Single-Breath-Count Test: An Important Adjunct in the Triaging of Patients in a Mass-Casualty Incident Due to Botulism

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Abbreviations:
CDC = [US] Centers for Disease Control and Prevention
NIF = negative inspiratory force
SBCT = Singe-Breath-Count Test
START = Simple Triage and Rapid Treatment
VC = vital capacity

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Abstract

Clostridium botulinum toxins, the most poisonous substance known to humankind, are considered to be a [US] Centers for Disease Control and Prevention Category A bioterrorist agent. Despite this concern, little has been published with regard to the tactical aspects of triaging a mass-casualty event involving botulism victims arriving at an emergency department. Because neuromuscular-ventilatory failure is a principal reason for botulism's early morbidity and mortality, using a quick and sensitive test to evaluate this possibility is imperative. The purpose of this article is to propose the adoption of the Single-Breath-Count Test (SBCT). The ease and validity of the use of the SBCT in evaluating complications associated with various neuromuscular disorders make it an attractive adjunct for triage during a mass-casualty incident due to botulism. While education, immune globulin, antitoxin, and invasive airway techniques are well-recognized steps in treating botulism, incorporating a time-honored technique such as the SBCT, will be an important addition to the triage process.

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Introduction

Botulism as a Threat

The toxin elaborated by *Clostridium botulinum* is the most poisonous toxin known.[1] As little as 0.001 micrograms per kilogram will cause symptoms in the human.[2] Unlike smallpox—a non-existent disease that has generated global fears about terrorism and has caused the expenditure of excessive amounts of money, a disaster caused by botulism is not a theoretical disease. Instead, botulism is a disease that occurs with a certain degree of regularlity across the US and the world. Despite its virulence, botulism typically involves only a few cases (food-borne, wound, or infant varieties). Nevertheless, it must be recognized as a potential weapon of terrorists. Witness that the disease has achieved the dubious distinction of being listed as a [US] Centers for Disease Control and Prevention (CDC) Category A, bioterrorist agent due, in part, to Iraq's admission that it stockpiled 19,000 liters of the toxin in the 1990s.[2,3] To underscore the significance of this admission, a mathematical model has predicted that 1 gram of the toxin in commercially-distributed milk consumed by more than 550,000 urban dwellers could result in 100,000 casualties and 500,000 casualties if contaminated with 10 grams of toxin.[4] Therefore, unlike a hypothetical smallpox epidemic, the threat of a mass-casualty incident from botulism should be considered a definite and credible threat. Hence, substantial efforts should be undertaken to develop strategies and tactics in response to such an assault, accidental or otherwise. Yet, when the US Department of Homeland Security published 15 catastrophic scenarios, none specifically addressed a botulism mass-casualty incident.[5]

Scenario

The local public health agency has announced that, based upon a surge of patients exhibiting gastrointestinal and neurological symptoms, a presumptive exposure to a botulism epidemic currently is underway. Hundreds of patients have presented to various healthcare venues with complaints of nausea, vomiting, abdominal cramping and/or cranial nerve dysfunction, shortness of breath, and generalized weakness. Dozens have required aggressive airway management.

Neither the locus nor the explanation behind the contamination has been established. The CDC has been contacted by public health and a formal request for release of both botulism immune globulin and antitoxin has been made. Given the toxicity of the poison, the initial nonspecificity of the manifestations and its incubation period, officials warn that thousands of people over the next week may present for screening, evaluation, and possibly treatment.

Either because of symptomatology or because of fears fueled by the media, the public will seek out multiple venues for treatment or assurance. The following patients are seen by the Emergency Department Triage Officer for evaluation:

1. Patient 1: 25-year-old male, hypertensive smoker with sudden vomiting and blurry vision. Pulse = 88/minute (min), Ventilations = 24/min, Blood Pressure- 140/94 mmHg, oxygen saturation (SaO_2) = SaO_2 = 96%;
2. Patient 2: 68-year-old female, status-post hip replacement two weeks earlier, complains of a one-day history of difficulty seeing, slurred speech, and shortness of breath. Other than arthritis, she is in good health. Medications include methotrexate and ibuprofen. Pulse = 96 min, Ventilations = 18/min, Blood Pressure = 130/84 mmHg, SaO_2 = 94%;
3. Patient 3: 16-year-old male previously in good health, brought to the emergency department by his mother because his eyelids are "droopier than normal". Pulse = 78/min, Ventilations = 16/min, Blood Pressure = 110/64 mmHg, SaO_2 = 98%; and
4. Patient 4: 88-year-old male with myriad co-morbidities, presents with nausea, non-specific weakness, numb face, and "can't get the words out of my mouth just right". Pulse = 116/min, Ventilations = 24/min, Blood Pressure = 160/114 mmHg, SaO_2 = 95%.

Armed with interim definitions of "probable" and "possible" botulism cases, the Triage Officer must assess and prioritize these patients. He/she must factor in the possibility that they might deteriorate quickly should their symptoms be related to botulism. Because of the increasing influx of patients, the Triage Officer expeditiously must decide to which zone (Red, Yellow, or Green) each patient must be transported for appropriate attention. While, in this scenario, the Triage Officer may be afforded the advantage of complete vital signs (Blood Pressure, Pulse, Ventilatory Rate, and SaO_2), there is no guarantee that there will be the necessary resources to obtain those vitals as hundreds of patients present virtually simultaneously.

Moreover, the traditional vital signs lack the necessary sensitivity and specificity to determine whether a given patient is in danger of impending ventilatory arrest due to neuromuscular fatigue. Pulse oximetry (SaO_2), while important, does not have the required specificity to detect ventilatory insufficiency as early as other modalities—all of which require special equipment and, at least, a modicum of training. This is particularly relevant if triage is occurring at improvised alternative care sites staffed by non-traditional healthcare personnel.

Given the limitations of the conventional vital signs, this concept paper proposes the addition of another vital sign, The Single-Breath-Count Test (SBCT) that will assist with making the proper disposition of a presumed botulism patient without imposing any unnecessary risks.

Improving the Triage of Presumed Botulism Patients

One of the challenges that require exploration is the conduct of triage in light of a presumptive botulism epidemic. Triage is considered a critical skill.[6] Despite its application during the Napoleonic Wars.[7] it still remains a nebulous art cloaked within an imperfect science. No one triage system has been sufficiently validated to be considered the standard. This includes such popular instruments like Simple Triage and Rapid Treatment (START) and JumpSTART. Even when a new triage system is proposed (i.e., SALT), which comprises the best features of the more traditional methods, it is acknowledged by its developers that it will not work for a large-scale biological incident in which patients are presenting at different times and to different venues.[6]

The principal reason for triage is to quickly identify victims who require timely intervention. However, the conventional set of vital signs will not be sufficient to triage and monitor a patient with suspected botulism. During the triage process, as an adjunctive tool, the Single-Breath-Count Test (SBCT) will help to identify those presumed botulism-exposed patients who are deteriorating or who may deteriorate. This will allow for arranging for an expeditious disposition of threatened patients to a venue with the appropriate skill mix.

Botulism is a disease of the peripheral nervous system involving the toxin; the toxin binds to presynaptic receptors at neuromuscular junctions, postganglionic nerve endings, and peripheral ganglia. Botulinum toxin interferes with the release of acetylcholine causing paralysis of the affiliated muscle systems.[8] This pathophysiology results in botulism's two principal early causes of morbidity and mortality: (1) aspiration/airway obstruction due to paresis of the muscles of deglutition; and (2) ventilatory distress, failure and suffocation due to paralysis of the ventilatory musculature.[2,9,10] Historically, 20% of patients with food-borne botulism and 60% of patients with infant botulism have required intubation and mechanical ventilation.[2]

As botulism-suspected patients enter the healthcare system, an assessment of the respiratory status of each individual is critical. With botulism, ventilatory insufficiency can spiral to failure with alarming speed.[11]

An objective evaluation of ventilatory status is even more critical for this disease, since visual cues may be lacking due to the progressive paralysis of the muscles of facial expression.[12] As previously mentioned, the commonly-used vital signs, plus SaO_2 are part of the patient assessment paradigm but are neither sensitive nor specific enough to evaluate impending failure of the ventilatory system.

Two pulmonary function tests have the necessary sensitivity and specificity to quantify ventilatory muscle strength.

Vital Capacity (VC) measures the volume of air taken in during maximal inspiration after a full, forced expiration. Negative Inspiratory Force (NIF) measures the inspiratory muscular strength upon deep inspiration.[12] Unfortunately, these tools are neither typically taught to nor employed by prehospital or emergency department personnel. Since specialized training is required, they are not appropriate for just-in-time training should a botulism mass-casualty incident occur. Reliance on respiratory care professionals or intensive care unit nurses to perform these tasks during the crisis would be problematic given the likelihood that they will be occupied with increasing numbers of critical and mechanically ventilated patients. Other tests, such as blood gases and end-tidal CO_2, also would require equipment, time, and expertise that will impede the triage process.

The Single-Breath-Count Test

In light of the need and the urgency to identify ventilatory muscular deterioration quickly, a tool must be adopted that has the following attributes: (1) improves triage, not impede it; (2) has the necessary sensitivity and specificity to assess ventilatory muscular strength; (3) be inexpensive; (4) be easily reproducible; (5) be easily taught; (6) be easily learned; and (7) be easily administered.

Such a tool has been available and meets the requirements necessary to be an effective triage instrument in the assessment and disposition of suspected botulism poisoning. The tool is the "Single-Breath-Count Test" (SBCT). It has been used to evaluate the ventilatory status of patients with suspected or extant neuromuscular compromise (e.g., myasthenia gravis, Guillain-Barre syndrome, and botulism).[13–15] The test is performed by having the patient count out loud after taking one deep breath. Most adults with normal ventilatory function are able to count to 50 in a single breath.[13] A single breath count of <15 is consistent with significant impairment of the patient's vital capacity.[13–17]

The SBCT is not meant to replace any of the usual triage tools that currently are contained in one's protocols or guidelines. Rather, it is meant to be an adjunct, another vital sign to augment the other parameters. Given its simplicity, it easily could be incorporated into the triage protocol should a botulism epidemic or assault result in a large or massive number of exposed or symptomatic individuals. One of the few shortcomings of the SBCT is that it may not be appropriate for use with infants, young children, and persons with cognitive impairment.

To illustrate the potential of the SBCT, it is helpful to revisit the hypothetical patients, adding information from the SBCT. As the patients reach the Triage Officer, they will undergo the SBCT. That number will be added to their triage tags with a time stamp. To a certain extent, the patient's SBCT will help determine the patient's triage status.

For example, for Patient 3, the finding of ptosis might compel a Triage Officer to triage him to the Red Zone. However, with a Single-Breath-Count of 44, both the patient and the Red Zone would be better served if the patient were triaged to the Yellow or even Green Zone. There is no need at this point for the patient to utilize a critical care bed since there is objective evidence demonstrating that, as of yet, the patient is in no ventilatory crisis. Naturally, triage is a dynamic process and this test should be given to the patient at frequent intervals and charted in order to assess ventilatory deterioration.

With regard to Patient 4, with the vagueness of the complaints and the unremarkable set of vital signs, it is likely that the patient will be sent to an area other than the Red Zone. However, if the Single-Breath-Count is administered and reveals a value of 20, there would be ample evidence that the patient requires more critical evaluation by respiratory technologists and the other healthcare professionals.

Finally, Patient 2 underscores the concept that the SBCT should not be the only parameter to make a triage decision. Her value was 40, demonstrating good ventilatory muscular strength, but the fact that she recently had major surgery recently should compel the Triage Officer to send her to a critical care venue for an expeditious pulmonary embolus evaluation. In the meantime, the SBCT still can be administered at intervals since she also may have been exposed to the botulinum toxin.

Discussion

The administration of the SBCT is not meant to begin and end upon the patient's first encounter with the healthcare system. For example, a patient with ptosis and slurred speech and a SBCT of 15 likely will go to the Red Zone for a more detailed evaluation and testing and possible airway intervention. On the other hand, a patient with ptosis and slurred speech and a SBCT of 45 may be directed to the yellow zone for timely but delayed care. In any case, the triaging of these patients does not cease at the point of entry. The SBCT is a simple way for responders to assess a patient at regular and frequent intervals. It even can be done by familial and other caregivers attending the patient. Similarly, using this additional vital sign in the prehospital arena may help decide whether a botulism-poisoned patient may be safely monitored and cared for an alternative sites, until the over-burdened hospital system re-acclimates itself.

Recently, the US Congressional Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism published its report entitled, "The World at Risk".[18] In the report, the authors indicated their belief that the world will more than likely be victimized by a terrorist attack employing a weapon of mass destruction by 2013. That weapon, they concluded, could well be biological. In fact, the Commission has chastised the last administration's efforts to prevent such a bio-attack. Botulinum toxin, given its availability and toxicity, easily could be the agent of choice for terrorists.

Given its potential for causing a mass-casualty incident and its status as a Category A bioterrorist agent, it is incumbent upon healthcare providers and emergency personnel to develop strategies and tactics that will minimize the morbidity and mortality associated with botulism. Education, immune globulin, antitoxin, and invasive airway techniques are well-recognized steps in this process. However, looking at this situation in terms of a mass-casualty incident requires evaluation of the ability to assess, process, and triage these patients in an efficacious manner. Using a time-honored technique such as the SBCT will be an important adjunct in this process.

It not only has been validated as a technique that evaluates ventilatory muscular strength, but it is easily taught,

administered, and reproducible. It is a technique that can be administered by any healthcare provider or volunteer in any healthcare venue, including improvised alternative care sites. With proper instruction, it can even be learned and administered by the patient's family. Any evidence of change or deterioration of the number value can be easily be corroborated by more specific tests such as VC, non-invasive flow (NIF), arterial blood gases (ABGs), or end-tidal CO_2.

Theoretically, this neuromuscular assessment tool can be a screening tool for the average citizen at home. In the event that there is an attack, public health officials and specific healthcare experts can appear on television to teach the SBCT to a concerned, largely ignorant public. Interwoven with additional advice and critical caveats, this instruction could allay fears and direct one to an appropriate healthcare responder/receiver and to an appropriate facility.

Conclusions

Botulinum toxin is the most poisonous toxin known to man, which makes the possibility of a mass-casualty-incident more than just theoretical. Given its unique manifestations and various presentations, it is incumbent upon practicing clinicians to utilize a screening tool that will enhance the ability to triage multiple casualties expeditiously and safely. The SBCT is just such an adjunct that not only generates no cost, it allows for just-in-time training and is a reproducible patient monitoring tool. Therefore, emergency personnel should become familiar with this proven technique.

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