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 s 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.

THREATS to civilian populations from conventional combustion of toxic agents, such as sulfuric acid,1,2 and from unconventional nerve agents3,4 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.1,9 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 conditions10 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 humans12 as well as in monkeys,13 has gained popularity outside the operating room, e.g., in emergency departments14 and during resuscitation8,12 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 ± 0.9 yr (mean ± 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).

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., 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-
Ohmeda, Helsinki, Finland), which enabled five-lead electrocardiographic recording, measurement of non-invasive 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 face mask. 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 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 the attending anesthesiologist was effective and oxygen saturation was 98% or greater, the designated anesthetist, who was wearing either the antichemical gear or the protective gear but in a 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 hypoxic events were analyzed using the Fisher exact test. P ≤ 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
Vital signs immediately after confirming capnography

− SpO2, oxygen saturation measured by pulse oximetry.
− Data are presented as mean ± SD.

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

<table>
<thead>
<tr>
<th></th>
<th>Endotracheal Intubation</th>
<th>Laryngeal Mask Airway Insertion</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Surgical Attire</td>
<td>Protective Gear</td>
</tr>
<tr>
<td><strong>Systolic blood pressure, mmHg</strong></td>
<td>75.4 ± 10.2</td>
<td>72.1 ± 13.6</td>
</tr>
<tr>
<td><strong>Diastolic blood pressure, mmHg</strong></td>
<td>134.5 ± 15.2</td>
<td>149.7 ± 30.3</td>
</tr>
<tr>
<td><strong>SpO2, %</strong></td>
<td>97.5 ± 0.6</td>
<td>98.1 ± 0.9</td>
</tr>
<tr>
<td><strong>Diastolic blood pressure, mmHg</strong></td>
<td>86.2 ± 6.5</td>
<td>85.5 ± 10.2</td>
</tr>
<tr>
<td><strong>Heart rate, beats/min</strong></td>
<td>77.7 ± 12</td>
<td>69.9 ± 11.5</td>
</tr>
<tr>
<td><strong>SpO2, %</strong></td>
<td>97.8 ± 0.9</td>
<td>97.9 ± 0.7</td>
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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. 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, muscle paralysis, 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, and care providers may not be as experienced as trained anesthetists are.

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. 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, including the capability required for insertion of an intravenous line.

Over the years, the accepted standard for management of the airway has been the endotracheal tube. 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, and it has been shown to be relatively safe and efficient in a variety of situations.

Several extraglottic airway devices have become avail-
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 airway choice for our study population being treated by protected personnel. Previous uncontrolled studies that lacked specific endpoint data to measure the completion of the insertion16,17 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 SpO2 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’ SpO2 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 anesthesiologists 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 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.
could be measured and readjusted, and the supervising
anesthesiologist could also confirm the placement of the
mask airway with a stethoscope; these conditions prob-
ably would not exist in the disaster area because of the
caregiver’s hermetic headgear.10

We chose to assess airway management by endo-
tracheal 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 un-
conventional attacks on civilians.10 It proved to be a
valuable tool for securing the airways in cases of dif-
ficult 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 air-
way seems better secured with tracheal intubation than
with a laryngeal mask, especially in cases in which bron-
chorrhea is anticipated and the stomach is expected to
be full.12 The occurrence of gastric aspiration may oc-
cur, especially in high-risk patients8,28,29; tracheal intu-
bation 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 because high inspira-
tory pressure in the presence of the mask airway may
result in air-leak, inadequate ventilation and gastric dis-
tension.30 In addition, victims are moved from the disas-
ter 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 sce-
nario 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 casu-
alties 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 can-
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 vic-
tim’s airway during conditions of unconventional disas-
ters similar to the ones we describe above. We recom-
mend that caregivers should opt for the device with
which they have expertise from among the available
choices. Those not previously trained to intubate agi-
tated a person with a possible dif-
ficult 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 ef-
ciency 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 di-
rect 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 re-
quire more time than mask airway insertion by anesthe-
tists wearing antichemical gear.

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Fig. 4. An algorithm for guiding caregiv-
ers in choosing between an endotracheal
tube (ETT) and a laryngeal mask airway
(LMA) in an unconventional mass casual-
y event. Unlike in conventional mass
 casualty scenarios, caregivers will prob-
ably not be informed of the exact type of
toxic agent or the number and severity of
the victims. There will be no time to prac-
tice or make a last-minute check of the
equipment, and they must protect them-
selves as best they can. With rare excep-
tions, victims will not have an intrave-
nous line, and forceful management of
their airway can pose further risk to the
patient.

NON-CONVENTIONAL MASS CASUALTY EVENT

You are an anesthetist

ETT

Patient calm

OK

Failed

2" attempt ETT

OK

Failed

You are a non-anesthetist

LMA

Patient agitated

OK

Failed

Repeat LMA 2 more times
then cease attempts

Secure airway
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