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ORIGINAL ARTICLE

Department of Homeland Security national planning scenarios: a spectrum of imaging findings to educate the radiologists

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Abstract Following the events of the September 11th attack, there has been an increasing concern about the possibility of a future attack on our homeland. In response, the United States Department of Homeland Defense has planned for a future attack by formulating multiple scenarios which may occur in the event of such a disaster. Radiology will play a key role in each of these scenarios, assisting with triage, diagnosis, and therapy of the large populations which potentially could be involved. This article describes some of these scenarios as well the response which will be expected of the radiology community in the event of such a disaster.

Keywords Disaster · Homeland security · Terrorism · Blast injury · Nuclear · Biological

Introduction

In an effort to learn from past events like the atomic bomb detonations over Hiroshima and Nagasaki, severe acute respiratory syndrome, the World Trade Center attacks, and Hurricane Katrina and to prepare for any such future event, the Department of Homeland Security has outlined 15 different national planning scenarios for disaster preparedness. These scenarios include different blast, biological, chemical, nuclear, and natural disasters. Radiology has a significant role in many of these scenarios because it stands at the crossroads of screening, decontamination, diagnosis, treatment planning, and perhaps long-term patient care.

The objective of this article was to describe some of the radiologic findings that may be anticipated in several of the 15 national planning scenarios which deal with risk in particular to the health of the general population as well as have a significant impact on the radiology community. In addition, the following is meant to help stimulate thought and discussion in radiology departments across the country as well as to help departments formulate ideas to help prepare themselves for a disaster should it occur in their local area.

Scenario 1: Nuclear detonation—10-kiloton improvised nuclear device

In the first scenario, a 10-kiloton nuclear device is detonated in the central business district of a large American city. Most of the buildings within 1,000 m (~3,200 ft) of the detonation will be severely damaged. Subsequent injuries from flying debris (missiles) will possibly be observed out to 6 km (~3.7 miles) [1]. Patients will present primarily with burns to exposed skin and eyes (flash burns), projectile, crush, and translational injuries (Fig. 1) as well as acute radiation syndrome [1]. Gas-filled organs such as the ears, lungs, and gastrointestinal tract will be the most vulnerable to the blast effect, with lung injury as the primary cause of morbidity and mortality. Individuals directly exposed to the radiation will result in additional long-term health care sequelae. Many of these victims will have an

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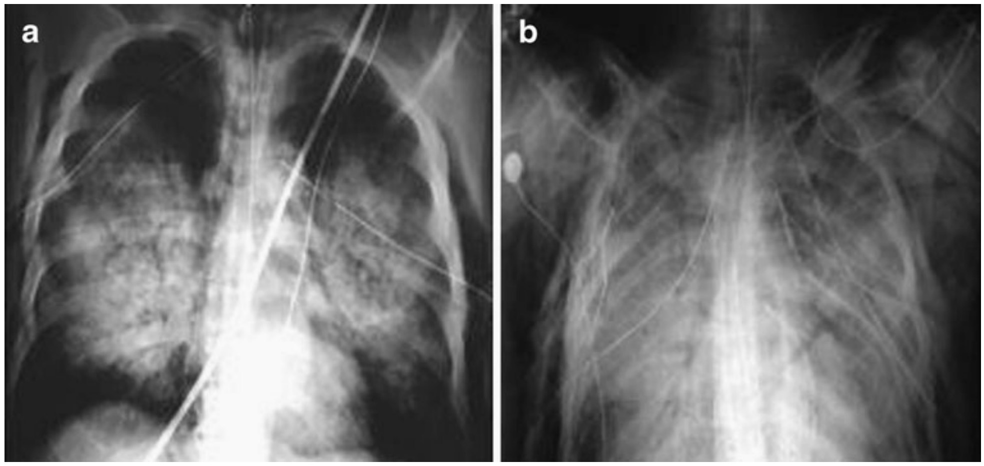

Fig. 1 Blast injury to lungs. **a** Initial chest radiograph shows bilateral perihilar pulmonary infiltrates in butterfly pattern. **b** Follow-up radiograph shows further deterioration with complete whitening of the lungs (images courtesy of www.ajronline.org)

increased future risk of developing subsequent malignant neoplasms. Of these malignancies, leukemia is the most likely; however, some patients may also develop thyroid, breast, lung, or salivary gland cancer [2]. In addition to providing immediate trauma imaging assistance, radiologists may be asked to provide expert advice in concert with a health physicist (if available) to assist with radiation detection, patient triage, decontamination, and management of the victims of acute radiation syndrome.

Scenario 2: Biological aerosol attack—anthrax

In the second scenario, anthrax spores are delivered to the target by insurgents using an aerosol device. This most likely will result in inhalational anthrax, which occurs when the bacterial organism, *Bacillus anthracis*, is inhaled directly into the lungs with a progressively worsening infection to follow. A single anthrax aerosol attack in a city could be performed by using a truck with a concealed improvised spraying device in a densely populated urban area, producing a subsequently profound health risk to the affected general population [1].

Assuming more than 300,000 exposures, one could expect the possibility of more than 13,000 infections—almost all which could be fatal. The most common presenting physical symptoms would be malaise, fever, cough, nausea, and vomiting. Night sweats, chest pain, tachycardia, and headache may also be seen in many of the patients [3]. Patients may present with respiratory distress without radiographic findings of pneumonia, a history of trauma, or chronic lung disease. Radiologists would be at the forefront of diagnosing such an anthrax outbreak by detecting abnormal chest radiographic findings such as mediastinal widening, pleural effusions, pulmonary consolidation, and mediastinal or hilar lymphadenopathy (Fig. 2). CT findings such as hemorrhagic mediastinitis and lymphadenitis could be additionally observed [4].

Scenario 3: Biological disease outbreak—pandemic influenza

The third scenario describes what could happen during an influenza pandemic without an effective preplanned health care response. This scenario starts with a local outbreak in a small village in South China with about 25 cases. Following several weeks, the virus could spread around the world, including many major US cities, with an estimated 87,000 fatalities, 300,000 hospitalizations, 18.1 million outpatient visits, and 21.3 million ill outpatients [1].

Using chest radiography and CT scanning, radiologists will be required to provide prompt diagnosis, assist in determining disease extent and severity, help monitor treatment response, and to assist in assessing for treatment complications [5]. Radiographic findings on chest films could include bronchopneumonia, segmental atelectasis, consolidation, or consolidation with effusion (Fig. 3) [6], with similar findings on CT.

Scenario 4: Biological attack—plague

Bubonic plague is the best-known manifestation of the bacterial disease called “plague,” caused by the bacterium *Yersinia pestis*. Bubonic plague is often used synonymously for plague, but it does in fact refer specifically to an infection that enters through the skin, travels through the lymphatics, and is seen in flea-borne infections. However, in this fourth scenario, terrorists will release aerosolized pneumonic plague into three main areas of a major metropolitan city. Initially, those who had direct contact with the aerosol will be affected; however, it will rapidly spread throughout the local population.

Pneumonic plague is the most virulent and least common form of plague. Primary pneumonic plague results from inhalation of aerosolized infective droplets which can be transmitted from human to human without involvement of

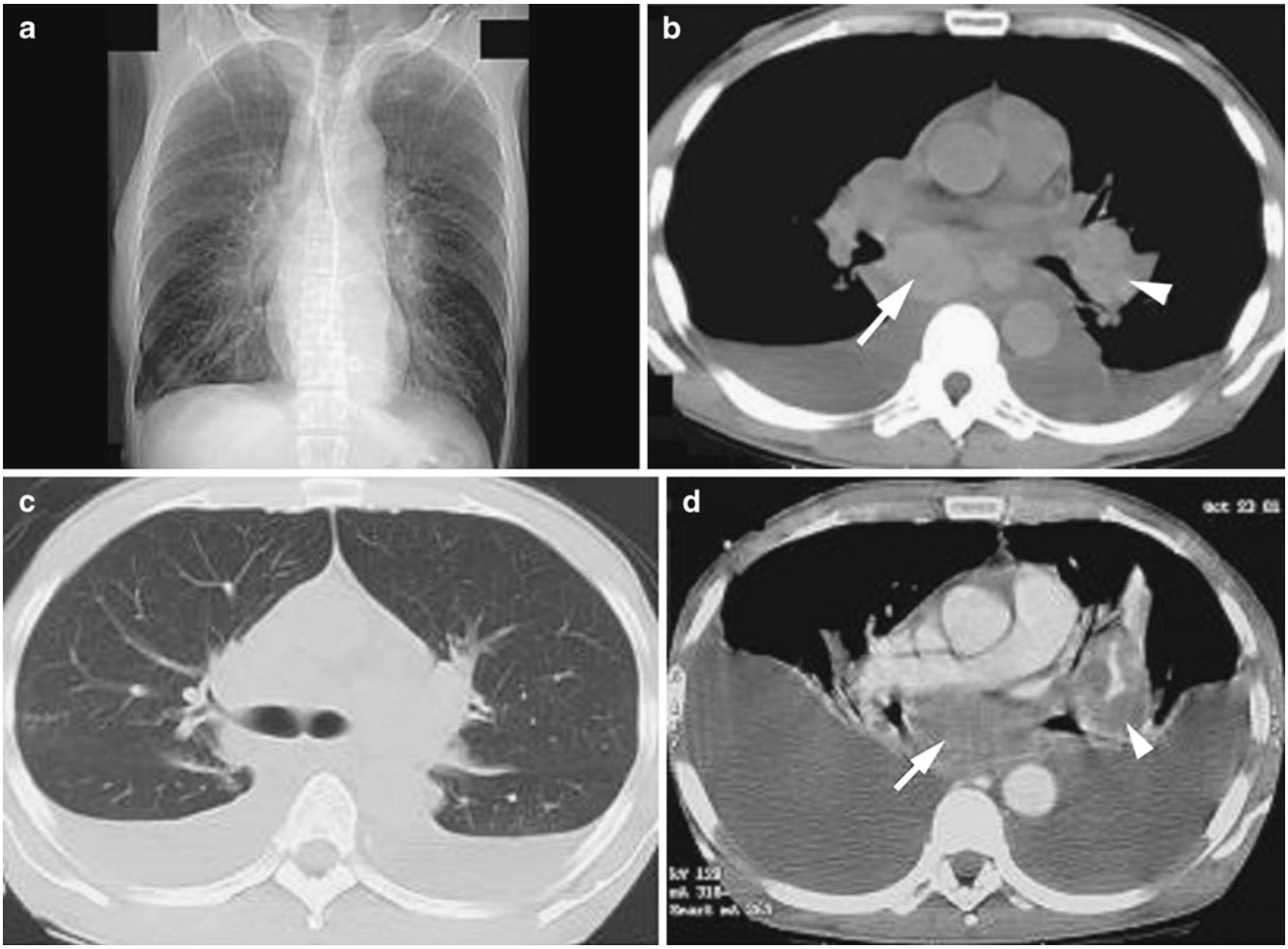

Fig. 2 A case of inhalational anthrax. A 56-year-old male postal worker with a 3-day history of fever, chills, chest heaviness, malaise, and minimally productive cough. **a** Scout image from a chest CT reveals mediastinal widening and bilateral hilar enlargement. **b** Unenhanced chest CT (mediastinal window) through the middle lobe reveals enlarged hyperdense hemorrhagic lymph nodes in the subcarinal region (*arrow*) and the left hilum (*arrowhead*). There are bilateral pleural effusions. **c** Chest CT (lung window) through the right upper lobe bronchus shows bilateral pleural effusions and strikingly normal lung parenchyma. **d** Chest CT (enhanced) obtained 4 days after the first examination reveals massive enlargement of subcarinal (*arrow*) and left hilar lymph nodes (*arrowhead*) which distort the left pulmonary artery (images courtesy of Inova Health System/Inova Fairfax Hospital)

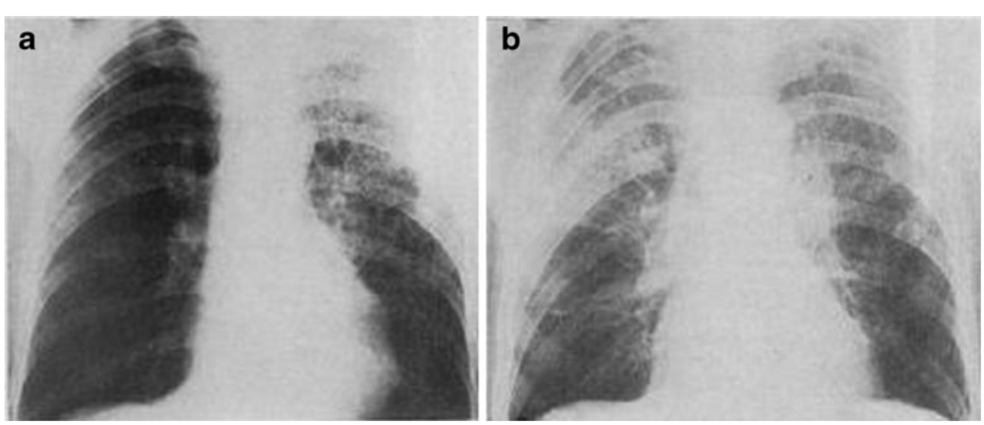

Fig. 3 Pandemic influenza. **a** Initial chest radiograph showed left upper lobe pneumonia. **b** Follow-up chest radiograph revealed worsening of the left upper lobe consolidation, with new right apical airspace opacities. The patient's clinical condition fluctuated from day to day, as did his radiological findings, with gradual deterioration until his death (images courtesy of Canadian Medical Association Journal, 1969)

Fig. 4 Pneumonic plague. Radiograph shows extensive lobar consolidation in left lower and left mid-lung fields (image from Centers for Disease Control and Prevention, Division of Vector-Borne Infectious Diseases, Fort Collins, CO)

fleas or animals. In the USA, there are projected to be approximately 7,348 illnesses and 2,287 fatalities caused by a pneumonic plague outbreak [1]. One to 6 days following exposure, patients will develop symptoms. If they do not receive rapid antibiotic therapy within 24 h, death will occur within the next few days.

The presenting symptoms of pneumonic plague include fever, headache, weakness, shortness of breath, chest pain, cough, and sometimes bloody or watery sputum. Pneumonia develops rapidly and eventually progresses after 2 to 4 days into respiratory failure and shock. In contrast to secondary pneumonic plague, a feature of primary pneumonic plague includes the absence of buboes (except, rarely, cervical buboes). On pathologic examination, there is severe pulmonary disease, with areas of profound lobular exudation and bacillary aggregation. Prominent gastrointestinal symptoms may present, to include nausea, vomiting, abdominal pain, and diarrhea [7]. The sudden appearance of a large number of previously healthy patients with fever, cough, shortness of

Fig. 5 Pneumonic plague. This anteroposterior X-ray reveals a bilaterally progressive plague infection involving both lungs (image courtesy of CDC Public Health Image Library (ID no. 4136))

Fig. 6 Pneumonic plague. This anteroposterior X-ray reveals the resolution of a plague infection with clearing of the lungs (image courtesy of CDC Public Health Image Library (ID no. 4135))

breath, chest pain, and a fulminant fatal course should suggest the possibility of pneumonic plague or inhalational anthrax [7]. Radiographic findings are variable, but most commonly include bilateral parenchymal consolidations, mediastinal, cervical, or hilar adenopathy, all of which may be present in both the bubonic and pneumonic forms of plague (Figs. 4, 5, and 6) [7].

Scenario 6: Chemical attack with toxic industrial chemicals

In this scenario, terrorists would land several helicopters at fixed facility petroleum refineries. They would quickly launch rocket-propelled grenades and plant improvised explosive devices (IEDs) before re-boarding and departing, resulting in major fires following the explosions. A simultaneous attack at a nearby port would have multiple

Fig. 7 Chest radiograph of patient with ARDS characterized by inflammation of the lung parenchyma with bilateral alveolar infiltrates (image courtesy of www.en.wikpedia.org; Author: Samir 04:51, 17 September 2007 (UTC), modified by Delldot 07:55, 28 April 2008 (UTC). Permission: GFDL

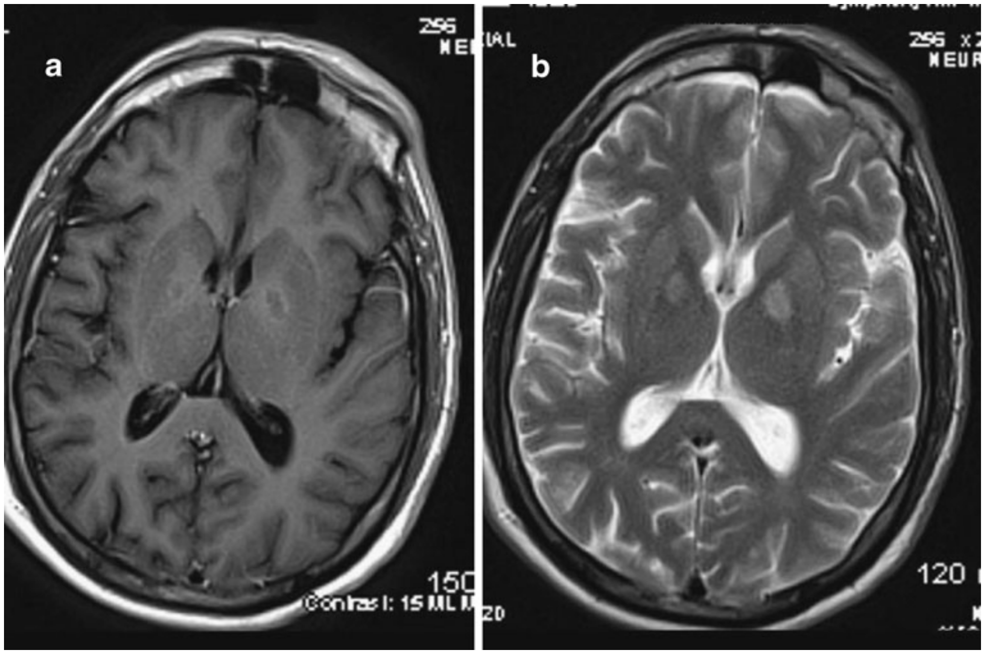

Fig. 8 Smoke inhalation resulting in carbon monoxide poisoning. Unenhanced MRI images of the brain reveal low signal lesions bilaterally within the globus pallidus on T1 imaging (**a**), with corresponding high signal seen within the same region on the T2 image (**b**) (images courtesy of Steven Goldstein, MD)

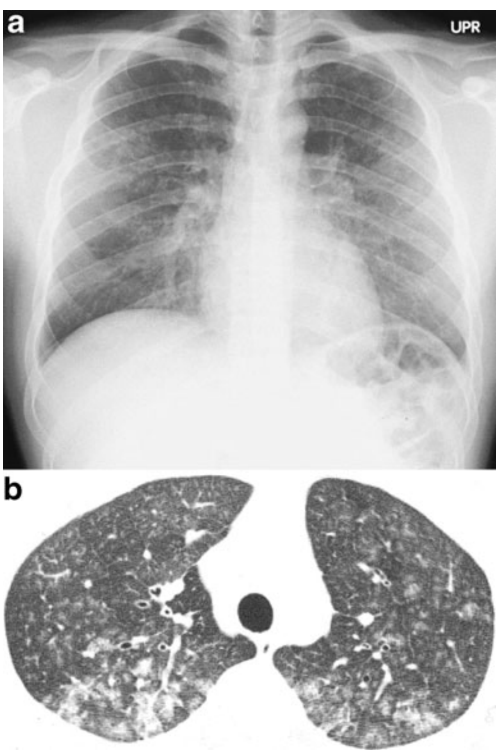

Fig. 9 Chlorine gas exposure resulting in ARDS or pulmonary edema. **a** Frontal chest radiograph obtained 36 h after an accidental chlorine gas exposure at a community swimming pool showed diffuse small nodular opacities [14]. **b** Thin-section computed tomogram of the chest demonstrated ill-defined centrilobular nodules along the peribronchovascular structure, particularly in the dependent portions of the lungs, as well as mild air trapping, without bronchial wall thickening or bronchiectasis—findings consistent with diffuse bronchiolitis [14] (image courtesy of Respiratory Care Journal, 2004)

cargo containers exploding onboard or near several cargo ships, with rapid spread of fires subsequent to the explosion. This attack is estimated to result in 1,000 hospitalizations and 350 fatalities due to the direct effects of the explosives and fires. Injuries to be expected would include direct blast trauma, burns, smoke inhalation, acute respiratory distress syndrome (ARDS), exacerbation of chronic preexisting respiratory conditions, seizures, and coma [1].

In addition to the specific radiological findings of blast trauma (which will be discussed later in scenario 12), chest radiographs of patients suffering from primary blast injury often present with symptoms of ARDS, which is usually characterized by bilateral alveolar infiltrates (Fig. 7). Smoke

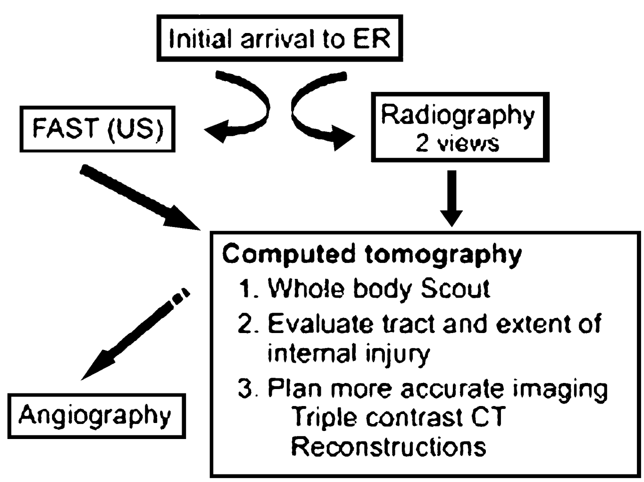

Fig. 10 Work flowchart for imaging of victims of blast injury includes radiography, focused abdominal sonography for trauma (*FAST*), CT, and angiography. *ER* emergency room (image courtesy of www.radiology.rsnajnls.org)

Fig. 11 Primary blast injury. Frontal chest radiograph obtained in a 24-year-old woman several hours after blast injury shows bilateral opacities in a butterfly distribution, representing pulmonary contusion (image courtesy of www.radiology.rsnajnls.org)

inhalation injury may result in carbon monoxide poisoning, with CT and MRI demonstrating characteristic findings. CT scans are usually positive within 24 h, and MRI demonstrates findings even sooner. On MRI, carbon monoxide poisoning produces low or high signal intensity foci on T1-weighted sequences and high intensity foci on T2-weighted sequences within the globus pallidus bilaterally (Fig. 8). A characteristic CT finding is bilaterally symmetric low attenuation lesions within the globus palladi. There may also be low-density lesions in the cerebral and cerebellar white matter, with sparing of the subcortical fibers [8].

Scenario 8: Chemical attack with a chlorine tank explosion

In this scenario, terrorists could infiltrate an industrial facility and release a large quantity of chlorine gas downwind of the site. Assuming a high-density population area, as many as 700,000 people could potentially be in the downwind area, which may extend as far as 25 miles. Of these, approximately 5% (35,000) can be expected to receive potentially lethal exposures, and half of these (2.5% of the affected population) will die before or during treatment. An additional 15% are likely to require hospitalization, and the remainder could be treated and released at the scene by Emergency Medical Service personnel [1].

Fig. 13 Secondary blast injury. Coronal whole-body CT scout image demonstrates multiple metal objects projected over the chest. Two additional metal objects (*arrows*) that had not previously been noted on conventional chest radiographs are seen projected over the neck and mid-abdomen (image courtesy of www.radiology.rsnajnls.org)

Patients affected by such an attack will often suffer from ARDS or pulmonary edema. Chest radiographs may show vascular congestion, consolidation, and nodules, as well as

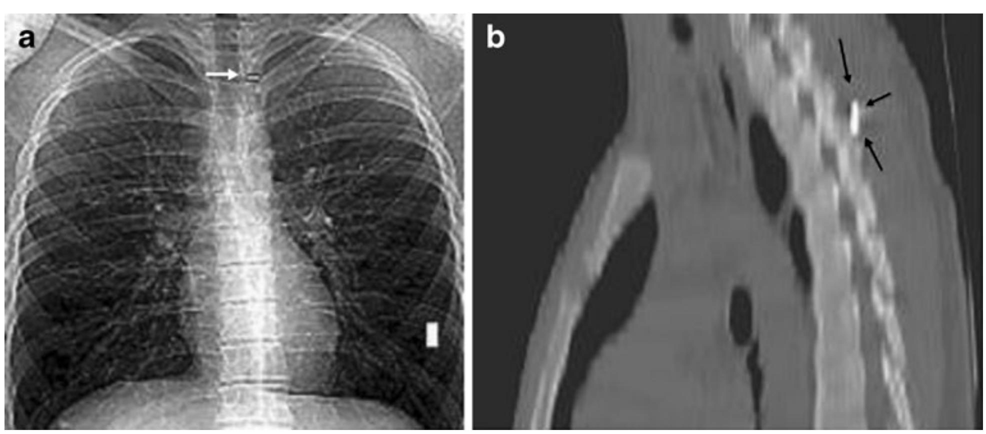

Fig. 12 Secondary blast injury. **a** CT scout view shows metallic object (*arrow*) projected over the mediastinum in a 35-year-old blast victim. **b** Sagittal multiplanar CT reconstruction demonstrates that this object (*arrows*) is located in the deep soft tissues (images courtesy of www.radiology.rsnajnls.org)

pulmonary edema in severe cases (Fig. 9). Radiographic changes will often clear within 1 week, however may persist for up to 10 weeks in the more severe of cases. The majority of the injured will recover in approximately 7 to 14 days, with the exception of those with severe lung damage who will require long-term monitoring and treatment [9, 10].

Scenario 11: Radiation attack—radiation dispersal devices

A radiation dispersal device is considered by many experts to be the most likely of these scenarios due to the widespread availability of explosives and radioactive materials such as cesium-137 from waste, hospital, or test sources and their relative ease of assembly [11]. Following detonation from a radiation dispersal device, cesium would be spread over an area of approximately 36 city blocks, with concentrations ranging from 5 to 500 μCi/m^2. Casualties in this scenario are estimated at approximately 180 fatalities, 270 injuries, and 20,000 detectible personal contaminations (at each exposed site). The only immediate injuries to be expected would include direct blast injuries that are a result of the primary detonation of the explosive [1], which will be discussed in further detail in scenario 12.

Cesium-137 (137Cs) causes direct skin damage similar to thermal burns due to radioisotope decay by both the beta and gamma radiation emitted. In addition, cesium-137 is particularly dangerous if accidentally ingested or inhaled as it is readily absorbed by the lungs and gastrointestinal tract. The US Nuclear Regulatory Commission has determined that approximately 200 μCi of inhaled cesium-137 would result in an approximately 5-rem exposure (10 CFR Appendix B to part 20). Given the variability in weather, as well as exposure conditions, doses up to 543 rem have been estimated by this particular route [12], with decreasing exposure with greater distance. Despite the dangers which cesium-137 poses to those directly within the blast area, the majority of patients presenting to medical facilities, however, would likely present due to psychosomatic illness brought on by widespread public panic from radiation exposure assuming they were outside the immediate area of exposure and considering weather patterns within the area at the time of the exposure. Finally, the long-term effects of a radiation detonation within the affected population (i.e., increased risk of cancers) would depend upon the cumulative exposure of the population, which would be based upon the amount of aerosolized and surface contamination as well as proximity to the epicenter of the blast [1].

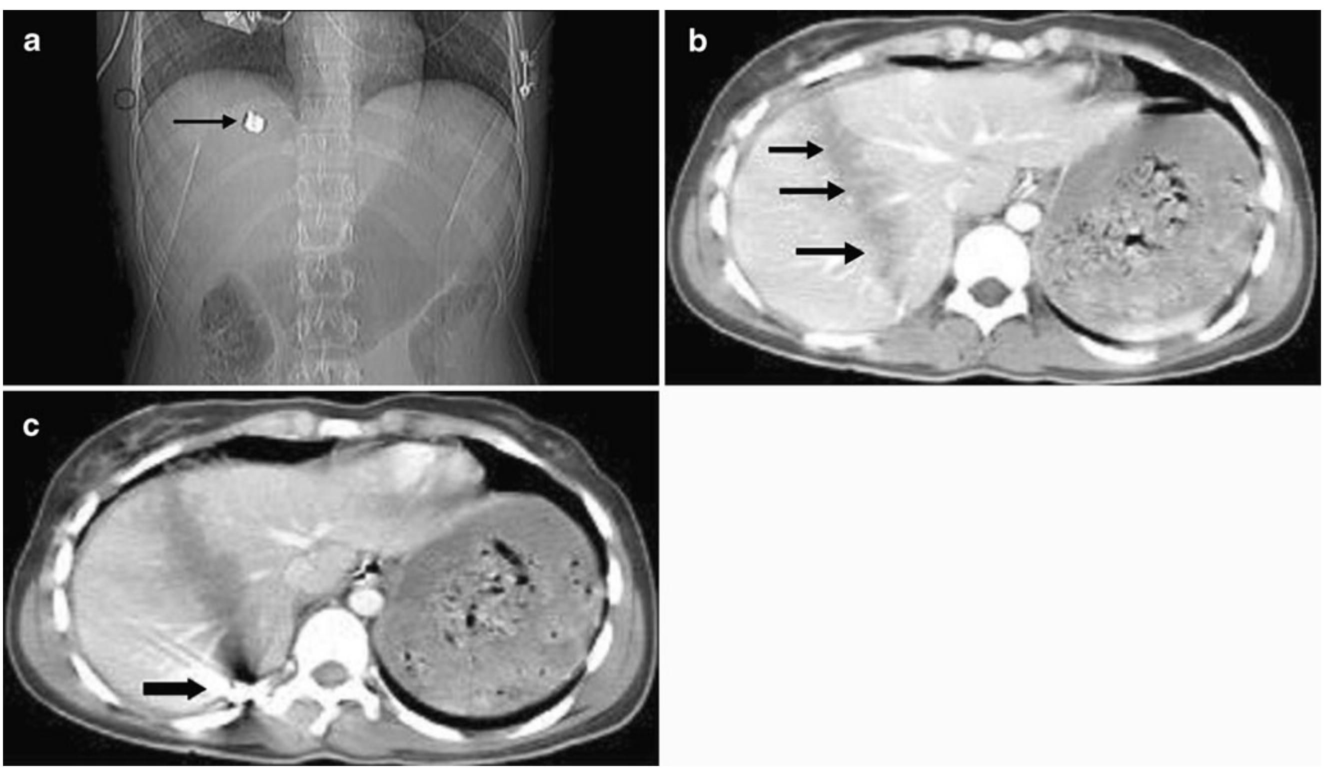

Fig. 14 Secondary blast injury. **a** Coronal CT scout image of upper abdomen demonstrates a single metal object (*arrow*) projected over the liver. **b**, **c** Transverse CT scan images of the abdomen reveal the anterior-to-posterior trajectory of this shrapnel. The object (*arrow* in **c**) is located in posterior paraspinal region after causing liver laceration (*arrows* in **b**) (images courtesy of www.radiology.rsnajnls.org)

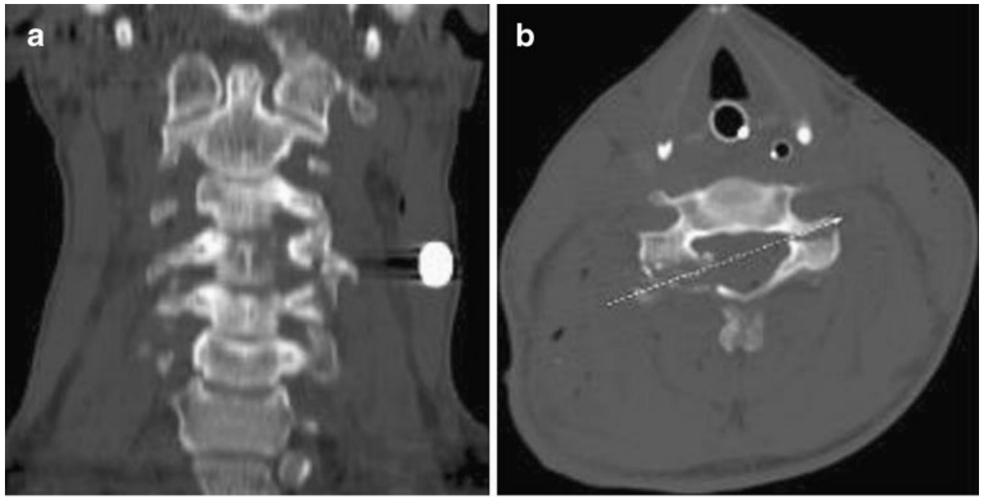

Fig. 15 Secondary blast injury resulting in penetrating neck trauma. **a** Coronal multiplanar CT reconstruction shows metal object in left side of the neck. **b** Transverse CT scan at level of the object demonstrates soft tissue damage and fractures of the lamina. *Arrow* suspected trajectory of the shrapnel (images courtesy of www.radiology.rsnajnls.org)

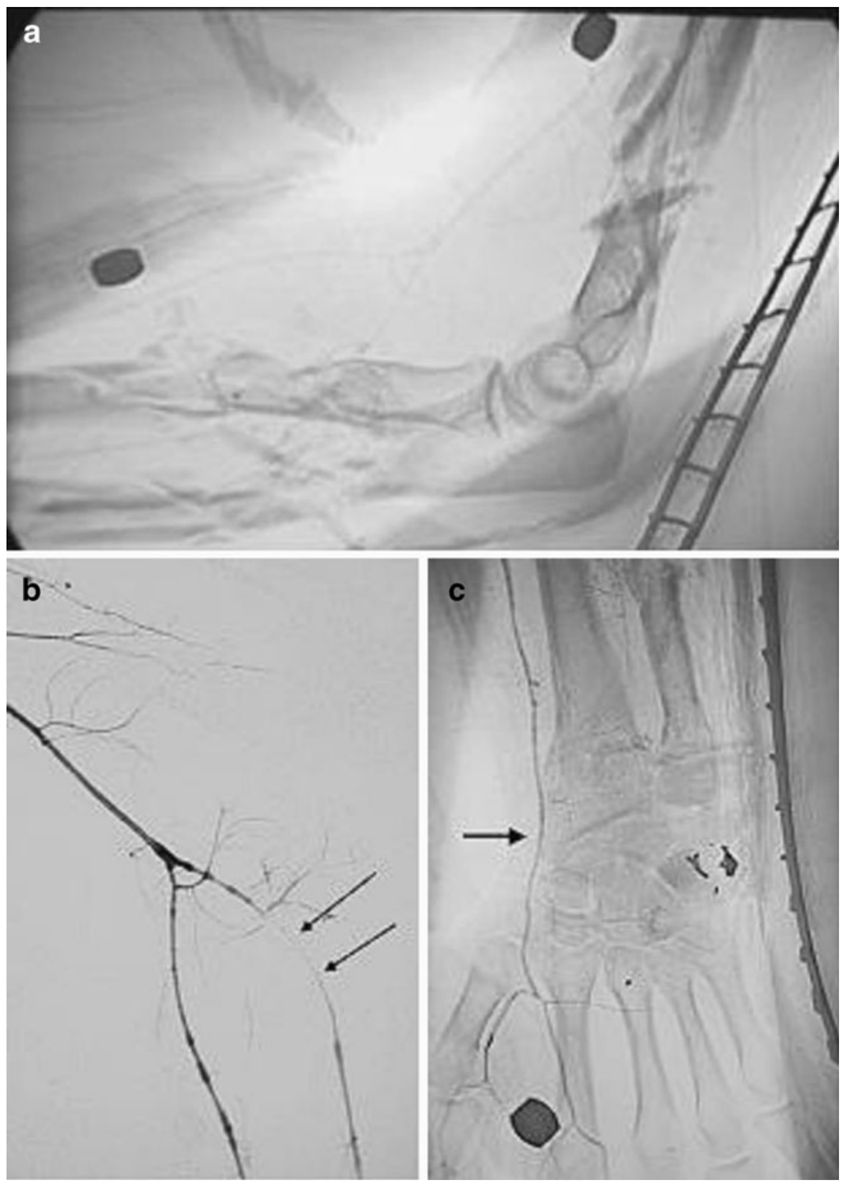

Fig. 16 Secondary blast injury. Multiple soft tissue injuries to the left arm and hand of a 40-year-old terror attack victim. **a** Lateral radiograph of the arm shows shrapnel and comminuted fractures of the humerus, radius, and ulna. **b** Lateral digital subtraction angiogram of the arm demonstrates spasm (*arrows*) of the vessels, without bleeding. **c** Anteroposterior non-subtracted angiogram of the hand shows multiple shrapnel and a thin radial artery (*arrow*) (images courtesy of www.radiology.rsnajnls.org)

Scenario 12: Explosives attack—bombing using improvised explosive device

In this final scenario, IEDs would be detonated inside a large sports arena, as well as a parking facility near the entertainment complex, with an additional series of devices to be detonated in the lobby of the nearest hospital emergency department. Injuries will result from structural collapse, secondary and tertiary blast effects, exposure to products of combustion, thermal effects, and possible crowd surge at the complex. There will be loss of traffic controls within the area, and fleeing citizens would subsequently cause multiple traffic accidents which will further worsen the situation [1].

Specific injuries caused by explosives are classified into three categories—primary, secondary, and tertiary. Primary blast injuries are caused by a shock wave that passes through the body and surrounding air. Primary blast injuries predominantly affect air-containing organs, resulting in pulmonary hemorrhage and edema, gastrointestinal hemorrhage, as well as perforation of eardrums. Secondary injuries are due to objects being propelled directly outward by the force of the explosion, producing patterns of injury similar to the orthopedic and penetrating types often observed in patients following the impaction of a motor vehicle accident. Finally, tertiary injuries occur when the victims are physically displaced by the blast wave and subsequently collide with nearby objects, resulting in subsequent penetrating or blunt trauma [13].

Of particular interest to this scenario, terrorists and insurgents often add metallic objects to their IEDS in order to inflict more trauma, which may include nails, screws, bolts, and ball bearings (Fig. 12). These objects readily penetrate the body at a high speed, lacerating the organs that they pass through as well as producing injury secondary to the associated shock wave as is often seen in bullet injuries. The result of these differing mechanisms is that victims often have combined blast and shrapnel injuries, requiring a multimodality approach to imaging [14].

The modalities involved in imaging victims of blast injury include conventional radiography, focused abdominal sonography, CT scanning, and angiography (Fig. 10). Common radiologic findings within the chest may include pulmonary contusions, which appear as airspace opacities on radiographs and consolidations on CT scans (Fig. 11). These findings generally tend to clear over the course of approximately 1 week. In addition, radiologic findings related to the chest secondary to blast injury would include pneumothorax, hemothorax, and hemopericardium [14].

Radiographs can additionally be used to triage those patients with shrapnel injuries that need further imaging with CT scanning. A trauma radiographic series may be requested as part of the initial workup of a blast victim and should include chest, cervical spine, and pelvic radiographs with additional images performed at the sites of penetrating injuries. Specific radiographs are performed to evaluate superficially located objects from those which are positioned in deeper tissues adjacent to vital organs, with multiple views often needed for accurate localization prior to treatment [14].

Multisection helical CT scans reveal the true course a penetrating object has traveled as well as the full scope of a patient's injuries (Figs. 12, 13, and 14) [14]. Therefore, it is important to perform CT in all patients with penetrating shrapnel injuries caused by an explosion and is particularly important in patients with penetrating head and neck injuries (Fig. 15) due to the potential for extensive devastating injuries. CT angiography may be additionally used if there is a possibility of vascular injury (Fig. 16), as well as in the case of a foreign body positioned within the neck near a large vessel. CT with contrast should also be used in cases of shrapnel in and around the pelvis in order to evaluate the trajectory of the objects and involvement of adjacent bowel (Fig. 17) [14].

Conclusion

As demonstrated, the role of the radiologist in these scenarios is critical and quite daunting. Therefore, the radiology community must be prepared to know what specific imaging findings to look for in order to rapidly recognize, triage, and treat their patients accordingly. They must also be prepared logistically to handle the large numbers of casualties and injuries that will present to their facilities as well as be prepared to handle conditions in the event that their own facilities are affected by the disaster.

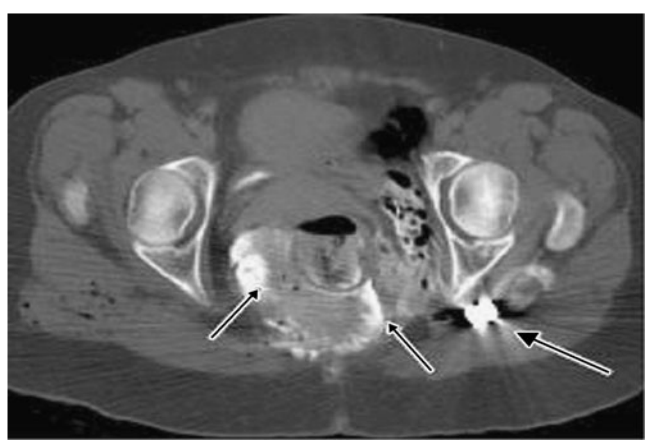

Fig. 17 Secondary blast injury. Transverse CT scan of pelvis of a 40-year-old woman after administration of rectal contrast material. Shrapnel is noted on the left (*thick arrow*); however, it has penetrated and caused a rectal tear, as shown by extraluminal contrast material (*thin arrows*) (image courtesy of www.radiology.rsnajnls.org)

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