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Antichemical Protective Gear Prolongs Time to Successful Airway Management

A Randomized, Crossover Study in Humans

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Background: **Airway management is the first step in resuscitation. The extraordinary conditions in mass casualty situations impose special difficulties in airway management, even for experienced caregivers. The authors evaluated whether wearing surgical attire or antichemical protective gear made any difference in anesthetists' success of airway control with either an endotracheal tube or a laryngeal mask airway.**

Methods: **Fifteen anesthetists with 2–5 yr of residency and wearing either full antichemical protective gear or surgical attire intubated or inserted laryngeal masks in 60 anesthetized patients. The study was performed in a prospective, randomized, crossover manner. The duration of intubation/insertion was measured from the time the device was grasped to the time a normal capnography recording was obtained.**

Results: **Endotracheal tubes were introduced significantly ($P < 0.01$) faster when the anesthetist wore surgical attire (31 ± 7 *vs.* 54 ± 24 s for protective gear), but the mean times necessary to successfully insert laryngeal masks were similar (44 ± 20 s for surgical attire *vs.* 39 ± 11 s for protective gear). Neither performance failure nor incidences of hypoxemia were recorded.**

Conclusions: **This first report in humans shows to what extent anesthetists' wearing of antichemical protective gear slows the time to intubate but not to insert a laryngeal mask airway compared with wearing surgical attire. Laryngeal mask airway insertion is faster than tracheal intubation when wearing protective gear, indicating its advantage for airway management when anesthetists wear antichemical protective gear. If chances for rapid and successful tracheal intubation under such chaotic conditions are poor, laryngeal mask airway insertion is a viable choice for airway management until a proper secured airway is obtainable.**

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THREATS to civilian populations from conventional combustion of toxic agents, such as sulfuric acid,[1,2] and from unconventional nerve agents[3,4] have challenged medical personnel to devise means for providing rapid but reliable emergent airway control. Irritation of the upper and lower airways, loss of consciousness, and the need for assisted ventilation rapidly evolve into respiratory failure that characterizes toxic vapor poisoning.[5,6] Airway management is an essential step in resuscitation and management of any medical emergency because the respiratory system is one of the most severely injured organs in toxic events.[7,8] Exposure of the civilian population to any airborne toxic agent is expected to injure large and varied populations of all ages and health conditions.[4,9] At the same time, the affected area and the injured people need to be decontaminated while the medical personnel need to protect themselves against the possible toxic agent.[7] To save the savable, there is a need for a rapid and reliable technique of airway control that will enable a limited number of medical providers to treat as many victims as possible in a chaotic environment.

Direct laryngoscopy and the insertion of an endotracheal tube has thus far been the classic and safe approach for airway control under any circumstances.[8] We previously reviewed bioterrorism-related conditions[10] in which large populations were the theoretical target of trauma and unconventional intoxication and raised the question of how well an anesthesiologist could perform in prehospital conditions if he/she were wearing antichemical gear. This kind of cumbersome outfit limits breathing, field of vision, movement, kneeling, holding small objects, and performing delicate tasks such as inserting an intravenous line.[11] New equipment that requires less expertise of airway management has recently become commercially available and is now becoming a part of the armamentarium of many anesthetists. The most familiar extraglottic device, the laryngeal mask airway, which can be inserted without the need for laryngoscopy in humans[12] as well as in monkeys,[13] has gained popularity outside the operating room, *e.g.*, in emergency departments[14] and during resuscitation[8,12] and trauma,[15] and has been successfully implemented by paramedical personnel.[16,17]

The purpose of the current study was to assess the effect of anesthetists' wearing either surgical attire or full antichemical protective gear on the speed and success rate in performing tracheal intubation in humans. We also evaluated the same anesthetists' performance in inserting laryngeal mask airways under both conditions and analyzed the time to secure the airway device.

Materials and Methods

Anesthetist and Patient Recruitment

Fifteen anesthetists participated in this prospective, randomized, crossover study. Their experience in managing airways was clinical training of 3.1 $\pm$ 0.9 yr (mean $\pm$ SD) in a tertiary, university-affiliated anesthesia department plus periodic (1 month/yr) military medical duty with victims as well as training on mannequins. According to the revised protocol for a mass casualty scenario of an unconventional attack in the catchment area of the Tel Aviv Medical Center, Tel Aviv, Israel, these physicians are the ones to perform the first intubation when the victims arrive for treatment. However, all practiced on a mannequin during a 30-min drill the day before their participation in the study. The only experience with the antichemical protective gear that the anesthetists had had before the commencement of this study was during joint military and civilian drills. At no time had they had the opportunity to intubate a patient while wearing the gear.

Sixty consecutive patients with American Society of Anesthesiologists physical status I–III who were scheduled to undergo various surgical or orthopedic interventions under general anesthesia were considered suitable to participate in this study. The study had been approved by the institutional human investigation committee of the Tel Aviv Sourasky Medical Center, Tel Aviv, Israel. All compliant subjects signed the institutional Helsinki Committee–approved informed consent form after having been given a detailed explanation of the interventions and the devices used. Exclusion criteria were allergy to latex, a history of chronic pain or of psychiatric disorders, and the use of centrally acting drugs of any sort. Patients younger than 18 yr; pregnant women; individuals who had recently experienced severe trauma to the central nervous system or to the face; patients who had undergone maxillofacial, head, or neck surgery; and patients who had a Mallampati score of 4 were also excluded from the study.

Antichemical Gear

The antichemical protective gear is a complete set that is currently used by the medical staff according to the regulations of the Israeli Defense Force Medical Corps, Tel Aviv, Israel. It includes butyl rubber boots and gloves (Supergum, Tel Aviv, Israel), a nylon shirt and pants covered by khaki (Chemoplast, Afula, Israel), and an antigas mask with active filter (Shalon, Tel Aviv, Israel; figs. 1 and 2).

Fig. 1. A physician wearing protective antichemical gear.

Airway Control Devices

A size 4 laryngeal mask airway (Gensia Pharmaceuticals, San Diego, CA) was used for all patients; in our experience and that of Grady *et al.*,[18] a lower rate of postoperative pharyngeal discomfort is reported with this size. A 7.5-mm-ID cuffed endotracheal tube and an 8.5-mm-ID cuffed tube (Portex; SIMS Portex Ltd., Hythe, Kent, United Kingdom) were used to intubate the tracheas of female and male patients, respectively. All tubes and mask airways were lubricated with 2% lidocaine in aqueous jelly (Rafa Laboratories, Jerusalem, Israel).

Study Protocol

In the operating room, all nonpremedicated patients were connected to a multimodal monitor (AS/3; Datex-

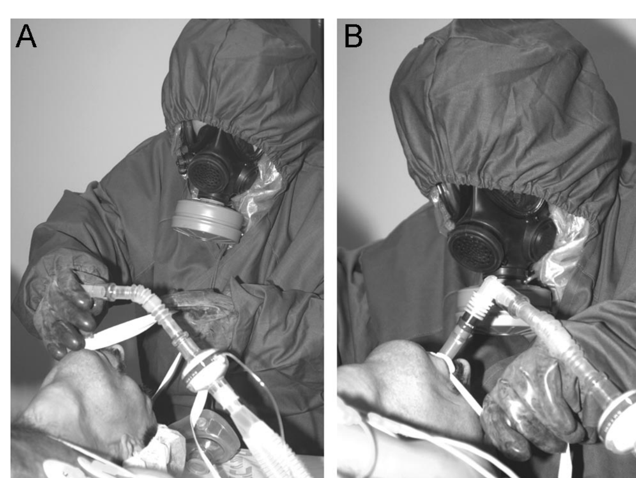

Fig. 2. A physician managing a patient's airway with an endotracheal tube (*A*) and with a laryngeal mask airway (*B*) while wearing antichemical gear.

Ohmeda, Helsinki, Finland), which enabled five-lead electrocardiographic recording, measurement of noninvasive systolic and diastolic blood pressures, measurement of respiratory rate, fingertip pulse oximetry, and exhaled (sidestream) capnographic tracing. The patients were first allowed to breathe 100% oxygen *via* a facemask. When all parameters reached normal and/or satisfactory values, 1–2 mg midazolam and 100 μg fentanyl were injected intravenously, followed by 2–2.5 mg/kg propofol injected over 30 s for the induction of anesthesia. Succinylcholine, 1.5 mg/kg, was added only for patients who underwent tracheal intubation because we usually refrain from using muscle relaxants during laryngeal mask airway insertion and instead use the jaw thrust as the indicator for the proper time of insertion. We also had to bear in mind that toxic nerve agents act pharmacologically at the same site as suxamethonium. We and others[4,10] have recommended that nerve agent victims should not be given any drug that further inhibits acetylcholine esterase activity. When manual ventilation by the attending anesthesiologist was effective and oxygen saturation was 98% or greater, the designated anesthetist, who was wearing either the antichemical gear or surgical attire, was notified as to which device was to be introduced. Randomization was based on computer-generated codes that were maintained in opaque envelopes until 5 min before airway management was initiated. Every patient received only one airway device from a physician with or without the protective gear and in a random order (fig. 2, A and B). After the device was in place, the cuff of the laryngeal mask airway was inflated with up to 30 ml air as recommended by the manufacturer or as deemed sufficient to the study anesthetist. The cuff of the endotracheal tube was also inflated with air, aiming to obtain a minimal leak that was audible during manual airway inflation. We recorded the time necessary to perform the task, from the moment the anesthetist grasped the device until it was in place, it was connected to the capnograph, and the end-tidal carbon dioxide tracing and value (> 30 mmHg) were normal while the patient was being manually ventilated. Unsuccessful insertion was defined as misplacement of the tube or the mask airway or lack of the above indicators. Attempts that were associated with hypoxia, *i.e.*, oxygen saturation measured by pulse oximetry (Spo_2) less than 92%, were immediately interrupted, and the patient was reventilated manually with 100% oxygen by the supervisor. There was no imposed time limit for successfully inserting the device. After its insertion, the device was secured in place. During the pilot study, the anesthetists were frequently unable to apply surgical tapes for this purpose, and we used strings instead.

After the maneuvers, the supervising anesthesiologist monitored the pressure within the cuff of the endotracheal tube by a manometer (Control-Inflator; VBM, Sulz am Neckar, Germany), readjusting it to 22 cm H_2O.[19] The proper position of the laryngeal mask airway was also reconfirmed by lack of oropharyngeal airway leak, otherwise detectable by audible noise over the epigastrium, laterally to the thyroid cartilage and over the mouth,[20] while manually ventilating the patient *via* a semiclosed system using a generated peak inspiratory pressure of 22 cm H_2O, as well as by equal bilateral lung expansion.

Any untoward effect during the study was immediately treated, and its occurrence was recorded. The study concluded when the airway device was properly placed and anesthesia was administered as customary for the case. No additional data were recorded after this time.

Statistics

All values are given as mean ± SD. The analyses were performed at the Statistical Laboratory of the School of Mathematics, Tel Aviv University, Tel Aviv, Israel, using SPSS for Windows (version 11.01, 2001; Chicago, IL). A prestudy power table in which Δ (mean difference in time [in seconds] between the two groups of anesthetists with and without the protective gear) was 10, α was 0.05, and power was 0.8 resulted in the need for 15 anesthetists in every group. Because the distribution of the time periods necessary to successfully insert the devices slightly deviated from normal, data were analyzed by mean of the Wilcoxon signed-rank test. The rates of eventual failure or of hypoxemic events were analyzed using the Fisher exact test. $P \leq 0.05$ was considered significant.

Results

Sixty patients (34 men and 26 women; mean age, 44 ± 18 yr [range, 18–78 yr]; mean weight, 74 ± 16 kg [range, 42–105 kg]) undergoing various surgical procedures under general anesthesia were enrolled in this study. American Society of Anesthesiologists physical status classifications and Mallampati scores were similar among the study groups (data not shown). No patient in the laryngeal mask group or the endotracheal tube group needed the addition of any drug to facilitate the insertion of the device, and none experienced adverse intraoperative events (*e.g.*, coughing, retching, breath-holding, or laryngospasm).

The tracheal intubations were accomplished significantly ($P < 0.01$) more rapidly by the anesthetists when wearing surgical attire than when wearing the protective gear; times to laryngeal mask insertion were similar for each condition (fig. 3). All but one anesthetist who was wearing the gear successfully performed the intubation within less than 75 s. The laryngeal masks were inserted significantly ($P < 0.05$) more rapidly than the endotracheal tubes by anesthetists wearing protective gear but significantly ($P < 0.05$) more slowly by those wearing

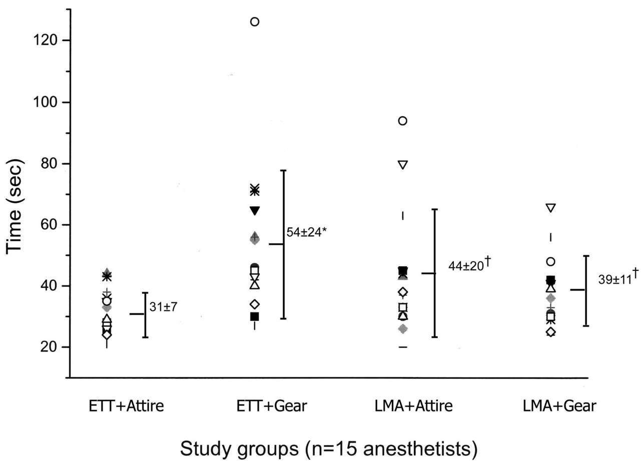

Fig. 3. Individual and mean time to proper airway management by anesthetists with various apparel. * *P* < 0.01 *versus* the corresponding surgical attire values; † *P* < 0.05 *versus* the tracheal intubation values. ETT = tracheal intubation; LMA = laryngeal mask airway insertion.

surgical attire (fig. 3). All intubations and insertions were properly accomplished with the first try, and in no case did Sp_{O_2} decrease to less than 92% during the attempts.

The time to secure tubes or mask airways was much longer when the anesthetists wore the butyl rubber gloves (2.3 ± 0.6 *vs.* 0.9 ± 0.1 min without gloves; $P <$ 0.001).

Blood pressure readings at the end of airway management were significantly ($P < 0.05$) lower compared with the premanagement values in all groups (table 1). Heart rate and Sp_{O_2} values were lower only in the mask-plus-gear group. The mean pressures of the tube cuff that were first measured by the supervising anesthesiologist after the devices were placed were similar among all groups (data not shown).

Discussion

Airway management is the first step in managing any emergency situation, be it medical, surgical, or traumatic, especially if it has a direct repercussion on respiration.[8] This also applies to a mass casualty event. In the prehospital phase of an unconventional mass casualty event, where respiratory failure may be the result of lung injury caused by inhalation of toxic agents from any source or intent,[5,6] muscle paralysis,[21] or conventional injuries, airway management may be much more problematic because of chaotic conditions. At the same time, the number of the expected victims would be large and variable in terms of age, airway characteristics, and state of health,[4,9] and care providers may not be as experienced as trained anesthetists are.[22]

In toxicologic events that afflict the airways and the lungs, securing of the airway is even more important because of the associated severity of respiratory failure and asphyxia.[7] Therefore, the device to be chosen for the management of the airway is the most important issue that needs to be addressed. It must be simple to use even when the medical team itself is in a compromised situation, such as the need to wear antichemical gear. The cumbersome outfit that was used in the current study includes two layers of clothing, rubber boots, thick rubber gloves, and an antigas mask, which hamper breathing, movement, kneeling, vision, and dexterity,[10] including the capability required for insertion of an intravenous line.[11]

Over the years, the accepted standard for management of the airway has been the endotracheal tube.[8] The safest method of airway management in a comatose, chemically intoxicated patient is tracheal intubation with a cuffed tube. However, the best extraglottic airway device for resuscitation has not been established. The laryngeal mask airway has recently gained popularity as an airway management device, not only during anesthesia but also in surgical, internal medicine and traumatic emergency situations,[14,15] and it has been shown to be relatively safe and efficient in a variety of situations.[14–17]

Several extraglottic airway devices have become avail-

Table 1. Patients' Hemodynamic, Respiratory, and Laryngeal Mask and Endotracheal Tube Insertion Data

	Endotracheal Intubation		Laryngeal Mask Airway Insertion	
	Surgical Attire	Protective Gear	Surgical Attire	Protective Gear
Vital signs immediately before insertion of airway device				
Heart rate, beats/min	75.4 ± 10.2	72.1 ± 13.6	81.9 ± 14.7	81.7 ± 15.3
Systolic blood pressure, mmHg	134.5 ± 15.2	149.7 ± 30.3	132.6 ± 19.1	130.3 ± 15.1
Diastolic blood pressure, mmHg	86.2 ± 6.5	85.5 ± 10.2	83.5 ± 10.9	82.3 ± 6.8
Sp_{O_2}, %	97.5 ± 0.6	98.1 ± 0.9	98.7 ± 1.0	98.3 ± 0.9
Vital signs immediately after confirming capnography				
Heart rate, beats/min	77.7 ± 12	69.9 ± 11.5	75.4 ± 13.8	77.3 ± 14.0*
Systolic blood pressure, mmHg	119.4 ± 14.5*	111 ± 22.4*	116.3 ± 21.4*	111.3 ± 14.7*
Diastolic blood pressure, mmHg	74.7 ± 9.7*	70.9 ± 13.8*	73.4 ± 16.2*	69.7 ± 10.3*
Sp_{O_2}, %	97.8 ± 0.9	97.9 ± 0.7	98.4 ± 1.0	97.6 ± 2.1*

Data are presented as mean ± SD.

* $P < 0.05$ *vs.* values immediately before the insertion of the tracheal tube or the laryngeal mask airway.

Sp_{O_2} = oxygen saturation measured by pulse oximetry.

able more recently, including the esophageal tracheal Combitube (Kendall Company, Mansfield, MA), the cuffed oropharyngeal airway, and two newer versions of the classic laryngeal mask airways (*ProSeal™* [Laryngeal Mask Company Limited, San Diego, CA] and the intubating laryngeal mask). Most earlier studies evaluated the extraglottic devices' performances in the operating room on anesthetized patients, but few studies assessed their role in emergency or emergency-like setups.[12,14,23,24] Mark *et al.*[15] evaluated the performance of corpsmen in inserting an endotracheal tube, a laryngeal mask, and a Combitube in combat-like conditions. Although the three devices were found to be suitable for emergency-like setups, the study did not include a mass casualty pattern, nor did it use the unconventional outfit that we describe. Also, in the latest guidelines for adult advanced life support published by the European Resuscitation Council,[25] only the laryngeal mask and the Combitube were mentioned as alternatives to the endotracheal tube. More important, the laryngeal mask has a well-deserved status in the American Society of Anesthesiologists difficult airway algorithm.[26] The mask is also the most commonly used and most studied extraglottic device.[27] When dealing with a chemical mass casualty scenario, the medical provider's goal is to manage the victims' airways while attempting to provide respiratory support to as many of them as possible. Unlike the relative serenity of a hospital operating room setup, the possibility of introducing a nasogastric tube *via* the *ProSeal™* laryngeal mask or intubating the patient *via* the intubating laryngeal mask in the chaotic prehospital phase does not seem to be an option. The physician also would probably not have time for second thoughts about approaching the same patient, and this would be done by an experienced anesthesiologist, preferably after the patient was transported to a decontaminated area. Furthermore, the classic laryngeal mask (*LMA-Classic*™; Laryngeal Mask Company Limited) is the most commonly available device that we have at our disposal in peacetime (*i.e.*, the Israeli Defense Forces Medical Corps and the civilian emergency services, Tel Aviv, Israel). This is partly because the mask is considered the second-best device in the operating room that has become increasingly economically affordable in many countries. Therefore, although we were aware of the availability of the newer extraglottic devices and of their characteristics, we designed our study to focus on the *LMA-Classic*™ and the endotracheal tube as the definitive standard devices during an unconventional mass casualty toxic event.

The results of the current study show that, as expected, the use of antichemical gear led to tracheal intubation taking longer than without the gear. In contrast, laryngeal mask insertion took an equal duration of time under both conditions. Also, when the anesthetist wore the protective gear, the time for insertion of a mask was shorter (by a mean of approximately 15 s) than the time needed for the insertion of an endotracheal tube but was not longer than without the outfit. Interestingly, we also found that the insertion of mask airways took longer than tracheal intubation when the anesthetist wore the attire but that the rate of success in all instances was 100%. Although the slower mask airway insertion *versus* tracheal intubation by anesthetists wearing surgical attire seems to stem from their greater expertise in performing intubation, the shorter time to placement of mask airway *versus* the longer time to proper tracheal intubation by anesthetists wearing the protective gear indicates that the mask is the more advantageous route for our study population being treated by protected personnel. Previous uncontrolled studies that lacked specific endpoint data to measure the completion of the insertion[16,17] suggested that laryngeal mask airway insertion may be easier than tracheal intubation; the results of this first study in humans support this assertion even in conditions of special physical limitations. Although the time differences in the performance of each route were statistically significant, the scores lacked clinical implication because there were no cases of Spo_2 desaturation or hemodynamic disturbances associated with the longest required time (*i.e.*, 126 s for an endotracheal tube, with the anesthetist wearing protective gear). Nevertheless, during an actual chaotic event, this time interval may become crucial for the intoxicated victims, who are already physically compromised and hypoxic.

The current study has several limitations. The most important limitation stems from the ethical conditions imposed by the Tel Aviv Sourasky Medical Center's Institutional Helsinki Committee, which led to the patients' conditions being dissimilar to the prehospital chaotic conditions that would characterize mass casualty occurrence. Our patients were relatively healthy, with an intravenous line enabling full sedation and relaxation, and in optimal hemodynamic and ventilatory induction conditions (including oxygenation), with no airway reaction to the insertion of the device, which would most likely not be the case during actual disaster conditions. There were no changes in the patients' Spo_2 values, even after a long-lasting laryngeal mask airway placement. The study took place in calm conditions, and the equipment was in excellent working order. The anesthetists were responsible for one patient at a time, did not experience the effects of excessive heat load induced by the multiple-layer overgarment, and were not unduly stressed. Moreover, the patients' oral cavities were clear of secretions and vomit, and no patient had multiple injuries (*e.g.*, not hypovolemic), convulsions, or hypoxemia, as might be the case during an actual toxic event. No patient had a reflex reaction, retched, or held his or her breath when undergoing tracheal intubation or laryngeal mask insertion. The pressure within the cuff of the tube

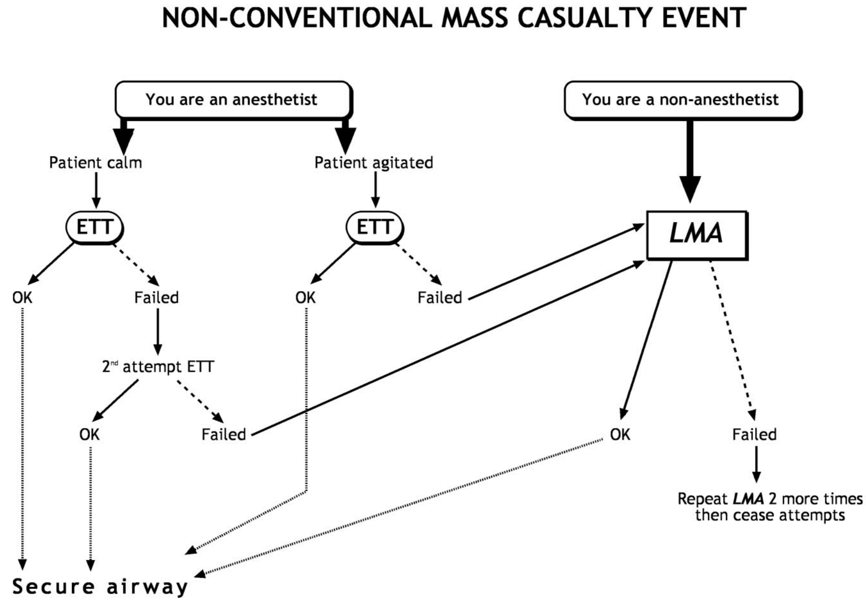

Fig. 4. An algorithm for guiding caregivers in choosing between an endotracheal tube (ETT) and a laryngeal mask airway (LMA) in an unconventional mass casualty event. Unlike in conventional mass casualty scenarios, caregivers will probably not be informed of the exact type of toxic agent or the number and severity of the victims. There will be no time to practice or make a last-minute check of the equipment, and they must protect themselves as best they can. With rare exceptions, victims will not have an intravenous line, and forceful management of their airway can pose further risk to the patient.

could be measured and readjusted, and the supervising anesthesiologist could also confirm the placement of the mask airway with a stethoscope; these conditions probably would not exist in the disaster area because of the caregiver's hermetic headgear.[10]

We chose to assess airway management by endotracheal tube and laryngeal mask airway because we have previously raised the question of the usefulness of each device in times of confusion and stress that follow unconventional attacks on civilians.[10] It proved to be a valuable tool for securing the airways in cases of difficult intubation,[27] and we found that the mask airway was inserted faster than the endotracheal tube and with no failure under both study conditions. However, the airway seems better secured with tracheal intubation than with a laryngeal mask, especially in cases in which bronchorrhea is anticipated and the stomach is expected to be full.[12] The occurrence of gastric aspiration may occur, especially in high-risk patients[8,28,29]; tracheal intubation is then preferred to the laryngeal mask.[12] Because positive-pressure ventilation may be required in these patients, an endotracheal tube would also seem to be preferable to the laryngeal mask airway[29,30]: high inspiratory pressure in the presence of the mask airway may result in air-leak, inadequate ventilation and gastric distension.[30] In addition, victims are moved from the disaster area to the decontaminated medical area while they are ventilated, which requires a fully and reliably secured airway. According to the plans for a mass casualty scenario involving an unconventional attack in the area of the Tel Aviv Medical Center, anesthetists perform the intubation while high school students and nonmedical personnel of the medical center bag-ventilate the casualties as they are being transferred (see ANESTHESIOLOGY Web site). It is crucial that the airway is maximally secured (not by tape; see Materials and Methods) when the caretakers are not trained medical personnel.[30] The difficulty we encountered in securing the devices to the patients' faces when the anesthetist wore butyl gloves is noteworthy because under actual conditions, these cannot be removed at will. This may affect the stability of these implements during transportation, a risk that would be present with either devices, but to a lesser extent after tracheal intubation.

We designed an algorithm (fig. 4) that is intended to assist the inexperienced anesthetist in deciding which device would be more appropriate for managing a victim's airway during conditions of unconventional disasters similar to the ones we describe above. We recommend that caregivers should opt for the device with which they have expertise from among the available choices. Those not previously trained to intubate agitated a person with a possible difficult airway should consider the laryngeal airway mask as the first choice because its insertion is simple and rapid and affords a high rate of success while not requiring the intravenous use of neuromuscular blocking agents. Reassessment of the appropriateness of the choice of the device and its efficacy to maintain sustained airway patency would be done later, on an individual basis, at a medical facility.

In conclusion, we demonstrated that the wearing of protective gear interfered with the speed and efficiency of providing ventilatory support. Tracheal intubation, the definitive standard for airway management, was found to be a less favorable choice time-wise than the laryngeal mask airway for airway management when anesthetists were wearing protective gear. Although direct extrapolation from this study to chaotic conditions during a toxic gas event is a theoretical exercise, it is reasonable to expect that tracheal intubation would require more time than mask airway insertion by anesthetists wearing antichemical gear.

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