Radiography 22 (2016) 223–227

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Computed radiography versus indirect digital radiography for the detection of glass soft-tissue foreign bodies

N. Sheridan [a, b, *], J.P. McNulty [a]

[a] Radiography and Diagnostic Imaging, School of Medicine, University College Dublin, Health Sciences Centre, Belfield, Dublin 4, Ireland
[b] X-Ray (Radiology) Department, The Adelaide and Meath Hospital, Dublin, Incorporating the National Children's Hospital, Tallaght, Dublin 24, Ireland

ARTICLE INFO

Article history:
Received 28 July 2015
Received in revised form
29 January 2016
Accepted 13 February 2016
Available online 2 March 2016

Keywords:
Computed radiography
Digital radiography
Exposure factors
Foreign bodies
Soft-tissue

ABSTRACT

Aim: The principle aim of this study was to compare computed radiography (CR) and indirect, flat-panel, digital radiography (DR) for the visibility of radio-opaque glass foreign bodies.
Methods: An image-quality study was undertaken using a chicken thigh, as the soft-tissue model, implanted with varying sizes of glass particles (1 mm, 2 mm and 3 mm) which were imaged using CR and DR. Observers rated the acquired images based on the presence or absence and conspicuity of the foreign body. Ratings were then analysed in order to identify significance of any findings.
Results: CR (median = 4, interquartile range (IQR) = 1.0, $n = 240$) was found to be superior to DR (median = 3, IQR = 3.0, $n = 240$) in the detection of glass foreign bodies in soft-tissue ($p = 0.001$). Decreasing size of foreign bodies did not affect the performance of CR ($p = 0.298$), but did for DR with x^2 $(2, n = 240) = 12.22$, $p = 0.002$. The selected exposure factors were a limiting factor for DR but not for CR.
Conclusion: For the systems used in the current study, CR should be considered ahead of DR for glass particles less than 3 mm while for the larger glass particles either CR or DR is appropriate. Finally, careful consideration should be taken when selecting exposure factors for imaging foreign bodies.

Introduction

The detection and removal of embedded foreign bodies is often a difficult task, and foreign bodies within the soft-tissue are regularly undetected on first examination.[1] If undetected, there is a possibility of infection, long-term pain, deformities, and a reduction in functionality.[1] Wound trauma involving glass accounts for 13% of all cases presenting to the emergency department.[1] A 1997 US study identified glass as the most common foreign body retained after treatment and as a result these retained glass foreign bodies constituted 53% of malpractice claims according to a 7 year review of insurance claims records.[2] Misdiagnosis of retained glass can cause potential harm to a patient and it has been noted that missed glass foreign bodies can result in damage to nerves or adjacent blood vessels.[3] It is therefore of paramount importance that the most suitable imaging modality is used to detect and localise foreign bodies in order to ensure that removal will be as quick and accurate as possible, and that the patient will have minimal associated complications.

There have been many studies evaluating the accuracy of radiography and specialist techniques including ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) in the detection of foreign bodies.[4–6] However, no such studies have directly compared computed radiography (CR) and digital radiography (DR).

In order to compare overall clinical image quality of both imaging systems, observer performance studies are required. Visual grading analysis (VGA) is such an approach that can be used to determine the differences in image quality between two imaging systems.[7] Several studies have investigated the limitations in visualising glass foreign bodies, and the one resonating theme among all studies is that size is the main limiting factor in visualising glass on radiographic images.[8–10] A study in 1999 investigating the visualisation of glass on plain film radiographs, involving a cadaver foot, found that as the size of glass foreign bodies decreases, the detection rates also decrease.[9] The exact location of a foreign body can also be classified as a limitation especially when overlying bone in which case visibility can be affected.[8] These limitations could lead to a potential misdiagnosis for the patient, if the most appropriate imaging technique is not chosen.

* Corresponding author. Radiography and Diagnostic Imaging, School of Medicine, University College Dublin, Health Sciences Centre, Belfield, Dublin 4, Ireland. Tel.: +353 1 7166545.
E-mail addresses: nicolasheridan2411@gmail.com (N. Sheridan), jonathan.mcnulty@ucd.ie (J.P. McNulty).

http://dx.doi.org/10.1016/j.radi.2016.02.003
1078-8174/

The aim of this study was to compare CR and DR for the visibility of radio-opaque glass foreign bodies. A further objective of the study was to consider the influence of foreign body size and radiographic exposure factors.

Methods

Due to the challenges posed by using a cadaveric foot i.e. inherent rigidity and damage from repeat insertion and extraction of the foreign bodies, chicken thighs (containing bone, soft-tissue and skin) were chosen as the soft-tissue model. These have been employed in previous studies involving foreign bodies as soft-tissue models of the extremities as the muscle groups, bone, fat and skin, approximate the densities and characteristics of a human extremity.[4,5,10]

In order to assess the limits of visibility, shards of clear, unleaded, annealed glass were engineered to various sizes (3 mm, 2 mm and 1 mm) in a controlled environment. These sizes were selected based on past studies conducted using glass[4] with three sizes chosen to determine if there was a difference between CR and DR in displaying the foreign body based on decreasing foreign body size.

A ceiling suspended General Electric Maxiray 100 tube was used for all radiographic exposures (General Electric Company, Milwaukee, USA) powered by a GE JEDI 80 RD IT generator. The inherent filtration of this tube was 3.6 mm aluminium equivalent. The DR detector system used was the GE Revolution XR/d a Si-FPD which is based on a caesium iodide (CsI) scintillator (indirect conversion) (Table 1). A Kodak Direct View CR500 image processor and Kodak Direct View GP phosphor screen cassettes (Eastman Kodak Company, Rochester, New York), measuring 18 × 24 cm, were used to record the CR images (Table 1). Both systems were installed on the same centre in 2006. The X-ray system and both receptors had recently undergone routine quality assurance testing and were conforming to all required standards as per the Institute for Physics and Engineering in Medicine (IPEM) 2005.[11] These tests included kVp consistency and accuracy, dose output consistency, and for the CR and DR systems, uniformity, sensitivity, threshold contrast resolution and limiting spatial resolution.

Pilot study and image acquisition

An initial pilot study was undertaken under the same conditions as proposed for the study proper. The largest sized foreign body was used (3 mm) and the images were acquired, using CR and DR, while varying peak kilovoltage (kVp) and milliampere seconds (mAs) to maximise contrast resolution. A small incision was made into a raw chicken thigh, using a needle, to mimic the soft-tissue damage on insertion of the foreign bodies but no material was introduced. The chicken thigh was then placed on the detector and all other imaging parameters remained fixed with a source to image receptor distance (SID) of 100 cm, no anti-scatter radiation grid and a focal spot size of 0.6 mm. A radio-opaque marker was positioned over the area of incision, within the primary beam, as in clinical practice, when a patient indicates the approximate entry point or region where the foreign body is located. The sets of exposure factors chosen represented those used in previous, plain-film studies involving chicken thighs[6] and a total of twelve exposure combinations were used with kVp ranging from 40 to 55 and mAs ranging from 1.6 to 3.2. These images which did not contain a glass foreign body were all considered control images for the study proper. Next, a 3 mm piece of glass was placed along the tract made by the needle. The same imaging technique was applied as for the control images. Once again the area of insertion was indicated using a radio-opaque marker placed within the primary beam (Fig. 1). This amounted to forty-eight images in total, with antero-posterior (AP) and lateral projections, as per standard foreign body protocols, and was repeated for CR and DR. The default manufacturer post-processing algorithms for radiography of the hand were used for both CR and DR. These DICOM images were placed randomly into a PowerPoint presentation. The direct importation of DICOM images,

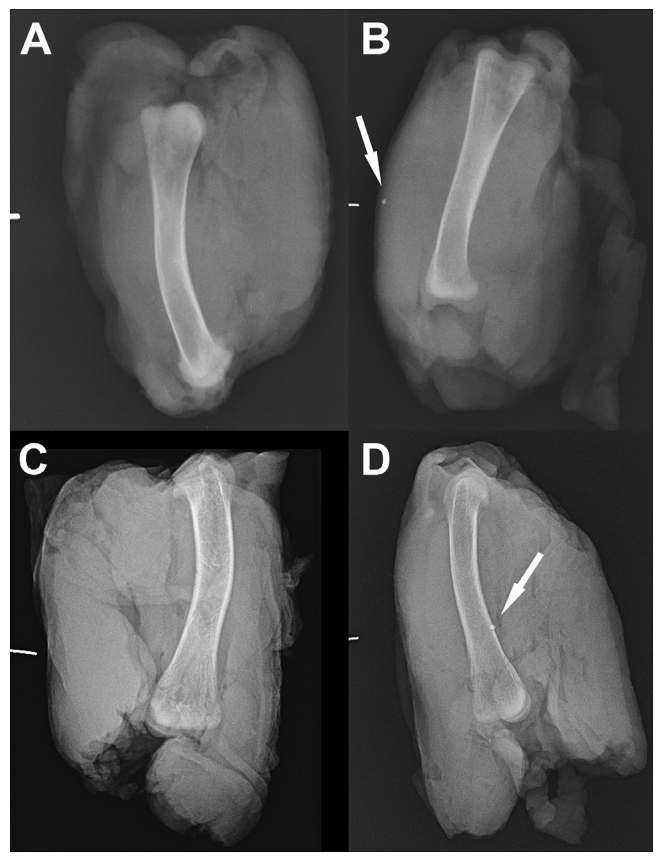

Figure 1. Sample images from study proper (Image A: computed radiography (CR) antero-posterior projection (control image), B: CR antero-posterior projection, C: indirect digital radiography (DR) lateral projection (control image), D: DR lateral projection (arrows indicate location of the 1 mm^3 glass foreign body).

Table 1
Specifications of General Electric Revolution XR/d a Si-FPD and the Kodak Direct View GP phosphor screen cassette.

General Electric Revolution XR/d a Si-FPD *(commercially available from 2001)*		Kodak Direct View GP phosphor screen cassette (*commercially available from 2003*)	
Feature	Specification	Feature	Specification
Detector	Caesium iodide scintillator	Screen	Phosphor
Readout	Thin film transistor matrix		
Detector dimensions	41 × 41 cm	Detector dimensions	18 × 24 cm
Pixel array	2048 × 2048	Pixel array	1792 × 2392
Pixel pitch	200 μm	Pixel pitch	100 μm