Radiologic Features of Blast Injuries from 2015 Bangkok Bombing

Kampon Yuenyongsinchai MD*, Thanisa Tongbai MD*, Teerachai Chaitusaney MD*, Natthaporn Tanpowpong MD*, Numphung Numkarunarunrote MD*, Panruethai Trinavarat MD*

* Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand

Objective: *To describe the radiologic findings of blast injuries from the Bangkok bombing on August 17, 2015, as primary, secondary, tertiary, and quaternary blast injuries.*

Material and Method: *Twenty patients that presented at the emergency department and underwent radiologic investigation on August 17, 2015 were included in this study. The clinical information and imaging findings were retrospectively reviewed from the medical record and Picture Archiving and Communication Systems (PACS).*

Results: *Conventional radiography and computed tomography (CT) scan were the imaging modalities of choice in the acute blast setting. Acoustic barotrauma was observed in eight patients, and blast lung injury was detected in one patient. One hundred seventy three shrapnel fragments were identified in 16 of 20 patients. Most shrapnel fragments were located in lower extremities and pelvis (77.5%). Most of bone fractures, identified in six patients, were categorized as secondary blast injuries. Five patients had skin burn and two patients showed signs of inhalation injuries.*

Conclusion: *Radiologic findings of blast injuries in the 2015 Bangkok bombing were predominantly from secondary blast injuries, and most of the shrapnel fragments were found in soft tissue of lower extremities and pelvis.*

Keywords: *Blast injuries, 2015 Bangkok bombing, Terrorism, Radiologic findings*

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Over the past years, we have witnessed many incidents in which mass casualties needed to be treated following an act of terrorism in the civilian setting. These attacks are occurring with increasing frequency and severity[1-3]. The medical approaches to these events are somewhat different from the case of a single multiple-trauma patient. The initial evaluation and management within a short period in an overwhelmed emergency department is a complicated task even for experienced medical personnel. Furthermore, those real incidents always occur when no one is expecting it.

In Thailand, on August 17, 2015, at approximately 6:55 pm, a bombing took place inside the Erawan Shrine at the Ratchaprasong intersection in Pathumwan district, Bangkok, killing 20 people and injuring 125 people[4]. The survivors were transported or self-presented at the nearby hospitals, including King Chulalongkorn Memorial Hospital (KCMH), a 1,460-bed level-1 trauma center.

Due to the complexity of injuries encountered in terror attack victims, radiology plays an important role in the initial management and triage by assisting to determine which patients need immediate surgery and which patients can be treated conservatively[2,3,5,6]. This awareness is vital in helping to reduce the morbidity and mortality for civilian blast victims[5]. Therefore, the medical personnel who work in an urban setting need to be able to recognize the spectrum of injuries that can potentially be inflicted by the explosions, both those in common with any severe trauma and those specific to the blast phenomenon.

The aim of the present study was to describe the radiologic findings of blast injuries in the 2015 Bangkok bombing as primary, secondary, tertiary, and quaternary blast injuries to make awareness of the spectrum of radiologic findings that could be found in blast victims.

Material and Method

Twenty patients who presented at the emergency department and underwent radiologic investigation at the emergency department of KCMH on August 17, 2015, were included in the present study. Two critically injured patients, who were directly transported to the operating room without undergoing initial imaging evaluation at the emergency department, were excluded from the study. Five patients, who did

Correspondence to:
Yuenyongsinchai K. 25/33 Wutthakat Road, Thalat Phlu, Thonburi, Bangkok 10600, Thailand.
Phone: +66-85-8027445
E-mail: kampon.y@hotmail.com

not undergo any radiologic investigation, were also excluded.

The Institutional Review Board approval was obtained with waiver of informed consent for the retrospective medical record and imaging review. The clinical information and imaging findings were retrospectively reviewed from the medical record and Picture Archiving and Communication Systems (PACs).

The imaging findings of these patients were evaluated for radiologic findings of primary, secondary, tertiary, and quaternary blast injuries[1,3,6-9].

• Primary blast injuries were caused by the direct effect of an overpressure wave, affecting air-filled structures, for example: lung, middle ear, and hollow viscus organ of the gastrointestinal tract.

• Secondary blast injuries were injuries from flying debris, including objects that were intentionally included in the device or those that were propelled as part of the blast effect. The presence of shrapnel fragments with or without fracture had prompted the diagnosis of secondary blast injuries.

• Tertiary blast injuries occured when the victims themselves were thrown by the blast wind of the explosion and subsequently collided with nearby objects, which could cause both penetrating and blunt injuries. The presence of fractures without evidence of soft tissue breach or shrapnel fragment was considered diagnostic of tertiary blast injuries.

• Quaternary blast injuries encompassed all other injuries caused by explosions. These lesions included burn, inhalations injury, chemical or radioactive exposure, asphyxia, and exacerbation of the victim's underlying medical condition, for example, asthma, chronic obstructive pulmonary disease, and angina.

The medical records were also reviewed for additional information, for example, physical examination and the patient's underlying condition.

The statistical analysis was described using percentile for categorical data and mean for continuous data.

Ethical considerations

The Institutional Review Board of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand had approved the study (IRB No.155/59), which was to be carried out in compliance with the International Guidelines for Human Research Protection as declared of Helsinki, the Belmont Report, Council for International Organizations of Medical Sciences (CIOMS) Guideline and International Conference on Harmonization in Good Clinical Practice (ICH-GCP).

Results

The age of the patients included in the present study ranged from 11 to 62 years (mean ± SD = 35.0±14.9 years). There were twelve men and eight women. The first patient presented at the emergency department 30 minutes after explosion. Fourteen patients arrived at the emergency department within one hour from the blast incident, and six patients arrived between one and two hours. Fifteen patients were admitted, and five patients were treated as outpatient.

On the date of blast incident, at the emergency department, conventional radiography was performed in 17 patients, included 82 studies, primarily of the extremities and chest (Table 1). Computed tomography (CT) scan was performed in 10 patients, included 33 studies (Table 2). Focused assessment with sonography for trauma (FAST) to detect free fluid was done at bedside by the clinician. No magnetic resonance imaging or ultrasonography was requested on that day.

Primary blast injuries

Tympanic membrane perforation was found in five patients (25%), and hemotympanum was

Table 1. Type and number of conventional radiography performed in 17 patients at KCMH in response to the 2015 Bangkok bombing

Type of conventional radiography	Number (%)
Skull	1 (1.2)
C spine	1 (1.2)
L-S spine	1 (1.2)
Ribs	1 (1.2)
Acute abdomen	1 (1.2)
T-L spine	3 (3.7)
Arm	3 (3.7)
Forearm	3 (3.7)
Knee	4 (4.9)
Ankle	4 (4.9)
Shoulder	5 (6.1)
Pelvis	11 (13.4)
Leg	11 (13.4)
Chest	16 (19.5)
Thigh	17 (20.7)
Total	82 (100)

C = cervical; L-S = lumbosacral; T-L = thoracolumbar; KCMH = King Chulalongkorn Memorial Hospital

Fig. 1 The conventional radiography of left leg, lateral view, of a 62-year-old male patient showed open comminuted displaced fractures of left tibia and fibula with multiple metallic fragments (arrow) and a screw (arrowhead). These lesions were categorized as secondary blast injuries.

Fig. 2 The conventional radiography of left leg, anteroposterior view, of a 28-year-old female patient showed a ball bearing (arrow) in soft tissue at lateral aspect of left upper leg. No fracture or dislocation was observed.

detected in three patients (15%). Blast lung injury was observed in one patient, presenting with pneumothorax without penetrating wound or rib fracture. There was no case of bowel perforation in the study group.

Secondary blast injuries

Shrapnel fragments were identified on conventional radiography and CT scan in 16 of 20 patients (80%). In each of these 16 patients, the number of foreign bodies ranged from 1 to 61, with 173 shrapnel fragments identified. The type and number of shrapnel fragments identified included 155 metallic fragments, 15 ball bearings, one screw, and two others (glass and plastic) (Fig. 1, 2).

The shrapnel fragments were identified most often in leg (37.0%) and thigh (35.5%). The soft tissue of lower extremities and pelvis (Fig. 3) accounted for 134 (77.5%) of the 173 shrapnel fragments (Table 3). Shrapnel fragments were identified in the brain in one patient (Fig. 4) and the thoracic cavity in three patients (Fig. 5). None of the shrapnel fragment penetrated peritoneal cavity.

Fractures were seen in six patients, at femur, tibia, fibula, metatarsal and phalangeal bones of foot, humerus, rib, and transverse process of one thoracic vertebra. Most of these fractures, except the metatarsal and phalangeal bone, had shrapnel fragments near the fracture sites and were classified as secondary blast injuries (Fig. 1).

Table 2. Type and number of CT scan performed in 10 patients at KCMH in response to the 2015 Bangkok bombing

Type of CT scan	Number (%)
CTA (thoracic aorta)	1 (3.0)
CT cervical spine	4 (12.1)
CT brain	5 (15.2)
CT chest	7 (21.2)
CT upper abdomen	8 (24.2)
CT lower abdomen	8 (24.2)
Total	33 (100)

CT = computed tomography; CTA = CT angiography

Tertiary and quaternary blast injuries

Without evidence of skin breach or shrapnel fragment, the metatarsal and phalangeal bone fractures, seen in one patient, were classified as tertiary blast

Fig. 3 The axial-oblique image of noncontrast MDCT scan of the lower pelvis of a 21-year-old male patient showed a ball bearing (arrow) abutting right bulbocavernosus muscle with hemorrhagic tract (arrowhead) from lateral aspect of right thigh through right tensor fascia lata, right vastus lateralis and right rectus femoris muscles. The hemorrhagic tract was just anterior to right superficial femoral artery (black arrow).

Fig. 4 The axial noncontrast MDCT scan of the brain in a 22-year-old male patient showed a ball bearing at right anterior interhemispheric region (white arrow) with intraparenchymal hemorrhagic tract (white arrowhead) from right parietal lobe to right frontal lobe. There was comminuted right parietal bone fracture with multiple bone fragments in right parietal lobe. Subdural hematoma at right fronto-parietal convexity (black arrow), pneumocephalus (black arrow head) and midline shift were also observed.

injuries (Fig. 6). The other nine patients (45%) had physical findings of skin abrasion, contusion, and laceration wound.

Five patients (20%) had skin burn, and two patients (10%) had signs of inhalation injuries, which were categorized as quaternary blast injuries.

Discussion

On August 17, 2015, after the bombing took place, hospital personnel were notified by a variety of means to be alert and prepared. Current emergency department patients were rapidly admitted to inpatient units or discharged home to build capacity for the incoming patients.

Table 3. Location and number of shrapnel fragment found on radiologic evaluation

Location of shrapnel fragment	Number (%)
Shoulder	2 (1.2)
Foot	3 (1.7)
Head	4 (2.3)
Forearm	4 (2.3)
Abdomen	4 (2.3)
Neck	7 (4.0)
Arm	7 (4.0)
Pelvis	9 (5.2)
Chest	11 (6.4)
Thigh	58 (33.5)
Leg	64 (37.0)
Total	173 (100)

For radiology department, all of the elective and non-urgent patients scheduled for imaging on CT scanners or nearby fixed radiographic units were cleared to create additional capacity for the incoming patients. The radiologists, radiology residents, and technicians who were nearby the hospital came to the emergency department to aid in image acquisition and rapid, real-time interpretation. Many radiologists were stationed in the CT scanner area in the emergency department to provide real-time protocol and verbal interpretations of important radiologic findings.

Conventional radiography and CT scan are the imaging modalities of choice in the acute blast setting because images can be quickly acquired and can readily detect fractures as well as foreign bodies that are embedded in the body[1]. Like the other studies, no magnetic resonance imaging or ultrasonography was needed on the day of the bombing[1,10]. In spite of its excellent soft tissue resolution, magnetic resonance imaging is not indicated in the acute blast setting owing

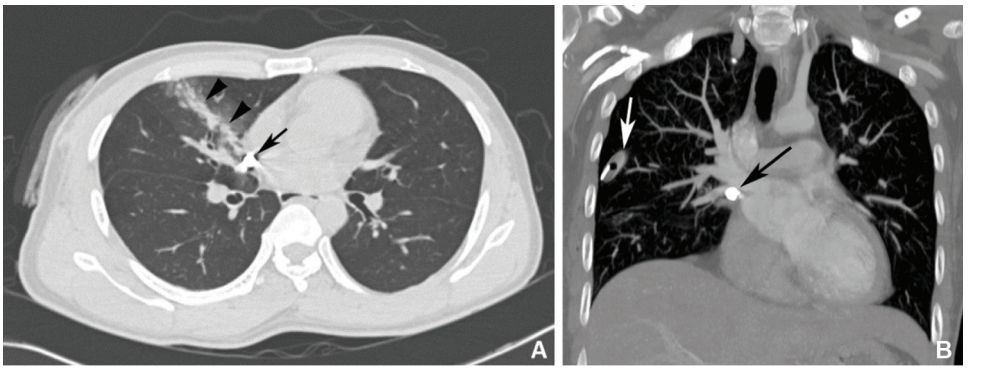

Fig. 5 The axial-oblique (A) and coronal (B) MDCT scan of the chest in a 37-year-old male patient showed a ball bearing (black arrow in A and B) just inferior to right superior pulmonary vein. Tract of lung laceration and contusion was observed in the right middle lobe (black arrowhead in A). Right pneumothorax was detected (not shown), and insertion of right intercostal drainage tube was done (white arrow in B). No contrast extravasation was demonstrated in the delayed phase MDCT scan (not shown). Eventually, the foreign body in this patient was not removed.

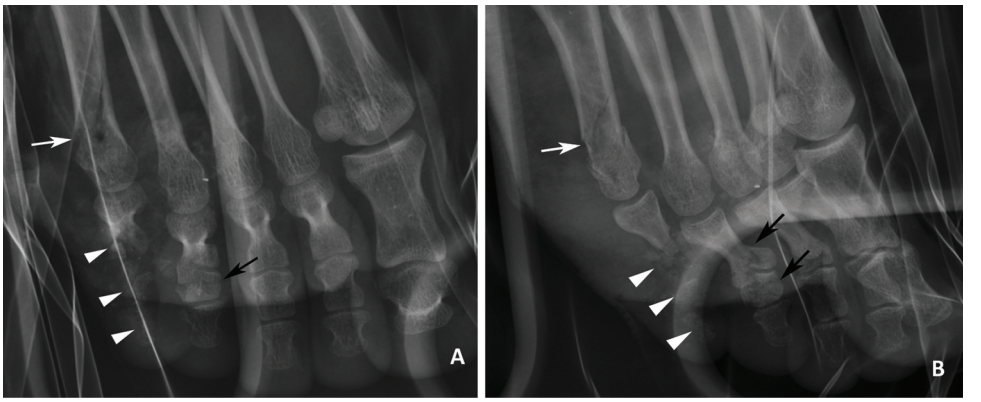

Fig. 6 The conventional radiography of right ankle, AP (A) and oblique (B) views, in a 37-year-old female patient showed spiral fracture of the fifth metatarsal shaft (white arrow) and comminuted fractures of proximal, middle and distal phalanges of the fifth toe (white arrowhead) and proximal and middle phalanges of the fourth toe (black arrow). No sharpnel fragment was identified near the fracture site. These lesions were categorized as tertiary blast injuries.

to the high likelihood of presence of metallic foreign bodies and longer acquisition time compared to CT scan. Likewise, ultrasonography is of limited value in this setting due to longer scan time and its inability to assess deep structures and a large area of interest simultaneously[1].

Blast injuries have the potential to cause soft tissue as well as skeletal injuries from either blast wave, shrapnel fragment, or blast wind[7].

Primary blast injuries are caused by a blast wave produced by the explosion (i.e., the rapid conversion of a solid or liquid to a gas, resulting in a sudden release of energy)[3]. These injuries potentially cause damages to the air-containing organs, for example, middle ear, lung, and hollow abdominal viscera (e.g., colon). Entrapped gases in hollow organ compress and then expand rapidly, resulting in visceral organ disruption[3].

Tympanic membrane rupture is the most common primary blast injury[9]. The relatively low positive pressure wave of five pounds per square inch (psi) can damage the tympanic membrane (1 atm is equal to 760 mmHg or 14.7 psi). The other acoustic barotrauma that can be found in the patient with primary blast injuries includes hemotympanum and ear ossicle disruption.

Damage to the lung and bowel requires relatively higher pressures of 56 to 76 psi (3.8 to 5.2 atm)[3,6]. Blast lung injury can occur without external chest wall injury and is caused by the overpressure primary blast wave pushing the chest wall towards the spine, causing transient high intrathoracic

pressure. This effect can lead to pulmonary contusion, hemothorax, pneumothorax, traumatic emphysema, bronchopleural fistula, and acute gas embolism. Due to containing most of the air in abdomen, colon is the most common site of hemorrhage and perforation from primary blast injuries.

In the present study, there were five patients (25%) with tympanic membrane perforation and three patients (15%) with hemotympanum. The acoustic barotrauma rate had been variously reported to range from 9% to 47% in different studies[7,11-13].

Blast lung injury was observed in one patient who had pneumothorax without external wound or rib fracture. No bowel injury from the primary blast wave was observed. The reason for low incidence of primary blast lung and bowel injuries in the present study was probably due to be the open space where the explosion took place. The explosion in open space produces lower morbidity and mortality than the explosion in confined space, resulted in lower incidence of primary blast injuries[3,5,6].

Secondary blast injuries are injuries from shrapnel fragments, either included in the container intentionally, created by the destruction of the container itself or from the surrounding environment, which are traveling at a high-speed to the patients[3]. The radiologic evaluation of secondary blast injuries involves identification of the shrapnel fragments and associated soft tissue and skeletal injuries caused by the penetrating force[7,8]. Because the shrapnel fragments follow unpredictable paths through the body and may have only minimal external wound, some authors suggest performing CT scan in all patients with penetrating shrapnel injuries caused by an explosion[2].

Sixteen of 20 patients in the present study (80%) had secondary blast injuries. This result is consistent with the results from other studies, that secondary blast injury is the most common cause of explosion-related injury[5,7,8,10,14]. Because the explosive devices were placed on the ground, most of shrapnel fragments in the present study were found in soft tissue of lower extremities and pelvis. Many other studies also showed the predilection of lower extremity injuries from secondary blast injuries[7,11,15,16].

Tertiary blast injuries occur when the victims themselves are thrown by the blast wind and subsequently collide with the nearby objects, which can range from simple bruise and abrasion to traumatic amputation[3,6-8]. One patient in the present study had metatarsal and phalangeal fractures without external wound or foreign body near the fracture site, categorized as tertiary blast injuries. Skin abrasion, contusion and laceration wound were found in nine patients (45%).

Quaternary blast injuries encompass all other injuries caused by explosions, including burn, inhalations injury, chemical or radioactive exposure, and exacerbation of the victim's underlying medical condition[3,6,7]. In the present study, five patients (25%) had burn injuries. Two patients (10%) showed signs of inhalation injuries, which required endotracheal intubation and emergency cricothyroidotomy at the emergency department.

The potential bias and limitation of the present study were exclusion of more severely injured patients, who were directly transported to the operating room without undergoing initial radiologic evaluation, in the study group.

Conclusion

The radiologic findings of blast injuries in the 2015 Bangkok bombing were predominantly from secondary blast injuries, and most of the shrapnel fragments were found in soft tissue of lower extremities and pelvis.

Extensive use of radiologic investigation in this incident confirms its role in initial management and triage by assisting to determine which patients need immediate surgery and which patients can be treated conservatively. With competency in seeking out and recognizing the spectrum of injuries that can potentially be inflicted by the explosion, the radiologist plays an important role in a multidisciplinary team of emergency department to reduce morbidity and mortality of the blast victims.

What is already known on this topic?

Terrorism in urban setting with many casualties like this event for Thailand is quite rare, and no original research about this topic has been conducted before.

What this study adds?

This study is conducted to share the knowledge of radiologic findings that can be found in blast injuries, for the radiologist, emergency physician, traumatologist, and other medical personnel.

Potential conflicts of interest

None.

References

1. Guermazi A, Hayashi D, Smith SE, Palmer W, Katz JN. Imaging of blast injuries to the lower

extremities sustained in the Boston marathon bombing. Arthritis Care Res (Hoboken) 2013; 65: 1893-8.
2. Sosna J, Sella T, Shaham D, Shapira SC, Rivkind A, Bloom AI, et al. Facing the new threats of terrorism: radiologists' perspectives based on experience in Israel. Radiology 2005; 237: 28-36.
3. Lemonick DM. Bombings and blast injuries: A primer for physicians. Am J Clin Med Res 2011; 8: 134-40.
4. Bangkok Post. Bomb toll revised: 20 dead, 125 injured [Internet]. 2015 [updated 18 Aug 2015; cited 6 Dec 2015]. Available from: http://www.bangkokpost.com/archive/bomb-toll-revised-20-dead-125-injured/659848
5. Hare SS, Goddard I, Ward P, Naraghi A, Dick EA. The radiological management of bomb blast injury. Clin Radiol 2007; 62: 1-9.
6. Peleg K, Aharonson-Daniel L. Blast injuries. N Engl J Med 2005; 352: 2651-3.
7. Singh AK, Goralnick E, Velmahos G, Biddinger PD, Gates J, Sodickson A. Radiologic features of injuries from the Boston Marathon bombing at three hospitals. AJR Am J Roentgenol 2014; 203: 235-9.
8. Benjaminov O, Sklair-Levy M, Rivkind A, Cohen M, Bar-Tal G, Stein M. Role of radiology in evaluation of terror attack victims. AJR Am J Roentgenol 2006; 187: 609-16.
9. Centers for Disease Control and Prevention. Blast injuries: essential facts [Internet]. 2008 [updated 25 Mar 2008; cited 6 Dec 2015]. Available from: https://emergency.cdc.gov/masscasualties/pdf/blastinjuries.pdf
10. Nye PJ, Tytle TL, Jarman RN, Eaton BG. The role of radiology in the Oklahoma City bombing. Radiology 1996; 200: 541-3.
11. Ritenour AE, Baskin TW. Primary blast injury: update on diagnosis and treatment. Crit Care Med 2008; 36 (7 Suppl): S311-7.
12. Almogy G, Luria T, Richter E, Pizov R, Bdolah-Abram T, Mintz Y, et al. Can external signs of trauma guide management?: Lessons learned from suicide bombing attacks in Israel. Arch Surg 2005; 140: 390-3.
13. Mellor SG, Cooper GJ. Analysis of 828 servicemen killed or injured by explosion in Northern Ireland 1970-84: the Hostile Action Casualty System. Br J Surg 1989; 76: 1006-10.
14. Brunner J, Rocha TC, Chudgar AA, Goralnick E, Havens JM, Raja AS, et al. The Boston Marathon bombing: after-action review of the Brigham and Women's Hospital emergency radiology response. Radiology 2014; 273: 78-87.
15. Edwards DS, McMenemy L, Stapley SA, Patel HD, Clasper JC. 40 years of terrorist bombings - A meta-analysis of the casualty and injury profile. Injury 2016; 47: 646-52.
16. Walsh RM, Pracy JP, Huggon AM, Gleeson MJ. Bomb blast injuries to the ear: the London Bridge incident series. J Accid Emerg Med 1995; 12: 194-8.

สิ่งตรวจพบทางรังสีวิทยาจากเหตุระเบิดในกรุงเทพมหานคร พ.ศ. 2558

กัมพล ยืนยงสินชัย, ธนิศา ทองใบ, ธีรชัย ชัยทัศนีย์, ณัฐพร ตั่นเผ่าพงษ์, น้ำผึ้ง นำการุญอรุณโรจน์, ปานฤทัย ตรีนวรัตน์

วัตถุประสงค์: *เพื่อศึกษาสิ่งตรวจพบทางรังสีวิทยาจากเหตุระเบิดในกรุงเทพมหานคร พ.ศ. 2558 โดยแยกตามกลไกการได้รับบาดเจ็บจากระเบิดเป็นชนิดปฐมภูมิ ทุติยภูมิ ตติยภูมิ และจตุรภูมิ*

วัสดุและวิธีการ: *เก็บข้อมูลย้อนหลังจากเวชระเบียนและระบบ picture archiving and communication systems (PACS) ของผู้ป่วยที่ได้รับบาดเจ็บจากเหตุระเบิดในกรุงเทพมหานคร พ.ศ. 2558 และได้รับการส่งตรวจทางรังสีวิทยาเบื้องต้นที่ห้องฉุกเฉิน จำนวน 20 ราย*

ผลการศึกษา: *การตรวจทางรังสีวิทยาด้วย conventional radiography และ CT scan เป็นการตรวจที่เหมาะสมที่สุดสำหรับเหตุการณ์ระเบิด พบการบาดเจ็บจากระเบิดชนิดปฐมภูมิบริเวณหูชั้นกลางในผู้ป่วย 8 ราย และบริเวณทรวงอกในผู้ป่วย 1 ราย พบสะเก็ดระเบิดจากการตรวจทางรังสีวิทยาในผู้ป่วย 16 ราย จาก 20 ราย รวมทั้งสิ้น 173 ชิ้น โดยส่วนใหญ่พบอยู่ที่บริเวณขาและเชิงกราน (ร้อยละ 77.5) พบผู้ป่วยที่มีกระดูกหักจำนวน 6 ราย โดยส่วนใหญ่จัดอยู่ในการบาดเจ็บจากระเบิดชนิดทุติยภูมิ พบผู้ป่วย 5 ราย ที่มีการบาดเจ็บบริเวณผิวหนังจากความร้อน และพบผู้ป่วย 2 ราย มีการบาดเจ็บจากการสูดสำลักควัน*

สรุป: *สิ่งตรวจพบทางรังสีวิทยาจากเหตุระเบิดในกรุงเทพมหานคร พ.ศ. 2558 ส่วนใหญ่เกิดจากกลไกการได้รับบาดเจ็บจากระเบิดชนิดทุติยภูมิ และสะเก็ดระเบิดส่วนใหญ่พบอยู่ที่บริเวณขาและเชิงกราน*