Effect of introduction of mini C-arm image intensifier in orthopaedic theatre

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ABSTRACT

INTRODUCTION Image intensifier screening is commonly used in orthopaedic theatres. There has been concern regarding the cumulative radiation dose to surgeons and theatre personnel. The mini C-arm intensifier has been reported to scatter less radiation and have a reduced radiation dose to patients and theatre staff.

MATERIALS AND METHODS A 2-month prospective survey of usage of radiographer-operated large intensifier and surgeon-operated mini C-arm image intensifier in a district general hospital orthopaedic theatre department.

RESULTS A total of 153 cases required image intensifier screening – 63% used the large intensifier and 37% the mini C-arm intensifier. There were difficulties with equipment with the large intensifier in 16% of cases. There were delays in 11% of cases using the large intensifier. The total radiographer attendance time was 123 h. For the mini C-arm intensifier, there were no equipment difficulties or delays. The minimum radiographer time saved by using this machine was 21.9 hours.

CONCLUSIONS The mini C-arm intensifier has saved 15% of the radiographer workload with its current pattern of usage in our department. There have been no problems or delays as a result of its usage in theatre. Usage of the large image intensifier resulted in a 16% problem rate and 11% delay rate. Other departments are encouraged to consider acquisition of a mini C-arm intensifier to facilitate theatre throughput, reduce risk to the patient and theatre personnel, and reduce demands on the radiology department.

KEYWORDS

Image intensifier – Orthopaedics – Radiology

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Image intensifier screening has become an integral part of orthopaedic theatre practice, both for trauma and elective cases. Much has been written about the safety aspects, in particular the cumulative radiation dose to the operating surgeon and to supporting theatre personnel.^{1–7}

Mini C-arm image intensifiers have been promoted in the past few years with claims that they scatter less radiation and, therefore, have reduced risk to the surgeon, patient and theatre personnel.⁸ Because the intensifier is surgeon operated, there is no requirement for radiographer staffing, which may reduce unnecessary delays and demands on the radiology department.

The aim of this study was to identify the current pattern of usage of the mini C-arm intensifier and the standard large arm intensifier in a district general hospital, to examine the impact on radiographer workload, to review the current literature regarding image intensifier screening in orthopaedic theatres, and to propose suitable cases for mini C-arm intensifier screening in the future.

Materials and Methods

Musgrove Park Hospital, Taunton, is a large district general hospital staffed by 10 orthopaedic consultants. A regional spinal surgery service is provided for elective and trauma work. There are 3 dedicated orthopaedic theatres. There is one half-day and one 3-h evening trauma list per day during the week. At weekends, there is a 3.5-h dedicated trauma session each day. *Ad hoc* emergency work is performed as required out of these hours.

A radiographer-operated large C-arm image intensifier is the default machine for operative screening. Radiographers are provided as required from the accident and emergency radiographer staffing pool, and leave accident and emergency commitments during their attendance at theatre. There is no radiographer dedicated to orthopaedic screening. Radiographer staffing is reduced after 5 pm, and at weekends.

In 2004, a mini C-arm image intensifier (Premier Mini C-arm; Fluroscan, Bedford, MA, USA) was introduced, funded

Table 1 Timing of usage of respective intensifiers

	Mini C-arm	Large C-Arm
Daytime list	33 (62%)	63 (66%)
Twilight list	11 (21%)	15 (16%)
Weekend list	9 (17%)	15 (16%)
Out-of-hours	0 (0%)	3 (3%)

by donations from the League of Friends. All operating surgeons received training in the use of the mini intensifier and completed ionising radiation training. Individual surgeons were free to use whichever intensifier was felt to be most appropriate for the operative case. There was no agreed protocol for usage. The mini C-arm intensifier is surgeon-operated and there is no requirement for radiographer staffing during the case. The machine is particularly suitable for screening the distal extremities. Because of the smaller circumference of the C-arm, it can be difficult to screen proximal to the elbow or distal tibia. Dosage is

automatically adjusted to penetrate the extremity examined, but can be manually over-ridden if preferred. Tighter collimation of the beam can be achieved compared to the large intensifier. Printouts of saved images are routine.

Details of all cases utilising either form of intensifier screening for a 2-month period between January 2005 and March 2005 were recorded by theatre staff or radiographers when in attendance on a standard proforma. Where a radiographer-operated intensifier was used, the duration of radiographer attendance in theatre and, therefore, absence from usual commitments was recorded. The screening times and any difficulties with usage were recorded. For the mini C-arm intensifier, the duration of usage, screening time and any usage problems were recorded. Dosage information was only provided by the large intensifier and, therefore, was not used for comparison.

Results

The period of study was between January and March 2005, a 58-day period. This included 16 weekend sessions. A total of 153 cases utilised intra-operative screening during this period – 96 cases (63%) used the large C-arm intensifier and 57 cases (37%) used the mini C-arm intensifier. The timing of cases is shown in Table 1. Of cases utilising the mini C-arm intensifier, 75% were trauma cases; 66% of large intensifier cases were trauma cases. Breakdown of cases for the commonest procedures for each machine are shown in Tables 2 and 3.

For the large intensifier, the mean screening time was 28.9 s (range, 1–209 s). The mean radiographer attendance time was 77 min (range, 15–305 min). In comparison for the mini C-arm intensifier the mean screening time was 44 s (range, 3–176 s). The mean time the machine was in use was 23 min (range, 2–120 min). The large intensifier required a total of 7392 min of radiographer time during this monitoring period (123 h). This equates to 15.5 working days based on an 8-h day. The period of use and, therefore, the minimum radiographer time saved by use of the mini intensifier over this 2-month period was 1311 min (21.9 h or 2.7 radiographer days).

Difficulties with usage were reported in 15 large intensifier cases (16%). These were printer malfunction in 14 cases and power failure in 1 case. There were reported delays in 11% of large intensifier cases. There were delays because of poor communication in 6 cases (6%). Five cases required the use of the large intensifier at the same time in different theatres resulting in a delay (5% of large intensifier cases).

There were 7 instances where both machines were in use at the same time (5% of total cases).

There were no reported difficulties with usage for the mini C-arm intensifier and no operative delays as a result of using the mini C-arm intensifier.

Table 2 Case mix for mini C-arm intensifier

MUA wrist ± wires	16
Foot/ankle elective	7
ORIF forearm	6
Foot trauma	6
Ankle trauma	4
ORIF elbow	3
Hand ORIF	2
Removal wires	2

Table 3 Case mix for large C-arm intensifier

Spinal surgery	26	
Hip fracture fixation	24	
Long bone nailing	8	
Shoulder trauma	7	
Injection	5	(4 hip, 1 ankle)
Ankle trauma	6	
Ex-fixator	5	
Hip dislocation	3	
Elbow trauma	3	
Hand/wrist trauma	3	

Discussion

Intra-operative fluoroscopic screening has become an integral part of the orthopaedic surgeons workload. A large proportion of trauma cases require screening to monitor fracture reduction, or to confirm implant position or fixation. Elective cases require screening to identify anatomical level especially in spinal surgery or to identify intra-articular placement of injections, for example. By printing hard copies of intra-operative images, the need for postoperative departmental radiographs may be abolished.^{9,10} All medical radiation exposure should be kept to a minimum under the ALARA (as low as reasonably achievable) principle.¹¹ Therefore, any technology that reduces exposure must be welcomed.

Much has been written regarding the exposure of the orthopaedic surgeon to radiation from intra-operative fluoroscopic screening. Studies have concluded that, in general, the whole body dose to orthopaedic surgeons is well within the recommended level but have emphasised caution due to the uncertainty of long-term effects of low-dose radiation.^{1,5} Of note was the further reduction of the previous recommended limits of exposure in 1991 by the International Commission on Radiological Protection, fuelling this concern.¹¹ Smith *et al.*⁷ point out that the dose to an individual part of the body is the critical factor in assessing a radiation hazard rather than the total body dose. Whilst lead aprons provide adequate protection to the torso, the greatest risk may be to the head, neck and hand regions.⁵ An editorial suggested that orthopaedic surgeons also bear responsibility for minimising the radiation exposure to their patients.¹²

It has been shown that the use of a machine that allows surgeon control of the foot pedal can significantly reduce screening times and doses.⁴ Another method to reduce exposure and radiation dose markedly is by allowing tighter collimation of the beam.⁶ These are all features of the mini C-arm intensifier used in this study. The exposure rate of a mini C-arm intensifier has been reported to be about 10% that of a large C-arm intensifier.⁶

Badman *et al.*⁸ studied the use of a mini C-arm intensifier and found that regardless of the position, distance or relative duration of exposure, the exposure rates for mini C-arm intensifiers were 1 to 2 orders of magnitude lower than those reported for large C-arm intensifiers. Because the scatter produced by the mini C-arm intensifier was reduced, the radiation received by theatre personnel on the periphery of the case was also markedly reduced. They concluded that the mini C-arm intensifier should be used whenever feasible in order to eliminate concerns of cumulative radiation hazards of large intensifier exposure.

In our department, the introduction of the mini C-arm intensifier has been a success. There has been a dramatic reduction in the need for radiographer attendance. Although,

in our unit, there is no daily radiographer allocation to theatre, the reduced demand on the provision of a radiographer from the accident and emergency radiographer pool could have an impact on through-put within the emergency department itself and also on the radiology department, both with their own performance targets to meet. The calculations for time saved are the absolute minimum based on the total time the machine is switched on. In reality, where a radiographer is required, there is time taken for that person to leave the department, change into theatre attire, set up the large intensifier machine; thus, the true time saved would be even greater than the figure reported here.

In this study period, 7 cases utilised the two different machines at the same time which would have been a problem prior to introduction of the mini intensifier, but 5 required the use of the large image intensifier in two theatres at the same time. This was despite intentional booking of trauma cases for times when the most appropriate machine would have been available. Prior to the introduction of the mini C-arm intensifier, the incidence of such a clash was much higher which often meant delaying trauma cases that now can utilise the mini intensifier whilst the large intensifier is being used for screening elective cases.

It was not intended, in this study, to compare exposure rates or radiation doses for the two machines. The case mix for each machine was completely different and dosage information was not provided by the mini C-arm intensifier.

Following this survey of usage and review of the literature, it is proposed that all surgeons in our department utilise the mini intensifier whenever feasible. Suggested suitable procedures are those involving screening the elbow joint or more distally, or distal tibia, ankle, foot screening. We could have saved a further 740 min of radiographer time (10%) if all surgeons had screened using the mini C-arm intensifier for these procedures during the study period.

In the current National Health Service climate, introduction of a new technique or equipment often requires proof of cost-effectiveness. It was not the aim of the study to perform a detailed analysis of such issues. However, based on the cost of provision of a radiographer to orthopaedic theatre of approximately £19.50 per hour quoted by the trust, it would take about 10 years to cover the cost of this mini C-arm intensifier at the study hospital based on the reduction in requirement of radiographer attendance. This is only a crude analysis based on the minimum radiographer time saved as detailed elsewhere in the paper. A more formal analysis would involve attempting to cost the impact of operative delays for trauma cases, which traditionally have not been under such close scrutiny or financial penalties as delayed elective cases and have therefore proven hard to cost.

Many trusts are currently having difficulties recruiting the necessary quota of radiographers, and introduction of

equipment without the requirement for radiographer screening will obviously reduce the demands on already overwhelmed radiology departments. This was one of the most important factors leading to this trust purchasing the mini C-arm intensifier in 2004.

Far more important issues which ethically should outweigh financial issues are the reduction of exposure to the patient, theatre personnel and operative surgeon. These factors may become more important in the future than cost alone from a health and safety perspective as more information becomes available on the long-term exposure rates of image intensifier equipment.

Conclusions

The introduction of the mini C-arm intensifier has saved a minimum 15% of radiographer workload. Review of the literature suggests that its usage reduces the risk to the surgeon, patient and theatre personnel because of reduced screening time, surgeon control of screening, tighter collimation and reduced scatter. There have been no delays or difficulties in usage of the machine, as opposed to a 16% problem rate and 11% delay rate with a large intensifier. It is proposed to increase the number of cases utilising this machine. Acquisition of such a machine can facilitate theatre through-put and reduce demands of the radiology department.

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