An audit of the provision of orthogonal projections in forensic radiography to assist in the location of ballistic evidence by the Irish State Pathologist

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Purpose

Forensic imaging includes conventional radiography, fluoroscopy and computed tomography [C.T.] which utilise ionising radiation to produce an image, and non-ionising modalities such as Magnetic Resonance Imaging [M.R.I.]. Brogdon (1998a) noted that radiographs were submitted as forensic evidence in the courts of law within two months of Wilhelm Roentgen's discovery of x-rays in 1895, thus recognising the connection between radiology and forensic medicine which has developed the "forensic-pathological radiological approach" to the investigation of the deceased. More than a century after the first use of x-rays in a medico-legal case, radiography is still considered as one of the "most important supplements of modern autopsy technology" (Ludwig, 2002).

The use of radiography is unparalleled when determining and documenting the existence, number, localisation and identification of foreign material inside the deceased prior to autopsy (Rainio et al., 2001). Whole-body imaging assists in the chain of forensic documentation when the investigative team are searching for projectiles or foreign bodies, especially in severely decomposed bodies (Thali et al., 2003). The radiographic images produced in such cases may be used to supplement evidential documents submitted in court.

According to Viner (Cowan and Hunt, 2008), the most obvious use of x-rays in a potentially homicidal death is to demonstrate the location of bullet(s) within the victim’s body. Ballistic and bony fragments can be visualised using conventional radiography in two planes, but "small foreign bodies or those located close to the base of the skull may be masked," and as a result, may be 'missed' by the Pathologist and/or Radiologist (Karger et al., 1998). Even if the bullet is recovered without the aid of radiography, ballistic fragments can easily be missed in an unaided dissection and important information such as the tract of the projectile may be lost to the ballistics expert. Any radiographs which are taken for the purpose of a forensic investigation must be retained as permanent records and, if required, used as exhibits or produced in court as evidence.

Post-mortem radiology can assist in locating the projectile, depicting the bullet track, and may help in identifying the ammunition and weapon type used by facilitating the removal of the ballistic evidence present (Andenmatten et al., 2008). Many authors (DiMaio, 1998, Messmer, 1998, Brogdon, 1998b) note that the Forensic Pathologist can use x-rays to evaluate gunshot wounds in several ways:

1. The location of the bullet - whilst this may seem straightforward from external inspection of the body, bullets often end up in a site far distant from the entry site, particularly if they have entered the circulatory system or have
struck bone. The natural curvature of the ribs and skull can cause bullets to change trajectory significantly.

2. X-rays will also reveal whether there are **bullets of a different calibre** present. This can be valuable in cases where multiple weapons are involved. The number of bullets is also important and must be correlated with the entrance and exit wounds. A discrepancy may lead to a search for bullets at the scene. More than one bullet may enter through a single entrance wound, particularly when automatic weapons are used.

3. X-rays may also reveal information about the **angle and direction of fire**. Small metallic fragments produced when a bullet strikes bone may lead directly to the bullet and clearly indicate the bullet’s path. Correlating this information with the scene of the crime helps recreate the relative positions of the victim and the assailant. While the type of weapon can frequently be determined by eyewitness reports or recovery of the weapon from the scene, the radiographs may reveal clues as to the type of weapon.

4. X-rays may be the first indication that a **crime** has been committed when decomposed bodies are discovered. The normal putrefaction that occurs, with its associated bloating of the tissues and deformity of the body, can easily mask an entrance wound. Bodies partially destroyed by fire or skeletonised remains should always be x-rayed to determine unsuspected foul play. Retrieval of the metallic fragments can even help in the identification of remains if there is a gunshot wound in the past history of the deceased.

Determining the direction of travel of projectile(s) in gunshot deaths is an essential aspect of the post-mortem examination (Straathof et al., 2000). If post-mortem changes [e.g. decomposition, post-mortem insect or animal activity] have altered the entry or exit wounds, determining the direction of fire can be very difficult for the Forensic Pathologist based on the external examination and/or the internal examination. Traditionally, conventional radiographs were acquired in forensic cases. However, this reduces a three-dimensional body to a two-dimensional image (Andenmatten et al., 2008), thus requiring a minimum of two radiographs from different angles, i.e. orthogonal projections, to facilitate the localisation of foreign bodies within the deceased in three-dimensions (Stockman et al., 2007). Two perpendicular projections are essential to determine the path of the bullet and to begin to assess potential tissue damage. This is very time-consuming in practice, particularly if imaging is performed outside the X-ray department, as multiple x-rays must be performed in suboptimal conditions. The imaging equipment available in the mortuary is often old or donated, and the mortuary facility is usually remote from the x-ray department where processing facilities are located.

Following discussion with Professor Marie Cassidy (2010) on the use of imaging as part of the post-mortem examinations performed in Ireland, it was realised that radiography is most commonly requested in cases of gun-related deaths. Druid (1997) noted that 57% of the homicide victims in his study sustained more than one gunshot, which is acknowledged to result in high morbidity and mortality (Fu et al., 2008).
Methods and Materials

Method:

- A total of 586 radiographic images in the possession of the Office of the State Pathologist were reviewed.
- 126 individual cases from 2000-2009 were identified.
- The 'Cause of Death' was established for each of these 126 cases by accessing each of the case files.
- 77 cases cited 'homicide involving firearms' as the Cause of Death.
- The radiographs for each of these cases were then reviewed to determine whether or not orthogonal projections were provided to the State Pathologist.
- The database of the Office of the Irish State Pathologist was searched and resulted in 152 victims between 2003 and 2009 whose primary 'Cause of Death' was due to 'gunshot injuries.'
Results

The aim of this study was to audit the radiographic images in the possession of the Office of the State Pathologist for cases in which the Cause of Death was attributed to gunshot injuries. 77 cases of gun-related deaths were included in this audit, which was the most common indication for forensic imaging to be performed. Therefore, the types of cases were limited so that the results of the audit would be statistically significant in relation to current practice.

A review of 586 x-ray films in the possession of the Office of the State Pathologist showed that there were 126 cases in which x-rays were retained by the State Pathologists from 2000 to 2009. Correlation with the individual case files revealed that 77 of these cases were in relation to homicides involving firearms. The database search of the Office of the Irish State Pathologist resulted in 152 victims between 2003 and 2009 whose primary 'Cause of Death' was due to 'gunshot injuries' being identified. The discrepancy between the results of the database and the actual cases where the State Pathologist has retained the x-rays relates to the fact that hard copies of the images are not required by the State Pathologist if there is no evidence of projectiles demonstrated. If there is no suggestion of retained ballistic material within the body of the deceased [i.e. if the number of entry wounds matches the number of exit wounds], forensic imaging will not be requested.

55 cases (Table 1) in the custody of the Irish State Pathology Service demonstrated the presence of a projectile on imaging. An audit of these images shows that in 68% of these cases (Figure 1), an orthogonal projection was not provided by the Radiographer to assist the Pathologist in the accurate and timely localisation of the projectile. The provision of a second projection, usually at 90°, is a fundamental requirement in radiography (Whitley et al., 2005, Carver and Carver, 2006).
**Table 1:** Audit of Forensic Imaging in Ireland 2000-2009, including provision of orthogonal projection  *CT = Computed Tomography examination performed  *FL = Fluoroscopic survey performed

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Fig. 1: Percentage of cases where orthogonal projections were provided to the Irish State Pathologist

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Conclusion

The diagnostic potential of radiography to the State Pathologist during the post-mortem examination of gun-shot victims is enhanced when orthogonal projections of the regions of interest are provided. As far back as 1982, Schmidt and Kallieris advocated taking x-rays of the skull in two planes. This facilitates the Pathologist in locating the bullets within the three-dimensional cavity of the human body, from the information provided by the two-dimensional radiographic images. In certain cases, retrieval of the ballistic evidence has been delayed by the Pathologist trying to 'blindly' locate the projectiles. This will have a direct and negative impact on the criminal investigation. Straathof et al. (2000) classified forensic radiographic images which only provided a projection in one plane as "inadequate radiography." The Radiologist's Reports for the radiographic images attached (Figures 2, 3, 4, 5) visually demonstrate the usefulness of accurate and/or additional information that can be provided when an orthogonal [e.g. lateral] projection is provided. With the A.P. projection alone, the presence of a projectile is identified but the perception of depth [i.e. the third dimension] is lacking until an orthogonal [e.g. lateral projection] is provided. This facilitates the accurate localisation of the projectile for rapid evidence collection which contributes positively to the forensic analysis by ballistics experts.

Harcke et al. (2007) discuss the attempt to overcome the limitations of conventional radiography, which represents three-dimensional structures on a two-dimensional image, by acquiring orthogonal projections. Whilst Pathologists may request these in specific circumstances, the practicality of achieving lateral projections of the torso can be very challenging in post-mortem imaging. This is particularly true in cases where rigor mortis is present. It is time-consuming to perform whole-body radiography, and it is difficult to achieve optimal image quality when performing post-mortem lateral projections. Experienced forensic Radiographers are necessary in order to optimise the imaging examination in this situation.

This audit has shown that orthogonal projections were provided to the Irish State Pathologist in a mere 32% of cases involving firearms to assist in the localisation of ballistic evidence. Therefore, education and training of Radiographers in Ireland who provide forensic radiography services needs to be improved so that the imaging provided is of benefit to the State Pathologist in the post-mortem examination, contributing to more timely localisation of ballistic evidence.
“Radiopaque foreign body with the appearances of a bullet projected over the C5 vertebral body just to the right of the midline.”

Fig. 2: AP radiograph of Skull & Cervical Spine with Radiologist's Report

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“Correlation is made with the AP view. The lateral view demonstrates that the previously described bullet lies within the tissues of the posterior neck, posterior to the spinous process of the C5 vertebral body.”

Fig. 3: Lateral radiograph of Cervical Spine with Radiologist's Report

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Fig. 4: AP radiograph of Chest with Radiologist's Report

“Radiopaque foreign body projected over the mediastinum is consistent with a bullet.”
“Correlation is made with the AP view. The lateral view demonstrates that the bullet is shown to lie posterior to the sternum in the anterior mediastinum.”

Fig. 5: Lateral radiograph of the Chest with Radiologist's Report

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