Inadequate pelvic radiographs: implications of not getting it right the first time

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ABSTRACT

INTRODUCTION Pelvic radiography is a frequent investigation. European guidelines aim to ensure appropriate use and adequate quality. When initial images are inadequate, repeat radiographs are often required, which may have significant patient safety and economic implications.

OBJECTIVES The study aimed to assess the adequacy of pelvic imaging across three orthopaedic centres, to identify causes for inadequate imaging and to establish the cost of inadequate imaging from financial and patient safety perspectives.

METHODS Pelvic radiographs were identified on Picture Archiving and Communication System software at three UK hospitals. Radiographs were assessed against European guidelines and indications for repeat imaging were analysed.

RESULTS A total of 1,531 sequential pelvic radiographs were reviewed. The mean age of patients was 60 years (range 5 months to 101 years). Of this total, 51.9% of images were suboptimal, with no significant difference across the three hospitals ($P > 0.05$). Hospital 3 repeated radiographs in 6.3% of cases, compare with 18.1% and 19.7% at hospitals 1 and 2, respectively ($P > 0.05$). Hospital 3 identified pathology missed on the initial radiograph in 1% of cases, compared with 5.4% and 5.5% at hospitals 1 and 2, respectively ($P > 0.05$). Out-of-hours imaging is associated with a higher rate of suboptimal quality (69.1%) compared with normal working hours (51.3%; $P = 0.006$). Adequacy rates vary with age ($\chi^2 = 43.62$, $P < 0.001$). Risk of having a suboptimal radiograph increases above the age of 60-years ($\chi^2 = 4.45$, $P < 0.05$). The annual cost of repeat radiographs was £56,200 per hospital.

DISCUSSION AND CONCLUSION High rates of pelvic radiograph inadequacy can lead to missed pathology and the requirement for repeat imaging, which has significant patient safety and financial implications. Risk factors for inadequate radiographs include older patients and those having out-of-hours imaging.

KEYWORDS

Patient safety – Economics – Pelvis – Orthopaedics

Accepted 23 April 2017

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Introduction

Pelvic radiography is a frequently requested investigation in orthopaedic and accident and emergency departments. Radiographs are widely used in the diagnosis and evaluation of trauma, arthropathy, metabolic bone disease and malignancy, and in monitoring arthroplasty stability and wear. There are strict guidelines provided under the Ionising Radiation (Medical Exposures) Regulations as to when their use is justified in the UK.¹ These guidelines are in place to protect patients from exposure to potentially harmful and unnecessary radiation.² They also have the additional

economic benefit of reducing the number of costly investigations conducted, which may otherwise have been requested inappropriately.

The use of ionising radiation guidelines reflects a strong culture of patient safety and care quality which has been progressively developing since the 1990s. The first directive on patient radiation protection was adopted by member states of the European Union in 1984: all radiation exposures must be justified. This promoted the radiation safety initiative of ‘as low as reasonably achievable’.³ This is the principle of minimising radiation dose and the release of

radioactive materials by employing all reasonable methods, and is now a regulatory requirement for all radiation safety programmes.⁴ This led to the development of The European Guidelines on Quality Criteria for Diagnostic Radiographic Images (EGQCDRI), which aims to define key features which should be apparent in the ideal radiograph in order to answer any clinical indication.⁵ The focus has been on examinations of high frequency or associated with relatively high doses of radiation to the patient.

Pelvic radiographs are commonly requested investigations and are associated with around 0.7–0.8 mSv of radiation, approximately 40 times that of a plain chest radiograph.⁶ The guidelines state that the ideal pelvic radiograph should include symmetrical reproduction of the entire pelvis, with visually sharp reproduction of the sacrum and intervertebral foramina, sacroiliac joints, pubic and ischial rami, necks of femora and trochanters (Fig 1). Anecdotally, within our practice, it was noted that many pelvic radiographs failed to include these key anatomical landmarks. There were occasions when imaging was inadequate for the given clinical indication and had to be repeated to obtain an adequate view for diagnosis and management. Repeat imaging means additional radiation exposure for the patient, which clearly opposes the patient safety principles described above. It also carries potentially significant financial implications for the hospital, at a time when NHS funding is in crisis and trust deficits continue to deteriorate.⁷

We devised a retrospective study across three orthopaedic centres in the Greater London region, aiming to assess the adequacy of pelvic radiographs against EGQCDRI anatomical criteria, identify causes of inadequate pelvic radiographs and establish the risk to the patient and financial cost to the hospital of inadequate pelvic radiographs in these trusts.

Figure 1 A pelvic radiograph demonstrating the key anatomical landmarks which should be visualised in a visually sharp reproduction according to the European Guidelines on Quality Criteria for Diagnostic Radiographic Images criteria.

Methods

Pelvic radiographs were identified on Picture Archiving and Communication System (PACS) software with a search for 'XR pelvis' in the procedure window. Consecutive radiographs were reviewed across the same 2–3-week period in October 2015 to achieve approximately 500 films at each site. Data were collected by four doctors trained in the adequacy standards, for consecutive cases at each of three separate UK hospitals (anonymised as hospital 1, hospital 2 and hospital 3). Data collected included patient demographics, radiograph date and time, radiograph adequacy, whether the film was repeated, presence of pathology and missed pathology on the first radiograph. The adequacy of radiographs was assessed according to the EGQCDRI criteria. Images were considered 'optimal' if they included visualisation of the entire pelvis including iliac crests, sacrum and intervertebral foramina, sacroiliac joints, pubic and ischial rami, necks of femora and greater and lesser trochanters (Fig 1). Radiographs that missed one or more anatomical landmarks but did not require a repeat film were described as 'suboptimal'. Radiographs that missed key anatomical landmarks and required further repeat radiographs for safe diagnosis and management were considered 'inadequate'. 'Repeat' radiographs were defined as those that required repeat imaging of the same anatomical area within 24 hours, in the presence of a suboptimal initial radiograph. Repeat radiographs that had request information pertaining to a new trauma or alternative indication were excluded.

Statistical tests for non-parametric and three-way comparisons were employed to determine significance, using SPSS Version 22. Statistical analysis of inadequacy rates by age were carried out using a chi-squared test. To determine overall variation between age categories, an analysis was carried out against the null hypothesis of 'no difference in the proportion of suboptimal scans between age categories'. To demonstrate the significance of inadequacy rates in individual age categories, chi-squared tests were carried out using the null hypothesis 'the proportion of inadequate scans is 0.5'. The cost of one pelvic radiograph was established as £40, consistent with local radiology and financial services department pricings, after consideration of equipment and staffing costs.

Results

A total of 1,531 pelvic radiographs were reviewed across three hospitals (Table 1). Extrapolated figures give an estimated mean of 9,556 pelvic radiographs per hospital per annum. The mean age of patients was 60 years (range 5 months to 101 years). Analysis of demographic data found patients at hospital 3 to be significantly older than those at hospitals 1 or 2, as defined by a Kruskal–Wallis test ($P < 0.001$), which was consistent with patient demographics from census data.

A mean of 51.9% of images were deemed suboptimal against the prescribed criteria (Table 2). Suboptimal imaging rates were similar across the three sites, with no significant difference in adequacy detected ($P < 0.05$). There was,

Table 1 Patient demographics for those radiographs reviewed in the study

	Hospital 1	Hospital 2	Hospital 3	Mean average
Patients (n)	519	513	499	510
Radiographs/year (extrapolated)	6,228	13,328	9,113	9,556
Average age (years)	59	55	66	60
Range	7 months – 100 years	7 months – 100 years	5 months – 101 years	

Table 2 Rates of suboptimal and repeat imaging across the three sites, with associated costs

	Hospital 1	Hospital 2	Hospital 3	Significance ^a	Mean average
Suboptimal imaging (%)	51.8	50.1	53.7	$P > 0.05$	51.9
Repeat x-rays (%)	18.1	19.7	6.3	$P > 0.05$	14.7
Pathology not adequately seen (%)	5.4	5.5	1	$P > 0.05$	4
Cost of repeat imaging (£)	45,090	105,025	22,964	$P > 0.05$	57,693

^a Delineates significance of variation across the three sites, as ascertained by analysis of variance.

however, a significant difference in rates of repeat imaging, with hospital 3 reimaging 6.3% of all pelvic radiographs, compared with 18.1% and 19.7% at hospitals 1 and 2, respectively ($P < 0.05$). There was also a significant difference in the rate of missed pathology, with new pathology being found, on average, in 4% of repeat imaging. The rate of missed pathology based on the first radiograph, when repeat imaging was undertaken, was 1% in hospital 3, 5.4% in hospital 2 and 5.5% in hospital 3 ($P < 0.05$).

A further subgroup analysis was performed within hospital 3, with data collection including date and time of each radiograph, which allowed a more detailed analysis of radiography performed out-of-hours (defined as any time on a Saturday or Sunday and on weekdays between 5pm and 8am) compared with normal working weekday hours (radiographs taken Monday to Friday between 8am and 5pm). Out-of-hours imaging was shown to have a significantly higher chance of being suboptimal (47/68, 69.1% out-of-hours radiographs inadequate, vs. 221/431, 51.3% normal working hours radiographs; $P = 0.006$, Mann-Whitney U test).

Radiographs across the three hospitals were also analysed by patient age. Patients were grouped into age categories 0–10 years, 11–20 years, 21–30 years, 31–40 years, 41–50 years, 51–60 years, 61–70 years, 71–80 years, 81–90 years and 91+ years. A chi-squared test, using a null hypothesis of no significant difference between adequacy rates in different age categories, demonstrated very significant variation in adequacy rates between age categories by rejection of the null hypothesis ($\chi^2 = 43.6195$, 9 degrees of freedom, $P = < 0.001$; Table 3). The risk of having a suboptimal radiograph increases significantly beyond the age of 60 years and continues to rise with age (Table 4; Fig 2).

The average rate of repeat imaging was 1,405 radiographs per hospital per annum. At an approximate cost of £40 per radiograph, the average financial cost of repeat radiographs per year across the three hospitals was £56,200 per site (Table 2).

Discussion

To the authors' knowledge, this is the first study to assess image quality of pelvic radiographs in the UK. It comes at a time when pressures on the NHS are mounting and simple strategies for improvement in care quality and efficiency are highly sought after.⁸ Pelvic radiography is a simple investigation that, in isolation, poses a low level of risk to the patient and cost to the trust. However, owing to the frequency of their use, the collective contribution to radiation dose and hospital costs are considerable.

In our retrospective study, the majority of pelvic radiographs (51.9%) performed across three large orthopaedic centres in the UK were deemed to be suboptimal when compared with the EGQCDRI.⁵ Through a breakdown of patient demographic and radiograph details, we have been able to identify two independent significant risk factors for having a suboptimal radiograph: (1) being over the age of 60 years, and (2) radiographs taken outside normal working hours.

Older patients come with recognised difficulties in radiography. Areas requiring particular attention in older patients are communication, patient safety and patient handling, all of which can impact on the final image quality if the comorbidity is severe and due attention is not given.⁹ This is particularly true of patient's whose comorbidities often include dementia or delirium, which are common contributors to falls and can significantly hinder cooperation.

Table 3 Radiograph adequacy analysis according to patient age. Chi-squared statistic was ascertained against the null hypothesis that there is no difference in adequacy rates between different age categories

Age (years)	Radiograph adequacy		Total in age group (n)		Proportion of patients	Suboptimal scans		
	Optimal (n)	Suboptimal (n) (%)				Expected (n)	Observed (n)	Discrepancy between O and E
1–10	90	30 25	120		0.08	61.82	30	16.38
11–20	43	23 34.85	66		0.04	34	23	3.56
21–30	28	23 45.1	51		0.03	26.27	23	0.41
31–40	28	19 40.43	47		0.03	24.21	19	1.12
41–50	79	44 35.77	123		0.08	63.37	44	5.92
51–60	98	90 47.87	188		0.12	96.85	90	0.48
61–70	113	147 56.54	260		0.17	133.94	147	1.27
71–80	139	191 57.88	330		0.22	170.01	191	2.59
81–90	98	166 62.88	264		0.17	136.01	166	6.62
91+	19	48 71.64	67		0.04	34.52	48	5.27
Total	735	781 47.8	1,516		1	781	781	43.62 ^a

^a χ^2 statistic, 9 degrees of freedom, $P < 0.001$ (null hypothesis rejected). E, expected; O, observed.

Table 4 Radiograph adequacy analysis according to patient age. Chi-squared statistic was ascertained for each group against the null hypothesis that the proportion of adequate radiographs is 0.5 (50%)

Age (years)	Radiograph adequacy		Total in age group (n)	χ^2	P-value
	Optimal (n)	Suboptimal (n) (%)			
1–10	90	30 25	120	30	< 0.001
11–20	43	23 34.85	66	6.06	< 0.025
21–30	28	23 45.1	51	0.49	> 0.05
31–40	28	19 40.43	47	1.72	> 0.05
41–50	79	44 35.77	123	9.96	< 0.005
51–60	98	90 47.87	188	0.34	> 0.05
61–70	113	147 56.54	260	4.45	< 0.05
71–80	139	191 57.88	330	8.19	< 0.005
81–90	98	166 62.88	264	17.52	< 0.001
91+	19	48 71.64	67	12.55	< 0.001

Outside normal working hours, additional external factors are likely to play a role. It is unknown exactly what factors may be implicated in this finding. It is essential that patients receive sufficient analgesia and can comprehend instructions to be able to perform the optimal image at the first attempt. This may be further impaired by radiographers working alone, with insufficient resources to position the patient safely in an optimal position for the radiograph.

Repeat imaging was deemed necessary in 14.7% (range 6.3–19.7%) of cases for safe and accurate diagnosis. This is the percentage of the total number of radiographs taken, rather than the percentage of suboptimal radiographs alone. This can be considered the true inadequacy rate, as it was deemed impossible to make management decisions without a better quality film. It should be stressed, however, that an image being ‘suboptimal’ against the prescribed criteria

Figure 2 Radiograph inadequacy (percentage) by age.

does not automatically mean it should be repeated. Indeed, the EGQCDRI state that ‘under no circumstances should an image which fulfils all clinical requirements but does not meet all image criteria ever be rejected’.⁵ This is because dual pathology would typically be considered a rarity and repeat radiographs would only benefit a very small cohort of patients. The guidelines are important in setting a benchmark against which to audit but the authors are not aware of any UK radiology departments that employ their use clinically. Full exposure of all anatomical landmarks is not required in the majority of cases. This is reflected in our results, where it is noticeable that we choose to repeat significantly fewer radiographs than are technically deemed to be suboptimal (14.7% repeat radiograph rate, vs. 51.9% suboptimal rate).

Somewhat reassuringly, our rates of suboptimal imaging corroborate with those found in the EGQCDRI’s own audit work, which found only 33.1–35.2% of anteroposterior chest radiographs and 57.3–59.2% of anteroposterior lumbar spine radiographs failed to fulfil all of their stipulated criteria (no data are cited for pelvic radiographs).⁵ We identified a rate of repeat imaging which varied from 6.3% to 19.7%. The use of repeat imaging is of clinical importance as this exposes the patient to additional radiation, increases costs and may delay the underlying diagnosis and ongoing treatment. This series shows that subsequent imaging found new pathology in 4.0% of cases.

When repeat radiographs are taken, the patient is exposed to additional doses of radiation that might have been avoided if adequate radiographs had been obtained initially. Doses will vary considerably, depending on a host of factors such as machine and manufacturer, machine settings and patient metabolism; however, an approximate dose

associated with a single pelvic radiograph in an average sized adult is 0.7–0.8 mSv (for comparison, an individual will receive approximately 3 mSv of background radiation every year and a plain chest radiograph equates to 0.02–0.06 mSv of radiation).² This will be relatively higher in smaller patients such as children.¹⁰ Overall this equates to a ‘low’ increased risk; however, any increased risk is unacceptable if it is potentially avoidable according to the ‘as low as reasonably achievable’ principle. If the film appears adequate to answer the question that has been asked, a repeat will not be performed. The high rate of repeat imaging in this series, ranging from 6.3% to 19.7%, highlights the need for improvements in optimising the patient in preparation for, and during radiographic exposure. Although many initial radiographs would have been technically suboptimal, if they demonstrated the expected pathology they may have been deemed sufficient, thus avoiding repeat imaging. This places the onus on the requesting doctor to specify in the request whether further anatomy needs to be visualised so that the radiographer is aware of this requirement. A simple measure to improve adequacy would be to ask for a clinically focused radiograph of the pelvis, aimed to answer a specific question. Such an example would be ordering hip radiographs when a neck of femur fracture was suspected. In general, however, fear of radiation exposure should not deter from repeating an inadequate film if clinical suspicion is high, particularly in the older population where the long-term effects of additional radiation are less relevant.

Recognition of the difficulties in the history, examination and imaging of geriatric trauma patients has prompted several authors to advocate the replacement of simple radiography with full-body computed tomography or ‘pan scan’.^{11,12} In our study, 4% of inadequate cases had a repeat

radiograph that enabled visualisation of pathology not identified on the original film. This implies that patients with suboptimal films who did not have a repeat radiograph could potentially have missed pathology, misdiagnosis and mismanagement based on an initial inadequate radiograph, owing to the obscuration of pathology. Indeed, a potential limitation of our study is that it does not include such patients and it may be interesting to ascertain those who have been discharged from accident and emergency following an apparently normal pelvic radiograph but have since returned, either to accident and emergency or through an outpatient clinic, and had repeat imaging which demonstrated pathology.

In addition to the concern of patient safety, there is a financial burden associated with repeat imaging. Calculations based on an estimated £40 per radiograph give a cost of £56,200 per hospital per year. Savings of this kind could contribute significantly to the 4% efficiency savings required of commissioners and NHS trusts.⁷ In the year 2012/2013, the average target saving across our three sites was £40.1 million.¹⁵

There are certain limitations to our work. Radiographers are able to screen their own imaging before being sent to PACS. The details of any discarded images screened by the radiographer cannot be traced and thus cannot be quantified during this study. This highlights, however, that the 51.9% of suboptimal imaging may in fact be an underestimation of the true value. We were unable to ascertain potential for gender bias in relation to variations in patient size and the difficulty this could pose to a radiographer. We note, however, that although there is evidence of the exposure index varying between genders in chest radiographs,¹⁴ we have been unable to find evidence of gender influencing adequacy with regards to anatomical boundaries in the literature in pelvic, or other radiographs. Therefore, based on this previous research, the fact that all of our radiographs had appropriate exposure and our clinical experience, we do not believe that gender would affect the adequacy of the radiographs as we have defined it in this manuscript, with regards to anatomical boundaries.

Conclusions

Inadequate pelvic radiographs carry significant patient safety and financial implications. Improving the adequacy of the initial radiograph and focusing radiographs on the suspected pathology will likely reduce the need for repeat

imaging. Ensuring adequacy of the first pelvic radiograph we take is a simple and reproducible measure that will likely save money, without compromising patient care.

This study showed no significant difference in the frequency of suboptimal imaging across three separate sites, indicating this is likely to be a systemic problem across all regions of the UK. Indeed, the findings may affect other imaging modalities beyond that of the pelvic radiograph. The authors therefore encourage others to consider similar investigations and interventions in their own centres, as a means of improving both patient care, and hospital finances.

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