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Performance of portable emergency suction devices in pre-hospital conditions: a pilot study in the fire brigade

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Abstract: Aim: Assessment of the effectiveness and efficiency of three mobile (portable) rescue aspirators models in the opinion of state fire service officers. Comparison with the use of the medical simulation element.
Material and Methods: The study was conducted in organizational units of the State Fire Service (24-hour officers). The research consisted in carrying out the task with the use of three models of mobile rescue aspirators (manual, hand-foot, battery). Each participating firefighter had the task of sucking up an equal amount of fluid (100 ml, respectively) with each model of an aspirator. The test fluid was water at room temperature in a homogeneous 1:1 mixture with sugar (increased viscosity and density, simulated real conditions). Immediately after three suction attempts (with measured suction time), each officer completed a questionnaire on the three models used. Descriptive statistics were used to characterize the variables. The following measures were calculated for the variables: mean (M) and standard deviation (SD), minimum, maximum. The following measures were calculated for categorical variables: number (n) and frequency (%).
Results: 184 officers (182 M and 2 F) took part in the study, including commanders 18.43%, rescuers 65.22%, drivers 16.30%. In the study area 1,609 officers serve in the combat division as at the end of 2021. The studied group accounts for 11.43%. Age of respondents M 34.04 SD 8.24 Min 21 Max 52, length of service M 8.48, SD 7.20 Min 1, Max 25. The longest mean time of completing the task was recorded for model 2 (hand-foot) and it was 6.77 sec.
Conclusions: SFS officers highly appreciated the usefulness and effectiveness of the battery-operated automatic aspirator. This assessment may contribute to the widespread introduction of such a model to

rescue sets in the SFS. Time of performing the task by mode 1 was significantly longer by elderly people. People with experience with the model 1 during rescue and firefighting operations had a significantly shorter time of performing the task with the use of the model 2. According to the subjective assessment of firefighters, the most effective is model 3, which is confirmed by the suction time obtained at the work station.

Keywords: airways, medical emergency suction device, rescue and firefighting activities.

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Introduction

Maintaining the air passages unobstructed in unconscious victims is the priority task for rescue units on the scene. Firefighters are often first to arrive to the scene, and they can provide medical aid on the advanced first aid (AFA) level. The operation of those units is based on 20 rescue procedures concerning help for traumatic and nontraumatic victims, and during rescue actions they use medical rescue kits R1 which include equipment, devices and medical measures as listed, among them, procedures to open the airways. Unblocking the airways is carried out mainly by entities of the Emergency Medical State (EMS) as the leading service in medical rescue in Poland. Both services are equipped with supraglottic airway devices (SAD), or airway suctioning [1–3].

In many cases manual clearance of the air passages (device-free operation) is ineffective because of foreign bodies or fluids whose presence results from a trauma (blood, vomit) or sudden loss of consciousness. Clearing of the air passages is of importance before starting the ventilation of a victim. An important role is played here by a rescue suction device used to suck out retained foreign bodies and fluids. Suctioning is important before proceeding to cardiopulmonary resuscitation (CPR) as well as in the course of CPR when re-suctioning of secretions from the oral cavity is required.

In many situations rescue suction devices constitute invaluable medical equipment, and their application enables one to implement further rescue procedures. Suctioning of foreign bodies is the prerequisite for using other pieces of equipment used for maintaining the patency of the air passages in out-of-hospital conditions (endotracheal tubes, laryngeal masks, I-gel mask). Due to the construction and the principle of operation, medical rescue services use mechanical manual rescue suction devices, manual-foot operated rescue suction devices and automatic battery-supplied ones. The presence of foreign bodies in the air passages and the decision on suctioning or resorting to SAD often requires a rescuer's visual control. A supplement to the kit for clearing the air passages is a diagnostic torch — very helpful in fast and efficient inspection of the oral cavity [3–4].

Scope

An assessment of the efficiency and performance of three mobile (transportable) models of rescue suction devices in the opinion of State Fire Service officers — a comparison accompanied by an element of medical simulation.

Material and Methods

An analysis was carried out in the organizational units of the State Fire Service (SFS) in the Lublin voivodeship among firefighters who are directly involved in rescue operations. From that group excluded were the firefighters who are on duty every day (viz. 8 hours) and civilian workers.

Research setting

In order to illustrate better the efficiency and the performance of the respective types of rescue suction devices, the authors made use of a simple experiment in simulation conditions. The firefighters who agreed to participate in the survey were asked to perform a simple task by using the three models of rescue suction devices on the station prepared in advance.

The test consisted in performing a task by means of the three models of mobile rescue suction devices. Each device under testing is included in EMS's or FPU's equipment. The authors left out stationary devices which are installed permanently in the building facilities, available in hospital wards, treatment rooms or dental offices. To pursue the research objective there were used 3 rescue suction devices with different constructions and various principles of generating the suction force.

1. A pistol grip manual rescue suction device — the smallest device among all used in the analysis, included in the FPU's rescue kits. For its small dimensions it can be carried in a backpack or a medical bag. It is universal in all conditions because it operates without any external supply; the suction force is generated by hand (the suctioning process is managed by pressing rhythmically the pump grip). A rescue suction device weighing less than 200 g is easy to operate, generates an underpressure of up to –55 kPa. The jar provided for secretions has a volume of 300 ml. The kit includes 3 sizes (different diameters) of catheters.
2. A manual-foot operated pedal rescue suction device, universal in all conditions because it operates without any external supply; the suction force is generated by exerting a pressure by hand or by foot on the working area (resembling a car pedal); it weighs 850 g and generates an underpressure of up to –80 kPa. Its jar for secretions has a volume of 650 ml. The kit includes 3 types of catheters dedicated to various age groups: infants, kids and adults.

3. A battery — mains power supplied rescue suction device is provided with a built-in 12 V battery with which the device can work up to 60 minutes. According to the manufacturer's specification, it generates underpressure of up to –89 kPa, is easy to operate, and it weighs 4.5 kg with accessories. Provided with a charger to supply the device either from the mains or in a car. Possible adjustment of the suction force, which offers a precise control to the user. For its weight and dimensions, it cannot be carried in rescue kits, like bags or backpacks. Provided with a grip. Its jar for secretions has a volume of 1,000 ml. The kit includes catheters with various sizes, dedicated to various age groups.

Research procedure

Each firefighter participating in the study will be assigned a task of suctioning an equal volume of fluid (100 ml each, respectively) by using each rescue suction device model (8 mm diameter catheter was used). The testing fluid is water of room temperature, in a 1:1 homogenous mix with sugar. The mix will increase the density and viscosity of the fluid used in testing as well as the difficulty of suctioning and will reliably simulate secretions which often causes an obstruction in the air passages during real actions. Before a suctioning test, the trainee will have to prepare a rescue suction device for use (an item not subject to rating in the test). In the test was measured the time of each suctioning test (T1 expressed in seconds). Successful test criteria: suctioning the intended fluid volume (100 ml) within the maximum dedicated time (Tmax 30 seconds).

Immediately upon completion of three suctioning tests, each firefighter filled out the questionnaire regarding three models of rescue suction devices used.

Ethical considerations

The personal data of the participants shall not be disclosed to any third parties whatsoever; nor shall be used for any tests. The study will be anonymous and voluntary, and the firefighters were informed about it.

On 06.09.2021 obtained was a permit from the Voivodeship Commander-in-Chief of SFS in Lublin (eastern Poland) for performing the study in the FPU within the voivodeship. The study participants are entirely anonymous, and the analysis complies with the principles of the Declaration of Helsinki. Moreover, obtained was the consent from the Bioethics Committee of University of Natural Sciences and Humanities Siedlce no. 9/2021, dated 20.10.2021.

Intervention records

The survey questionnaire constituting the base for the firefighters to assess each model of rescue suction device consisted of 12 questions:

— questions 1–4 — respondent's particulars: sex, age, years of service, type of prevailing service (rescuer, driver, commander)

— questions 5–6 — applied was a 5-point Likert scale (range: –2, –1, 0, +1, +2)

— questions 7–11 — single choice questions concerning the efficiency, effectiveness, ergonomics, ease of use of rescue suction devices and AFA procedures pertinent to the clearing of the air passages, used in the NRFS

— question 12 — the respondents were asked to juxtapose the rescue suction device types tested in the sequence starting from the most to the least useful (efficient) in real actions.

Statistical analysis

The database was prepared in Microsoft Excel using MS Office 2016 for Windows 10. Descriptive statistics were used to characterize the variables. The following measures were calculated for the variables: mean (M) and standard deviation (SD), minimum, maximum. The following measures were calculated for categorical variables: number (n) and frequency (%). A two-sided P value <0.05 was considered statistically significant for all tested null hypotheses. All statistical calculations were performed using STATISTICA software version 13.3 (TIBCO Software, Palo Alto, California, USA).

Results

184 officers (182 Male and 2 Female) took part in the study. As at the end of 2021, 1,609 officers were serving in the operational area where the study was conducted. The study group accounted for 11.43%. All officers performed the correct planning of the task within the scheduled time, tmax of 30 seconds. The characteristics of the study population, including sex, age, seniority and the nature of the most frequently performed service, are described in Table 1.

Questions 5–9 from the survey included the knowledge and experience of the respondents on the knowledge of procedures and rescue equipment related to clearing the airways, the results are presented in Table 2.

The longest average time for performing the task was recorded for model 2 (6.77 sec.), which considerably departed from the average task performance time recorded for model 1 (4.64 sec.) and 3 (4.21 sec.). There was no statistically significant difference in the average task performance times for models 1 and 3 data are presented in Fig. 1.

Table 1. General characteristics of the study group.

	N	%
Gender		
Female	2	1.09
Male	182	98.91
Type of service		
Commander	34	18.48
Rescuer	120	65.22
Driver	30	16.30

	Mean	SD	Minimum	Maximum
Age	34.04	8.24	21.0	52.0
Years of service	8.48	7.20	1.0	25.0

Table 2. Experience with the procedure and use of airway equipment.

		N	%
Are the currently used procedures in the fire brigade to open the airways sufficient?			
	I strongly disagree	6	3.26
	I rather disagree	2	1.09
	I have no opinion	37	20.11
	rather agree	108	58.70
	I definetly agree	31	16.85
Is the airway management equipment currently in use in SFS effective?			
	I strongly disagree	2	1.09
	I rather disagree	10	5.43
	I have no opinion	50	27.17
	rather agree	95	51.63
	I definetly agree	27	14.67
In the last year of his service, did he use a rescue suction devices during rescue and firefighting activities?			
	Never	150	81.52
	Once	24	13.04
	More than once	10	5.43

Table 2. cont.

		N	%
Which model did he use during rescue and firefighting?			
	model 1	85	46.20
	model 2	6	3.26
	model 3	10	5.43
Which model did he use e.g. during exercises, training?			
	model 1	166	90.22
	model 2	23	12.50
	model 3	32	17.39

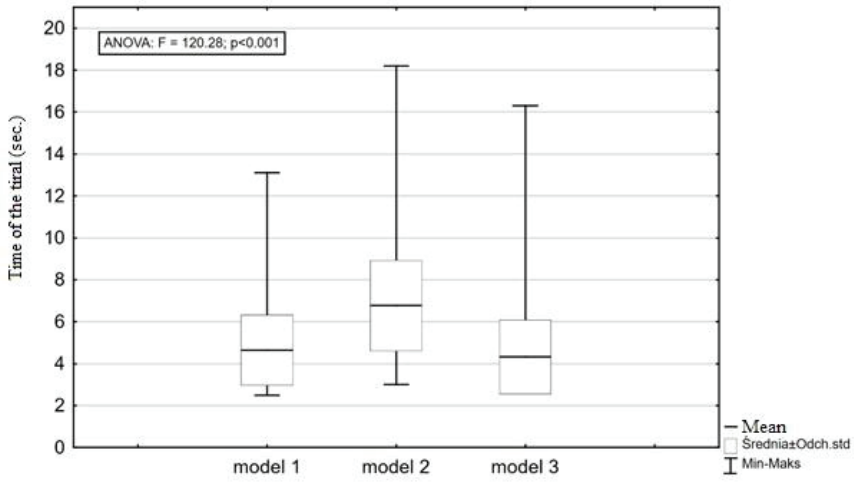

Fig. 1. Average time of suction attempt of 100 ml of fluid at the workstation.

Several factors influencing the time of the suction attempt related to the service experience of the officers were observed. The results are presented in Tables 3 and 4.

The older the person, the time of performing the task using model 1 was significantly longer.

People with experience with the model 1 during rescue and firefighting operations had a significantly shorter time of performing the task with the use of model 2.

For model 3, no significant factors influencing the time of task completion were observed.

Questions 10–12 in the questionnaire, the results of which are presented in Table 5, concerned the assessment of individual models by firefighters after completing the task with an element of medical simulation.

Table 3. Factor influencing the test time for model 1.

	b	Beta (ß)	–95% CI	+95% CI	t	P
	3.147				3.075	0.002
Age	0.057	0.277	0.008	0.547	2.032	0.044

Table 4. Factor influencing the test time for model 2.

	b	Beta (ß)	–95% CI	+95% CI	t	P
	6.701				5.244	0.000
Respondent used the model during rescue and firefighting operations	–0.565	–0.260	–0.449	–0.071	–2.723	0.007

Table 5. Evaluation of rescue emergency suction devices.

		N	%
Which model is the easiest to handle?			
	model 1	88	47.83
	model 2	4	2.17
	model 3	92	50.00
Which model is the most effective for activities?			
	model 1	64	34.78
	model 2	14	7.61
	model 3	106	57.61
The best model in terms of weight of the device, dimensions, difficulty and preparation time for use, suction performance, reliability?			
	model 1	92	50.27
	model 2	7	3.83
	model 3	84	45.90
The worst model in terms of weight of the device, dimensions, difficulty and preparation time for use, suction capacity, reliability?			
	model 1	54	29.35
	model 2	99	53.80
	model 3	31	16.85

The results of this part of the study indicate that firefighters considered the model 2 to be the most difficult to use and the least effective during real operations, which correlates with the average highest test execution time using this model.

Discussion

The presented study with the collected opinions, expressed by firefighters, on the medical equipment used in rescue and firefighting actions, based upon a practical task, was for them at the same time a good opportunity to remind of the use and the principle of operation of medical devices which are not used often every day. According to the results, seldom is it necessary to use a rescue suction device in real actions, and only 18.47% of respondents indicated at least one use of a rescue suction device in the preceding year of their service. The firefighters used rescue suction devices more often during exercises, training workshops or for an obligatory certification of the AFA rescuer's qualifications. AFA recertification is held at a year's intervals and concerns each firefighter, except persons with medical education background and performing their statutory in-service training in compliance with the EMS Act. (4 in the group tested) [5–6].

Many authors of studies as well as the guidelines concerning rescue medicine describe how important role in the rescue process is the maintaining of the air passages unobstructed; however, most publications regard supraglottic airway devices as alternative to endotracheal intubation. Soar [7] in a review paper on the guidelines of the European Resuscitation Council (ERC), Länkimäki [8] in his paper in 2015.

Keeping the air passages unobstructed, viz. through suctioning foreign bodies and the application of supraglottic airway devices is the prerequisite for correct and efficient ventilation of victims with respiration disorders or apnea. In his paper Bigham [9] reminds of fundamental physiology. In the case of a sudden cardiac arrest (SCA) in normothermia, hypoxia progresses rapidly and the body's oxygen reserve is sufficient merely for 3–5 minutes; then, irreversible changes will occur in the central nervous system. One of crucial issues in cardiopulmonary resuscitation is the clearing of the air passages and starting the victim's ventilation.

This is corroborated by a many other authors who enumerate a large choice of alternative equipment for restoring and keeping the air passages unobstructed. Piegeler [10] tested six various devices for clearing the air passages in view of their possible protection against regurgitation and aspiration in the course of CPR actions. Eismann [11] writes that videolaryngoscopy is a safe procedure for coping with hard air passages. Krzyżanowski [12] describes some techniques of clearing air passages with reference to the regulations governing the qualifications of paramedics in FPU.

The time of suction a volume of 100 ml of fluid, obtained in our own test, refers somehow to the standards of emergency medicine. Enterlein [13], invoking the guidelines, writes that keeping the air passages unobstructed is an activity entailing from rescuers not only knowledge of anatomy of the air passages but also manual dexterity, and that time should not be longer than 30 seconds (in our own test we assumed Tmax dedicated to get a rescue suction device and suctioning the volume assumed).

The airway suction procedure in the pre-hospital environment was investigated by other researchers. Peri *et al.* showed that currently available devices are either too heavy and bulky to be carried in real rescue operations [14].

Raczek *et al.* showed that effective suction is a critical component of airway clearance. The study looked at battlefield casualties. The own study concerned the officers' opinions on the ergonomics of working with the device. Mobile devices should be lightweight and small in size. In our own study, the devices were not tested due to their size, weight and transport difficulties, which may be the aim of further research [15].

Bolland [16] describes advanced medical procedures in the USA, carried out by firefighters, incl. clearing the air passages in the absence of emergency medical staff on the scene. Authors of other investigations believe that firefighters seldom avail themselves of procedures for suctioning the air passages and of supraglottic airway devices, although in the statistics can be found cases of unconscious people, both traumatic and non-traumatic, on whom firefighters might use appropriate procedures; yet, firefighters often avoid them. The reason may be one's lacking experience and inappropriate training, lack of training, no refresher training, which gives an opportunity of consolidating the knowledge, skills and becoming familiar with the updated guidelines [17–18]. Similar conclusions may be drawn in our own study basing upon the survey research results. Polish firefighters have well-equipped kits for emergency medicine, they undergo appropriate training and in their ranks serve officers with medical education background, and eventually they perform many actions of medical nature; however, the procedures pertinent to keeping the patency of the air passages are seldom used.

Limitations

Our study had a small sample. It is a single-center study, although the goal in the future is to increase the research sample, and to transfer the study to other regions of Poland, including the analysis of fire schools which, in the course of training cadets, conduct classes in medical rescue with the use of emergency suction devices.

Conclusions

Firefighters highly appreciated the usefulness and efficiency of an automatic battery-supplied rescue suction device. The usefulness of a battery-supplied rescue suction device can be higher in those units which — according to the statistics and analyses — often perform medical actions with underestimated EMS units in the operational area. The operation of a rescue suction device in the simulated conditions did not create any difficulties to the firefighters involved, although according to their assess-

ment, the hand-foot model is the most difficult to use. Practical utilization of medical equipment should be regular so as to maintain initial skills on a high level before more difficult real actions accompanied by stress, challenging field conditions, adverse weather and time pressure. More training sessions are required and practical exercises by making use of elements of medical simulation so that the most difficult medical procedures should be performed in conditions very similar to reality. The current AFA equipment does not allow firefighters to objectively assess the effectiveness of ventilation.

Conflict of interest

None declared.

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