Improved fracture detection using the mammographic film-screen combination

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Received 12 April 2005; received in revised form 6 June 2005; accepted 10 June 2005

ABSTRACT

Aim: The single emulsion or single screen system is usually reserved for mammography since its use in general radiography is limited. The purpose of this study is to compare the mammographic film-screen combination (MFC) and the standard film-screen combination (SFC) in terms of fracture and soft tissue injuries detection.

Patients, methods and materials: In this prospective study, 41 patients from Accident and Emergency suspected of having injury in the hands, wrists, ankles and feet regions were radiographed using both MFC and SFC. These were compared in terms of image quality, presence of fractures and soft tissue injuries. The two different film-screen combinations were also compared in terms of detection of bony fragments, film characteristics such as film speed, contrast and spatial resolution, dose and cost.

Results: The MFC gives statistically better image quality compared to SFC. In 10% of patients, fractures were detected only in the MFC, which also detects tiny bone fragments that may not be resolved by the SFC.

The spatial resolution of the MFC is greater than the SFC. The film speed and contrast of the MFC are lower than that of the SFC. The doses of MFC were higher compared to SFC.

Conclusions: The MFC detects fractures better compared with SFC. However, the entrance skin dose for the mammographic film-screen combination was about 35% to 55% higher than the standard film-screen combination. © 2005 Biomedical Imaging and Intervention Journal. All rights reserved.

Keywords: Fracture, detection, film-screen combination, mammography

INTRODUCTION

Plain radiography is an important diagnostic tool in the Accident and Emergency Department (A&E). The effectiveness of the radiograph as a diagnostic tool is firstly dependent on good radiological quality and secondly on minimization of oversight in fracture detection. On admission, 23% of fractures are overlooked on initial radiographs by radiologists resulting in mismanagement of patients. Some of these fractures were missed because of technically inadequate X-rays while others with adequate X-rays had fractures that could not be identified on admission films [1]. Clearly, a higher quality radiograph could be instrumental in achieving higher rate of detection of fractures and soft tissue injuries and hence resulting in better management.

The purpose of this study is to compare both the detection of fractures and soft tissue injuries using a mammographic film-screen combination (MFC) and the standard film-screen combination (SFC). The abilities of these two film-screen systems in detecting fractured fragments in vivo are also analyzed. The characteristics of these two film-screen systems i.e. contrast, speed, spatial resolution, entrance skin dose as well as cost were compared.

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In vivo detection of bone fragments

A piece of cadaveric metacarpal bone was intentionally broken into fragments of different sizes to simulate bony fractures. These bone fragments were measured in length and width (mm) and suspended in a wax mould to approximate the soft tissue density of the extremities. This phantom was exposed using both MFC and SFC. The number and size of the fragments visualized in each type of film were noted and compared.

Assessment of film characteristics

The film characteristics i.e. the characteristic curve (H&D curve), speed, contrast, spatial resolution and dose of each film-screen combination were assessed as below.

Characteristic curve, speed and contrast – using a densitometer, an optical density versus step number graph were obtained for both single and double film-screen combination. From this the speed, contrast and base plus fog level were obtained.

Using a resolution metal bar test object manufactured by Nuclear Associates New York, Nr 86633, the two film-screen combinations were exposed. The spatial resolution for each system was then derived.

Using a dose meter, the radiation dose in terms of mGy/mAs was calculated for the different exposures. The entrance skin dose in mGy for each region was then obtained.

RESULTS

Image quality and detection of fractures and soft tissue injuries

The scores were tabulated and statistically analyzed using the Wilcoxon Signed Ranks Test [StatView software 5.0 (SAS Institute Inc. North Carolina)]. Hand and wrist radiographs were performed in 25 patients, ankle radiographs in 12 patients and foot radiograph in four patients. The hands and wrists were rated together as the size and thickness of these two regions are almost similar. The image quality of the MFC radiographs for the hands and wrists were statistically better (p<0.05) compared with the SFC radiographs (Figures 1a and 1b).

For the foot and ankle regions however, the difference in image quality of radiographs taken using the two different systems was not statistically significant.

In the 41 patients seen, fractures were detected in 20 patients, giving a detection rate of 48.8%. Both fractures and soft tissue injuries were statistically better detected (p<0.05) on MFC compared with SFC for the hand and wrist regions (Figures 2a and 2b). Again, the ankle and foot regions showed no statistical significance in depicting fractures and soft tissue injuries between the two film-screen combinations. Interestingly, in the 20 patients with fractures, two of these fractures were seen on the MFC but not on the SFC resulting in a 10% increase in the detection of fracture with MFC (Figures 3a and 3b).
Figure 1 Image quality was better on the (a) MFC radiograph compared with (b) SFC radiograph. Soft tissue and outline of carpal bones are better depicted in MFC radiograph as well. Note that break in the cortex at distal radius with overlapping of fracture outline (arrow) is better appreciated in the MFC radiograph.

Figure 2 Fracture at distal phalanx of the ring finger (arrow) was better outlined due to better spatial resolution in (a) MFC compared to (b) SFC.

Figure 3 Fracture at distal posterior tibia (arrow) was only seen on MFC image (a) but was missed on SFC image (b).

In-vivo detection of bone fragments

The MFC was able to resolve up to the second smallest fragment i.e. 0.7 mm × 1.0 mm whereas the SFC could only display up to the third smallest fragment measuring 1.0 mm × 2.0 mm. Furthermore the specks of bone in the centre were better appreciated in numbers and delineation on the MFC radiograph (Figures 4a and 4b).

Film characteristics

MFC and SFC was compared in terms of film curve, film contrast, film speed, spatial resolution, entrance skin dose and cost. The base plus fog levels of these two films were almost similar i.e. 0.27 for MFC and 0.25 for SFC. The curve of the single emulsion film is steeper than the double emulsion film. The contrast index of MFC is 1.53 while the contrast index for SFC is 1.88. These are comparable to the steepness of the different curves for the different film-screen combinations seen. The contrast of MFC is comparable to SFC up to the density of 3.0. At higher densities, the contrast of SFC is higher. The speed indices for MFC and SFC are 1.20 and 2.44 respectively.

Using the resolution bar test object, the spatial resolutions of both systems were attained. The spatial resolution of MFC is 10 lp/mm whereas the resolution of SFC is 6 lp/mm.

Figure 4 Images of bones intentionally broken then suspended in a phantom. Specks of bone fragments in the centre are better resolved in the MFC image (a) compared to the SFC image (b).
Why fractures are misdiagnosed is multifactorial. Attritions have been made to poor clinical inspection or failure on the part of physician to consider certain clinical entities [10], failure to request for appropriate radiographic views [11] or failure on part of clinician to recognize a fracture on the radiograph [12]. The quality of the radiographic image also plays a part in the misdiagnosis of fractures. Review of the literature shows there are no references made to the type of the film-screen combination used in these instances where fractures were missed. Since the double film-screen combination is the most conventional system, it is fair to assume that in these cases, a SFC was employed. SFC is commercially available, has a wide exposure latitude, is easy to process and the dose to patient is reduced due to less X-ray photons used. However, SFC due to its front and back luminescent screens, give rise to lack of image sharpness. MFC, on the other hand due to its high-resolution capabilities, would make a reasonable alternative.

In comparing SFC with MFC, it was found that MFC generally gave a better image quality. This is attributed to the higher spatial resolution of MFC resulting in clearer outlines of structure. The absence of the front screen in an MFC system decreased the parallax effect, which is responsible for producing a shift in the image on two sides of film [13]. Fractures and soft tissue injuries were also better seen on MFC, where 10% of these fractures were seen only on MFC. In these two cases, the doctors attending to these patients in the A&E were informed of the fractures and proper treatment was instituted. These patients under normal circumstances would have been discharged, only to subsequently return with increased morbidity. These findings have been confirmed by the in vivo study where MFC detected small fragments of bone and specks of calcification better than SFC. A study by Oestmann et al. revealed similar results when film geometry was similar i.e. no magnification [14]. This indicated that in a clinical setting, tiny bone fragments (from an avulsion fracture perhaps) would be better detected if MFC rather than SFC was used.

The shape of the H&D curve is usually independent of the screen used and is determined only by the characteristics of the film and the processing condition [13]. Although the mammographic film is usually processed using a dedicated 2.5 min processor in mammography, the film may be developed using the standard 90s processor. The base plus fog levels remained unchanged; while the speed and contrast indices were increased [15]. Film contrast is higher with SFC compared with MFC especially with densities higher than 3.0. This renders MFC with a narrow exposure latitude and thus there is not much flexibility in the exposures that can be used to form an image of optimal density. This is a major drawback, as accurate exposure factors need to be ensured before exposing the patient. This is difficult to determine as patients come in different sizes and shapes. This was not noticeable in the hand and wrist radiographs but proved detrimental in imaging of thicker parts such as the foot and ankles. Film
speed is higher for SFC compared with MFC. This is because removal of the front screen in MFC decreased the number of light phosphor being emitted from the screen, but this decreased the crossover exposure effect commonly seen with SFC, significantly increasing its resolution [13, 16]. A major drawback is the increased radiation dose with MFC. This is because of the decrease in speed, which therefore increased the exposure time. There is also a concomitant increase in kVp for MFC (about 20 kV higher). The other drawback of the MFC system is its cost. Although it is slightly more expensive than SFC [15], the huge number of radiographs exposed in a large hospital everyday may incur huge costs. There would also be added costs in having to purchase new cassettes for this endeavour. In addition, the types of single film available in a country such as ours, is limited.

The paediatric patients were excluded from the study, as the exposure factors required for imaging of paediatric group would be different. It would be interesting to document whether MFC could show fractures better in this group. The study had also been limited to the extremities of upper and lower limbs. Further work with the elbow and knee regions could be carried out. This could prove beneficial especially in the knee as a number of fractures and injuries in this region are difficult to diagnose and remain undetected on SFC. The ability of MFC to display fractures and soft tissue injuries could be compared with other imaging modalities that have been shown to be superior to plain radiographs such as bone scan and magnetic resonance imaging.

CONCLUSION

MFC gives better visualization in terms of image quality and fracture detection in the hand and wrist regions, compared with SFC. It also gives better detection of tiny bone fragments that may not be resolved by SFC. The film speed and contrast of MFC are lower than that of SFC. The spatial resolution of MFC is greater than SFC.

The radiation dose to the patient is however increased with MFC. Although radiation dose in imaging of the extremities is limited [15], patients confirmed to have fractures would need repeated radiographs and hence the radiation dose would add up considerably. Nevertheless, we believe that MFC would contribute significantly in reducing misdiagnosis of fractures as well as increasing the detection of avulsion injuries.

REFERENCES

1. Born, C.T., Ross, S.E., Iannacone et al. Delayed identification of skeletal injury in multisystem trauma. The “missed” fracture. Trauma 1989; 29:1643.
2. Britton C, Gabriele O, Chang T et al. Subjective quality assessment of computed radiography hand images. Jour Dig Imag 1996; 9: 21-4.
3. Johansson H, Raf L. A compilation of diagnostic errors in Swedish health care. Missed diagnosis is most often a fracture. Lakartidningen 1997; 94: 3848-50. [Article in Swedish]
4. Thomas HG, Mason AC, Smith RM, Ferergusson CM. Value of radiographic audit in an accident service department. Injury 1992; 23: 47-50.
5. Grover R. Clinical assessment of scaphoid injuries and the detection of fractures. J Hand Surg (Br) 1996; 21:341-343.
6. Parvizi J, Wayman J, Kelly P, Morgan CG. Combining the clinical signs improves diagnosis of scaphoid fractures. A prospective study with follow-up. J Hand Surg (Br) 1998; 23: 324-327.
7. Robinson PJ, Wilson D, Coral A, Murphy A, Verow P. Variation between experienced observers in the interpretation of accident and emergency radiographs. Br J Radiol 1999; 72: 323-330.
8. Lufkin KC, Smith SW, Matticks CA, Brunette DD. Radiologists' review of radiographs interpreted confidently by emergency physicians infrequently lead to changes in patient management. Ann Emerg Med 1998; 31: 202-207.
9. Pillai A, Jain M. Management of clinical fractures of the scaphoid: results of an audit and literature review. European Journal of Emergency Medicine 2005; 12(2): 47-51.
10. Moore MN. Orthopaedic pitfalls in emergency medicine. South Med 1988; 81: 371-8.
11. Zeitoun F, Frot B, Sterin P, Tubiana JM. Views necessary for the traumatic wrist. Ann Radiol 1995; 38: 255-65.
12. Saab M, Stuart J, Randall P, Southworth S. X-ray reporting in accident and emergency departments – reducing errors. Eur J Emerg Med 1997; 4: 213-6.
13. Higashida Y, Frank P, Doi K. High-speed, single-screen/single-emulsion film systems: Basic imaging properties and preliminary clinical applications. Radiology 1983; 149: 571-7.
14. Oestmann JW, Kopans DB, Linetsky L et al. Comparison of two screen-film combinations in contact and magnification mammography: detectability of microcalcifications. Radiology 1988; 168: 657-9.
15. BJJ Abdullah, H Kaur, KH Ng. An in vitro study comparing two different film-screen combinations in the detection of impacted fish bones. Br J Radiol 1998; 71:930-33.
16. Haus AG. The AAPM/ RSNA physics tutorial for residents. Measures of screen-film performance. Radiographics 1996; 16: 1165-81.

Table 2 Questionnaire for (a) independent rating of image quality; (b) detection of fractures and soft tissue injuries

(a) Image quality

| Type of radiograph | Rating |
|--------------------|--------|
| Soft tissue        |        |
| Bone               |        |
| Cortex             |        |
| Medulla            |        |
| Joint              |        |

Ratings: 0 – non diagnostic; 1 – poor but diagnostic; 2 – textbook and diagnostic; 3 – excellent and diagnostic

(b) Detection of fractures and soft tissue injuries

| Type of radiograph | Rating |
|--------------------|--------|
| Fractures          |        |
| Soft tissue injuries|       |

Ratings: 0 – not seen at all; 1 – seen but of poor diagnostic quality; 2 – seen and of fair diagnostic quality; 3 – seen and of excellent diagnostic quality.
Table 3 Questionnaire for comparable rating of (a) image quality; (b) detection of fractures and soft tissue injuries

(a) Image quality

| Image quality | Rating |
|---------------|--------|
| Soft tissue   |        |
| Bone          |        |
| Joint         |        |

Rating: 1 – soft tissue seen better SFC than MFC; 2 – soft tissue seen equally well on both SFC and MFC; 3 – soft tissue seen better on MFC than SFC; 4 – bone seen better on SFC than MFC; 5 – bone seen equally well on both SFC and MFC; 6 – bone seen better on MFC than SFC; 7 – joint seen better on SFC than MFC; 8 – joint seen equally well on both SFC and MFC; 9 – joint seen better on MFC than SFC

(b) Detection of fractures and soft tissue injuries

| Detection of | Rating |
|--------------|--------|
| Fractures    |        |
| Soft tissue injuries | |

Rating: 1 – fracture seen only on SFC radiograph; 2 – fracture seen better on SFC than MFC radiograph; 3 – fracture seen equally well on both radiographs; 4 – fracture seen better on MFC than SFC radiograph; 5 – fracture seen only on MFC radiograph; 6 – no fracture seen in both radiographs; 7 – more fracture seen on MFC radiograph; 8 – more fracture seen on SFC radiograph; 9 – soft tissue injury seen only on SFC radiograph; 10 – soft tissue injury seen better on SFC than MFC radiograph; 11 – soft tissue injury seen equally well on both radiographs; 12 – soft tissue injury seen better on MFC radiograph; 13 – soft tissue injury seen only on MFC radiograph; 14 – no soft tissue injury seen in both radiograph