# *ECHO: Journal of the National Black Association for Speech-Language and Hearing*

***ECHO: Journal of the National Black Association for Speech-Language and Hearing*** is an international e-journal concerning communication and communication disorders within and among the social, cultural and linguistically diverse populations, with an emphasis on those populations who are underserved.

NATIONAL BLACK ASSOCIATION FOR SPEECH-LANGUAGE AND HEARING

**Volume 10, Number 1** **Summer 2015**

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The following individuals served as reviewers or otherwise contributed, editorially, to the journal during 2014. We thank them for their conributions to ECHO (any omissions were certainly unintentional):

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# About the Journal

*ECHO: Journal of the National Black Association for Speech-Language and Hearing* is a peer-reviewed, refereed journal that welcomes submissions concerning communication and communication disorders from practitioners, researchers or scholars that comprise diverse racial and ethic backgrounds, as well as academic orientations.

*ECHO* welcomes submissions from professionals or scholars interested in communication breakdown and/or communication disorders in the context of the social, cultural and linguistic diversity within and among countries around the world.

*ECHO* is especially focused on those populations where diagnostic and intervention services are limited and/or are often provided services which are not culturally appropriate. It is expected that scholars in those areas could include, but not limited to, speech-language pathology, audiology, psychology, linguistics and sociology.

Articles can cover any aspect of child or adult language communication and swallowing, including prevention, screening, assessment, intervention and environmental modifications. Special issues of *ECHO* concerning a specific topic may also be suggested by an author or through the initiation of the editors.

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## Guidelines for Authors

Topics accepted for publication in ECHO could include, but is not limited to, the following:

- Communication breakdowns among persons due to culture, age, race, background, education, or social status
- Use of the World Health Organization's International Classification of Functioning, Disability, and Health (ICF) framework to describe communication use and disorders among the world's populations.
- Communication disorders in underserved or marginized populations around the world
- Service delivery frameworks for countries' minority populations, including those who are minorities for a variety of reasons including race, religion, or primary language spoken.
- Dialectical differences and their effects on communication among populations
- Evidence base practice research with culturally and linguistic diverse populations
- Provision of communication services in low income/resource countries
- Provision of communication services in middle income/resource countries
- Provision of communication services to immigrant and/or refuge populations
- Effects of poverty on communication development and the provision of services
- Education/training issues in serving diverse populations
- Ethical issues in serving diverse populations
- Role of religion in views of communication disability and its effect on service delivery

Submissions may include:

- research papers using quantitative or qualitative methodology
- theoretical discussion papers
- works using disability frameworks or models
- critical clinical literature reviews
- tutorials
- clinical forums
- description of clinical programs
- scientifically conducted program evaluations demonstrating effectiveness of clinical protocols
- case studies
- letters to the editor.

## Manuscript Submissions

All manuscripts should be accompanied by a cover letter (e-mail) in which the corresponding author:

- Requests that the manuscript be considered for publication;
- Affirms that the manuscript has not been published previously, including in an electronic form;
- Affirms that the manuscript is not currently submitted elsewhere;
- Affirms that all applicable research adheres to the basic ethical considerations for the protection of human or animal participants in research;
- Notes the presence or absence of a dual commitment;
- Affirms that permission has been obtained to include any copyrighted material in the paper; and
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All manuscripts must be submitted electronically and should follow the style and preparation presented in the Publication Manual of the American Psychological Association (fifth edition, 2001; see Journal for exceptions to APA style) Particular attention should be paid to the citing of references, both in the text and on the reference page. Manuscript submissions and inquiries should be addressed to: nbaslh@nbaslh.org.

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# *Current Issue*

*This issue of ECHO contains a single article by Maida Bermúdez Bosch and Robert Mayo entitled "Blast Injury-Induced Communication Disorders in U.S. Combatants and the Role of the Speech-Language Pathologist." In the article, Bosch and Mayo identify traumatic brain injury as the signature injury resulting from the sustained wars in Iraq, Afghanistan, and now, from other regions in the Middle-East. The authors explain how explosive devices used in war can result in significant communication disorders, and how speech-language pathologists (and audiologists) are seldom involved in the initial stages of recovery and diagnosis of blast-wave survivors. The information contained in this article is particularly relevant to those communication disorders specialists who are now and who will increasingly engage veterans in the provision of rehabilitative services.*

# ECHO: Journal of the National Black Association for Speech-Language and Hearing

## *BLAST INJURY-INDUCED COMMUNICATION DISORDERS IN U.S. COMBATANTS AND THE ROLE OF THE SPEECH-LANGUAGE PATHOLOGIST*

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## ABSTRACT

Conflicts in Iraq and Afghanistan have resulted in numerous U.S. military combat casualties caused by improvised explosive devices (IEDs). Blast injuries involving IEDs and other explosive devices can result in injuries to the head, face, neck and chest, all parts of the body housing important structures necessary for communication. Mild traumatic brain injury is the signature wound of the Iraq and Afghanistan wars. Blast-induced injuries can produce a variety of communication disorders and can negatively impact language, cognition, speech and voice as well as the auditory system. By reviewing the current literature, we explain how explosive devices can result in communication and related disorders (i.e., cognitive-linguistic, voice, swallowing). We also note that presently, speech-language pathologists are seldom involved in the initial part of recovery and diagnosis of blast-wave survivors and only involved when rehabilitation services are required. Because post-traumatic stress disorder and mild traumatic brain injury have similar symptoms, misdiagnosis can occur, and incorrect treatments applied. Thus, we contend that speech-language pathologists are trained professionals who should be involved in the diagnosis and treatment of blast-wave survivors, not only when rehabilitation services are needed, but also during the initial stages post-injury. Continued research should involve case studies as well as short-term and long-term studies of blast-wave survivors and their impairments in communication, as current research mostly focuses on mild traumatic brain injury.

**KEY WORDS**: Blast wave injury, Combat trauma, Cognitive-linguistic processing disorders, Mechanisms of explosive devices, Role of the speech-language pathologist

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# BLAST INJURY-INDUCED COMMUNICATION DISORDERS IN U.S. COMBATANTS AND THE ROLE OF THE SPEECH-LANGUAGE PATHOLOGIST

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## INTRODUCTION

On September 11, 2001, the world witnessed one of the most devastating attacks on the United States of America. The destruction of the World Trade Center by terrorist attacks in New York City and Washington, D.C. changed the lives of many Americans and put into motion a series of events that led to Operation Enduring Freedom (OEF, Afghanistan, 2001 to present), Operation Inherent Resolve (OIR, Iraq and Syria, 2014 to present), Operation Iraqi Freedom (OIF, Iraq, 2003 to 2010), and Operation New Dawn (OND, Iraq, 2010 to 2011). More than two million soldiers were deployed to Iraq and Afghanistan during the United States' involvement into Afghanistan in 2001 and Iraq in 2003. Approximately 6,648 soldiers lost their lives and many more have been wounded. Data on the racial and ethnic distribution of deaths among military personnel during OIF and OND reveal that 83.6 percent were white, 9.9 percent were African American, 4.9 percent were Hispanic, 1.7 percent were Asian, and 1.0 percent were Native American. (Fischer, 2014).

Since the United States Civil War in 1861, the use of Improvised Explosive Devices (IEDs) has increased along with the quantity of injuries suffered by U.S. military personnel. Owens et al., (2008) analyzed and described the types of wounds suffered by U.S. military personnel in Iraq and Afghanistan between October 2001 and January 2005. A total of 6,609 wounds were reported in 1,566 soldiers and of these, 29.4 percent of injuries were to the head and neck region i.e., areas that contain structures critical for cognitive-linguistic processing, speech and voice production, hearing, and swallowing. Improved body armor, helmet head protection and battlefield medicine have led to better survival of military personnel in the OEF and OIF conflicts (Chan et al., 2012). Many of the survivors present with multiple complex injuries or polytrauma (Wallace, 2006) such as open wounds; traumatic amputations; traumatic injuries to the brain, spinal cord, eye, and musculoskeletal system; and psychiatric problems (DePalma et al. 2005; Scott et al. 2006; Wightman & Gladish, 2001). These injuries are also known as "blast injuries" (Scott et al. 2006). In a study of 188 service members treated for injuries during the first four years of OIF and OED, Sayer et al. (2009) reported that 93 percent of the patients sustained a traumatic brain injury and more than half of these were incurred secondary to blast explosions. Numerous studies describe trauma caused by blast injuries but few describe how this type of trauma impacts communication. Moreover, while the speech-language pathologist can serve many roles in the assessment and treatment of survivors of blast wave injury (Wallace, 2006), those roles have not been clearly delineated in the extant literature.

In this paper we describe the mechanism of explosives, types of blast waves, and injuries associated with blast waves. Next, we discuss traumatic brain injury types and classifications. We also discuss the speech, voice, cognitive-linguistic, and swallowing disorders seen in U.S. military personnel caused by blast injuries and describe the speech-language pathologist's role in the assessment and treatment of blast injury survivors. We conclude by describing areas in need of further research on this topic. While we recognize that damage to the auditory system resulting in hearing loss is a frequent clinical feature of blast injury, we will not provide focused discussion of this topic in this paper.

### Explosives and Blast Waves

An explosion is a chemical reaction in which a solid or a liquid is converted into a gas. When an explosion occurs, energy and heat are released and air molecules are compressed. This type of phenomenon is known as an exothermal reaction and the reaction is propagated as a "blast wave". DePalma, Burris, Champion, and Hodgson (2005) explain that blast waves consist of two parts, a shockwave of high pressure followed closely by a blast wind, which dissipates causing a reversal of wind back toward the blast and under pressurization. Explosive devices are frequently used in combat and military warfare. The most commonly used explosive devices are IEDs. Statistics from the Department of Defense demonstrate that more than 73% of OEF/OIF military casualties were caused by explosive weaponry, with the majority of deployment-related traumatic brain injury (TBI) resulting from improvised explosive devices (Galarneau, Woodruff, Dye, Mohrle & Wade, 2008). Other explosive devices that have caused injury among troops include rocket-propelled grenades, land mines, artillery, mortar shells, and aerial bombs (Gawande, 2004).

Explosive devices can contain propellants like gunpowder, which is a low-level explosive or chemicals like trinitrotoluene (aka, 'TNT'), which is a high-level explosive. Low-level explosives gradually release energy whereas high-level explosives rapidly release energy. Terrorist devices and military ordnance typically contain high-level explosives (Horrocks, 2001). High-level explosives produce high-pressure gases that disturb the atmospheric pressure in the medium in which they occur, usually air or water. These high-pressure gases rapidly expand from their point of formation to compress the surrounding medium and generate a pressure pulse carried as a blast wave in all directions (Wightman & Gladish, 2001). After a blast wave is set in motion, particles from the explosive device such as shrapnel, as well as fragments around the detonation area are propelled outward at high velocity. A blast wind is also created by the varying pressure differences, generating a vacuum that refills itself with air and draws fragments back towards the center of the explosion. When the blast wave comes in contact with a medium it is called a shock wave. The shock wave carries energy through the medium (Scheve, 2008).

Blast waves also interact with structures they come into contact with, reflecting in the same manner as sound waves do. Warden et al. (2005) explain that in an explosion, the air blast will move radially in an open field, but will deflect off surfaces in an enclosed space. Blasts that occur in open spaces produce a Frielander wave characterized by a positive phase in which pressure rises above atmospheric pressure, and a negative phase, in which pressure is below atmospheric pressure. If the blast occurs within an enclosure, the pressure-time history appears very different from a Frielander wave (Mayorga, 1997). The original blast wave is known as the incident wave, and when it reflects off a surface, the reflected wave will have greater pressure than the incident wave. This doubling of pressure is caused by the pressure of the reflected wave adding to the pressure of the incidence wave. The strength of the reflected and transmitted shock waves depends upon the material properties of the structure, its geometry and the incident blast wave (Cullis 2001).

**Types of Blast Injuries**

Blast-waves can generate four types of injuries, each caused by different mechanisms (See Table 1). Primary blast injuries are those caused by the blast-wave interacting with the body. Air-filled organs and air-fluid interfaces like the brain, lungs, ear and gastrointestinal tract are the organs most vulnerable. Most neural trauma is caused by primary blast injuries. Chen and Huang (2011) have identified two mechanisms by which a blast wave can lead to neural injury:

> (1) Impact injuries to the head can cause acceleration and deceleration of the brain causing coup and counter-coup injuries.
>
> (2) When the blast wave interacts with the body, blood vessels are compressed creating a volumetric blood surge that moves rapidly towards the brain, producing blood vessel rupture and damaging the blood-brain barrier (BBB). Damage to the BBB will cause secondary neural trauma characterized by diffuse axonal injury. (p. 643)

Another mechanism believed to result in trauma to the brain is caused by direct interaction of the blast wave with the head. Some studies like Moss, King and Blackman (2009) suggest primary blast injury alone can cause trauma to the brain stating that the skull can be compressed increasing intracranial pressure. Other studies like Cheng and Huang (2011) explain that the skull cannot be compressed because it is a solid structure, and therefore, mild TBI may not be the result of direct cranial transmission of the blast wave or skull flexure caused by action of the blast wave on the head.

Secondary blast injuries occur when objects accelerated by the energy of the explosion strike a victim, causing either blunt or penetrating ballistic trauma (Wightman & Gladish, 2001). Secondary blast injuries can cause trauma to any part of the body. Terrorists who make IEDs purposely add nails and other small metal objects to the explosive to maximize injury after detonation. Tertiary blast injuries are caused by the displacement of the body followed by immediate impact with surrounding structures and the ground. Tertiary injuries include crush trauma to any part of the body, but of most interest are impact injuries to the brain. Quaternary blast injuries include all other injuries including burns and inhalation of toxic gas vapor fumes. Figure 1 illustrates the mechanisms associated with primary, secondary, and tertiary blast injuries.

**TABLE 1.** ***Types of Blast Injuries, Causes and Potential Damage (Sources: Center for Disease Control, 2005; DePalma et al, 2005; Stuhmiller, 2008).***

| Type of Blast Injury | Caused By | Trauma Can Occur To | Resultant Injuries |
|---|---|---|---|
| Primary Blast Injury | Blast wave | Brain, auditory system, and lungs | Concussion (traumatic brain injury). Blast lung. Tympanic membrane rupture and middle ear damage. Surge in blood flow and pressure that may lead to tissue injury in the brain. |
| Secondary Blast Injury | Acceleration of debris particles and bomb fragments/shrapnel | Trauma to any part of the body | Penetrating wounds and/or blunt trauma to the skull resulting in coup/contrecoup injuries. Penetrating or laceration wounds to the face and neck. |
| Tertiary Blast Injury | Body displacement | Trauma to any part of the body. Primarily head/neck and extremities. | Fractures, contusions and closed- and open-head injuries. |
| Quaternary Blast Injury | Fire and toxic gases Crush injury | Trauma to any part of the body. Respiratory system. | Flash burns. Respiratory injuries. Post-traumatic stress disorders. |

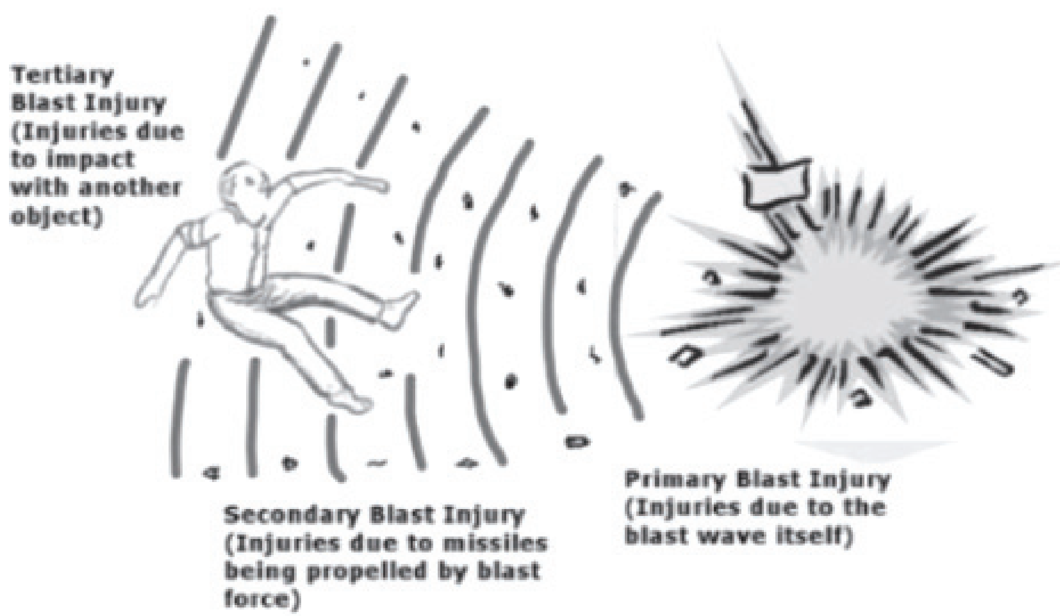


**FIGURE 1.** *Primary, Secondary, and Tertiary Injury from Blast (Source: Stewart, 2006).*

### Traumatic Brain Injury Types and Classification

Traumatic brain injury (TBI) is caused by external trauma to the brain, which can be the consequence of a fall, violent force or vehicular accident. In blast injury survivors, the manifestations of head injury are usually caused by secondary and tertiary brain injury mechanisms such as the effects of flying debris and shrapnel and being physically thrown (Cherney et al. 2010; Wightman & Gladish, 2001). According to statistics from the Walter Reed Army Medical Center, an estimated 60% of all combat-related blast injuries result in TBI (Warden, et al. 2005). In terms of actual numbers, estimates suggest there were upwards of 253,000 such TBI cases between the years 2000 and 2012 (Fischer, 2014). Thus, the importance of understanding the long-term sequelae of blast-related TBI cannot be overstated (Ryu et al. 2014).

There are two types of TBI: penetrating head injury (open head) and closed head injury (blunt). Penetrating injuries are those in which an external object penetrates the brain tissue. Closed head injuries are those in which there is no damage to the skull, but impact causes internal damage to the brain tissue, resulting in axonal damage. Damage to the brain can be classified as focal when a specific region of the brain suffers trauma, or diffuse when lesions occur to multiple areas of the brain. With closed head injury, blast overpressure waves can lead to a sudden increase in overall pressure inside both the thoracic and abdominal cavities. It creates a volumetric blood surge that moves quickly through large blood vessels to the low-pressure cranial cavity from the high-pressure ventral body cavity. The volumetric blood surge causes damage to both tiny cerebral blood vessels and the blood-brain barrier, thus further triggering secondary neuronal damage in the brain (Chen & Huang, 2011). The blood surge can also cause cerebral arterial air embolism-induced stroke. Secondary neuronal damage, which includes features such as hypoxia, neuronal cell death, or diffuse axonal injury (DAI), can be a major contributor to neurological and psychological impairments after mild TBI and battlefield post-traumatic stress disorder (PTSD). These relationships are described in Figure 2.

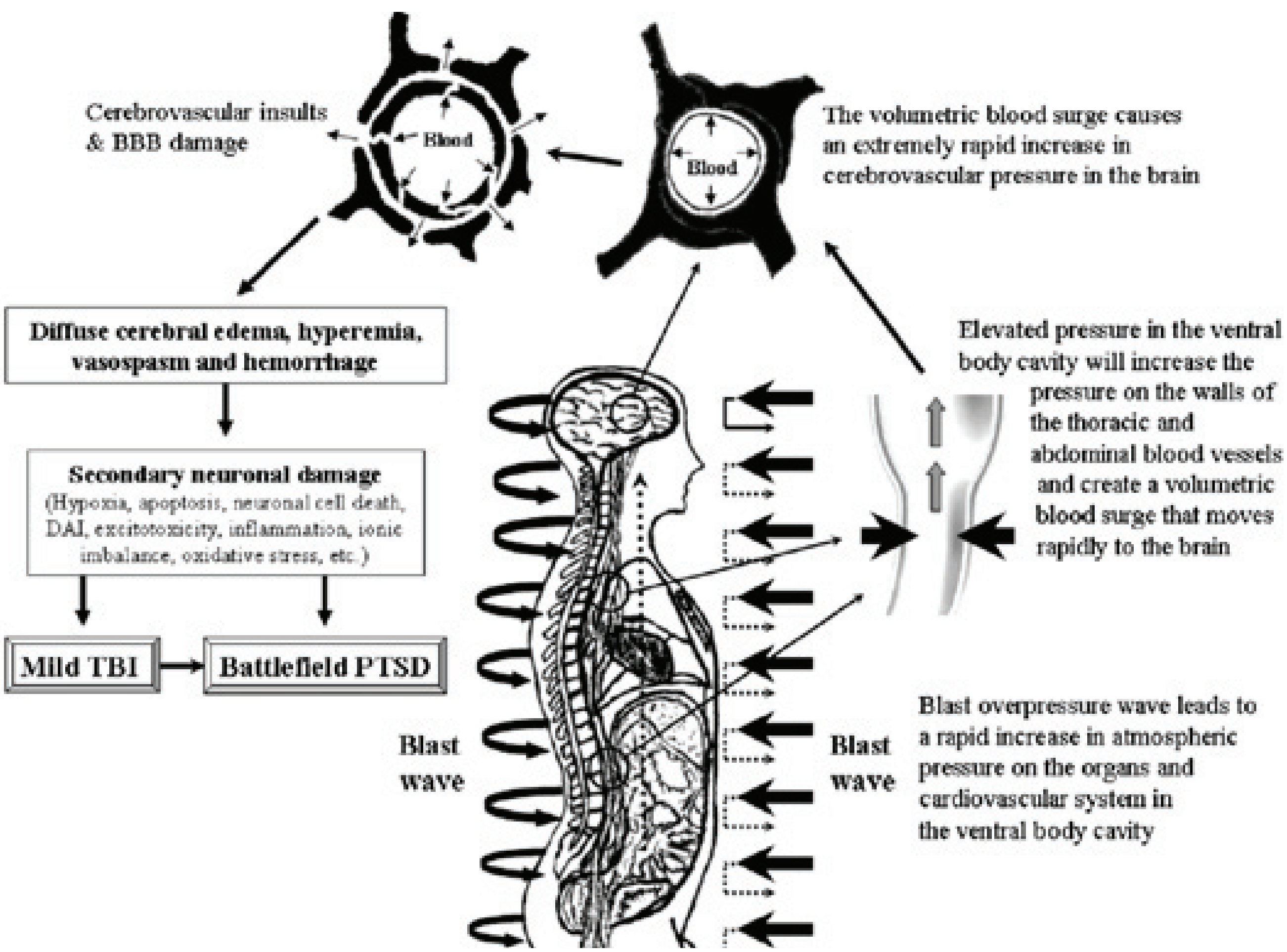


**FIGURE 2.** *The potential mechanism underlying blast-induced mild traumatic brain injury (Source: Chen and Huang, 2011).*

According to the Department of Defense and Veteran Brain Injury Center, a TBI can be classified as mild, moderate and severe and the severity is determined at the time of injury. When classifying TBI severity, three different criteria are considered: (1) duration of loss of consciousness (LOC), (2) duration of post-traumatic amnesia (PTA) and (3) Glasglow Coma Scale score (GCS). The GCS is used to determine an individual's state of consciousness and assesses eye opening abilities and verbal and motor responses (Center of Excellence for Medical Multimedia, 2013).

A mild TBI is characterized by LOC lasting less than 30 minutes, PTA lasting less the 24 hours and a GCS score between 13-15. A moderate TBI is characterized by LOC lasting more than 30 minutes but less than 24 hours, PTA lasting more than 24 hours but less than seven days and a GCS ranging from 9-12. A severe TBI is characterized by LOC lasting more than 24 hours, PTA lasting more than 7 days and a GCS of 8 or less. As members of TBI rehabilitation teams, speech-language pathologists and other specialists use assessment protocols such as the GCS and the Ranchos Los Amigos Levels of Cognitive Functioning Scale (Hagan, Malkmus, & Durham, 1974; Hagan, 2000; Malkmus, Booth, & Kodimer, 1980) to describes the stages of recovery from TBI based on the patient's behavior (from coma to near independence).

**Blast Wave Impact on Speech and Voice**

Blast injuries incurred by soldiers in combat frequently result in penetrating maxillofacial and neck trauma yielding a combination of complex lacerations, open fractures, wounds and burns (Brown-Baer et al. 2012; Hale et al. 2012). The maxillofacial complex (a) encompasses the bony and soft tissue structures anterior and inferior to the base of the skull, from the ears forward and from the brow down to the chin and (b) corresponds to head structures not protected by the Kevlar® helmets currently used by U.S. military personnel (Hale et. al. 2012) i.e., structures important for speech production such as the upper and lower jaws, oral and nasal cavities, teeth, tongue, lips, and cranial nerves V, VII, IX and XII.

Using the Joint Theater Trauma Registry, Chan, Siller-Jackson, Verrett, and Hale (2012) examined injuries to the craniomaxillofacial region incurred by U.S. combatants over the 10-year period of 2001-2011 during Operations Enduring Freedom and Iraqi Freedom. These researchers reported injuries to this structural region in 42% of patients (with a high preponderance of multiple wounds and fractures) and that the primary mechanism of injury involved explosive devices. Open wounds were seen in 65% of their patients and involved from most to least frequent the forehead, jaw, cheek, lips, and mouth. Additionally, six percent of the patients with craniomaxillofacial trauma presented with nerve injuries with the facial nerve (34%) most commonly injured.

Some possible functional consequences of blast injuries on speech production are presented in Table 2. These speech production disorders can be the result of direct trauma to structures of the speech mechanism or the consequence of surgical procedures designed (a) to save the life of the wounded combatant; (b) preserve structures needed for basic functions such as breathing and deglutition; and/or (c) reduce the disfigurement associated with the injury.

Blast injuries to the head and neck can also have an impact on voice production. Norman et al. (2013) conducted a study of the prevalence of communication disorders secondary to traumatic brain injury in veterans of the wars in Iraq and Afghanistan. They reported that out of 303,716 soldiers, 1,848 were found to have a communication disorder and that voice disorders were the most prevalent diagnosis (3.5 per 1,000). Wade, Dye, Mohrle and Galarneau (2007) examined 643 head, face and neck battle injuries seen in service members from the Navy and Marine Corps from March 1, 2004 through September 30th, 2004 who participated in Operation Iraqi Freedom II. Of these 643 injuries, seven percent were injuries to the neck. Elsewhere, Brennan et al. (2011) examined operative logs of six head and neck surgeons deployed to Iraq between 2004 and 2007, who performed exploratory neck surgery in patients who suffered from high-velocity penetrating neck trauma. Of all of the penetrating injuries seen, 77% were located between the cricoid cartilage and the angle of the mandible, which is an area of the body containing structures important for voice production. Damage observed by Brennan et al. (2011) included vascular and arterial trauma, nerve injury (CN X, CN XI) and trauma to the thyroid and cricoid cartilages which are the major skeletal structures of the larynx.

**TABLE 2.** *Summary of Possible Functional Consequences of Blast Injury to the Systems Supporting Speech, Swallowing, Voice, Language and Cognition.*

| Supporting Systems | Causes and Functional Consequences | |
|---|---|---|
| **Craniomaxillofacial and Neck Structures** | **To Speech and Swallowing**<br>• Tongue laceration/traumatic amputation; Trauma to mandible/maxillae and/or oropharynx; Dental trauma; Soft tissue fibrosis and burn scarring leading to contractures of oral-facial structures; Surgical management<br>◦ Articulation disorder, Oral resonance disorder; Oral motor feeding/swallowing disorder<br>• Damage to cranial nerves that support speech motor and swallowing control (e.g., CN VII)<br>◦ Dysarthria<br>◦ Dysphagia<br>• Trauma to the nose, nasal cavity and/or nasopharynx<br>◦ Nasal resonance disorder | **To Voice**<br>• Blast overpressure injury; Inhalation burn injury and scarring of vocal folds and tissues lining the larynx; crush injuries to the larynx. Blast injury to the lungs<br>◦ Aphonia and dysphonia<br>• Penetrating injury to CN X branches<br>◦ Vocal fold paralysis<br>◦ Aphonia and dysphonia<br>• Surgical endotracheal intubation<br>◦ Aphonia and dysphonia associated with edema, granuloma, laceration, or hematoma of the vocal folds<br>• Spinal cord injury<br>◦ Respiratory insufficiency for speech and voice |
| **Brain and Central Nervous System** | **To Cognition**<br>• Traumatic Brain injury<br>◦ Concussion<br>◦ Poor concentration<br>◦ Memory issues<br>◦ Executive functions<br>◦ Problem solving issues<br>◦ Reduced processing speed<br>◦ Posttraumatic Stress Disorder<br>◦ Psychogenic stuttering<br>◦ To Speech and Swallowing<br>◦ Neurogenic stuttering<br>◦ Dysarthria, Apraxia of speech<br>◦ Dysphagia | **To Language**<br>• Traumatic Brain Injury, Stroke<br>◦ All types of aphasia<br>◦ Difficulty reading, writing and spelling<br>◦ Auditory processing disorder<br>◦ Affective language processing deficits (aprosodia) |

Air-containing organs such as the larynx are sensitive to blast injury (Stuhmiller, 2010). In 1997, Mayorga described how blast wave overpressure (BOP) can produce petechiae or ecchymosis in tissues lining the larynx including the true and false vocal folds and vestibule. According to the Mayo Clinic (2012) petechiae are round red spots measuring less than 3 mm that appear under the skin as a result of bleeding and ecchymosis are red spots that are 1 cm or larger. Sharpnack, Johnson and Phillips (1991) explain that stripped and/or ulcerated epithelium with associated fibrocellular clots may also be observed as a result of BOP. Petechiae and ecchymosis, which result in edema of the tissues lining the larynx, are most likely consequences of primary blast injury as a result of the blast-wave exerting pressure on the larynx via the same mechanism it does with other organs like the lungs and gastrointestinal tract. Within the larynx, the vestibule, posterior epiglottic surface and the arytenoids are particularly affected by mucosal bruising (Horrocks, 2001). Additionally, stripped and/or ulcerated epithelium and fibrocellular clots of the tissues of the vocal folds most likely result from quaternary blast injuries. All four types of blast injuries can affect the larynx resulting in different types of trauma.

Secondary blast injuries to the laryngeal structures are of great concern because acceleration of fragments can produce one or a combination of lacerating, incising or penetrating wounds to the larynx. These can damage supporting structures like ligaments, cartilage, muscles and nerves necessary for voice production.

The recurrent laryngeal nerve (RLN) is a branch of the vagus nerve that supplies motor control to all of the intrinsic laryngeal muscles except the cricothyroid muscle (Sapienza and Ruddy 2013). Secondary blast injuries penetrating the neck can damage the RLN producing varying voice disorders including aphonia and dysphonia. The superior laryngeal nerve (SLN) is another branch of the vagus nerve, which serves to bilaterally innervate the cricothyroid laryngeal muscles (Sapienza & Ruddy, 2013). Secondary blast injuries can also damage the SLN and could produce dysphonia, aphonia and problems adjusting vocal pitch.

Tertiary blast injuries to the larynx can cause crush wounds. Laryngeal crush injuries can lead to life-threatening airway obstruction due to fracture of the hyoid bone, epiglottis, thyroid and cricoid cartilages or tracheal rings (Goldenburg, Goltz, Flax-Goldenburg & Joachims, 1997). Also, edema of the true and false vocal folds and the tissues lining the subglottic area of the larynx and tearing of the thyroarytenoid muscles and vocal ligament may occur in combatants subjected to this form of blunt force trauma (Heman-Ackah & Sataloff, 2002).

Quaternary blast injuries can result in burn/inhalation injuries that affect voice quality resulting in a voice disorder. A voice disorder is accompanied by a change in the quality, pitch or loudness of the voice that is different from what is expected for someone of the same age or sex (Smith, Verdolini, Gray, et al., 1996). Changes in vocal quality following burn/inhalation injury are not well documented. Casper, Clark, Kelley and Colton (2002) explain the consequences of burn/inhalation injuries and their effects on laryngeal and respiratory function as follows:

> Injury to the laryngeal mucosa may result in scarring, which stiffens the cover of the vocal folds and interferes with their vibratory behavior. Injury to the posterior larynx may result in scar bands or vocal fold weakness/paralysis that disrupts the ability of the vocal folds to open and close adequately. Respiratory limitations restrict the airflows and pressures required for normal voice production. (p. 236)

Inhalation/burn injuries typically result in dysphonia. In a long-term follow up study by Casper et al. (2002), 10 patients were examined 18 years after suffering from a burn injury. Only four of the patients examined suffered an inhalation/burn injury. Three of these patients were found to have mild-severe dysphonia, however, factors unrelated to burn injuries like smoking, alcohol abuse and poor vocal hygiene were not documented. The lining of the larynx is mostly made up of non-keratanized squamous epithelium. Because there is no keratin protecting this tissue, it is extremely vulnerable to heat. As a result, patients who suffer from a burn/inhalation injury require immediate intubation because edema of the respiratory airway is an involuntary response to heat. Patients in an unconscious state require intubation as well as those who suffer from inhalation/burn injuries. Endotracheal intubation for short and extended periods of time can cause scarring of vocal fold tissues, granulomas, dislocation of the arytenoids, impair mobility of the vocal folds by exerting pressure on the recurrent laryngeal nerve (Ellis & Bennet, 1977), and negatively impact acoustic and physiologic characteristics of voice such as fundamental frequency, pitch perturbation and mucosal wave symmetry (Beckford, Mayo, Wilkinson & Tierney, 1990; Hamdan, Sibai, Rameh & Kanazeh, 2006). Some possible functional consequences of blast injuries on voice production are presented in Table 2.

Blast injuries may also inflict trauma directly onto the lung tissue. Sasser, Sattin, Hunt and Krohmer (2006) explain that blast lung injury is a direct result of the blast wave upon the body, and is a consequence of the complex and dynamic interaction between the pressure wave, the chest wall, the lung tissue, and pulmonary vasculature. When the blast wave travels through the chest wall, the pressure exerted on the lung tissue produces implosions and acceleration and deceleration of tissues. Patients will present difficulty breathing, coughing, respiratory discomfort and hemoptysis. In a one-year follow up study, Hirshberg et al. (1999) discussed blast lung injuries seen in 11 patients who were victims of a suicide bomber in Jerusalem. Upon examination, all patients were diagnosed with a blast lung injury and presented severe respiratory failure. Five patients were examined three months after injury and spirometric testing revealed a mild restrictive pattern in respiratory function. One year after initial injury all patients' respiratory function was within normal limits.

While numerous studies describe the effects blast-waves can have on the lungs, they rarely explain the effects these forces can have on speech breathing following recovery from injury. We do know that the respiratory system provides the basic energy source for all speech and voice production and is involved in the regulation of such important parameters as speech and voice intensity, pitch, linguistic stress, and the division of speech into various units (Hixon, 1973). Thus, blast injuries to the systems that regulate and control respiration can impair the aforementioned parameters of speech and voice resulting in reduced speech intelligibility (McHenry & Minton, 1998; Murdoch et al. 1992).

**Blast-Wave Impact on Cognition and Language**

Blast injury to the brain is the signature injury of recent conflicts in Iraq (Operation Iraqi Freedom; OIF) and Afghanistan (Operation Enduring Freedom; OEF) (Ryu et al., 2014). About 68% of the more than 33,000 service members wounded in action in 2008 experienced blast-related injuries (Beck & Sigford, 2008) and as mentioned earlier, it is estimated that 60% of all blast injuries result in traumatic brain injury (Warden et al. 2005). Additionally, Bogdanova and Verfaellie (2012) report that an estimated 15% to 23% of OEF and OIF personnel have experienced a TBI and that mild traumatic brain injury (mTBI) is the most common type of traumatic brain injury among OEF/OIF military personnel (Fischer, 2014). Most of the reports of the effects of primary blast exposure on the human brain detail damage related to direct head impact (MacDonald et al. 2011; Sponheim et al. 2011). Thus, the effects of mTBI caused by blast injury and their subsequent effects on language and cognition (i.e., cognitive-communication disorders) have received increased clinical and research interest.

The acute symptoms of mTBI include physical (e.g., headaches, dizziness, sleep-wake disturbances), cognitive (e.g., poor concentration, memory problems) and emotional symptoms (e.g., irritability, anxiety, depression) (Bogdanova & Verfaellie, 2012). The cognitive sequelae of mTBI are apparent on tasks involving working memory, executive functions, processing speed and learning, and can be sufficiently severe to interfere with everyday activities. For example, blast survivors recovering from mTBI may have difficulty participating in conversation in noise or in groups; exhibit disorganized verbal expression; show difficulty learning new information; display disfluent speech; have word-retrieval problems; and demonstrate difficulty in planning, problem solving, judgment, and decision making (Cherney et al. 2010). Helm-Estabrook and Albert (2004) explain that executive functions:

> Is a term applied to what may be regarded as the highest level of human cognition. Executive functions include the ability to plan, sequence, and accomplish goal-directed activities in a flexible manner as demanded by situational and environmental changes. Attention and working memory skills are fundamental to these higher order, problem-solving processes. (p. 149)

Interestingly, research indicates that blast etiology is not categorically different from other TBI mechanisms (e.g., motor vehicle accident), at least with regard to cognitive sequelae on select measures and cognitive sequelae following TBI are determined more by severity of injury than mechanism of injury on verbal learning and memory measures (Belanger et al. 2009).

Recent published clinical reports indicate that victims of TBI secondary to blast injury may frequently present with a combination of cognitive and language impairments such as aphasia. For example, Norman et al.'s (2013) previously-mentioned study of the prevalence of communication disorders resulting from traumatic brain injury in veterans of the wars in Iraq and Afghanistan revealed that irrespective of the severity of the TBI, aphasia was diagnosed in 1.9 per 1,000 patients. The authors concluded from their findings that individuals with a TBI diagnosis were more likely to have a diagnosis of aphasia.

There are a few published clinical case studies that describe cognitive-linguistic disorders secondary to blast-related TBI. Warden, French, Shupenko, Fargus, et al. (2009) described a case study of a 50-year-old female soldier who sustained a blast injury to the left side of her body while deployed in Iraq. The patient reported dizziness, balance problems and thinking difficulties. Although the patient did not develop any language impairments, she did present with a transitory cognitive impairment. Elsewhere, Rosen at el. (2009) reported the case of a 23-year-old male combatant who suffered two blast exposures (two months apart) while deployed in Iraq in 2004. Loss of consciousness was not suffered during the first blast but was experienced by the soldier following the second encounter. The patient was evaluated, but returned to duty after both blast exposures. In 2005, he attempted to finish his college degree but was unsuccessful because of difficulty with communication. The patient presented with numerous symptoms including "slow vision", difficulty hearing, impaired memory, stuttering and "mumbling". A MRI with diffusion tensor imaging showed damage to the arcuate fasciculus of the patient's left cerebral hemisphere.

The arcuate fasciculus is a neural pathway composed of fiber bundles that extend anteriorly from the posterior portion of the temporal lobe to the posterior region of the inferior prefrontal lobe, thereby linking the expressive (i.e., Broca's area) and receptive (i.e., Wernicke's area) language centers of the cortex (Kolb, & Whishaw, 2003; Loring, 1999). In terms of neurocognitive functioning, the arcuate fasciculus is said to play a vital role in repetition (Filley, 2001). Specifically, as auditory information comes into the neural system that is to be repeated, it is first processed by the receptive center of the brain (i.e., Wernicke's). Upon clinical evaluation by a speech-language pathologist and neuropsychologist, Rosen et al. (2009) reported that their patient was diagnosed with conduction aphasia and neurogenic stuttering. They noted the patient's spontaneous speech was characterized by hesitations and disfluencies with reduced content but was grammatical. Auditory comprehension was preserved but confrontation naming was mildly impaired. Additionally, the patient presented with moderate-to-severe dysfunction with affective language processing ("aprosodia") as exemplified by his inability to produce and repeat affectively (angry, happy, sad, and indifferent) modulated sentences. Some possible functional consequences of blast injuries on cognition and language are presented in Table 2.

In a recently published clinical report, the axonal injuries of five veterans with a history of blast exposure were studied and compared to axonal injuries of patients with a history of opiate abuse, anoxic-ischemic encephalopathy, motor vehicle crashes and healthy control subjects (Ryu et al., 2014). Three of the subjects with a history of blast injury died of opiate and/or alcohol abuse. Testing was done by immunohistochemistry for proteins that accumulate in damaged axons including amyloid precursor protein (APP) and neurofilament proteins. This study revealed a honeycomb-shaped pattern (APP+) in the superior and middle frontal white matter and cingulate gyri. Similar patterns were observed in the white matter of the anterior and middle temporal lobe. This honeycomb-shaped pattern was not seen in any of the brain tissues from individuals who died from non-blast injury causes. It is important to note from a functional standpoint where these honeycomb-shaped patterns were observed. The frontal lobe is responsible for regulating cognitive functions including reasoning, self-regulation and monitoring, abstract thinking, planning, decision making, executive functions and pragmatic behavior. The temporal lobe plays an important role in language comprehension and memory. Although these findings cannot be used to draw any major conclusions, they do reveal that blast injuries can result in trauma to the brain that can only be seen post-mortem. These injuries could explain the reported cognitive deficits seen in military personnel, which include chronic problems with memory, attention and executive functions that are frequently treated as Post Traumatic Stress Disorder (PTSD) with no reports of improvement.

As described earlier, cognitive deficits can impair an individual's ability to communicate effectively. Cognitive-communication disorders are frequently documented in the TBI population, however, the opposite occurs when blast injuries are involved. One explanation for this shortcoming involves some of the similarities between mTBI and PTSD, which include irritability, problems concentrating, memory dysfunction, depression, and mood swings (see Figure 3). These behavioral similarities make mTBI and PTSD difficult to separate and diagnose. Note that the symptoms described above are frequent complaints of patients diagnosed with cognitive-communication disorders. Symptoms of mTBI such as loss of consciousness (LOC), Post Traumatic Amnesia (PTA), disorientation and confusion rapidly resolve (Blyth, Scott, Bond & Paul, 2011) and mTBI is rarely evidenced on imaging techniques making diagnosis challenging. It is important to note that military personnel in combat zones who subsequently suffer a blast injury have already met one of the eight criteria used to diagnose PTSD, making its diagnosis more frequent than in other situations. Williamson and Mulhall (2009) explain that:

> Troops returning from combat may experience a wide range of psychological responses. Many veterans experience some level of sleeplessness, anxiety, irritability, intrusive memories, or feelings of isolation: the severity of these symptoms varies widely between individuals, and a single veteran's symptoms usually fluctuate over time. If these symptoms become severe or persistent, they are often diagnosed as Post Traumatic Stress Disorder or major depression. In addition to these psychological injuries, some troops who have suffered concussion in theatre may be experiencing the effects of Traumatic Brain Injury, including mood changes and cognitive problems. (p. 3)

Finally, there is a stigma regarding head injuries, more so in the military than in other settings (Friedemann-Sanchez, Sayer, & Pickett, 2008). Many soldiers avoid reporting injuries for fear of being medically discharged or for fear of being labeled as having a disability. Some military personnel consider an injury a weakness and they fear being portrayed as weak (Sagalyn, 2011).

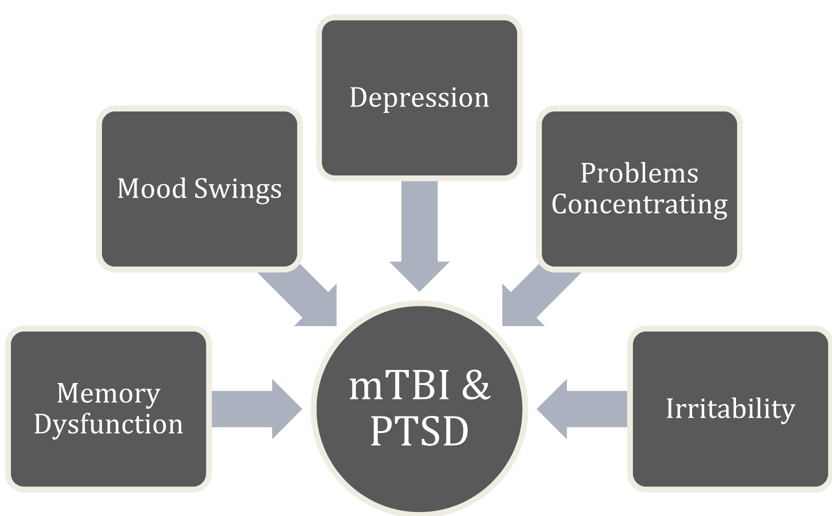


**FIGURE 3.** *Mild TBI (mTBI) and Post-Traumatic Stress Disorder (PTSD) Symptoms.*

Wong, Murdoch, and Whelan (2010) indicate that research into the cognitive-communication deficits following mTBI is necessary for determining treatment priorities for individuals with cognitive-linguistic impairments occurring secondary to mTBI in order to facilitate their return to work, school, and normal social activities. Cognitive-communication disorders can limit the amount of work individuals can perform and in some cases impede a soldier's return to normal duties, which can result in social isolation, depression, and/or financial hardship (Department of the Army, 2012).

**Blast-Wave Impact on Swallowing**

Swallowing or deglutition is a highly coordinated neurological process that involves 31 pairs of muscles (Dodd, Stewart and Logemann, 1990). Deglutition involves four phases: (1) oral preparatory phase, (2) oral phase, (3) pharyngeal phase and (4) esophageal phase. A fifth stage was proposed by Leopold and Kagel (1983; 1997) called the pre-oral anticipatory phase (Morgan & Ward, 2001). They suggest that this stage encompasses the interaction of pre-oral motor, cognitive, psychosocial and somatoesthetic elements involved during mealtimes. The first two stages of swallowing are voluntary and require fine neuromotor control. Lazarus (1989) explained that:

> Several neuromuscular events occur during the oral preparatory phase. Lip closure maintains the bolus within the oral cavity. Buccal tone is necessary to prevent spillage of material into the lateral sulci. Lingual lateralization maneuvers the bolus to the teeth, retrieves the bolus from the teeth during mastication, mixes it with saliva and returns it to the teeth. (p. 34-35)

During the oral phase, the tongue moves the bolus to the back of the oral cavity in preparation for the pharyngeal phase. The oral phase ends when the bolus enters the pharynx. The pharyngeal phase also requires fine neuromotor control. Lazarus (1989) describes six stages of the pharyngeal phase: (1) elevation of the velum, (2) tongue base retraction to the pharyngeal wall, (3) elevation and anterior movement of the larynx, (4) closure of the larynx, (5) pharyngeal peristalsis, and (6) relaxation of the cricopharyngeus muscle. The pharyngeal stage ends when the bolus enters the esophagus. The esophageal stage begins when the bolus enters the esophagus and ends when the bolus enters the stomach.

Swallowing disorders can involve any one of the four stages of swallowing resulting in danger of aspiration and/or malnutrition. Moreover, blast injuries to the head, face, oral cavity, and neck can impact the soft tissue and skeletal structure, musculature, and neural innervation of swallowing. Mackay, Morgan and Bernstein (1999) explain that adequate nutrition is vital for patients with brain injuries who are at risk of malnutrition secondary to trauma, dysphagia and other complications. Brooke et al. (1989) reported that the average weight loss from head injury to rehabilitation admission was 29 pounds. This rapid weight loss is caused by hypermetabolism as a result of head injury and is also observed in burn victims. Hayes (1992) described other factors that affect nutritional intake including cognition, drug therapy and constipation.

Head injured patients are frequently prescribed numerous medications that produce varying side effects including changes in metabolism, loss or increase in appetite, constipation, or taste alteration. Constipation delays gastric emptying therefore affecting food intake. Hayes (1992) explains that weight management in head injured patients can be very challenging because of the frequent surgical procedures and medical investigations, swallowing dysfunction and difficulty predicting and maintaining the high calorie and protein needs of these patients. In cases where oral intake is not an option, alternative methods of nutritional intake need to be provided.

Swallowing disorders following traumatic brain injury are well-delineated in the literature; however, swallowing disorders in patients with TBI caused by a blast injury are less well-described and researched. Some possible functional consequences of blast injuries on feeding and swallowing are presented in Table 2. Additionally, in their overview of combat-related blast injury and dysphagia seen in military personnel, Newman, Gillespie, and Brigger (2007) provided the following important observations that are worthy of note by SLPs.

1. Blasts can result in multiple injuries associated with impaired swallowing function, including neurologic deficits, and damage to oral, pharyngeal and/or laryngeal structures.
2. The most severe forms of damage have included avulsions of facial structures including mandible, floor of mouth, tongue, teeth, palate, lips, and larynx. These patients may require multiple reconstructive procedures and long-term swallowing therapeutic intervention to regain the ability to eat orally.
3. Swallowing disorders are not always overtly present at the time of emergency care; however, dysphagia may become a critical health issue during an individual's recovery and rehabilitation.
4. These patients can experience traumatic brain injury with its consequent cognitive deficits and possibly a stroke.
5. Multiple other issues adversely affect the clinician's ability to diagnose and treat swallowing disorders in blast injury victims. A primary hurdle is the multifactorial reduced level of consciousness secondary to polytrauma, brain injury, pain medication and/or sedation.
6. The level of consciousness may be complicated by post-traumatic stress and cognitive deficits which impact the patient's ability to participate in a diagnostic swallow assessment, follow recommendations, or engage in a swallowing treatment protocol.
7. Some patients may require tracheostomy and/or mechanical ventilation secondary to the polytrauma and other issues previously described. Repeated endotracheal intubation and sedation for each surgical procedure may further affect swallowing function.

**Roles of the Speech-Language Pathologist**

Speech-language pathologists (SLPs) are professionals trained to prevent, assess, diagnose, and treat speech, language, social communication, cognitive-communication, and swallowing disorders in children and adults (ASHA, 2007). SLPs understand the five domains of language, which include semantics, syntax, morphology, phonology and pragmatics and recognize how these domains collectively function. SLPs are also skilled in language development, and the neurological aspects of communication. Some SLPs, by virtue of specialized training and/or professional work experience (e.g., 'medical SLPs'), are uniquely qualified to address the types of blast injury-induced communication and related disorders presented by military combatants.

It is important to understand that SLPs are one of several rehabilitation disciplines that contribute to defining the nature of the cognitive deficits resulting from blast-related TBI adding unique skills to the interdisciplinary management of the functional consequences of those deficits (Cornis-Pop et al. 2012). Additionally, SLPs understand the importance of employing evidence-based practice treatments to assist blast-wave survivors improve their overall functional outcome. Functional areas of concern that SLPs can examine following a blast-induced traumatic brain injury incurred by a combatant include (1) job performance (e.g. work, school); (2) need for job redesignation and/or Active Duty, work, or school restrictions or limitations; (3) differences between pre-injury performance and current functional status; (4) performance on simulators (e.g., rifle, flight) and work trials; (5) quality of life; and (6) community participation (Cornis-Pop et al. 2012).

**Approaches to Service Provision**

Because of the polytrauma associated with blast-injuries, it is important to consider the mechanism of the injury when evaluating and treating prospective patients. Scott, Belanger, Vanderploeg, Massengale and Scholten (2006) discussed two different approaches that are used when examining and treating patients with blast-related polytrauma. The primary symptoms-based approach (see Figure 4) is used in a typical clinical setting, where a patient complains of a symptom and the physician uses the patient's primary symptoms or a diagnosis based on routine tests to determine the course of treatment, including referral to a specialist. Additionally, Scott et al. (2006) note that if a new symptom arises, this sequential process is repeated. As explained by Scott et al. (2006), this approach has the potential to overlook certain blast-related injuries and delay referral for specialized assessment and/or treatment services (such as speech, language or swallowing). Most alarmingly, the primary symptoms-based approach has been found to be associated with premature closure of cases (McSherry, 1997) and with overall underdiagnosis and inferior quality of care (Scott et al. 2006). Conversely, the mechanism-of-injury approach (see Figure 5) considers the cause of the injury and relies on knowledge of the typical physical and psychological sequelae associated with a particular mechanism (cause) of injury to guide patient assessment and treatment. As Scott et al. (2006) explain, this approach has the advantage of "refocusing assessment and treatment efforts around the mechanism of injury---the blast---rather than solely on the primary symptom or injury [and] might provide a more comprehensive, efficient, and programmatic system of care." (p. 267). Some of the typical and commonly overlooked blast-related conditions in injured military personnel with polytrauma that may require the services of the SLP include concussion, PTSD, nerve damage, and hearing loss (Scott et al. 2006). In the mechanism-of-injury intervention context, once all life-threatening injuries are taken care of, the patient receives a full examination and appropriate referrals are made (Scott et al. 2006). This model uses an interdisciplinary team in which speech-language pathologists play a very important role.

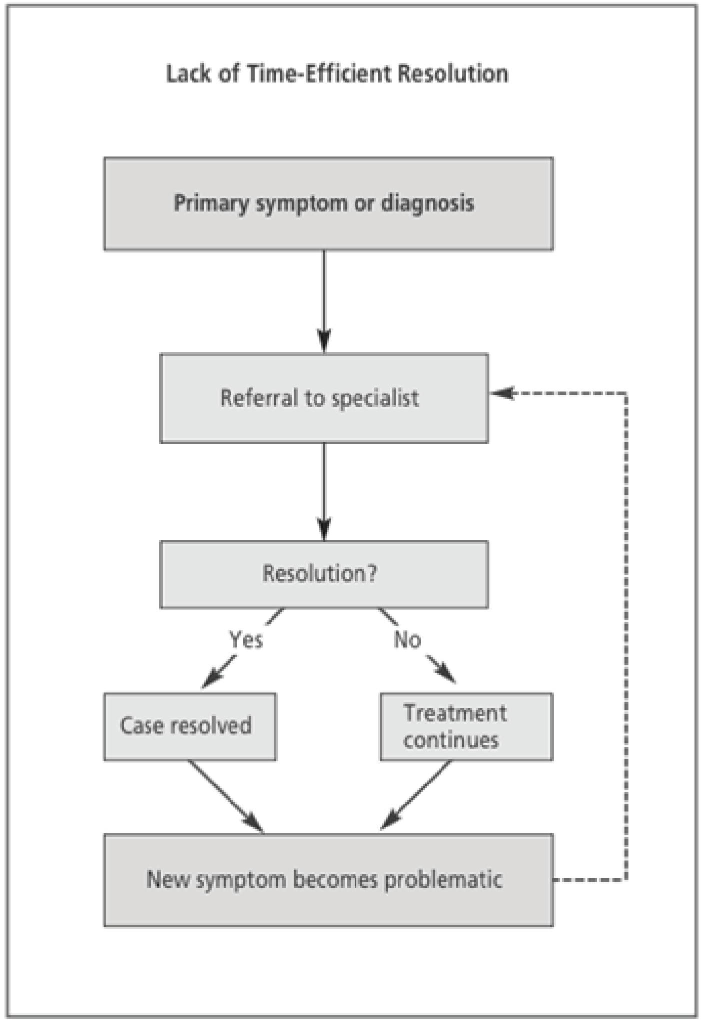


**FIGURE 4.** *The Traditional Primary Symptom-Based Approach to evaluating and treating patients with blast-related polytrauma (Scott et al. 2006).*

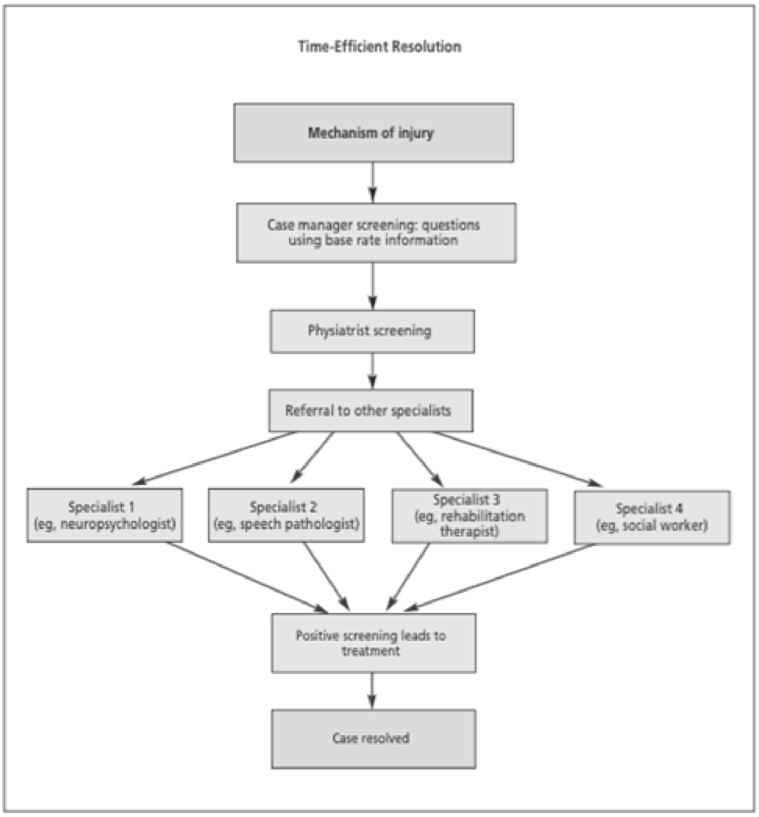


**FIGURE 5.** *The Mechanism of Injury Approach to evaluating and treating patients with blast-related polytrauma (Source: Scott et al. 2006).*

**When and Where?**

Wounded combatants should have access to diagnostic and treatment services from SLPs starting with their initial hospitalization and continuing throughout their reintegration into the community (Cherney et al. 2010). The U.S. Department of Defense has established five levels of medical care for personnel who are in combat zones. It is important to note that SLPs are not involved in all levels of this care (U.S. General Accountability Office, 2011). Level 1 care is administered to soldiers, marines, airmen, or sailors who are wounded on the field of combat. In Level 1 care, medics, corpsmen or battalion aid stations are the first responders. They provide immediate medical care and stabilization and prepare the wounded for evacuation to the next level. Level 2 care provides wounded soldiers with emergency medical care. This level of care is given near the initial area of injury such as an on-base or off-base medical facility. Medical personnel can provide surgical inpatient services such as critical care nursing and temporary holding. Level 3 care personnel provide the most advanced medical care available in Iraq and Afghanistan. They offer preventative and curative health care in Army combat support hospitals, Air Force theatre hospitals or Navy expeditionary medical facilities.

SLPs are involved with patient care in Level 4 and Level 5. Level 4 care is provided in overseas hospitals that render a full range of medical services including preventative, curative, acute, convalescent, restorative and rehabilitative care. At this level, SLPs are mostly involved with patients' feeding and swallowing issues. They may perform some informal assessments to determine a patient's ability to communicate, however, at Level 4, SLPs do not address any communication impairments noted during the evaluation. Any communication impairments identified are fully assessed and treated in Level 5. A major reason for not treating communication impairments in Level 4 involves spontaneous recovery. Some individuals may improve their overall communicative functioning as a result of improved circulation, reduced edema and/or absorption of damaged brain tissue (Cherney & Robey, 2008). Level 5 is provided in a medical facility inside of the United States. The services provided in Level 5 are the same as in Level 4. At Level 5, SLPs complete a full battery of assessments and provide evidence-based practice treatments for individuals who have difficulty communicating. Levels 4 and 5 facilities are designated as polytrauma centers.

**Services Provided by Speech-Language Pathologists**

In polytrauma rehabilitation centers, SLPs have standing orders to assess cognitive-communication and swallowing functions in blast-injury survivors within 24 to 48 hours of admission and then to treat the patient as indicated throughout their stay in rehabilitation (Cornis-Pop, 2006). In this setting (Level 5), SLPs are not exclusively involved when a communication problem arises; they are involved with that patient from the initial point of admission per the mechanism-of-injury approach to assessing and treating blast-injured patients. SLPs recognize the importance of establishing some method of communication for patients unable to speak as a result of their injuries. SLPs can meet this goal by using communication boards, or teaching a patient to use gestures. In some cases, the use of augmentative and alternative communication (AAC) devices may be warranted.

AAC devices are designed to provide patients with an alternative method of communication. SLPs are trained to assist patients in selecting the appropriate AAC device and provide instruction on the use of such systems. Additionally, SLPs assess swallowing function and determine the patient's risk for aspiration. In cases where signs and symptoms of aspiration are present, SLPs make diet modifications to meet the patient's nutritional needs and reduce the risk of aspiration. Another important factor to consider with blast-wave survivors is that some of them arrive to the acute care venue in comatose states and require intubation. As previously discussed, intubation has the potential to cause laryngeal tissue injury resulting in phonatory deficits. SLPs can assist patients improve vocal fold function and voice quality when intubation results in dysphonia.

Another major task SLPs are responsible for is patient, caregiver and family education and counseling. As mentioned earlier, blast injuries can impact communication at many different levels and some disorders are more severe than others. In cases where the severity of the communication disorder impacts rehabilitation or re-integration into social, educational and/or work environments, SLPs provide support and advocate for the needs of their patients. An example of such a situation involves patients with cognitive communication disorders following a TBI. Cognitive communication disorders present challenges to the patient because they can impact social interactions, information processing, executive functions, awareness, emotion and behavior, affecting an individual's overall quality of life.

As underscored in this paper, TBI is the hallmark wound of the war in Iraq and Afghanistan. TBI can negatively impact an individual's ability to obtain and retain employment. The most recent figures from the Bureau of Labor Statistics show that the unemployment rate among veterans who participated in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) is 10.2 percent (Bureau of Labor Statistics, 2014). The unemployment rate among veterans who served in OEF is 12.3% and those who served in OIF is 10.0%. Twamley et al. (2013) and Sturm, Gresenz, Pacula, and Wells (1999) predict that the unemployment rate among veterans with mental health conditions may be even higher, because mental health conditions in the general population are associated with three to five times higher rates of unemployment. SLPs can help patients with cognitive communicative deficits or other communication disorders by identifying the areas of communication strength and suggest an area of work in which they might be successful (Perry and Hux 2011). In the latter role, the SLP might work collaboratively with a vocational rehabilitation counselor.

While we cannot provide an exhaustive list and descriptions of the many possible roles assumed by the SLP in the management of blast-injured military personnel, we can provide a summary of those possible contributions. Table 3 lists roles and care activities SLPs may assume in working with this population. We highlight three role areas as a function of points in the recovery process when the SLP may be called upon to serve the needs of blast-injured patients. These phases of recovery include (1) after stabilization of life functions, (2) acute and post-acute phases, and (3) progress monitoring. Additionally, examples of services the SLP can offer the patient, family and rehabilitation team are delineated under each recovery phase.

**TABLE 3.** *Summary of Possible Roles of the Speech-Language Pathologist in the Care of Blast-Injured Military Personnel.*

| Possible Roles and Care Activities |
|---|
| I- After Stabilization of Life Functions: Assessment and Diagnosis |
| • Review of medical record for inventory of injuries and locations; operative, radiologic imaging, physician and nursing reports; list of medications. |
| • Be familiar with the commonly associated sequelae of blast-related injuries |
| • Coma assessment for purposes of identifying level of consciousness, level of cognitive function (e.g., response to verbal, auditory or tactile stimulation). |
| • Swallowing assessment to determine risk of aspiration; deglutition/nutritional intake methods (i.e., alternative means of nutrition, taking nutrition with support or independently) |
| • Respiration assessment to determine if patient is breathing independently or with support of tracheostomy/ventilation intubation. |
| • Oral-motor assessment for purposes of identifying problems with communication functions including: speech production, articulation, vocal quality and breath support for speech. |
| • Assessment of basic communication functions (vocal or non-vocal, verbal-non-verbal, reading, writing, gesture, gross hearing abilities, eye movement/eye tracking). |
| • Assessment of cognitive-linguistic abilities and determine the impact of deficits on activities of daily living and participation in social, educational, or work activities. |
| • Educate patient, family and interdisciplinary team about recovery expectations. |

**TABLE 3.** *Summary of Possible Roles of the Speech-Language Pathologist in the Care of Blast-Injured Military Personnel.*

| Possible Roles and Care Activities |
|---|
| II- Acute and Post-Acute Phases of Recovery: Treatment<br>• Identify and treat 'hidden' injuries in the primary care and/or post-acute care setting (e.g., muscle weakness, undiagnosed hearing loss, memory problems)<br>• Work on cognitive-linguistic deficits (attention; memory; executive function; information processing and speed; language processing and expression). Assist patient in developing and using compensatory strategies.<br>• Utilize holistic functional communication approaches and emphasis.<br>• Educate patient, family and interdisciplinary team about recovery expectations.<br>• Work on social communication skills.<br>• Address motor speech disorders, articulation and resonance disorders related to ablative injuries or surgeries to vocal tract structures.<br>• Identify and treat neurogenic stuttering or psychogenic stuttering.<br>• Promote generalizations of strategies and skills.<br>• Manage swallowing impairments.<br>• Address complication following intubation (e.g., aphonia, dysphonia).<br>• Determine need for Alternative and Augmentative Communication system(s). Provide patient with systems that meet their immediate and future needs.<br>• Develop and employ outcome measures to validate the efficacy of cognitive-communication interventions. |
| III- Progress Monitoring<br>• Provide follow-up care or refer to local SLP, Audiologist, and other rehab specialists.<br>• Monitor changes in cognition, communication and swallowing<br>• Serve as family support resource (connect with local TBI support groups, veterans' groups, etc).<br>• Advocate for other services or modifications as needed (e.g., modifications to the work environment, support efforts to obtain AAC device and/or funding for device). |

**Areas of Research Need**

As the federal government commits funds and resources to investigate the effects and rehabilitation of blast injuries, it is important that researchers in speech-language pathology and audiology be an integral part of the interdisciplinary research team (Cherney, et al. 2010). Research that can provide further insight into blast-injuries and their impact on communication should include studies that describe the most common communication disorders seen following a blast-injury. Research should include a large cohort of individuals who have sustained a blast-injury within the last six months who are three months post-injury. A full communication assessment battery should be performed to determine the type of communication disorder that is present, the severity of the disorder and prognosis for recovery. Assessments should also be used to monitor progress. Additionally, information regarding functional outcomes should be collected. These studies should aim to answer the following questions: How many individuals who have a blast-induced communication disorder, without any comorbidities, return to their military career? How many of them are honorably discharged and why? How does the communication disorder impact their family and their re-integration into the community, work or school setting? How many individuals are able to find and sustain a job? How many of these individuals suffer from PTSD? How many individuals have an additional impairment? (e.g., lost a limb).

Currently, research involves retrospective studies and case studies, which present numerous limitations. Case studies provide insight into blast injuries and communication impairments; however, conclusions cannot be made based on one individual. Retrospective studies present additional limitations because they rely solely on databases to obtain research data. The accuracy of the information used can be difficult to determine. If the data used contains information on diagnosis (e.g., aphasia, fluency disorder), the level of expertise of the individual who provided the diagnosis cannot be determined. Similar to case studies, retrospective studies are also considered low evidence research. Thus, well-controlled prospective studies and evidence based research will help SLPs and other professionals acquire the knowledge and skills needed to improve the services they provide to blast wave survivors. To achieve this goal, it is necessary to improve current research practices involving blast injuries and their impact on communication. Furthermore, it is important to discuss how blast-induced communication disorders impact functional outcomes in order to provide service members with the highest quality of care and support post-injury.

**Conclusions**

Many of the injuries associated with blast injury such as loss of limbs or disfiguring burns are for the soldier and his or her family, life changing. Because blast injury survivors typically sustain wounds that are life threatening, the need to treat impairments in communication becomes secondary to managing life threatening injuries. However, the communication disorders described in this paper can also cause transient or permanent changes in the lives of blast-wave survivors. Explosive devices can cause polytrauma in one or more of the systems necessary for speech and voice production, language and cognition, respiration, swallowing and hearing function. Further research is needed to evaluate on a larger scale how blast-wave injuries affect communication, swallowing and hearing; to understand the cognitive-linguistic deficits associated with mTBI; and recognize the patterns of recovery from blast-related communication disorders. As we note in this paper, the SLP has an important role in identifying and servicing the needs of these patients. Further research will also allow speech-language pathologists and other healthcare professionals to adapt current protocols and create new ones for the effective treatment of blast-injury survivors thereby enhancing their recovery and quality of life.

**References**

American Speech-Language-Hearing Association. (2007). *Scope of Practice in Speech-Language Pathology*. Retrieved February 12, 2015, from http://www.asha.org/uploadedFiles/SP2007-00283.pdf.

Beck, L., & Sigford, B. (2008). Update on Health Care VA TBI Screening Program, U.S. Washington, D.C., U.S. Department of Veterans Affairs.

Beckford, N. S., Mayo, R., Wilkinson, A., & Tierney, M. E. (1990). Effects of short-term endotracheal intubation on vocal function. *Laryngoscope*. 100(4), 331-336.

Belanger, H.G., Kretzmer, T., Yoash-Gantz, R., Pickett, T., & Tupler, L.A. (2009). Cognitive sequelae of blast-related versus other mechanisms of brain trauma. *Journal of the International Neuropsychological Society, 15*, 108.

Blyth, T., Scott, A., Bond, A., & Paul, E.A. (2011). Comparison of two assessments of high level cognitive communication disorders in mild traumatic brain injury. *Brain Injury. 26*(3), 234-240.

Bogdanova, Y. & Verfaellie, M. (2012). Cognitive sequelae of blast-induced traumatic brain injury: Recovery and rehabilitation. *Neuropsychology Review*. 22, 4-20.

Brennan, J., Lopez, M., Gibbons, M.D., Hayes, D. Faulker, J., Dorlac, W.C., & Barton, C. (2011). Penetrating neck trauma in Operation Iraqi Freedom. *Otolaryngology-Head and Neck Surgery*. 144(2), 180-185.

Brooke, M.M., Barbour, P.G., Cordng, L.G., Tolan, C., Bhoomkar, A., & McCall, G.W. (1989). Nutritional status during rehabilitation after head injury. *Journal of Neurological Rehabilitation*. 3, 27-33.

Brown-Baer, P.R., Wenke, J.C., Thomas, S.J., & Hale, R.G. (2012). Investigation of severe craniomaxillofacial battle injuries sustained by U.S. service members: A case series. *Craniomaxillofacial Trauma Reconstruction*, 5, 243-252.

Bureau of Labor Statistics. (2014). Table 10. Employment status of Gulf War-era II veterans 18 years and over by location of service. Retrieved February 12, 2015, from http://www.bls.gov/news.release/vet.t10.htm

Casper, J.K., Clark, W.R., Kelley, R.T., & Colton, R.H. (2002). Laryngeal and phonatory status after burn/inhalation injury: A long term follow-up study. *Journal of Burn Care & Rehabilitation*. 23(4) 235-243.

Center of Excellence for Medical Multimedia. (2013). A Caregiver's Journey. *Traumatic Brain Injury*. Retrieved from http://www.traumaticbraininjuryatoz.org/The-Caregivers-Journey/Session-Two/Communication-Effects/Not-Speaking-Clearly

Chan, R.K., Siller-Jackson, A., Verrett, A.J., & Hale, R.G. (2012). Ten years of war: A characterization of craniomaxillofacial injuries incurred during operations Enduring Freedom and Iraqi Freedom. *Journal of Trauma and Acute Care Surgery*, 73 (Suppl 5), S453-458.

Chen, Y., & Huang, W. (2011). Non-impact, blast induced mild TBI and PTSD: Concepts and caveats. *Brain Injury*. 25(7-8), 641-650.

Cherney, L.R., Gardner, P., Logemann, J.A. Newman, L.A., O'Neil-Pirozzi, T., Toth, C.R., & Solomon, N.P. (2010). The role of speech-language pathology and audiology in the optimal management of the service member returning from Iraq or Afghanistan with a blast-related head injury: Position of the communication sciences and disorders clinical trials research group. *Journal of Head Trauma and Rehabilitation*. 25(3), 219-224.

Cherney, L.R. & Robey, R.R. (2008). Aphasia Treatment: Recovery, Prognosis and Clinical Effectiveness. In R. Chapey, L.R. Cherney & R.R. Robey (eds.), *Language Intervention Strategies in Aphasia and Related Neurogenic Communication Disorders (5th ed.)*, (pp. 186-202), Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Cornis-Pop, M. (2006). Blast injuries: A new kind of patient for speech-language pathologists. *ASHA Leader*, 11, 9.

Cornis-Pop, M., Mashima, P. A., Roth, C.R., MacLennan, D.L., Picon, L.M., Hammond, C.S., Goo-Yoshino, S., Isaki, E., Singson, M., & Frank, E.M. (2012). Cognitive-communication rehabilitation for combat-related mild traumatic brain injury. *Journal of Rehabilitation Research and Development*, 49(7), 11-31.

Cullis, I.G. (2001). Blast waves and how they interact with structures. *Journal of the Royal Medical Corps*, 147, 16-26.

DePalma, R.G., Burris, D.G., Champion, H.R., & Hodgson, M.J. (2005). Blast injuries. *The New England New Journal of Medicine*. 352, 1335-1342.

Department of the Army. (2012). *Army 2020. Generating Health & Discipline Ahead of the Strategic Reset Report 2012*. Washington, D.C.: Headquarters, Department of the Army.

Dodd, W.J., Stewart, E.T., & Logemann, J.A. (1990). Physiology and radiology of the normal oral and pharyngeal phases of swallowing. *American Journal of Radiology*. 154, 953-963.

Ellis, P.D.M. & Bennet, J. (1977). Laryngeal trauma after prolonged endotracheal intubation. *The Journal of Laryngology and Otology*. 91(1), 69-74.

Filley, C.M. (2001). *Neurobehavioral anatomy* (2nd ed.). Boulder, CO: University of Colorado Press.

Fischer H. (2014). *U.S. Military casualty statistics: Operation New Dawn, Operation Iraqi Freedom, and Operation Enduring Freedom.* Congressional Research Service. Washington, DC: Library of Congress.

Friedemann-Sanchez, G., Sayer, N.A., & Pickett, T. (2008). Provider perspectives on rehabilitation of patients with polytrauma. *Archives of Physical Medicine and Rehabilitation*, 89, 171-178.

Galarneau, M.R., Woodruff, S.I., Dye, J.L., Mohrle, C.R., & Wade, A.L. (2008). Traumatic brain injury during operation Iraqi freedom: findings from the United Stated Navy-Marine Corps Combat Trauma Registry. *Journal of Neurosurgery*. 108(5), 950-957.

Gawande, A. (2004). Casualties of war---Military care for the wounded from Iraq and Afghanistan. *New England Journal of Medicine, 351,* 2471-2475.

Goldenburg, D., Golz, A., Flax-Goldenburg, R., & Joachims, H.Z. (1997). Severe laryngeal injury caused by blunt trauma to the neck: A case report. *Journal of Laryngology-Otology*, 111(2), 1174-1176.

Hagen, C. (2000, February). Rancho Levels of Cognitive Functioning-Revised. Paper presented at TBI Rehabilitation in Managed Care Environment: An Interdisciplinary Approach to Rehabilitation. Continuing Education Program of America, San Antonio, TX.

Hagen, C., Malkmus, D., Durham, P. (1974). *Ranchos Los Amigos Levels of Cognitive Function Scale - Revised*. Downey, CA: Communication Disorders Service, Rancho Los Amigos Hospital.

Hale, R.G., Hayes, D.K., Orloff, G., Peterson, K., Powers, D.B., & Mahadevan, S. (2012). Maxillofacial and neck trauma, In E. Savitsky and B. Eastridge (eds.), *Combat Casualty Care: Lessons Learned from OEF and OIF*. Fort Detrick, MD: Office of The Surgeon General, Borden Institute.

Hamdan, A., Sibai, A., Rameh, C., & Kanazeh, G. (2006). Short-term effects of endotracheal intubation on voice. *Journal of Voice*. 21(6), 762-768.

Hayes, M.K.M. (1992). Nutrition in the severely head-injured patient. *Clinical Rehabilitation*. 6, 153-158.

Helm-Estabrook, N. & Albert, M.L. (2004). *Manual of Aphasia and Aphasia Therapy, 2nd Edition*. Austin, TX: Pro Ed.

Heman-Ackah, Y.D. & Sataloff, R.T. (2002). Blunt trauma to the larynx and trachea: Considerations for the professional voice user. *Journal of Singing, 59*, 41-47.

Hirshberg, B., Oppenheim-Eden, A., Pizov, R., Sklair-Levi, M., Rivkin, A., Bardach, E., Bublil, M., Sprung, C., & Kramer, M.R. (1999). Recovery from blast lung injury: One year follow up. *Chest*, 116(6), 1683-1688.

Hixon, T.J. (1973). Respiratory function in speech. In F. Minifie, T. J. Hixon & F. Williams (eds.), *Normal Aspects of Speech, Hearing and Language* (pp. 75-125). Upper Saddle River, NJ: Prentice Hall.

Horrocks, C.L. (2001). Blast injuries: Biophysics, pathophysiology and management principles. *Journal of the Royal Army Medical Corps*. 147, 28-40.

Kolb, B., & Whishaw, I.Q. (2003). *Fundamentals of Human Neuropsychology* (5th ed.). New York: Worth Publishers.

Lazarus, C.L. (1989). Swallowing disorders after traumatic brain injury. *Journal of Head Trauma and Rehabilitation*. 4(4), 34-41.

Leopold, N.A., & Kagel, M.A. (1983). Swallowing, ingestion, and dysphagia: A reappraisal. *Archives of Physical Medicine and Rehabilitation*. 64, 371-373.

Leopold, N.A., & Kagel, M.A. (1997). Dysphagia-ingestion or deglutition?: A proposed paradigm. *Dysphagia*. 12, 202-206.

Lindfords, J.W. (1987). Children's Language and Learning (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Loring, D.W. (1999). *INS dictionary of neuropsychology*. New York: Oxford University Press.

MacDonald, C., Johnson, A.M., Cooper, D., Nelson, E.C., Werner, N.J. et al. (2011). Detection of blast-related traumatic brain injury in U.S. military personnel. *New England Journal of Medicine, 364*, 2091-2100.

Mackay, L.E., Morgan, A.S., & Bernstein, B.A. (1999). Swallowing disorders in severe brain injury: Risk factors affecting return to oral intake. *Archives of Physical Medicine and Rehabilitation*. 80, 365-371.

Malkmus D., Booth B.J., & Kodimer C. (1980). Rehabilitation of the Head Injured Adult: Comprehensive Cognitive Management. Downy, CA: Professional Staff Association of Rancho Los Amigos Hospital, Inc.

Mayo Clinic (2012, May 5). Ecchymosis. *Mayo Clinic*. Retrieved November, 12, 2013, from http://www.mayoclinic.com/health/petechiae/my01104 .

Mayorga, M.A. (1997). The pathology of primary blast overpressure injury. *Toxicology*. 121, 17-28.

McHenry, M.A. & Minton, J.T. (1998). Speech breathing analysis procedures for speakers who are difficult to assess. In M.P. Cannito, K.M. Yorkston & Beukelman, D.R. (eds.) *Neuromotor Speech Disorders: Nature, Assessment and Management*. (pp. 167-180). Baltimore: Paul Brookes Publishing Company.

McSherry, D. (1997). Avoiding premature closure in sequential diagnosis. *Artificial Intelligence Medicine*, 10, 269-283.

Morgan, A.T. & Ward, E.C. (2001). Swallowing: Neuroanatomical and physiological framework. In Murdoch, B.E. & Theodoros, D.G. *Traumatic Brain Injury: Associated Speech, Language, and Swallowing Disorders*. (pp. 313-329). San Diego, CA: Singular Publishing.

Moss, W.C., King, M.J., & Blackman, E.G. (2009). Skull flexure from blast waves: A mechanism for brain injury with implications for helmet design. *Physical Review Letters*. 103(10), 1-17.

Murdoch, B.E., Chenery, H.J., & Stokes, P.D. (1991). Respiratory kinematics in speakers with cerebellar disease. *Journal of Speech and Hearing Research*. 34, 768-780.

Murdoch, B.E., & Theodoros, D.G. (2001). *Traumatic brain injury: Associated Speech, Language, and Swallowing Disorders*. San Diego, CA: Singular Publishing.

Murdoch, B.E., Theodoros, D.G., Stokes, P., & Chenery, H.J. (1992). Abnormal patterns of speech breathing in dysarthric speakers following severe closed head injury. *Brain Injury*. 7, 295-308.

Newman, L.A., Gillespie, A.I., & Brigger, M. (2007). Blast injury and dysphagia. *Perspectives on Swallowing and Swallowing Disorders, 16*, 7-11.

Norman, R.S., Jaramillo, C.A., Amuan, M., Wells, M.A., Eapen, B.C., & Pugh, M.J. (2013). Traumatic brain injury in veterans of the wars in Iraq and Afghanistan: Communication disorders stratified by severity of brain injury. *Brain Injury*, 27(13/14), 1623-1630.

Owens B.D., Kragh J.F., Wenke J.C., Macaitis J., Wade C.E., & Holcomb J.B. (2008). Combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom. *Journal of Trauma.* 64(2), 295-299.

Perry, P. & Hux, K. (2011) Transitioning to work. In *Assisting Survivors of Traumatic Brain Injury: The Role of Speech-Language Pathologists.* (2nd ed.) (pp. 353-381). Austin, TX: PRO-ED Inc.

Rosen, A., Zhang, Y., Zhan, W. Kasprisin, A., Martinson, S., Cheng, J., Weiner, M., Yesavage, J.A., Folio, L., & Ashford, J.W. (2009). Radiology corner. Case 41. Arcuate fasciculus damage seen on DTI in a blast-exposed soldier with mild traumatic brain injury (mTBI) with associated conduction aphasia. *Military Medicine*, 174(11), v-vi.

Ryu, J., Horkayne-Szakaly, I., Xu, L., Pletnikova, O., Leri, F., Eberhart, C., Tronsco, J.C., & Koliatsos, V.E. (2014). The problems of axonal injury in the brains of veterans with histories of blast exposure. *Acta Neuropathologica Communications, 2*:153 (25 November). Retrieved from http://www.actaneurocomms.org/content/2/1/153.

Sagalyn, D. (2011). Army General Calls for Changing Name of PTSD. Newshour (pbs.org). Retrieved from http://www.pbs.org/newshour/updates/military-july-dec11-stress_11-04/.

Sapienza, C. & Ruddy, B. (2013). Neurologically based voice disorders. In *Voice Disorders*. (2nd ed.) (pp. 183-206). San Diego, CA: Plural Publishing.

Sasser, S.M., Sattin, R.W., Hunt, R.C., & Krohmer, J. (2006). Blast lung injury. *Prehospital Emergency Care*. 10, 165-172.

Sayer, N.A., Cifu, D.X., McNamee, S., Chiros, C.E., Sigford, B.J., Scott, S., & Lew, H.L. (2009). Rehabilitation needs of combat-injured service members admitted to the VA polytrauma rehabilitation centers: The role of PM&R in the care of wounded warriors. *Physical Medicine & Rehabilitation*, 1, 23-29.

Scheve, T. (2008). How blast resistant clothing works. How stuff works. Retrieved from http://www.howstuffworks.com/blast-resistant-clothing1.htm

Scott, G.S., Belanger, H.G., Vanderploeg, R.D., Massengale, J., & Scholten, J. (2006). Mechanism-of-injury approach to evaluating patients with blast-related polytrauma. *The Journal of the American Osteopathic Association*. 106(5), 265- 270.

Sharpnack, D.D., Johnson, A.J., & Phillips Y.Y. (1991). The pathology of primary blast injury. In: Institute TB, editor. *Conventional Warfare: Ballistic, Blast and Burn Injuries: Department of Army, Office of the Surgeon General.* 271-291.

Smith, E. Verdolini, K., Gray, S., Nichols, S., Lemke, J. Barkmeier, J., Dove, H., & Hoffman, H. (1996). Effects of voice disorders on the quality of life. *Journal of Medical Speech Language Pathology*. 4(4), 223-244.

Sponheim, S.R., McGuire, K.A., Kang, S.S., Davenport, N.D., Aviyente, S., et al. (2011). Evidence of disrupted functional connectivity in the brain after combat-related balst injury. *Neuroimage, 54*, Suppl. 1 S21-29.

Sturm, R., Gresenz, C. R., Pacula, R. L., & Wells, K. B. (1999). Datapoints: labor force participation by persons with mental illness. Psychiatric Services (Washington, D.C., 50, 11.)

Stuhmiller, J.H. (2010). Blast Injury: Translating Research into Operational Medicine. Office of the Surgeon General at TMM Publications, Borden Institute: Washington, D.C.

Twamley, E.W., Baker, D.G., Norman, S.B., Pittman, J.O. E., Lohr, J.B., & Resnick, S.G. (2013). Veterans health administration vocational services for Operation Iraqi Freedom/Operation Enduring Freedom veterans with mental health conditions. *Journal of Rehabilitation Research and Development*, 50(5), 663-670.

U.S. Government Accountability Office. (2011). Military Personnel: *DOD Addressing Challenges in Iraq and Afghanistan but Opportunities Exist to Enhance the Planning Process for Army Medical Personnel Requirements*, GAO-11-163 (Washington, D.C., February, 2011).

Wade, A.L., Dye, J.L., Mohrle, C.R., & Galarneau, M.R. (2007). Head, face and neck injuries during Operation Iraqi Freedom II: Results from the US Navy- Marine Corps Combat Trauma Registry. *The Journal of Trauma, Injury, Infection and Critical Care. 63*(4), 836-840.

Wallace, G. (2006). Blast injury basics: A primer for the medical speech-language pathologist. *The ASHA Leader*, 11(9), 26-28.

Warden, D.L., French, L.M., Shupenko, L., Fargus, J., Riedy, G., Erickson, M.E., Jaffee, M.S., & Moore, D.F. (2009). Case report of a soldier with primary blast injury. *Neuroimage*. 47, 152-153.

Warden, D.L., Ryan, L.M. Helmick, K.M., Schwab, K., French, l., Lu, W., et al. (2005). War neurotrauma: the Defense and Veterans Brain Injury Center (DVBIC) experience at Walter Reed Army Medical Center (WRAMC). *Journal of Neurotrauma*. 22(10), 1178.

Warden, D.W. (2006). Military TBI during the Iraq and Afghanistan wars. *Journal of Head Trauma Rehabilitation. 21*(5), 398-402.

Wightman J., & Gladish S. (2001). Explosions and blast injuries. *Annals of Emergency Medicine. 3*(3), 243-250.

Williamson, V. & Mulhall, E. (2009). *Invisible Wounds: Psychological and Neurological Injuries Confront a New Generation of Veterans*. Issue report published by the Iraq and Afghanistan Veterans of America. Retrieved from STEM Artifacts and Resources Online https://tsar.omeka.net/items/show/59.

Wong, M.N., Murdoch, B., & Whelan, B-M. (2010). Language disorders subsequent to mild traumatic injury (MTBI): Evidence from four cases. *Aphasiology*. 24(10), 1155-1169.

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