Future Developments in the Management of Explosive Incidents

Joshua Bucher, MD*; Colleen M. Donovan, MD; Robert Eisenstein, MD; Clifton R. Lacy, MD

*Corresponding Author. E-mail: bucherjt@rwjms.rutgers.edu.

0196-0644/$-see front matter

http://dx.doi.org/10.1016/j.annemergmed.2016.09.010

[Ann Emerg Med. 2017;69:S46-S51.]

Blast injury is common in war and terrorism and is likely to become more common. Most of our knowledge about its management has come from military experience and previous mass casualty incidents. These actual scenarios have provided significant insight in preparing for situations involving explosives. However, as bombs and their associated technology evolve, providers must also broaden our horizons to optimize our current management and be aware of cutting-edge developments that will help improve patient care in the future.

Tranexamic acid has been mentioned previously in this journal supplement. It has been shown to improve mortality and decrease bleeding in patients with trauma-induced hemorrhage in both civilian and military environments.[1,2] Implementing this new treatment into already existing protocols is a potential area for improvement. A postinterven tion study after the implementation of tranexamic acid in the aeromedical response unit in the United Kingdom found that their on-scene time was 22 minutes, with a time to tranexamic acid administration of 32 minutes from first patient contact.[3] The intervention was performed after the primary survey and did not delay any immediate lifesaving interventions as defined by advanced trauma life support protocols. The Israeli Defense Force implemented an out-of-hospital tranexamic acid protocol in 2011. Tranexamic acid was administered to eligible patients after ground or air medics completed the secondary survey. It did not delay any immediate lifesaving interventions as defined by advanced trauma life support. The authors did not find any situations in which there was a delay in transport because of tranexamic acid administration.[4] In both studies, tranexamic acid was administered within the time frame of fewer than 3 hours before injury. In the future, more emergency medical services (EMS) systems should develop protocols to initiate out-of-hospital administration of tranexamic acid without concern that it would require sacrificing any of the basic or advanced life support principles of treatment of blast injury or delay any lifesaving interventions.

Although the most common use of tranexamic acid is intravenous, there is significant evidence for its topical use as a potential application in blast injury. An experimental model of topical tranexamic acid combined with a chitosan powder was found to have statistically significantly improved hemostatic properties in a study focusing on animal liver hemorrhage.[5] A randomized trial performed in 2013 explored the option of using injectable tranexamic acid topically compared with anterior nasal packing for patients with anterior epistaxis. The study found that topical tranexamic acid was better at stopping bleeding within 10 minutes compared with anterior nasal packing.[6] Furthermore, a Cochrane review conducted in 2013 examined all of the previous studies on topical use of tranexamic acid. Twenty-nine trials involving 2,600 patients were analyzed. Twenty-eight of the trials involved patients undergoing surgery and 1 involved patients with epistaxis (a separate study from the one above). They found that tranexamic acid statistically significantly reduced blood loss by 29% compared with the percentage for patients who did not receive tranexamic acid and reduced the need for blood transfusions by 45%. They concluded there is "reliable evidence that topical application of tranexamic acid reduces bleeding and blood transfusion."[7] According to this evidence, there is a potential role for topical tranexamic acid use for the treatment of severe hemorrhage caused by blast injury. Further study is needed to compare topical tranexamic acid to topical hemostatic agents such as QuikClot (Z-Medica, Wallingford, CT), SurgiCell (Ethicon, Bridgewater, NJ), and HemCon (HemCon Medical Technologies, Portland OR).[8]

One area of improvement noted is the infrequent use of tourniquets by civilian EMS providers. Although the military has used this product for many years successfully, especially during Operation Iraqi Freedom and Operation Enduring Freedom, there has been a certain stigma about

the use of tourniquets in civilian out-of-hospital care. Despite that it has been shown in military medicine to be very effective at reducing external hemorrhage as a result of a multitude of injuries, including blast injuries, its use in civilian EMS is not as widely implemented. There still exists a fear that the use of a tourniquet will lead to complications, such as loss of a limb or venous thromboembolic events. Lakstein et al[9] found that, in an Israeli study of 110 patients who were treated by the Israeli Defense Force for extremity trauma with a tourniquet, only 5 patients were found to have neurologic injury and none had thromboembolic events. It is unclear whether the neurologic complications were from tourniquet application or from ischemic time caused by the traumatic injury because the longest tourniquet time was 187 minutes, and the mean was less than 2 hours. In addition, the majority of these patients experienced additional blast injuries.

The National Association of EMS Physicians recently released their evidence-based guidelines on the out-of-hospital control of external hemorrhage. This joint article with the American College of Surgeons–Committee on Trauma recommends that external hemorrhage not controlled with direct pressure or a pressure dressing, or hemorrhaging unable to be controlled, be treated with a tourniquet. For any wound not amenable to a tourniquet, they recommend a topical hemostatic agent with direct pressure.[10]

The use of tourniquets must have appropriate protocols and continuing education for out-of-hospital and hospital providers. A small Canadian retrospective study of 190 patients with isolated extremity trauma and arterial bleeding found that, of the 4 out-of-hospital tourniquets applied, all were applied by bystanders or police and not by EMS. Of the 8 deaths in the study, all were due to exsanguination. They do not postulate why EMS did not apply more tourniquets; however, they proposed that out-of-hospital application of the tourniquets might have prevented some of the deaths.[11]

Although not recently examined in the literature, regional or local hypothermia has been used effectively to treat patients with tourniquets to prevent tourniquet-induced neuropathy. Swanson et al[12] found that, in 78 patients undergoing reconstructive surgery of the upper extremity, local hypothermia increased the ischemic time without any increase in complications. These results have been replicated in animal studies as well.[13,14] These findings may help reduce provider concern over tourniquet-induced injury and can lead to future research in the use of tourniquets for extremity trauma in blast injuries.

A review article by Doyle and Taillac[15] examined the history of military and civilian use of tourniquets. They recommended that, especially in a mass casualty incident such as blast injuries, tourniquets be moved to first-line therapy for control of external arterial bleeding of an extremity or any life-threatening hemorrhage amenable to tourniquet placement. The requirement for the tourniquet can be reevaluated after the patient has been triaged and the secondary survey has been finished. In accordance with advanced trauma life support training, this should be accomplished during the primary survey because the need to stop potentially life-threatening hemorrhage qualifies under circulation. Furthermore, a review of mass casualty incidences involving blast injuries revealed that large numbers of victims with complicated injuries, especially musculoskeletal, will be encountered and require prompt triage and treatment. Therefore, the authors recommended that tourniquets be emphasized in the out-of-hospital environment in the United States, which has not yet occurred in a widespread fashion.[15] They also endorsed the combat care protocol described by Sebesta.[16]

Sebesta[16] examined his experience at the 31st Combat Support Hospital for Operation Iraqi Freedom from 2003 to 2004. The largest number of trauma admissions was caused by blast injury; hemorrhage was the most common cause of death. The hospital's medics are trained in tactical combat casualty care before deployment. The mnemonic MARCH is used in combat care and mass casualty incidents and stands for massive hemorrhage, airway, respiration, circulation, head injury/hypothermia. Similar to the American Heart Association's shift from the "ABCs" to the "CABs" in cardiac arrest, the US military has changed the emphasis on the management of trauma from airway, which is the first step in a primary survey according to advanced trauma life support, to circulation and massive hemorrhage that must be controlled by a tourniquet or hemostatic agent.[16,17] The first intervention before airway is to immediately control obvious external hemorrhage to allow all other interventions to be performed without potential prolonged life-threatening hemorrhage with possible exsanguination. This is supported by the *Tactical Combat Casualty Care* guidelines.[18] This is another protocol that may be used by civilian EMS during blast incidents.

Furthermore, Beekley et al[17] estimated that, in Operation Iraqi Freedom, approximately 57% of battlefield deaths caused by exsanguination might have been prevented by early tourniquet use. In another review of battle casualty survival of patients with extremity trauma, with the majority (70%) of patients experiencing a blast injury, Kragh et al[19] found that patients were more likely to survive with out-of-hospital application of a tourniquet (89% versus 78%; $P<.01$) and application before the onset