Patriots’ Day is usually a working day for physicians in hospitals but it is a holiday for schools and universities in Massachusetts. It is certainly a wonderful day to meet thousands of marathon runners. In the early afternoon of Patriots’ Day 2013, a sunny Monday on April 15th, numerous runners of the Boston Marathon approached the finish line on Boylston Street, Boston, Massachusetts, USA and spectators cheered at them with joy. My wife and three children were spectators along the marathon route near our home in Newton Centre, around 4 miles (approx. 6 km) from the arrival line. I had to work that day and was enjoying talking to my Residents since the workload was light. At 2:50 PM, we were ordered to remain at work until new order because of two explosions that occurred near the marathon finish line. My first reaction was to assure my colleagues. I said, “Do not worry, the explosions must be the result of old pipes and canalisation in the downtown Boston”.

However, I was certainly nervous, and the worst was to be disclosed with the first X-ray I had to interpret. I saw the unmistakable: a comminuted fracture of the calcaneus with huge soft tissue dilapidation and multiple shrapnel. I was overwhelmed with mixed feeling of sadness and anger and I had one message for my co-workers: “This is no doubt a deliberate attack”. I called my wife to check if my family was OK. They were, so I told them that I was going to work late to help with the incoming casualties.

At the finish line of the marathon, the celebratory mood abruptly came to an end when two pressure cooker bombs exploded one after the other at approximately 2:50 PM. A peaceful city centre of Boston was instantly transformed – people panicked and ran for their lives, while the victims of the blast lay on the ground, either silently or desperately crying for help. There were 3 fatalities and 264 casualties needing hospital treatment¹, including a number of people requiring amputations. Reportedly, two bombs were placed on the ground when they exploded, causing predominantly lower extremity injuries in the victims who were near the bomb. At the site of explosion, the investigators found shrapnel that contained pieces of metal, nails and bearing balls, which were also found embedded in many of the casualties transported to six Boston-area hospitals including Boston Medical Center, Massachusetts General Hospital and Brigham and Women’s Hospital².

While blast injuries are commonly sustained by military personnel in combat zones³,⁴ they are extremely rare in a civilian environment and unpredictably occur following an attack⁵ or accidental explosion. The incident in Boston reminded us that even sports physicians serving non-military patients need to be aware of the spectrum of injuries which can occur as the direct or secondary result of a bomb explosion. We were forced to realise that a sport event such as a marathon attracts thousands of spectators and can potentially be a target for unpredicted attacks or disasters. The relevance of this incident to sports physicians is that not only can the athletes become injured but also the spectators. Musculoskeletal injuries in athletes can potentially cause long-term concern following the initial recovery period from an acute blast injury as the athlete needs to be able to return to play and play at the pre-injury standard. Merely getting out of

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₁ Written by Ali Guermazi, USA

³,⁴,⁵ Image by: Nelson B 2006
the hospital is not a sufficient outcome for athletes and sports physicians. Some sports physicians may even have experience treating victims who, after recovery from a blast injury, decide to participate in high-level sports with artificial limbs e.g. those who compete in the Paralympics.

The soft tissue and musculoskeletal systems have the highest incidence of bodily injury in the survivors of bombings\(^6\). Traumatic amputation is reported to happen in 1 to 3% of blast victims\(^6\). An injury resulting from the various effects of explosions are collectively called a blast injury, which can be classified according to the mechanism by which it is produced\(^7\).

Primary blast injuries occur from the overpressurisation force of the blast wave damaging mainly the air-containing organs such as the lungs and bowel, as well as tympanic membrane rupture\(^8\). However, if the victim is exposed to a combination of blast waves and blast wind of sufficiently high intensity, extensive soft tissue damage (Figure 1), limb fractures (Figure 2) and amputations, usually through the bony shaft rather than joint disarticulations, may result\(^9\). Traumatic amputation from primary blast injury is commonly considered to be an indication for a fatality, especially if the explosion occurs in a crowded civilian environment\(^7\).

Secondary blast injuries refer to penetrating trauma caused by metallic or other fragments from the bomb, flying glass or from local materials made airborne by proximity to the explosion\(^6\). In the case of the pressure cooker bombs utilised in the Boston Marathon attack, it has been reported that the bombs contained nails and ball bearings. Radiographic images obtained from the victims confirmed this. Wound contamination may occur from the traumatic implantation of biologic material from victims in proximity to the blast\(^6\).

Tertiary blast injuries occur when the victim’s body is displaced by the blast wind and may include blunt/penetrating trauma, fractures and traumatic amputations\(^6\). Quaternary blast injuries refer to all other injuries from the blast such as asphyxia, toxic exposures and exacerbation of chronic illness, but of relevance to the lower extremities are burns from the heat of explosion\(^2\) or crush injuries from a collapsed building or an object near the blast\(^6\).

Each extremity needs to be examined systematically for musculoskeletal, neurological and vascular injuries. The vascular status of the blast-injured extremity should be thoroughly performed with an aid of angiography if indicated, since physical examination alone is thought to be less reliable for detection of vascular injuries\(^6\). Each open wound should be well-documented, including the record of the size of the lesion, exposed bone and type of contamination and photographs of a gross appearance\(^6\). Radiological imaging of injured extremities should be liberally performed. Initially, portable or conventional radiography can be used to detect retained foreign bodies and to define basic penetration patterns\(^6\). As a more advanced imaging method, CT should then be performed to undertake detailed anatomical assessment of the bony and soft tissue injuries\(^6\). The presence of air density indicates the extent of the lesion that may not be apparent externally. Radiography and CT can readily detect metallic fragments.

Figure 1: Victim with extensive soft tissue defect measuring approximately 6.4 cm in the craniocaudal dimension, in the lateral aspect of the knee. Anteroposterior (a) X-ray of the right knee confirms the large soft tissue defect lateral to the knee (arrow). No radiopaque foreign bodies are identified. Sagittal (b) and axial (c) CT images show a large soft tissue defect at the posterolateral aspect of the right knee, through which the medial and lateral heads of gastrocnemius are herniated (arrows). There is extensive stranding and subcutaneous emphysema tracking into the popliteal fossa and region of the popliteal artery and vein. Operative findings showed popliteal artery branch transection and multiple deep venous transections and massive lower limb muscular injury with a large defect, together with a likely common peroneal nerve injury.
from the exploded bomb⁹, as well as glass fragments¹¹ which may have become embedded within the victim following rupture of a glass window located near the blast. These materials have a significantly higher density than soft tissues and are usually radiopaque on radiography and CT, making them readily detectable¹⁰,¹¹.

The scout view obtained before acquisition of the CT images is helpful for quickly scanning through the whole body to grasp the total extent of injuries and to detect the presence of additional fractures or foreign bodies in unsuspected anatomical locations. Patients with suspected vascular injuries should undergo CT angiography. The patient may then need conventional angiography in order to undergo vascular intervention under fluoroscopic guidance if on-going acute bleeding is thought to be likely or to clarify the diagnosis should CT angiography findings be equivocal. Despite its excellent delineation of soft tissues, MRI is not indicated at an acute stage of injury in blast victims because of a high likelihood of the presence of metallic foreign bodies and the longer acquisition time compared to CT that will delay the overall management at an acute setting. In a similar fashion, ultrasound is of limited use in these situations because it cannot scan a large area of anatomical region at one time or accurately assess deep-seated structures.
In general, small metallic objects retained within soft tissues only do not require urgent removal because they effectively remain inert\(^{12}\), unless they are associated with large wounds with or without infection or gross contamination\(^1\). If the foreign body contains lead and is located within an intra-articular space, it should be removed immediately to prevent the known complication of lead arthropathy\(^{11}\).

Even with small entrance wounds, a thorough debridement should be performed because deep contamination and devitalised tissue can produce highly morbid infections\(^6\). Imaging will aid clinicians to estimate the depth of the wound preoperatively. All open fractures should be considered contaminated and early antibiotic treatment should be initiated. Tetanus prophylaxis may be needed, depending on the patient’s immunisation history. Surgical intervention includes initial debridement and bony stabilisation in the operating room. Surgeons should continue efforts to save the limb where possible, but despite recent advances in the limb salvage techniques, amputations of the severely damaged portion of the lower extremity may be inevitable, particularly when the patient is physiologically unstable and critically unwell\(^{14}\). Clinicians should be aware that the available lower extremity injury scores should not be used as the sole criterion by which amputation decisions are made\(^{15}\). Scores at or above the amputation threshold should be used cautiously by the surgeon, who must also take into account the anatomical and overall clinical indications for the limb salvage or the amputation. Also, the initial absence of plantar sensation in the injured extremity is not predictive of amputation, since 50% of patients have been reported to regain this protective sensation over time\(^{16}\).

In summary, blast injuries in the civilian environment are very rarely encountered, but when they do occur the severity of injuries as well as the need to treat a large number of victims at the same time will pose enormous treatment challenges to the healthcare providers. Sports physicians may be required to treat athletes who unexpectedly sustain these blast injuries during a sporting event. Radiography is useful for initial detection of retained foreign bodies and to obtain the overall picture of the injury and CT imaging is useful for detailed anatomical evaluation of the injury. Angiography should be deployed in suspected vascular compromise. Radiology resources should be used liberally, as much as possible, to allow swift patient management including life- and limb-saving treatments. I sincerely hope that this type of incident will not happen again, but being aware of how we manage these patients in these situations will make sports physicians and musculoskeletal radiologists better prepared and enable us to function more effectively when required.

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References