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ORIGINAL ARTICLE

The forensic imaging techniques of portable X-ray units used in render safe operations of improvised explosive devices (IEDs)

CrossMark

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KEYWORDS

Video camera unit (VCU);
Control display unit (CDU);
Improvised explosive device (IED);
Distance;
Angle;
Pulse

Abstract In this study, it was aimed to get a proper image of the components, (battery, cable, firing mechanism, main charge etc.) of a $48 \times 35 \times 11$ cm simulated improvised explosive device (IED) placed into a suitcase, using appropriate X-ray beam angle, distance and pulse. A-600 portable X-ray imaging system (Vidisco Inc.) was used as the experiment equipment.

The imaging relation among the ray-source, video camera unit (VCU) and control display unit (CDU) was studied by using geometric formations to avoid shooting mistakes. The optimum shooting distance, angle and pulse parameters for simulated suitcase IED were determined in a closed environment under normal conditions. With the determined parameters, X-ray images were taken from three main directions to obtain a 2-dimension image of a 3-dimension substance. With the shootings from these main directions, the images taken onto the VCU were determined as square, rectangular and hexagonal. The picture enhancement techniques were also determined to avoid the blurring, enlargement and penumbra shadow on the images taken. It was concluded that the proper images of simulated IED placed in a suitcase were taken with 150 cm distance, 99 pulse and 90° main and 45°/135° supporting side angles.

1. Introduction

It is highly important for the bomb technicians and the forensic scientists to obtain and interpret the inner components of a suspected briefcase, box etc. by using a trustable and validated imaging method. For as long as the law enforcement agencies perform their duties during life threatening situations, it is a priority to get the image of the inner components prior to an engagement with it (1).

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The digital images taken by portable X ray units provide many advantages compared to the traditional X-ray imaging techniques with tablets (2). Digital imaging techniques enable the user to interpret the image in a short duration of time. Time consuming procedures of film developing and bathing in traditional method are no longer needed. Enlargement and polarization specialties provide enhancement for a better, faster and healthier image interpretation (3).

As a reality that today's terrorism techniques use more complex initiating systems, it is a high risk to intervene the suspected item without determining and understanding the initiation system type (4).

Law enforcement agencies and forensic services still have got a burden to define the initiation system of the IEDs. Despite that digital imaging technique is stated as a very safe and effective one, there is still a need to put validated imaging techniques and methods.

In this study, it was aimed to determine imaging techniques for IED render safe operations to enable the law enforcement agencies' intervention to the item to be more practical and efficient.

2. Materials and methods

2.1. Equipment

As equipment, A-600 Portable X-ray Unit (Israel, Vidisco) was used, a portable unit with three main components which are video camera unit (VCU), control display unit (CDU) and X-ray generator (5).

The VCU is a transit component of the unit which holds the image on its screen and transfers it to the CDU. Control display unit takes this image on its screen and saves it to enable a physical image examination being carried out (6).

XR200 (Golden Engineering Ltd., USA) which is an X-ray source was used. It produces 150 kwp level of energy in short intervals as of each 60 nano seconds. The energy produced by XR-200 was stated in manual that had the capacity to penetrate 1 cm (0.4 inch) steel. The produced dosage was also stated as so low compared to a fixed 1 mA X-ray source (7).

A suitcase with $48 \times 35 \times 11$ cm dimensions was used as the simulated IED. A dummy TNT cover as main charge, a training blasting cap, electronic card, cables and two switches simulated the IED inside the suitcase.

In this study, the X-ray unit was used according to the Turkish Atomic Energy Authority (TAEK) rules.

2.2. Method

In this study, $10 \times 10 \times 10$ cm steel was used as pre-testing material to establish the general geometric formations in radiographic techniques for IED imaging. It was aimed to put forward to establish proper shooting environment, shooting distances, shooting angle and X-ray pulse.

The simulated IED prepared into a suitcase was stationed in a closed environment under normal conditions (Photo 1).

It was decided to get better known the basic geometric formations in radiographic technique for a better understanding of the image taken. To define the geometric formations, $10 \times 10 \times 10$ cm steel cube was used. X-ray images were taken from three main directions to put forth the formations that would remain on the screen.

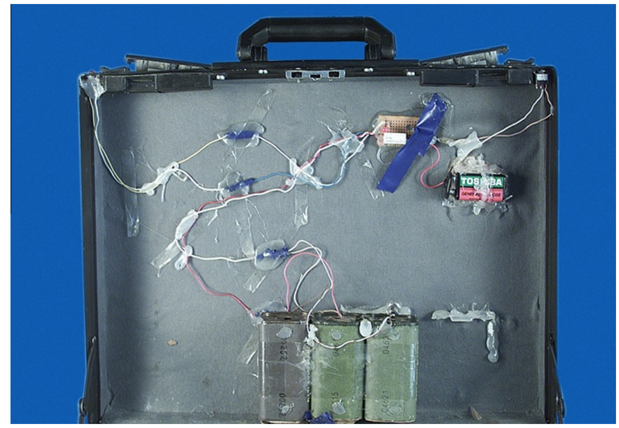


Photo 1 The inner view of on simulated IED inside a suitcase.

X-ray images were taken with a main angle of 90° and 45°/135° supporting side angles with 50, 100, and 150 cm distances. The optimum pulses for optimum image clarity were determined as 72p and 99p.

2.2.1. Shadowing

Shadowing is mainly based on getting a 2D image of a 3D substance on a flat surface. To establish the geometric formations, $10 \times 10 \times 10$ cm steel cube was X-rayed from the predefined main directions as A–C (Fig. 1).

The image of steel cube from the direction A was observed as square (Fig. 2 and X-ray image 1).

The image of steel cube from the direction B was observed as hexagonal (Fig. 3 and X-ray image 2).

The image of steel cube from the direction C was observed as rectangular (Fig. 4 and X-ray image 3).

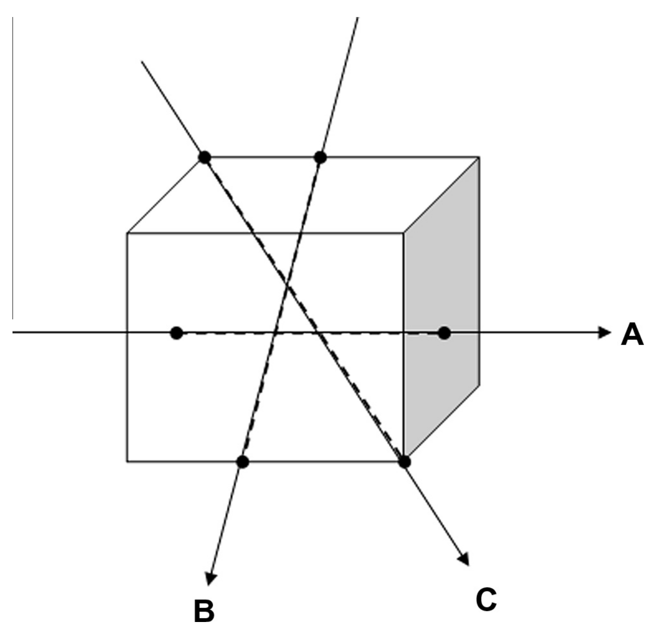
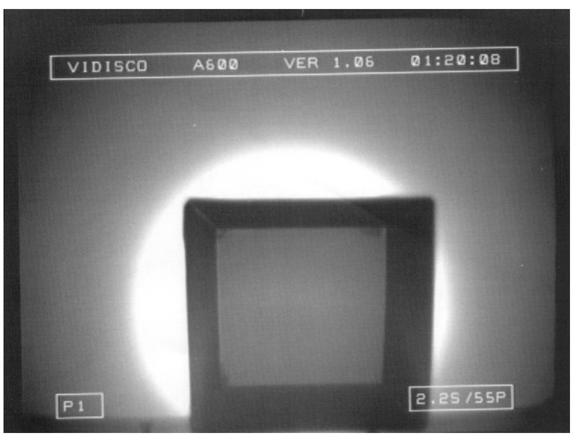


Fig. 1 Shadowing with main directions.

Fig. 2 Direction-A shadow.



X-ray image 1 X-ray image from direction A.

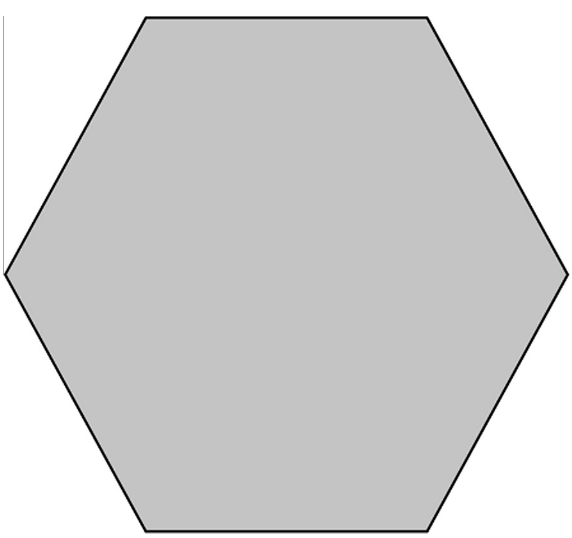
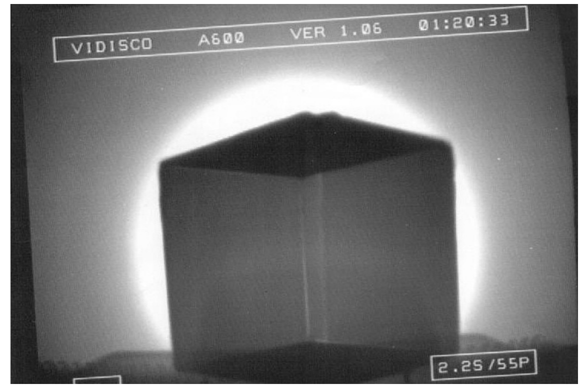


Fig. 3 B-direction shadow.

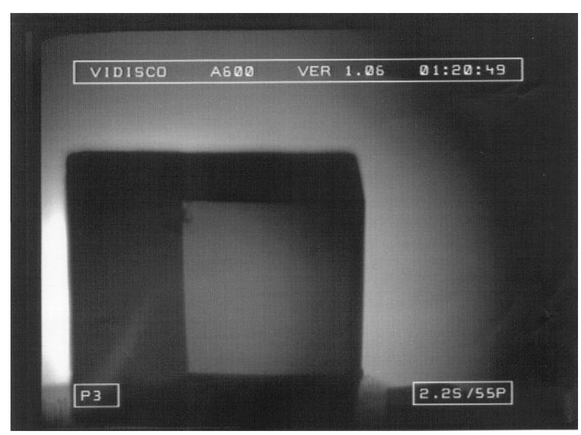
2.2.2. Size

X-ray sent from different angles directly affects the size of the image gathered on the screen. It was also observed that the



X-ray image 2 X-ray image from direction B.

Fig. 4 Direction-C shadow.



X-ray image 3 X-ray image from direction C.

X-ray image size was directly proportional to the distance of the item (IED) from the film (or VCU) (Fig. 5).

The distance between X-ray source and the film (or VCU) was increased and the item (ED) was placed slightly adjacent to the VCU. It was observed that the size deformation between the image and the item was relatively reduced. It was also concluded that the image would be blurred if the distance between the item and the VCU was big or/and a large angle focus was used (Fig. 6).

It was concluded that the image could be enhanced by using a smaller focus (Fig. 7).

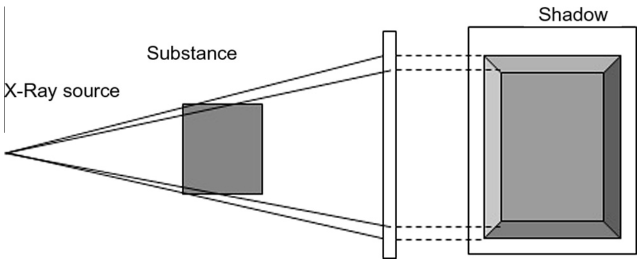


Fig. 5 Size.

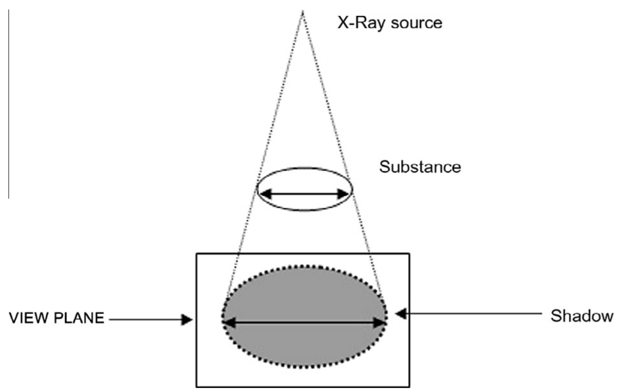


Fig. 6 Blurred picture.

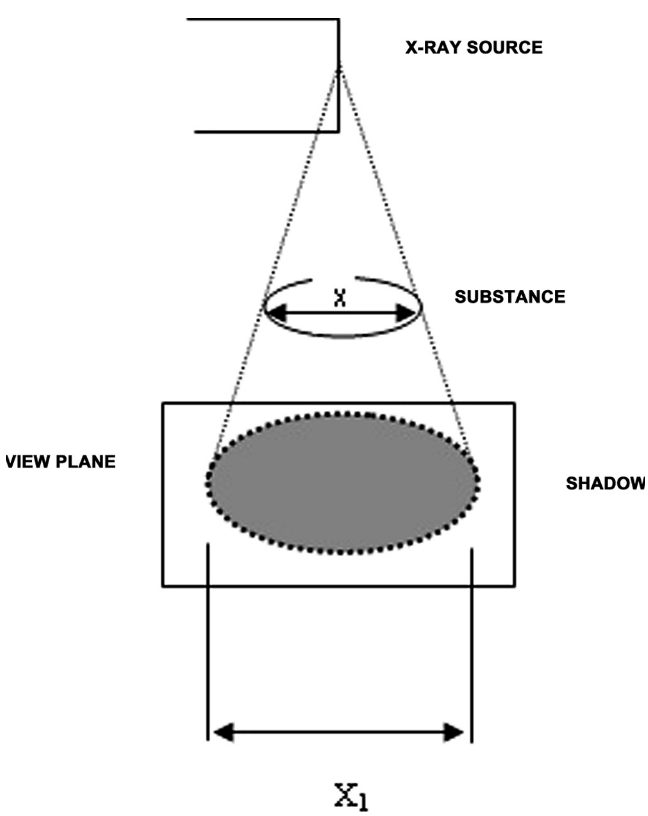


Fig. 7 Picture enhancement.

It was experimentally determined that optimum quality images are taken by using smaller focus and the possible adjacent distance of item to the film (VCU) (Fig. 8).

Despite that the film (or VCU) and the item were parallel to each other, a real image enlargement was observed if the X-ray beam was sent a different angle but 90° (Fig. 9).

It was also determined that image enlargement was observed if the film (or VCU) and the item (IED) were not straight (90°) to each other (Fig. 10).

The items with angled corners (rough edges) were X-rayed through their mid points. The priming and functioning units of

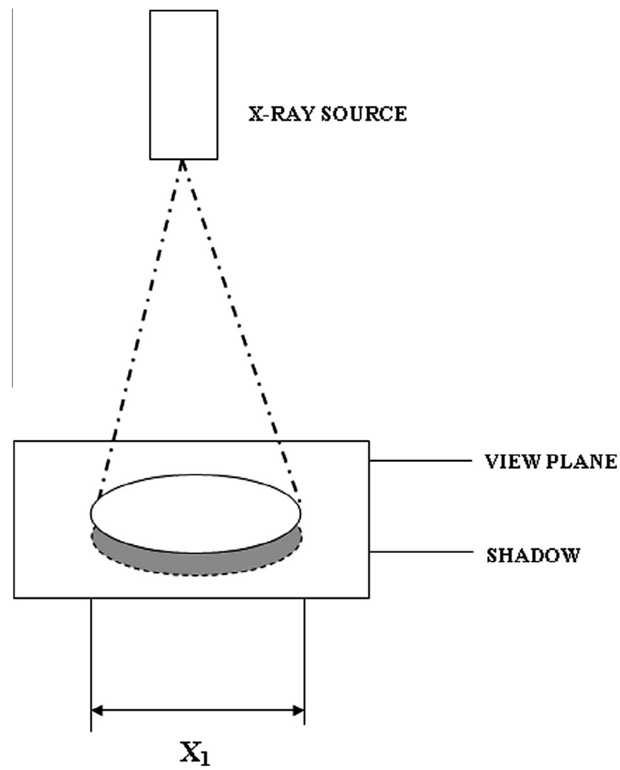


Fig. 8 Image with optimum quality.

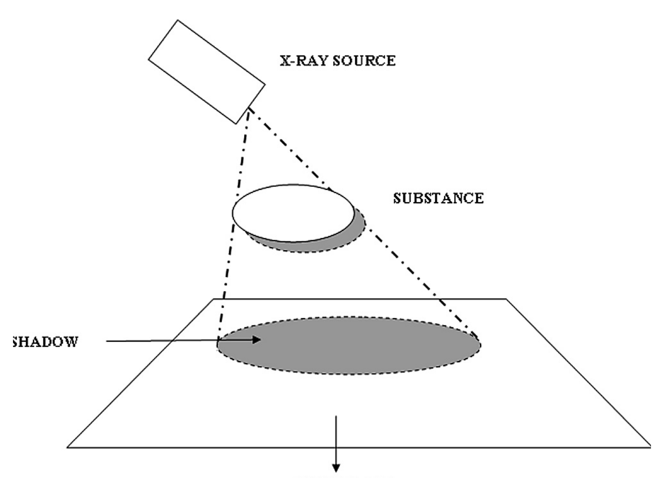


Fig. 9 Real image enlargement (1).

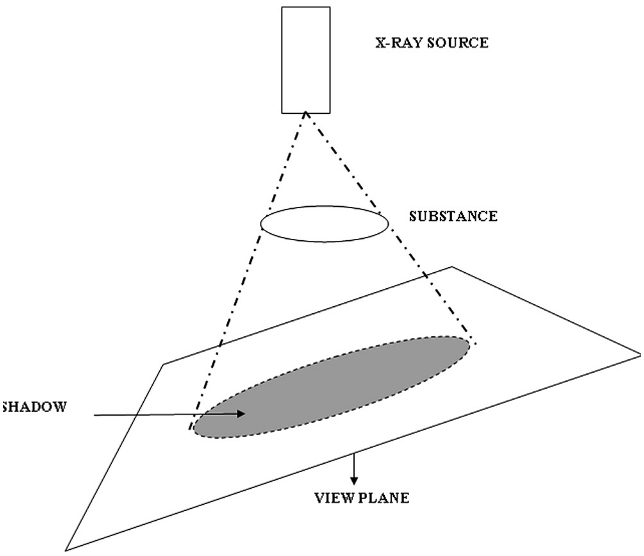


Fig. 10 Real image enlargement (2).

IEDs are generally fixed on a flat plane. It was determined that optimum clear image was obtained when the X-ray beam went through this plane in a perpendicular (90°) angle (Figs. 11 and 17), (X-ray image 4).

The length of the X-ray produces a shadow which overflows the normal shadow of the item which is called as penumbra shadow (Fig. 12). It was determined that penumbra shadow was mostly eliminated by reducing the distance between X-ray and the film (VCU) (Fig. 13.

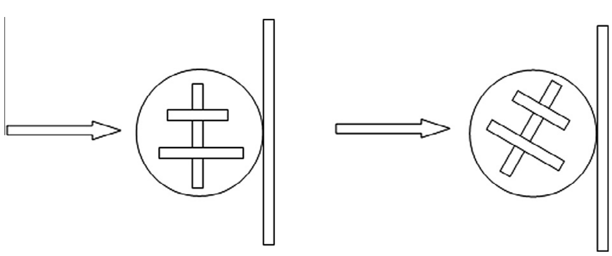


Fig. 11 Components' plane.

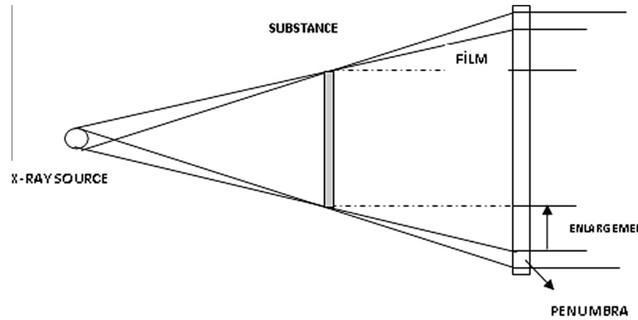


Fig. 12 Penumbra shadow.

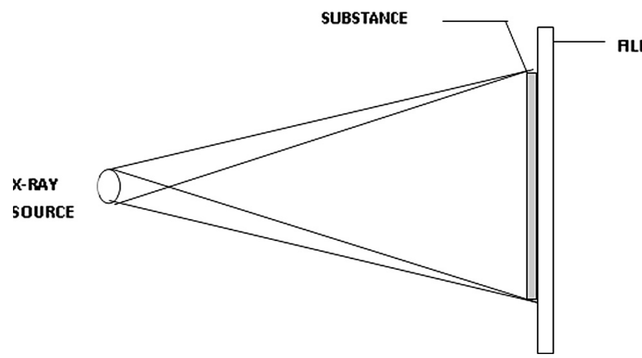


Fig. 13 Eliminating the penumbra shadow.

3. Results

The 90° angle shootings of the IED inside a suitcase with the pulse numbers and the distances are shown in Table 1, and the X-ray images are in X-ray images 5 and 6. In the trial shootings, it was distinguished that the full image of IED was not taken to the screen with 72 pulses from 50 and 100 cm. Then it was decided to take X-ray images with the distances 100 and 150 cm with the shootings of 99 pulses.

The X-ray shootings were done with 90° and 50, 100, 150 and 190 cm distances. The pulses used were 72p and 99p. It was considered the full image of the suitcase was not viewed on the screen with the distances less than 150 cm.

It was tried to get X-ray images from 75, 100 and 150 cm with different pulses and angles. It was observed that there

X-ray image 4 Components' plane.

Table 1 90° Shootings of IED inside a suitcase.

X-ray pulse (*p*)	Shooting distance (cm)			
	50	100	150	190
72			X	X
99	X	X	X	X

X-ray image 5 The X-ray image with 90°, 99 p and 190 cm distance.

X-ray image 6 The X-ray image with 90°, 99 p and 150 cm distance.

was much blurring and shadow on the images taken with 30° and 150°.

Then it was decided to maintain the minimum distance as 150 cm. The trials to get the optimum quality image with X-ray beam pulses were carried out with the predetermined pulses. 99 pulses were distinguished as the optimum pulse.

The shooting distances, pulses and various angles of the IED in a Suitcase are in Table 2 and the X-ray pictures are shown in X-ray images 7, 8 and 9.

It was experimentally concluded that the images taken from a suitcase with IED inside are of optimum quality to interpret the components with 99 pulse, 150 cm distance and 90° main angle. Supporting side angle shootings of 45° and 135° were distinguished as slightly shadowed. But it was understood that the side angle shootings were important to get an overall image of the components to enable better interpretation.

Table 2 The X-ray shootings of IED in a suitcase with different angles.

Distance (CM)	Angle(°)				
	30°	45°	90°	135°	150°
190/72			X		
190/99		X	X	X	
150/99	X	X	X	X	X
100/72		X	X	X	
100/99		X	X	X	

X-ray image 7 X-ray image with 45°, 150 cm distance and 99 p.

X-ray image 8 X-ray image with 90°, 150 cm distance and 99 p.

X-ray image 9 X-ray image with 135°, 150 cm distance and 99 p.

4. Discussion

With the established general rules, the simulated IED inside a suitcase was X-rayed to get the inner components' images. It was aimed to have the best image which was clear and of optimum size.

During the IED render safe operations carried out by law enforcement agencies and forensic services, radiological screening techniques are widely used to get a better understanding of the initiation systems and to designate the intervention style.

In these operations, the purposes of the radiological screening techniques are summed up as;

a. To distinguish whether the suspected item was a real improvised explosive device.
b. To take necessary precautions to prevent the unnecessary damage to the government or personal properties if the suspected item was not a hoax.
c. To provide a permanent forensic evidence that the suspected item was/was not an IED.

In this study, the general radiographic techniques were applied to the simulated steel cube to put forth the geometric formations. The formations and the general rules established are;

a. The square, hexagonal and rectangular shapes were seen on the screen with the X-ray sent to a steel cube from 3 main directions.
b. There will be an observable enlargement on the X-ray picture if the distance between VCU and the IED is big. X-ray sent from different angles directly affects the size of the image gathered on the screen. It was also observed that the X-ray image size was directly proportional to the distance of the item (IED) from the film (or VCU). This can also cause a blurred image. This can be enhanced by holding the distance between the VCU and IED minimum
c. The X-ray image will be with the real picture enlargement if the X-ray sent from X-ray source is not straight (90°) to the IED.
d. The appropriate technique to get X-ray image of an item with different angled corners is to send X-ray through its mid line.
e. The mixed and blurred view will be reduced if the X-ray was sent 90° straight to the plane on which the IED fits.
f. The penumbra shadow will be reduced if the distance between X-ray source and VCU increases and the IED put adjacently closer to the VCU.

Conflict of interest

The authors have no conflict of interest to declare.

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