide and the endotracheal tube were moistened with a slide agent dedicated for medical simulators.

Training phase. The participants received a 60-minute theoretical training on the indications for intubation in patients suspected of or infected with SARS-CoV-2 and on protecting medical staff against contact with such patients. Subsequently, the instructor demonstrated the correct technique of endotracheal intubation using all the devices tested. After the demonstration, the participants were allowed to familiarize themselves with the laryngoscopes before commencing the study; this phase included at least one successful tracheal intubation by each participant with each device. Demonstrations and training were all performed with the Laerdal Airway Management Trainer (Laerdal, Stavanger, Norway) under normal airway conditions, without chest compressions and withoutPPE.

Simulation scenario. An advanced SimMan 3G adult patient simulator (Laerdal, Stavanger, Norway) was used to simulate a patient with suspected/ confirmed SARS-CoV-2 infection. Endotracheal intubation was performed in two scenarios:

a) scenario A: normal airway without chest compressions;

b) scenario B: normal airway with uninterrupted chest compressions; the LUCAS3 mechanical chest compression system (Physio-Control Inc., Lund, Sweden) served to standardize chest compressions.

When intubating the patient, the participants wore an anti-chemical, antiviral, antibacterial suit of class F providing protection against organic and inorganic chemicals in high concentrations and against solid particles of less than 1 μm in diameter. The suit also protects against biological hazards and toxic agents (Maskpol Inc., Panki, Poland). In order to simulate real interventionsin a patient with SARS-CoV-2, the participants wore a protective mask with FFP1 filter, protective goggles, a visor, as well as double nitrile gloves (Figure 2).

Figure 2. – The appearance of paramedic

Рисунок 2. – Внешний вид парамедика

The paramedics had a maximum of three attempts of intubation with each device in each scenario. After the intubation attempts with a given laryngoscope, they had a 10-minute break, and then intubated the patient with the use of another technique. The order of both the participants and the endotracheal intubation methods was random. The Research Randomizer program (randomizer.org) was used for randomization.

Measurements. The primary endpoint was intubation time, which was recorded by an independent researcher, unaware of the study protocol. The intubation time was defined as the time between the laryngoscope passing the manikin's

teeth and the participant declaring the trachea to be intubated. Tracheal intubations that lasted more than 120 seconds were classified as unsuccessful. Failed tracheal intubations also included oesophageal intubations (not recognized by the participant) and tracheal intubations that required more thanthree attempts. When the participant recognized the intubation as oesophageal, it was counted as one attempt instead of unsuccessful intubation. If a participant, however, opted against a second or third attempt, the endotracheal intubation was registered as a failed attempt.

The secondary endpoints included the number of tracheal intubation attempts, the Cormack-Lehane grade [10] scored by the participant, as well as the percentage of glottic opening (POGO) score. Following the completion of a scenario, the subjects were asked to grade each device for the ease of its technical use (1 = easy, 100 = difficult) and the willingness to reuse (1 = would never use again, 100 = would like to use) in a relevant scenario, but they were discouraged from overall ranking of the devices. Also recorded were demographic data, which included the participants' experience in emergency medicine.

Statistical analysis. The sample size was based on expected differences of time to intubation and calculated with G*Power 3.1 using a two-tailed t-test (Cohen's d = 0.8, alpha error = 0.05, power = 0.95). We determined that a minimum of 32 participants were required for a pairwise comparison of our samples.

All analyses were performed with the statistical package Statistica 13.3EN (Tibco Inc., Tulsa, OK, USA). The data were blinded for the team interpreting the results. Categorical data were presented as raw numbers and as frequencies, and continuous and ordinal data as medians and interquartile ranges (IQR). Non-parametric tests were used because the data distribution was not typically based on Shapiro-Wilk and Kolmogorov-Smirnov tests. The Kruskal-Wallis one-way analysis of variance (ANOVA) with post-hoc Dunn's test wereapplied to assess pairwise differences between the devices for the following variables: intubation time, POGO score, ease of use, and willingness to reuse. Chi-square tests were used to evaluate differences between the devices for the rate of successful tracheal intubation. The values of $p \leq 0.05$ were considered statistically significant.

Results

A total of 32 paramedics (14 female, 45.2%) participated in the study. All participants worked in teams of emergency medical services. Their mean age was 28.3±5.6 years, and mean work experience time equalled 2.9 ± 1.6 years.

Scenario A: without chest compressions. The intubation results in scenario A are presented in Table 1.

The intubation time for the subsequent devices equalled 35 s (IQR: 29–46) vs. 44 s (IQR: 35–67) vs. 49 (IQR: 34–72) (p=0.003). The total efficacy of each intubation method was 100%; however, the efficacy of the first intubation attempt was highest for McGrath MAC (90.6%), followed

Table 1. – Intubation details in scenario A, without chest compressions. Data are presented as median (IQR) or as number (%)

Таблица 1. – Детали интубации при сценарии А без компрессии грудной клетки. Данные представлены в виде медианы (IQR) или числа (%)

Intubation parameter	(A) Macintosh laryngoscope	(B) Airtraq laryngoscope	(C) McGrath MAC laryngoscope	p values for between-device differences			p
				A vs. B	A vs. C	B vs. C	
Intubation time (s)	44 (35–67)	49 (34–72)	35 (29–46)	0.027	0.047	0.004	0.003
Overall success rate (%)	32 (100%)	32 (100%)	32 (100%)	1.0	1.0	1.0	1.0
Success of intubation attempt: 1st 2nd 3rd	22 (68.1%) 10 (31.3%) –	20 (62.5%) 12 (37.5%) –	29 (90.6%) 3 (9.4%) –	0.116	**0.012**	**0.008**	**< 0.001**
Cormack-Lehane grade (%) 1 2 3 4	22 (68.7%) 10 (31.3%) – –	13 (40.6%) 19 (59.4%) – –	30 (93.7%) 2 (6.3%) – –	**0.037**	**0.021**	0.007	0.011
POGO score (%)	60 (50–90)	60 (60–85)	90 (80–100)	0.265	**0.009**	**0.004**	**0.007**
Ease of intubation (1–100)	60 (30–70)	70 (40–75)	10 (5–20)	0.512	**< 0.001**	**< 0.001**	**0.012**
Willingness to reuse (1–100)	30 (10–40)	20 (10–30)	100 (80–100)	0.327	**< 0.001**	**< 0.001**	**0.005**

Table 2. – Intubation details in scenario B, with chest compressions. Data are presented as median (IQR) or as number (%)
Таблица 2. – Детали интубации при сценарии В с компрессией грудной клетки. Данные представлены в виде медианы (IQR) или числа (%)

Intubation parameter	(A) Macintosh laryngoscope	(B) Airtraq laryngoscope	(C) McGrath MAC laryngoscope	p values for between-device differences			p
				A vs. B	A vs. C	B vs. C	
Intubation time (s)	83 (49–103)	80 (55–110)	39 (30–48)	0.127	**< 0.001**	**< 0.001**	**< 0.001**
Overall success rate (%)	22 (68.7%)	15 (46.9%)	32 (100%)	**0.001**	**< 0.001**	**< 0.001**	**< 0.001**
Success of intubation attempt: 1st 2nd 3rd	 5 (15.6%) 4 (12.5%) 13 (40.6%)	 2 (6.3%) 10 (31.3%) 3 (9.4%)	 16 (50.0%) 13 (40.6%) 3 (9.4%)	**0.001**	**0.028**	**0.001**	**< 0.001**
Cormack-Lehane grade (%) 1 2 3 4	 11 (34.4%) 18 (56.2%) 3 (9.4%) –	 5 (15.6%) 26 (81.3%) 1 (3.1%) –	 17 (53.1%) 15 (46.9%) – –	**0.031**	**< 0.001**	< 0.001	< 0.001
POGO score (%)	45 (30–60)	40 (20–60)	80 (65–90)	0.328	**< 0.001**	**< 0.001**	**0.001**
Ease of intubation (1–100)	80 (50–90)	80 (60–90)	30 (20–50)	0.671	**0.001**	**< 0.001**	**0.001**
Willingness to reuse (1–100)	30 (10–30)	20 (0–20)	100 (90–100)	**0.048**	**< 0.001**	**< 0.001**	**< 0.001**

by Macintosh laryngoscope (68.1%) and Airtraq (62.5%) (p<0.001). The best glottis visualization for both Cormack-Lehane and POGO scores were recorded when using McGrath MAC, and the worst glottis visualization was bound with the Airtraq laryngoscope. Also the ease of intubation and willingness to reuse were in favour of McGrath MAC.

Scenario B: with chest compressions. The data obtained in scenario B are shown in Table 2.

The time to intubation was the shortest with McGrath MAC (39 s [IQR: 30–48]) and was significantly longer with Macintosh laryngoscope (83 s [IQR: 49–103]; p<0.001), as well as with Airtraq (80 s [IQR: 55–110]; p<0.001). Overall success rate was reported 100% only with McGrath MAC, followed by 68.7% for Macintosh laryngoscope and 46.9% for Airtraq. However, the success rate of the first intubation attempt using McGrath, Macintosh, and Airtraq amounted to 50% vs. 15.6% vs. 6.3% (p<0.001).

Endotracheal intubation with McGrath was associated with a better glottic view in the Cormack-Lehane scale, as well as in the POGO score in comparison with Macintosh laryngoscope (p < 0.001) and Airtraq (p < 0.001). Intubation with McGrath was also reported as easier to perform in comparison with Macintosh laryngoscope (p < 0.001) and Airtraq (p < 0.001).

Discussion

This is the first study comparing endotracheal intubation for suspected/confirmed COVID-19 adult patient resuscitation scenarios performed by paramedics wearing PPE AGP. The current SARS-CoV-2 coronavirus pandemic requires medical personnel to take special measures, including the use of PPE to protect against new virus infection [9, 11, 12]. Hence, every action, especially in pre-hospital conditions, where paramedics are unaware of the patients' status, should be performed under special precautionary measures. Such precautions are crucial as carelessness may result in self-infection or infection of future patients during subsequent medical interventions [13]. Also, in any case of contact with a patient with suspected/confirmed COVID-19, if PPE AGP was not worn bythe medical personnel, it is necessary to isolate the emergency medical team until the patient confirms or excludes COVID-19 [14]. This, in turn, results in blocking the ambulance and its entire crew and thereby reduces the responsiveness of local emergency services.

Paramedics acting within the framework of emergency medical teams often face the necessityto adequately protect airway patency, including performing endotracheal intubation [15]. In the context of COVID-19 patients in severe condition requiring mechanical ventilation, endotracheal intubation still seems to be the gold standard for airway management [16]. The use of full protection in the form of PPE AGP may limit the effectiveness of medical procedures [17, 18]. This is also confirmed by Scott Taylor et al. [19]. In their research, emergency medicine residents and prehospital providers performed endotracheal intubation in a cadaveric model while wearing level C PPE or without any PPE. The success rate of the first intubation attempt with and without PPE

equalled 58% vs. 96%. Intubation performed with PPE also affects intubation time, extending the duration of the procedure [19]. Paramedics also feel more temperature-related discomfort during direct laryngoscopy when wearing PPE [20]. In turn, in a study by Wang et al. [21], PPE did not affect physicians' emergency airway placement time.

In the scenario without chest compressions, intubation with the McGrath MAC video-laryngoscope was associated with the shortest duration of the procedure compared with the Airtraq optical laryngoscope and with direct laryngoscopy performed with the Macintosh laryngoscope. Studies also indicate the advantage of videolaryngoscopy over direct laryngoscopy when using chemical, biological, radiation, and nuclear PPE [22, 23]. Claret et al. [24] revealed that the Macintosh laryngoscope was superior to the Airtraq laryngoscope in terms of endotracheal intubation speed, effectiveness, and overall ease of use. The above relationshiphas also been confirmed in our study. The total efficacy of MAC, Airtraq, and McGrath laryngoscopes intubation under the conditions of PPE AGP in the scenario where the chest was not compressed during intubation attempts was 100%; however, the efficacy of the first intubation attempt was 68.1% vs. 62.5% vs. 90.6%, respectively. It is worth emphasizing that during cardiopulmonary resuscitation, interruptions in chest compressions should be minimized; therefore, endotracheal intubation should be performed as soon as possible, with compressions resumed immediately after inserting the endotracheal tube between the vocal folds, or completely without interruptions in chest compressions [7]. Endotracheal intubation during continuous chest compressions may result in reduced effectiveness if chest compression is stopped for the duration of the procedure [25–27].

The scientific literature lacks studies concerning the efficacy of intubation under cardiopulmonary resuscitation with preserved chest compressions as performed by personnel dressed in PPE. In this study, intubation with the McGrath MAC videolaryngoscope was the most effective in terms of procedure duration and efficacy. In turn, Claret et al. [24] showed that in endotracheal intubation by physicians wearing chemical, biological, radiological, and nuclear PPE during infant resuscitation simulation, the orotracheal intubation success rate with the Airtraq laryngoscope was higher than that with the Miller laryngoscope and that intubation time with the Airtraq laryngoscope was lower than with the Miller laryngoscope. This is confirmed by the results of the study.

Limitations

The presented study has its limitations. One of them is the fact that the investigation was carried out under medical simulation conditions and not during real resuscitation activities. However, such a way of designing and conducting the study was purposeful because only medical simulation allows for full standardization of the performed procedures and their repetition without any harm to the health of the potential patient. The second limitation was the inclusion of only paramedics in the research group. This was also a deliberate decision, as it is this professional group operating in prehospital conditions that is in practice often faced with the need to protect airways and conduct cardiopulmonary resuscitation. The study also has its strengths. Among them, we can mention the fact that it was a single-blind multicentre randomized crossover trial. Another strong point is the evaluation of three intubation methods: direct laryngoscopy, optical laryngoscopy, and videolaryngoscopy. Moreover, this is the first study evaluating endotracheal intubation of a suspected/confirmed COVID-19 adult patient during resuscitation performed by paramedics wearing PPE AGP.

Conclusions

In conclusion, McGrath MAC videolaryngoscope offers better intubation conditions than the Macintosh laryngoscope or Airtraqin a suspected/confirmed COVID-19 adult patient resuscitation with and without chest compressions when paramedics wear PPE AGP. Further clinical studies are necessary to confirm these initial positive findings.

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СРАВНЕНИЕ РАЗЛИЧНЫХ ВИДОВ ИНТУБАЦИИ ВО ВРЕМЯ РЕАНИМАЦИИ ПАЦИЕНТОВ С COVID-19 БРИГАДОЙ ПАРАМЕДИКОВ В СРЕДСТВАХ ИНДИВИДУАЛЬНОЙ ЗАЩИТЫ

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Эндотрахеальная интубация – один из основных методов контроля дыхательных путей во время сердечно-лёгочной реанимации. В эпоху пандемии SARS-CoV-2 медицинский персонал может столкнуться с необходимостью реанимировать инфицированного пациента.

Цель. Сравнить три метода интубации трахеи при планируемой реанимации взрослых пациентов с COVID-19, выполняемой парамедиками в средствах индивидуальной защиты (СИЗ) при процедурах генерации аэрозоля (ПГА).

Материал и методы. В многоцентровом проспективном рандомизированном перекрестном имитационном исследовании участвовали 32 медработника. Участники в СИЗ при ПГА проводили интубации трахеи с помощью ларингоскопов MAC Macintosh, Airtraq и McGrath у пациента с подозрением на COVID-19 в двух сценариях реанимации. Сценарий А – без сдавливания грудной клетки, сценарий Б – с непрерывными компрессиями грудной клетки. Первичным результатом было время интубации.

Результаты. При сценарии А время интубации для соответствующих устройств составило 35 с (IQR: 29-46) против 44 с (IQR: 35-67) против 49 (IQR: 34-72) (p=0,003). Общая эффективность каждого метода интубации составила 100%; однако эффективность первой попытки интубации была самой высокой для McGrath MAC (90,6%), за которым следовали Macintosh (68,1%) и Airtraq 62,5%) (p<0,001). В сценарии В результаты с McGrath MAC были значительно лучше, чем у Macintosh и Airtraq (p<0,05) по всем анализируемым переменным.

Выводы. Видеоларингоскоп McGrath MAC предлагает лучшие условия интубации по сравнению с ларингоскопом Macintosh или Airtraq при реанимации взрослых пациентов с COVID-19.

Ключевые слова: *эндотрахеальная интубация, средства индивидуальной защиты, COVID-19, парамедик, сердечно-легочная реанимация.*

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