

Mechanism-of-Injury Approach to Evaluating Patients With Blast-Related Polytrauma

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Civilians and military personnel alike are increasingly being exposed to explosives in war zones and other regions of political conflict and, consequently, they are suffering associated blast-related polytrauma (multiple complex injuries). Although acute, emergency-based medical care for patients with blast-related trauma has been well described, postacute clinical management—which is of greatest interest to primary care physicians and rehabilitation specialists—has not been well discussed or researched. The authors offer a description of the common injuries seen in patients with blast-related polytrauma, as well as a conceptual model of a potential evaluation and treatment strategy in the postacute setting. Although medical evaluation of a patient typically proceeds in a sequential manner based on primary symptoms, the authors advocate a parallel approach to patient evaluation based on mechanism (cause) of injury. Such an approach relies on knowledge of the typical physical and psychological sequelae associated with a particular mechanism of injury to guide patient assessment and treatment. The authors highlight the mechanism-of-injury approach used with patients who have blast-related polytrauma at the Veterans Health Administration's (VHA) Veterans Affairs Medical Center in Tampa, Fla, site of one of the VHA's four Polytrauma Rehabilitation Centers.

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The likelihood of being exposed to high-energy blasts and explosions is increasing for both civilians and military personnel in war zones and other regions of political conflict around the world.^{1,2} More than half of all combat-related injuries sustained by US troops are the result of explosive munitions.³ Because improvements in body armor and surgical stabilization on the frontlines of combat are making it possible for more individuals to survive these types of incidents, more veterans are returning from war zones with polytrauma (multiple complex injuries) in unpredictable patterns.³ Common injuries in blast-related polytrauma include open wounds; traumatic amputations; injuries to the brain, spinal cord, eye, and musculoskeletal system; and psychiatric problems.^{2,4-7} These injuries, which are known generally as “blast injuries,” occur almost daily in the ongoing conflicts in Iraq and Afghanistan as a result of rocket-propelled grenades, improvised explosive devices, and land mines.³ In combat, military personnel may also sustain blast injuries caused by artillery, rocket and mortar shells, and aerial bombs. Civilians may sustain blast injuries during terrorist attacks, which often involve car bombs or package bombs.³

Within the medical system of the US Veterans Health Administration (VHA), treatment of injured veterans returning from Iraq and Afghanistan has become increasingly challenging as a result of the greater number of patients with blast-related polytrauma.⁸ Indeed, such patients are forcing a system-wide change within the VHA. In April 2005, the US Congress established Polytrauma Rehabilitation Centers in Minneapolis, Minn; Palo Alto, Calif; Richmond, Va; and Tampa, Fla.⁹ These four centers are charged with developing strategies for managing polytrauma cases, with conducting research in polytrauma, and with generating guidelines for best practices.

Although the *acute* clinical management of cases of polytrauma have previously been well described,^{5,6,10} the *postacute* clinical management of such cases in rehabilitation and primary care settings has not been adequately addressed in the literature.^{8,11} In light of the increasing threat of terrorist attacks on civilians, medical personnel from all points on the continuum of care should become familiar with the characteristics of these injuries and associated physical and psychological sequelae.

CLINICAL PRACTICE

Primary, Secondary, Tertiary, and Other Acute Injuries

Blasts cause injuries through multiple mechanisms and, as such, often lead to polytrauma. The severity and pattern of injuries depend on the composition of the explosive materials (high vs low explosive), the amount of materials involved in the blast, the surrounding environment (eg, water vs land, open space vs closed space), the delivery method (eg, artillery, improvised explosive device, car bomb), the distance between the blast and the injured individual, and the presence of intervening protective or hazardous barriers.⁷ The present discussion focuses on high and low explosive materials. Lavonas and Pennardt¹² offer a detailed discussion of the other factors related to severity and pattern of blast injuries.

Low explosives, such as black powder in fireworks, tend to deflagrate (burn at a slow rate) rather than detonate. High explosives, such as nitroglycerine in dynamite, burn quickly and detonate almost instantaneously. They also create more pressure than low explosives. Overpressurization *blast waves*, waves of intense pressure that are generated by high explosives, compress such materials as air-filled body organs and body organs surrounded by fluid-filled cavities. Both high and low explosives induce a *blast wind*, which refers to the forced superheated air flow that follows these blasts.⁷

Severe blasts may result in burns and inhalation injuries. For individuals closest to the explosions, there may be total body disruption and death.⁷

Blast injuries typically are divided into four categories: primary, secondary, tertiary, and quaternary (miscellaneous injuries).⁶ Individuals may sustain multiple injuries in one or more of these categories.

Primary blast injuries are caused by barotrauma (overpressurization from the blast wave followed quickly by underpressurization). Barotrauma primarily affects gas-containing or gas-fluid interfacing organ systems, with the most frequent injuries occurring to the lungs (rupture of alveolar septa, pulmonary rupture, and edema), bowel (perforation), and inner ear (tympanic membrane rupture).^{13–15} Animal models suggest that barotraumatic damage to the lungs may result in depletion of antioxidants and associated damage.¹⁶

Primary blast injuries to the eye include rupture of the globe, serous retinitis, and hyphema.⁵ Other possible primary blast injuries include traumatic or partial limb amputation.¹⁷ Such injuries make up many wartime casualties.⁴ Traumatic amputation of any limb is a marker for multi-system injuries.⁷

Secondary blast injuries are caused by metal fragments and other penetrating projectiles, which, in turn, can cause trauma to soft tissues and injuries to the head. Contamination of these fragments with microbial pathogens is an additional cause of concern for patients' health.¹⁸

Tertiary blast injuries result from displacement of the entire body by combined pressure loads (ie, shock waves and dynamic overpressure). Typically, only those individuals who are closest to the explosion sustain tertiary injuries—

Table
Commonly Overlooked Blast-Related Conditions
in Patients With Polytrauma (N=50)*

Condition	No. (%)
<input type="checkbox"/> Concussion	33 (66)
<input type="checkbox"/> Soft-tissue damage	31 (62)
<input type="checkbox"/> Posttraumatic stress disorder/ acute stress reactions	26 (52)
<input type="checkbox"/> Nerve damage	23 (46)
<input type="checkbox"/> Acute or chronic pain	21 (42)
<input type="checkbox"/> Hearing loss	21 (42)
<input type="checkbox"/> Chronic infections (eg, sinus)	14 (28)
<input type="checkbox"/> Vision changes	13 (26)
<input type="checkbox"/> Lung injury	11 (22)
<input type="checkbox"/> Tinnitus	10 (20)
<input type="checkbox"/> Vestibular problems	9 (18)
<input type="checkbox"/> Undiscovered fragments	4 (8)

* From a consecutive sample of patients with blast-related injuries seen at the Polytrauma Rehabilitation Center at the Veterans Affairs Medical Center in Tampa, Fla.

unless extremely high energy is produced and/or concentrated during the blast in some way.¹²

Quaternary blast injuries consist of such miscellaneous conditions as burns from fires and crush injuries from collapsed buildings and other displaced heavy objects. Exacerbations of pre-existing medical conditions (eg, asthma, diabetes mellitus) may also occur as the result of blasts.⁷ Less common miscellaneous injuries include respiratory problems from inhalation of dust, smoke, and toxic fumes.

Residual Injuries in Postacute Settings

Many blast-related injuries of patients will likely need to be addressed in the postacute phase of treatment—after life-sustaining efforts with the patient have been successful. These injuries may not be manifested during the acute phase of treatment. Because the nature of polytrauma requires that medical attention first be directed to primary life-threatening injuries, the role of the primary care physician or rehabilitation specialist is often to “uncover” these previously undiagnosed postacute injuries and administer subsequent treatment. For example, a recent review of neglected spinal injuries in acute settings revealed that the majority of such impairments occurred in patients with polytrauma, but the spinal damage went undetected because of distracting remote injuries.¹⁹

Although an exhaustive list of potential blast-related injuries is beyond the scope of this article and, indeed, may

not be possible, we offer a list of commonly missed injuries (*Table*) to ensure consideration of the most common sequelae. This list is based on a consecutive sample of blast-injured patients (N=50) seen at the Polytrauma Rehabilitation Center at Veterans Affairs Medical Center in Tampa, from August 2004 through August 2005.

Because patients with polytrauma typically have injuries at many levels of severity, certain injuries may be overlooked even in postacute settings. One such injury is concussion. Animal models of blast-related injuries have demonstrated the ubiquity of brain injury and consequent cognitive deficits associated with blasts.^{20,21} Primary blasts exert a compressive effect on air-filled and fluid-filled cavities, such as those in the brain and spinal cord. In addition, flying fragments and body displacement may cause head injury.^{20,21} The limited data available suggest that brain injuries are a common occurrence from blasts but often go undiagnosed and untreated because of the attention focused on more visible injuries.²² Of particular relevance to rehabilitation specialists, functional outcomes associated with severe brain injuries are worse than usual when associated with polytrauma.²³

In many cases, survivors of blasts develop acute stress reactions and/or posttraumatic stress disorder (PTSD),²⁴ which may impede functional outcome and go undetected during a patient's initial treatment phase. Such cases should be followed over time, with the patients screened periodically for neurologic or psychiatric sequelae. Checklist inventories for PTSD, which have been developed for use in primary care settings, represent an efficient way to track patients' emotional adjustment and to make decisions regarding referrals for psychiatric care.²⁵ For example, the PTSD Checklist-Civilian Version, used in the VHA Polytrauma Rehabilitation Centers, has short forms with adequate psychometric properties.²⁵ This checklist is in the public domain and available on the Internet (see <http://www.pdhealth.mil/guidelines/appendix3.asp>).

Finally, in regard to residual injuries in postacute settings, the importance of early and aggressive multidisciplinary pain management has consistently been demonstrated in the rehabilitation literature.²⁶ This type of management needs to be an important consideration with polytrauma patients as well.

The Primary Symptom-Based Approach

Because of the potential to overlook certain blast-related injuries, an examination of the process involved in evaluating and treating patients with polytrauma is warranted. The medical care of a patient, particularly within the primary care setting, often proceeds with the physician treating the patient according to the most prominent symptoms. The patient informs the physician of an ailment, presumably one that is causing some level of distress or dysfunction, and the physician decides on a treatment to resolve that ailment. Alternatively, a diagnosis is made based on routine tests,

followed by corresponding treatment to resolve the ailment. *Figure 1* depicts this traditional, sequential approach to patient care based on primary symptoms.

For the most part, the primary symptom-based approach to patient care works well. In certain circumstances, however, focusing on the mechanism of injury, rather than solely on primary symptoms, can create a more comprehensive and integrated program of patient care. Blast-related polytrauma represents such a circumstance.¹¹

In military medicine, treatment of an injured soldier typically follows the traditional symptom-based approach to care. For example, a soldier injured in Afghanistan who suffers a traumatic amputation, burn, or penetrating flesh wound in a high-explosive blast may receive treatment in the field consisting of airway protection, shock prevention, and wound or burn treatment. When he or she eventually reaches a medical facility, the treatment continues to focus on the wound, burn, or amputation. With the focus remaining on primary diagnosis in a sequential evaluation process (ie, resolving the primary symptom and then addressing the next one and so on), other ailments may be either overlooked entirely or not identified in a timely manner.

The primary symptom-based approach has been found to be associated with premature closure of cases,²⁷ as well as with overall underdiagnosis and inferior quality of care. In cases of blast-related injuries, for example, the burn patient who experiences a high-pressure wave may not be screened for potential auditory, visual, cognitive, or psychiatric problems, or for conditions affecting soft tissues or gas-filled organs. Yet, all of these problems are common following a blast-related injury. Refocusing assessment and treatment efforts around the mechanism of injury—the blast—rather than solely on the primary symptom or injury might provide a more comprehensive, efficient, and programmatic system of care.

The Mechanism-of-Injury Approach

Figure 2 provides a representation of a parallel approach to patient care based on mechanism of injury. Compared with the primary symptom-based approach depicted in *Figure 1*, the mechanism-of-injury approach demonstrates the greater efficiency inherent in first considering the base rate (ie, the true proportion of a given population having some condition) associated with a particular cause of injury and then making assessment and referrals as necessary.

The traditional, symptom-based approach to evaluating blast-related polytrauma is linear and, necessarily, more reactive than the mechanism-of-injury approach. The mechanism-of-injury approach is more proactive and, therefore, potentially more efficient and less costly than the symptom-based approach. Furthermore, timely intervention is made more likely by focusing on mechanism of injury. Early intervention allows the mechanism-of-injury approach to serve as a vehicle for secondary prevention, as has been demonstrated

CLINICAL PRACTICE

in fields as diverse as schizophrenia and cardiac care.^{28,29} Thus, the potential superiority of the mechanism-of-injury approach lies in its provision of a common, coherent framework for symptom explanations and in its increased ability to lead to early detection of blast-related physical and psychological conditions.

The frequency and unique nature of blast-related polytrauma create the need for a systematic, interdisciplinary consideration of patients in order to address their physical, psychological, rehabilitation, and prosthetic needs. The VHA Polytrauma Rehabilitation Center in Tampa is coordinated by the Physical Medicine and Rehabilitation Service at the Veterans Affairs Medical Center in Tampa. This Polytrauma Rehabilitation Center, like all four such centers that were created in the VHA system in 2005, operates on the mechanism-of-injury approach. The Physical Medicine and Rehabilitation Service uses an interdisciplinary team consisting of a physician, rehabilitation therapist, audiologist, speech pathologist, neuropsychologist/psychologist, social worker, and other healthcare professionals, providing patients with access to the full range of medical and support services within the hospital.

Patients at the Tampa Polytrauma Rehabilitation Center initially complete a series of questionnaires and receive a comprehensive medical evaluation by a physiatrist (a physician specializing in physical medicine and rehabilitation). This evaluation includes recording a self-reported medical history and current complaints, as well as a complete medical examination. Findings from these initial assessments trigger appropriate treatments and/or referrals to other specialists in the areas of brain-injury evaluation and treatment, amputation management and prosthetics, hearing impairment, or emotional adjustment/stress management (Figure 2). All of the patients at the Tampa Polytrauma Rehabilitation Center receive ongoing case management and follow-up services.

Figure 2 depicts the process used for the clinical management of patients within the VHA Polytrauma Rehabilitation Centers. However, a similar approach—in the form of consideration of common sequelae and appropriate treatment and/or referral—could also be applied in a primary care setting. Consideration of the mechanism of injury leads the clinician to think about the patient as a whole, rather than as a manifestation of the primary presenting injury. Of course, thinking of the patient as a whole is clearly in line with established osteopathic principles and practice.^{30,31}

Conclusion

Patients with blast-related polytrauma typically require a diverse set of medical services. Identification and treatment of “hidden” injuries in the postacute rehabilitation and/or primary care setting is paramount. Physicians in primary care settings should become familiar with the commonly associated sequelae of blast-related injuries. In the present article,

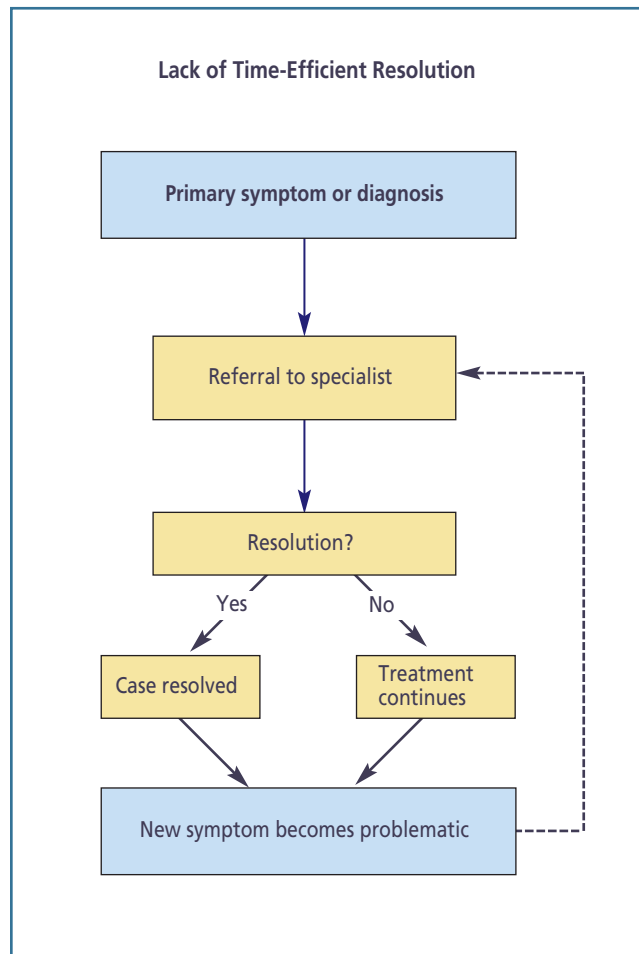


Figure 1. In the traditional, primary symptom-based approach to evaluating and treating patients with blast-related polytrauma, the physician uses the patient's primary symptoms or a diagnosis based on routine tests to determine the course of treatment, including referral to a specialist. If a new symptom arises, this sequential process is repeated. With the focus remaining on primary symptoms, other ailments may be overlooked or not addressed in a timely manner.

we have described the common sequelae of these injuries in an attempt to guide the assessment process in the postacute setting.

In addition, we advocate the conceptualization and implementation of a program of care based on mechanism of injury as the best way to provide comprehensive treatment to patients with blast-related polytrauma. In contrast to the traditional, symptom-based approach, the mechanism-of-injury approach is more likely to lead to treatment for conditions beyond the presenting ailment—thereby preventing even more disabling conditions from arising in the future. The

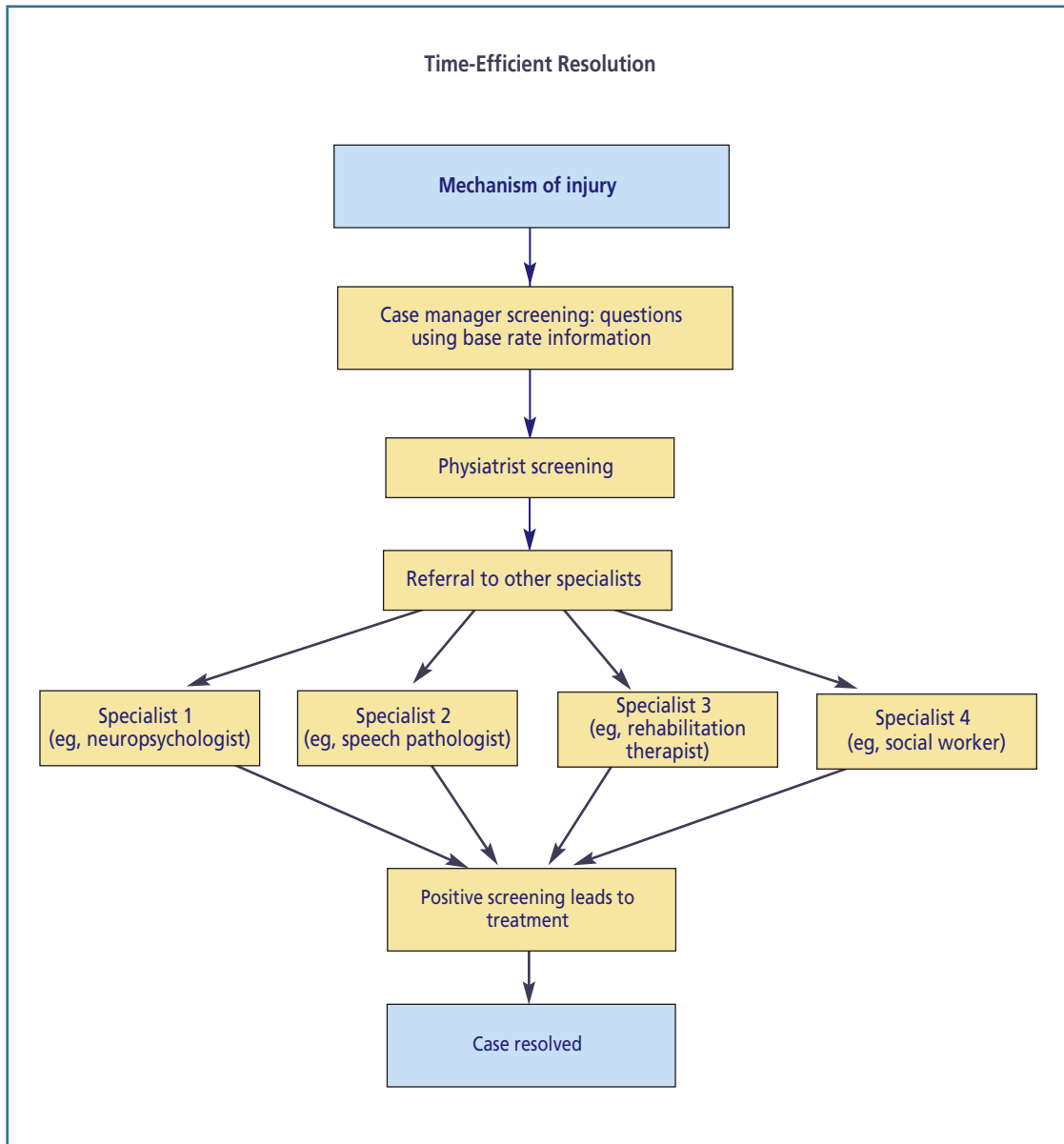


Figure 2. In the mechanism-of-injury approach to evaluating and treating patients with blast-related polytrauma, the base rate associated with a particular mechanism of injury, as well as medical evaluation by a physiatrist, are used to make assessments and referrals to other specialists in an interdisciplinary team. This approach, which is used at the Veterans Health Administration's Polytrauma Rehabilitation Centers, is more proactive and more likely to lead to early intervention and time-efficient resolution than the primary symptom-based approach.

use of the mechanism-of-injury approach as a vehicle for secondary prevention has been demonstrated in various patient populations.^{28,29}

The main potential superiority of the mechanism-of-injury approach to polytrauma management lies in its provision of a common, coherent framework for explanations of

injury and in its increased likelihood for detecting associated conditions. As increasing numbers of patients with blast-related polytrauma enter the VHA system and the private healthcare sector, future research will undoubtedly provide additional guidance for treating these patients.

(continued on page 270)

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