Conventional and Interventional Radiology in Mass Casualty Incidents

9

Amos Ofer, Maxim Leiderman, and Nira Beck-Razi

Dealing with MCI has become an increasingly important aspect of modern medicine due to the increase in terrorist and other mass casualty acts. Thus, almost every hospital is expected to be prepared for such incidents [1] which are usually caused by motor vehicle accidents, explosions, shootings, earthquakes, and other naturally caused disasters [2]. Estimates show a continuous rise of terrorist acts: According to the second edition of Global Terrorism Index, there was a five-fold increase in the number of people killed by terrorism from 2000 to 2013, resulting in approximately 18,000 deaths. Some well-known examples of the largest MCIs since 2000 including natural and man-made disasters are: the 9/11 Twin Tower attack (New York, 2001), the Indian Ocean tsunami (2004), the Madrid train bombings (2004), the hurricane Katrina (New Orleans, 2005), the Christchurch earthquake (New Zealand, 2011), the Rana Plaza collapse (Bangladesh, 2013), the Ebola outbreak (West Africa, 2014), the Mina stampede (Mecca 2015), and the Paris terrorist shootings (2015) [1].

The diagnostic radiologist and the interventional radiologist, have a central role in the management of such patients aiming to reduce mortality and morbidity [3]. Every radiologist should be able to recognize the spectrum of injuries inflicted by explosive devices, motor vehicle accidents, and other causes of MCI. Every imaging department including US, CT, and IR units should be trained in managing MCI. In MCI, the medical system is overwhelmed with a temporary disruption of the balance between resources and demands [1–3]. On such occasions, the classic paradigm of medical management of giving optimal treatment to every single patient is shifted

---

A. Ofer (✉) · M. Leiderman
Department of Medical Imaging, Rambam Health Care Campus, Haifa, Israel
e-mail: a_ofer@rambam.health.gov.il

N. Beck-Razi
Department of Medical Imaging, Rambam Health Care Campus, Haifa, Israel

The Ruth and Bruce Rappaport Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel

© Springer Nature Switzerland AG 2020
Y. Kluger et al. (eds.), *WSES Handbook of Mass Casualties Incidents Management*, Hot Topics in Acute Care Surgery and Trauma,
https://doi.org/10.1007/978-3-319-92345-1_9

towards decreasing mortality and morbidity for the entire population even at the cost of providing potentially less than routine treatment an individual patient [3, 4].

Imaging examinations including ultrasound, radiography (XR), and CT can be used to improve the accuracy of triage in MCIs. Imaging utilization has been reported as high as 93% of victims in one study in the military setting of three explosive MCIs in Iraq in 2008 and 72% of victims in a large civilian airplane crash in 2009 in the Netherlands [1, 5]. In our institute, 79% of physically injured patients admitted during the second Lebanon war underwent imaging in the radiology department [6]. Therefore, imaging providers must be prepared to support treatment teams during activation of MCIs [1].

Thus, the hallmark of MCI is the chaos imposed on the emergency and other event-dependent in-hospital departments. In order to deal with this chaos, the three main issues characterizing MCI involving the radiology department should be addressed:

1. The need for an extensive amount of medical and non-medical personal.
2. Change of the ordinary workflow of the radiology department.
3. Failure of the ordinary cellular phones-based communication.

9.1 Reinforcement of Radiological Staff

One of the main issues in managing MCI is the need for an extensive amount of medical and paramedical personal [3, 4]. Unlike everyday ordinary hospital activities, MCI is characterized by a spike-like burst of activity. Thus, every unit and department needs a predefined set of actions in order to reinforce the personal needed [6]. The best and most practical method is to have a pre-prepared binder in each department containing lists of personal to be called once an MCI has been announced [1]. This binder should also be backed up in the hospital's digital network. Each member of the radiology department should have a pre-planned emergency position which is also listed in the MCI binder. The head of the department, her deputy, and the senior doctor in charge of emergency events are notified immediately by the person receiving the MCI announcement. All directors of paramedical sectors including X-ray technicians, nurses, secretaries, and others are also notified. Upon arriving to the department, each worker is assigned to his/her pre-planned position: teams consisting of X-ray technicians, residents, and senior doctors are sent to the emergency room for US fast examinations. For each CT scanner, a team consisting of at least two radiologists is needed. At least two interventional radiologists are needed in the IR unit and the same for US unit. The most senior radiologist present can reinforce different units on line as needed [7].

9.2 Change of the Ordinary Workflow

Once an MCI has been announced all other non-emergency imaging procedures should be stopped [3, 7] and the patients involved are returned to their wards or discharged from the hospital. Unlike ordinary hospital activities in the setup of

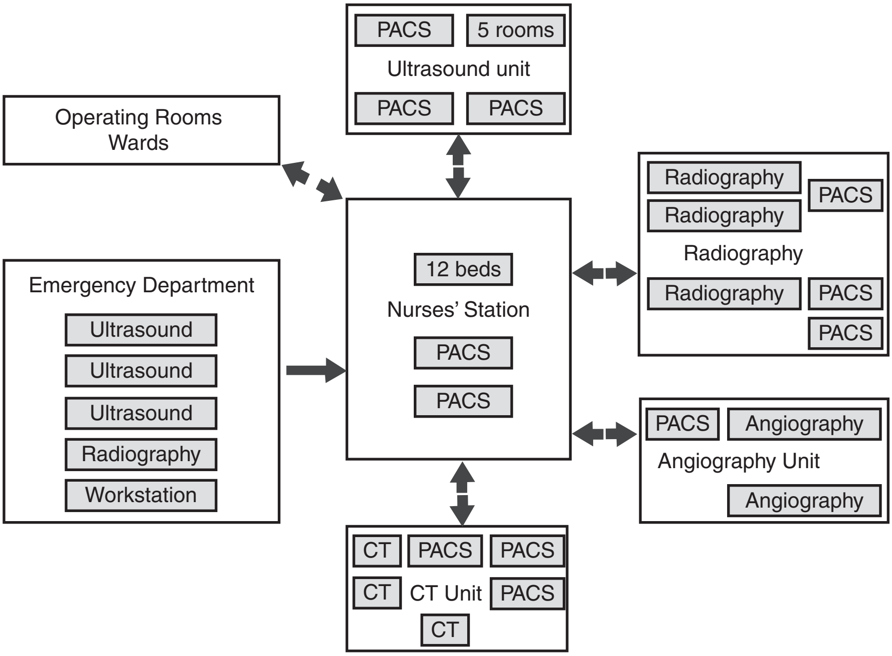

Fig. 9.1 Scheme of the imaging facilities in the radiology and emergency departments during an MCI: Unlike ordinary hospital activities patients are not returned to the emergency room once completing the diagnostic imaging process. This is illustrated by the single direction arrow from the emergency department

MCI, patients are not returned to the emergency room once completing the diagnostic imaging process. Patients should not be returned to the emergency room because of the need to prepare the emergency room for another wave of incoming patients: A pre-planned holding place, reinforced with nurses and clinical doctors, receives these patients before progressing to their next step/station of treatment [6]. This holding place is treated as a temporary extension of the emergency department during the whole MCI period (Fig. 9.1) [6].

Another notable change in the ordinary workflow is the increased usage in US [8]:

9.2.1 FAST in Multiple Casualty Incidents

Effective initial triage, defined as the art of sorting patients according to the severity of their injury, is the key to successfully dealing with a multiple casualty incident (MCI). In order to proceed to further triage and patient management, there is a need for a quick and efficient imaging diagnosing test. FAST [focused abdominal sonography for trauma] can be performed rapidly in the admission area, is repeatable, noninvasive, non-irradiating, and inexpensive. It is widely accepted as an effective initial tool to evaluate trauma victims with suspected blunt abdominal injuries [4, 5, 8, 9].

FAST may play an important role in the work-up of trauma patients in MCI due to the complexity of the injuries. Some controversies remain concerning the role of FAST in penetrating trauma [10]. We believe that FAST has an important part in evaluation of all trauma injuries, whether blunt or penetrating, and should be performed on all of them during the resuscitation phase. Ultrasound is fast, noninvasive, does not involve radiation, portable, and can be integrated into the resuscitation process in the trauma bay without disrupting it.

A negative FAST should be received with caution [4], especially in penetrating abdominal injury, because in such injuries it takes time to develop appreciable hemoperitoneum to be detected by ultrasound. Although the role of FAST in an individual trauma casualty has been reviewed in the literature, a few studies described the role of FAST in MCIs.

Miletic et al. described US screening of mass war casualties as an efficient and effective means for detection and on-site triage of abdominal injuries which were mostly penetrating (90%) with a similar sensitivity and specificity in war and civil conditions [11].

Sarkisian et al. [12] described a successful application of ultrasound after catastrophic earthquake in Armenia, which was largely a crush injury.

In a study we conducted on a 102 soldiers and civilians during the Second Lebanon War, we reported a sensitivity of 75% for hemoperitoneum detection. Injuries encountered were of blunt and penetrating combined. Our results show that FAST as the first imaging examination during continuous arrival phase in a setting of a war conflict-related MCI enabled immediate triage of casualties to laparotomy, CT, or clinical observation.

Due to the moderate sensitivity and the limitation in diagnosing solid organs or hollow viscous injury, a negative FAST in the presence of a strong clinical suspicion must be followed by CT or laparotomy according to clinical judgment [4, 13].

EFAST is known as the Extended FAST and includes examining the pleura for pneumothorax and the pericard for hemopericardium.

The pleura is scanned, to rule out pneumothoraxes when immediate surgery is needed, in order to prevent accumulation of a tension pneumothorax due to positive pressure ventilation in surgery. This can be of a benefit when there is no time or available mobile X-ray machines.

The pericard is examined as a part of the EFAST although its benefit in blunt trauma has been questioned [14].

9.3 Communications

In most modern hospitals, everyday in-house communication is done through personnel held cellular phones. This mode of communication is not sufficient during an MCI because of cellular system overwhelming usage [6]. In order to overcome this limitation, a simple, non-cellular communication system should be prepared. Simple, commercially available, cheap walkie-talkies handheld portable two-way radio transceivers can be used [6]. These should be held by radiological personal stationed in key positions: by the most senior radiological personal stationed in the emergency room, by the director of the department or the senior radiological staff member stationed in the entrance to the radiological department, by the senior radiologist in charge of the CT unit and by the radiologist staff member stationed in the holding place [6]. This will provide a simple and efficient way of maintaining contact between the radiological staff and keeping on line close coordination with the emergency department staff during the whole period of the MCI.

9.3.1 The Role of CT in MCI

CT is the modality of choice in multisystem trauma [5, 15] and can be used as a triage tool during an MCI [1, 5]. The protocols used should be simple and standard. A whole body protocol should be used liberally in order to avoid time-consuming discussions in attempts to limit CT coverage to specific body parts [16]. This will also reduce the need for repeated visits to the CT suite [1] because of a missing scan. Whole body CT produces a large number of images which are best viewed using dedicated workstations capable of doing secondary image reformation and 3D viewing [1, 15].

9.3.2 Blast Injuries

In the last decades, a large portion of MCI are caused by terror. These are usually due to various explosive devices that cause blast injuries. Thus, every radiologist should be familiar with this type of injury. This pattern of injury can be complex, unpredictable, and diagnostically challenging [17]. Characteristically, explosive injuries have a higher proportion of critically injured patients compared to other multitrauma events [17].

9.3.2.1 Blast (Explosive) Injury

Explosive injuries are classified into four categories: Primary, Secondary, Tertiary, and Quaternary [18]. Patients may be affected by one or more injuries from different categories [17, 19].

Primary Injuries

These are a result of the initial very high pressure wave impacting at air–liquid interfaces [15, 17]. The primary high pressure wave spreads radially at the speed of sound generating winds of high velocity up to several hundred km/h [19]. The degree of tissue injury is directly related to the proximity of the victim to the explosion [17]. Several systems and organs are prone to primary blast injury: limbs and earlobes may be traumatically amputated. Rupture of the inner ear, eardrum, blast lung injury, and viscous perforation of the gastrointestinal tract may occur. Primary blast lung injury may lead to an immediate death due to massive cerebral or coronary air embolism (Fig. 9.2) [17].

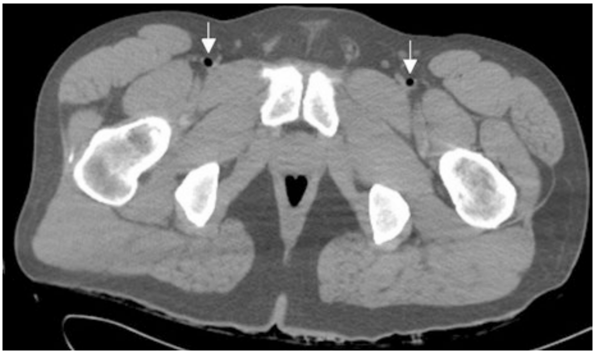

Fig. 9.2 Primary blast injury in a 30-year-old soldier. Air replacing blood is noted in the superficial femoral arteries below the inguinal ligaments (arrows)

Secondary Injuries

These are caused by flying bomb fragments and debris, metallic and nonmetallic, causing penetrating trauma similar to wounds seen in combat trauma [15, 17, 19].

Tertiary Injuries

These occur as a result of a long phase of negative pressure displacing the whole body that impacts onto fixed objects. This may cause blunt and penetrating injuries, head and cervical spine as well as orthopedic injuries [18].

Quaternary Injuries

These include all other injuries mainly burns and smoke inhalation [17–19].

9.3.3 Reporting of Radiological Findings

The radiologists should attempt to perform real-time on-site interpretation and communicate verbally [7, 8, 16] as soon as possible with the physicians and staff who are in charge of the patient. Direct verbal communication is essential to decrease confusion and increase efficiency especially regarding patients who are in critical condition. It is essential to have designated qualified physicians (e.g., surgeons or anesthesiologists) in the CT, US, or angiography suite accompany such patients. They are needed to monitor and treat any change in the patient's condition during the course of imaging studies or procedures. The verbal communication should be followed with an officially written report. Any change in the interpretation of the radiological finding should be in writing and confirmed by the accompanying clinical physician.

9.3.4 Conclusion of MCI

Announcing the end of an MCE is important because the intensity of work required in this situation cannot continue for a long period of time [3]. As soon as possible, all participants need to meet for a debriefing session to draw conclusions and lessons regarding the MCI. This often results in updates of protocols and determination of where gaps exist in workforce, knowledge, and equipment that needs to be changed for better performance in future MCI [3].

9.4 Interventional Radiology in MCI

Interventional radiology has a twofold role during MCI: diagnosing and treating vascular injuries.

9.4.1 Imaging Modalities in Arterial Injury Diagnosis

Different imaging modalities may be considered in the vascular evaluation of the traumatized patient.

9.4.1.1 Doppler Sonography

The advantages of Duplex sonography are well known. It is a noninvasive examination, mostly not painful, and can be done at the patient's bedside in the Emergency Room or in the Operating Theater [20]. In experienced centers, it offers high sensitivity in comparison to the gold standards: digital angiography and surgery [20, 21]. However, Doppler sonography is a time-consuming method and is highly operator dependent [22].

Moreover, this examination is not feasible in open wounds with large soft tissue defects, with surrounding edema, hematoma, and bony fractures [20, 21]. Duplex sonography is also limited by bulky dressings and orthopedic hardware [21]. In addition, Duplex sonography is focused to the suspected region of injury, while unsuspected pathology may be missed. Thus, US Doppler has little role in MCI.

9.4.1.2 Magnetic Resonance Angiography (MRA)

Magnetic resonance angiography is an excellent tool in the demonstration of vascular structures. However, in the setting of acute vascular trauma in most trauma centers, accessibility and monitoring of the critically wounded patient within the magnet is a major problem and not practical [21, 22]. In addition, with penetrating trauma there may be metal pellets that are not compatible with MRI and may result in artifacts [23]. Thus, MRA has no role in MCI.

9.4.1.3 Conventional Angiography (CA)

In the past, the gold standard in the evaluation of vascular injuries has been invasive conventional angiography [24].

Conventional angiography is a costly and time-consuming procedure that requires the presence of a trained and specialized team including an interventional radiologist, a technician, and a nurse. The time required for the team to arrive at the hospital and the duration of the procedure may delay the definitive treatment that might be critical in a state of emergency [20, 21, 25]. This disadvantage is emphasized in MCI due to the inherent shortage of resources. Thus, conventional angiography has a very limited role in vascular diagnosis in MCI.

Conventional angiography remains the tool of choice in diagnosing or excluding vascular injury when other noninvasive modalities, namely CT-angiography, fail to perform.

Conventional angiography has a major role when endovascular treatment is recommended [25].

9.4.1.4 CT-Angiography (CTA)

Imaging of vascular injuries has undergone a dramatic change since the introduction of Multi-Detector Computerized Tomography (MDCT). Improved CT technology, providing rapid acquisition of thin axial slices, led to the development of CT-angiography. Compared with conventional arteriography, CTA shows excellent sensitivity and specificity in diagnosing occlusive disease in the lower extremities and in other parts of the body [20, 24, 25].

Since 1999 CTA has shown excellent results for imaging traumatic arterial injuries [20–22] and is continuously replacing conventional catheter angiography as it is in other non-traumatic vascular evaluation [20, 24, 26, 27]. According to Soto et al., in an early study in 1999 using a single detector helical CT, and evaluating traumatized extremities, the sensitivity and specificity of CTA were 90–100% and 100%, respectively [26].

The same group published one more study several years later. Based on this study which also used a single detector helical CT, CTA had a sensitivity of 95.1% and a specificity of 98.7% in significant blunt and penetrating trauma to large extremity arteries [27].

In 2017, Madhuripan et al. summarized the use of CTA in emergencies of the extremities and concluded that CTA is currently the first-line investigation for this purpose with high specificity and sensitivity [24].

In addition to the high sensitivity and specificity, CTA offers a number of advantages over conventional angiography. It is a noninvasive examination, readily available in most institutions, it is not as time consuming as conventional arteriography, and it is cost-effective. Moreover, in order to carry out a CTA examination there is no need to assemble a specialized team; it allows the presence of monitoring equipment in close proximity to the critically wounded patient and the clinical team can remain at the CT console observing the patient and the evolving examination [20, 21].

Following data acquisition, multiplanar three-dimensional reconstructions can be easily obtained, facilitating the diagnosis and the planning of further management.

However, axial images should always be reviewed carefully because on the 3D images arterial lumen might be obscured by vascular calcifications as well as by foreign bodies and partial thrombosis (Fig. 9.3) [20, 23].

The advantages of CTA, mainly the speed of the acquisition and the accuracy of the CTA scan make it an ideal diagnostic tool for vascular imaging in MCI. Another very important advantage of CTA is the standardization of the diagnostic procedure.

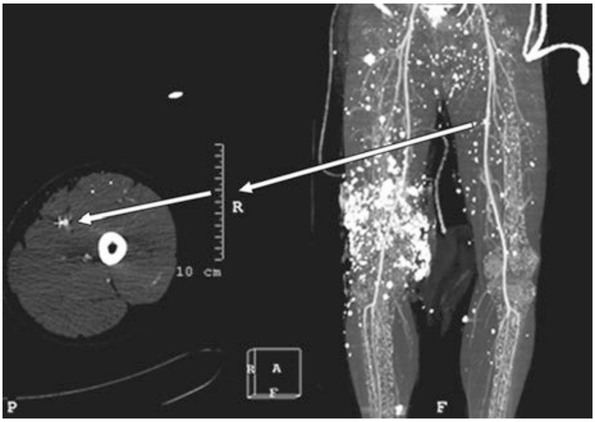

Fig. 9.3 A 27-year-old male soldier with multiple pellets in both legs. Correlation of coronal 3D reconstruction with axial CT-angiography scan allows identification of shrapnel requiring extraction because of threat to the superficial femoral artery (arrows)

During an MCI, the workflow of evaluation should be fast, simple, and standard for all patients. All of these requirements are optimally fulfilled by the CTA examination.

Despite the growing use of CTA as the main diagnostic tool in vascular trauma, there are a few disadvantages that must be brought into consideration. Radiation exposure and the use of iodinated contrast material with the possible allergic reaction or renal toxicity are of concern [20]. Radio-opaque metallic fragments create beam-hardening artifacts impairing CT-angiography [25]. In addition, in CT-angiography there is difficulty in the demonstration of the pedal arteries [20].

9.4.1.5 CTA Signs of Vascular Injury

CTA signs of vascular injury include:

Active contrast extravasation—indicates an ongoing bleeding manifested as a blush of extraluminal contrast material in vicinity to the injured vessel (Fig. 9.4) [20, 24]. Pseudoaneurysm—formation of an extraluminal sac filled with contrast material that is connected by a neck to the injured vessel.

A delayed scan is done in order to distinguish between active bleeding and pseudoaneurym: Active bleeding will usually spread in the delayed scan while pseudoaneurysm will remain in about the same size [24].

Hematoma—a hypodense mass infiltrating the space around an active bleeding or a pseudoaneurysm sac [20]. Hematomas can also be seen without active bleeding or pseudoaneurysm and may vary considerably in size.

Arterio-Venous Fistula—early venous filling on arterial phase, raises suspicion of AVF. Sometimes the exact site and nature of the communication between the artery and vein are not defined by CTA and conventional angiography is recommended [20, 27].

Acute vessel change in caliber or contour—focal stenosis on CTA may indicate the presence of spasm, dissection, or external compression [24]. Irregularity of the vessel wall with lumen narrowing represents wall injury with partial thrombosis [20]. Intraluminal filling defect—can represent thrombus or intimal flap.

Fig. 9.4 A 21-year-old male soldier with penetrating trauma to the right lower limb. (**a**) CT axial image at the level of the thighs shows a large hematoma (arrowhead) with air bubbles (thin arrows) and a blush of extravasated contrast material (thick arrow). (**b**) 3D-reconstructed image shows torn branches of superficial and deep femoral arteries (arrowhead)

Segmental vessel occlusion may result from transection or complete rupture.

The occlusion may vary in length and distal reconstitution may occur via collaterals [20]. Proximity of shrapnel less than 5 mm from a vessel should raise high suspicion of arterial injury [20].

9.4.1.6 Pitfalls

Occasionally, CT-angiography studies may result in poor diagnostic quality. These are due to improper technique, patient factors, and source artifacts [20, 22]. Poor timing of contrast material bolus resulting in inadequate vessels opacification is one of the most frequent pitfalls.

Injured patient's restlessness due to pain or altered mental status may result in motion artifacts. Inability of a wounded patient to raise his upper extremities overhead when performing upper extremity CT-angiography may lead to streak artifacts from the adjacent torso.

Streak artifacts as a result of metallic fragments in the soft tissues may interfere with the evaluation of an adjacent vessel and prevent exact diagnosis.

9.4.1.7 CTA Technique

A variety of protocols exist, utilizing a multi-detector CT [256, 64, or 16 detectors rows] or a dual energy CT machines. Images are transferred through a local hospital network system to a dedicated work station. Data reconstructions using volume rendering, maximum intensity projection and multiplanar reconstructions are vital in visualization of the arteries. In many institutes, the radiologist and vascular surgeon view the images jointly [20].

Many protocols for a variety of scanners exist. A typical protocol for a 64 slice CTA of the lower extremities usually includes the following parameters: Scan length 1200 mm, slice thickness 2 mm, increment 1 mm, Kv 120, mAs 300, resolution standard, collimation 64× 0.625, pitch 0.703, rotation time 0.5 s. FOV 350 mm, a sharp filter [13], matrix 512, scan time 22–26 s. For contrast injection, an 18 or 20 gauge venous accesses in the antecubital fossa is needed. Injection of contrast media is performed with a dual head injector enabling a "chaser" injection of 40 cc saline. Eighty to one hundred cubic centimeters of contrast media are injected at a rate of 4 cc/s or more.

Delay of scan is usually determined with a bolus tracking protocol with threshold set at 180 HU and a post threshold delay of 3 s. Oral contrast agent is not given.

Scanning is done from the level of the superior mesenteric artery to the feet for a full length lower extremity CTA. A subsequent scan, from the knees to the feet, is added in order to compensate for delayed arterial flow due to vascular injuries. For upper extremity CTA, the injured limb is raised above the head to decrease beam-hardening artifact from the torso and injection of contrast media is done from the contralateral arm. The newer CT scanners offer the ability to integrate peripheral CTA into the routine thoraco-abdominal trauma imaging protocols [20]. Increased acquisition speed of 3–6 s per each body segment allows peripheral CTA and chest or abdominal CTAs to be performed sequentially as needed. This is especially important in combat injury with multiple penetrating and blunt injuries in multilevel sites.

9.4.1.8 Endovascular Treatment

The introduction of CTA in the evaluation of suspected vascular injury has changed the role of conventional arteriography in the traumatized patient. In the authors' institution, conventional arteriography's main role is in the need for endovascular treatment. Another indication is inconclusive CTA due to metal fragments artifacts. Surprisingly, the use of endovascular treatment in MCI is usually very low: In our institute, out of the 849 casualty admitted to the emergency department during the Second Lebanon War only 4 [1%] underwent an endovascular procedure [6] .Yim et al. in a retrospective study from a single trauma center in 2014, reported a 5% usage of endovascular procedures [28] in trauma. Although higher than the author experience, this study was not specifically for an MCI. There is no specific or different recommendation for endovascular treatment in MCI compared to non-MCI vascular trauma and every case should be discussed individually on a case-specific base.

9.4.1.9 Percutaneous Transcatheter Embolization

Embolization in trauma can be used in every site of acute hemorrhage. In the abdomen and pelvis, there are no absolute contraindications to embolization in trauma [29]. Embolization to control active bleeding in the extremities is mainly done in the pelvic vessels and in the proximal branches of the femoral arteries [20]. Compartment syndrome, ischemia, or necrosis is known absolute contraindications for endovascular embolization as these patients should go directly to surgery [29].

When treating a pseudoaneurysm, distal and proximal embolization is important. This method, known as “the sandwich technique,” is substantial for obliteration of antegrade and retrograde flow to the pseudoaneurysm [23].

Embolic agents in use include gel foam, coils, and glue. A single agent or a combination may be used [23, 29].

9.4.1.10 Stent/Stent Graft

Indications for stent or stent-graft insertion in the setup of vascular injuries include acute pseudoaneurysm, perforation, AVFs, and dissection [20, 30].

Self-expandable stents are preferable in vascular injury because balloon-mounted stents may cause further damage to the arterial wall. Furthermore, in tortuous vessels, the flexibility of self-expandable stents enables rapid deployment whereas with balloon mounted stents, deployment may be difficult [31].

In general, in the traumatized patient, uncovered stents are indicated in dissections and covered stents in pseudoaneurysms and arterio-venous fistulae [31].

The use of stent graft in urgent aortic trauma, especially blunt trauma has been discussed elsewhere [32]. Although one might assume a thoracic aortic injury takes precedence over other injuries, a patient with a thoracic aortic injury can be observed for several days while additional injuries are treated, as long as appropriate blood pressure controls are observed [32]. This priority rank order fits well within the concept of MCI, e.g., postponing an individual lengthy complex procedure requiring a large number of highly specialized medical personal to a later time when the MCI has ended.

In a large series of treatment with covered stents, in 62 patients with peripheral vascular injuries, White et al., report injuries exclusion success rate of 94% [30].

Piffaretti et al. report ten cases of blunt trauma to peripheral arteries containing pseudoaneurysms, AVFs, dissections, and expanding hematomas, treated successfully with endovascular stents [31]. Limb salvage in this retrospective study was 100%.

Conclusions

In the last decades, there has been a continuous rise in terrorist and other mass casualty incidence. These include motor vehicle accidents, explosions, shootings, earthquakes, and other naturally caused disasters. Thus, every hospital is expected to be prepared for such events and to be trained in managing MCI. This compels every hospital and every department to have pre-planned solutions to the main issues characterizing MCI: the need for an extensive amount of personal, change of the ordinary workflow, and failure of the ordinary cellular phones-based communication.

FAST has an important part in evaluation of all trauma injuries, whether blunt or penetrating, and should be performed on all of them during the resuscitation phase. It is fast, portable, noninvasive, does not involve radiation, and can be integrated into the resuscitation process in the trauma bay without disrupting it.

CT is the modality of choice during an MCI. The protocols used should be simple and standard with a liberal use of whole body protocol in order to avoid time-consuming case-related discussions and reduce the need for repeated visits to the CT suites.

Currently, CTA is the best tool for vascular evaluation in MCI: The advantages of CTA, mainly the speed of the acquisition, the accuracy, and the standardization of the CTA scan, make it an ideal diagnostic tool for vascular imaging in MCI.

Conventional angiography has a very limited role in vascular diagnosis in MCI but has a major role when endovascular treatment is recommended.

References

1. Berger FH, Korner M, Bernstein MP, Sodickson AD, Beenen LF, McLaughlin PD, et al. Emergency imaging after a mass casualty incident: role of the radiology department during training for and activation of a disaster management plan. Br J Radiol. 2016;89:20150984.
2. Ferdia B, Ken L, Steve M, Eric R, Quynh N, Jeffrey R, Bruce L, Joel G. Emergency radiology and mass casualty incidents—report of a mass casualty incident at a level 1 trauma center. Emerg Radiol. 2017;24:47–53.
3. Sosna J, Sella T, Shaham D, Shapira SC, Rivikind A, Bloom A, Libson E. Facing the new threats of terrorism: radiologists' perspectives based on experience in Israel. Radiology. 2005;237:28–36.
4. Victoria SY, Heidi BE, Christine G, Pål AN, Tone E. Radiology response in the emergency department during a mass casualty incident: a retrospective study of the two terrorist attacks on 22 July 2011 in Norway. Eur Radiol. 2017;27:2828–34.

5. Postma ILE, Beenen LFM, Bijlsma TS, Berger FH, Heetveld MJ, Bloemers FW, Goslings JC. Radiological work-up after mass casualty incidents: are ATLS guidelines applicable? Eur Radiol. 2014;24:785–91.
6. Engel A, Soudack M, Ofer A, Nitecki S, Ghersin E, Fischer D, Gaitini DE. Coping with war mass casualties in a hospital under fire: the radiology experience. Am J Roentgenol. 2009;193:1212–21.
7. Brunner J, Rocha TC, Chudgar AA, Goralnick E, Havens JM, Raja AS, Sodickson A. The Boston Marathon Bombing: after-action review of the Brigham and Women's Hospital emergency radiology response. Radiology. 2014;273(1):78–87.
8. Gregan J, Balasingam A, Butler A. Radiology in the Christchurch earthquake of 22 February 2011: challenges, interim processes and clinical priorities. J Med Imaging Radiat Oncol. 2016;60:172–81.
9. Poletti PA, Wintermark K, Schnyder P, Becker CD. Traumatic injuries: role of imaging in the management of the polytrauma victim (conservative expectation). Eur Radiol. 2002;12:969–78.
10. Udobi KF, Rodriguez A, Chiu WC, Scalea TM. Role of ultrasonography in penetrating trauma: a prospective clinical study. J Trauma. 2001;50(3):475–9.
11. Miletic D, Fuckar Z, Mraovic B, Dimec D, Mozetic V. Ultrasonography in the evaluation of hemoperitoneum in war casualties. Mil Med. 1999;164:600–3.
12. Sarkisian AE, Khondkarian RA, Amirbekian NM, Bagdasarian NB, Khojayan RL, Oganesian YT. Sonographic screening of mass casualties for abdominal and renal injuries following the 1998 Armenian earthquake. J Trauma. 1991;31(2):247–50.
13. Beck-Razi N, Fischer D, Michaelson M, Engel A, Gaitini D. The utility of focused assessment with Sonography for trauma as a triage tool in multiple casualty incidents during the second Lebanon war. J Ultrasound Med. 2007;26(9):1149–56.
14. Press GM, Miller S. Utility of cardiac tamponade of FAST in blunt trauma. J Emerg Med. 2013;14:9–16.
15. Körner M, Geyer LL, Wirth S, Reiser MF, Linsenmaier U. 64-MDCT in mass casualty incidents: volume image reading boosts radiological workflow. Am J Roentgenol. 2011;197:W399–404.
16. Hare SS, Goddard I, Ward P, Naraghi A, Dick EA. The radiological management of bomb blast injury. Clin Radiol. 2007;62(1):1–9.
17. Singh AK, Goralnick E, George VG, Biddinger PD, Gates J, Sodickson A. Radiologic features of injuries from the Boston Marathon bombing at three hospitals. Am J Roentgenol. 2014;203:235–9.
18. Wolf SJ, Bebarta VS, Bonnett BC, Pons PT, Cantrill SV. Blast injuries. Lancet. 2009;374:405–15.
19. Engel A, Militianu D, Ofer A. Diagnostic imaging in combat trauma. Chapter 7. In: Lerner A, Soudry M, editors. Armed conflict injuries to the extremities. Berlin: Springer; 2011. p. 95–114.
20. Inaba K, Potzman J, Munera F, Mckenny M, Munoz R, Rivas L, Dunham M, DuBose J. Multi-slice CT angiography for arterial evaluation in the injured lower extremity. J Trauma. 2006;60:502–7.
21. Miller-Thomas MM, West OC, Cohen AM. Diagnosing traumatic arterial injury in the extremities with CT angiography: pearls and pitfalls. Radiographics. 2005;25:S133–42.
22. Doody O, Given MF, Lyon SM. Extremities-indications and techniques for treatment of extremity vascular injuries. Injury. 2008;39:1295–303.
23. Madhuripan N, Mehta P, Smolinski SE, Njuguna N. Computed tomography angiography of the extremities in emergencies. Semin Ultrasound CT MR. 2017;38:357–69.
24. Nitecki SS, Karram T, Ofer A, Engel A, Hoffman A. Management of combat vascular injuries using modern imaging: are we getting better? Emerg Med Int. 2013;2013:689473.
25. Soto JA, Munera F, Cardoso N, Guarin O, Medina S. Diagnostic performance of CT angiography in trauma to large arteries of the extremities. J Comput Assist Tomogr. 1999;23(2):188–96.
26. Soto JA, Munera F, Morales C, Lopera JE, Holguin D, Guarin O, Castrillon G, Sanabria A, Garcia G. Focal arterial injuries of the proximal extremities: helical CT arteriography as the initial method of diagnosis. Radiology. 2001;218:188–94.

27. Yim NY, Kim YT, Kim HO, Kim JK, Kang YJ, Park YC, Park CY. Role of interventional radiology in trauma care: retrospective study from single trauma center experience. Am J Emerg Med. 2014 Nov;32(11):1315–8.
28. O’Dell MC, Shah J, Martin JG, Kies D. Emergent endovascular treatment of penetrating trauma: solid organ and extremity. Tech Vasc Interv Radiol. 2017;20:243–7.
29. White R, Krajcer Z, Johnson M, Williams D, Bacharach M, O'malley E. Results of a multicenter trial for the treatment of traumatic vascular injury with a covered stent. J Trauma. 2006;60:1189–95.
30. Piffaretti G, Tozzi M, Lomazzi C, Rivolta N, Caronno R, Lagana D, Carrafiello G. Endovascular treatment for traumatic injuries of the peripheral arteries following blunt trauma. Injury. 2007;38(9):1091–7.
31. Hoffer EK, Forauer AR, Silas AM, Gemery JM. Endovascular stent-graft or open surgical repair for blunt thoracic aortic trauma: systematic review. J Vasc Interv Radiol. 2008;19:1153–64.
32. Kolbeck KJ, Kaufman JA. Endovascular stent grafts in urgent blunt and penetrating thoracic aortic trauma. Semin Intervent Radiol. 2011;28:98–106.