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Moving back: The radiation dose received from lumbar spine quantitative fluoroscopy compared to lumbar spine radiographs with suggestions for dose reduction

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ABSTRACT

Purpose: Quantitative fluoroscopy is an emerging technology for assessing continuous inter-vertebral motion in the lumbar spine, but information on radiation dose is not yet available. The purposes of this study were to compare the radiation dose from quantitative fluoroscopy of the lumbar spine with lumbar spine radiographs, and identify opportunities for dose reduction in quantitative fluoroscopy.
Methods: Internationally reported dose area product (DAP) and effective dose data for lumbar spine radiographs were compared with the same for quantitative fluoroscopy and with data from a local hospital for functional radiographs (weight bearing AP, lateral, and/or flexion and extension) ($n = 27$). The effects of procedure time, age, weight, height and body mass index on the fluoroscopy dose were determined by multiple linear regression using SPSS v19 software (IBM Corp., Armonck, NY, USA).
Results and conclusion: The effective dose (and therefore the estimated risk) for quantitative fluoroscopy is 0.561 mSv which is lower than in most published data for lumbar spine radiography.
The dose area product (DAP) for sagittal (flexion + extension) quantitative fluoroscopy is 3.94 Gy cm^2 which is lower than local data for two view (flexion and extension) functional radiographs (4.25 Gy cm^2), and combined coronal and sagittal dose from quantitative fluoroscopy (6.13 Gy cm^2) is lower than for four view functional radiography (7.34 Gy cm^2).
Conversely DAP for coronal and sagittal quantitative fluoroscopy combined (6.13 Gy cm^2) is higher than that published for both lumbar AP or lateral radiographs, with the exception of Nordic countries combined data.
Weight, procedure time and age were independently positively associated with total dose, and height (after adjusting for weight) was negatively associated, thus as height increased, the DAP decreased.

Introduction

Quantitative fluoroscopy (QF) of the lumbar spine allows inter-vertebral motion to be measured from fluoroscopic sequences where trunk motion is standardised for velocity and range. Sequences can be recorded using passive recumbent (i.e. no muscle or motor control) or active weight-bearing protocols in both the coronal and sagittal planes. Automated frame-to-frame image registration relies upon good digital image quality and provides continuous inter-vertebral rotational and translational data, giving more information about the function of the spine than AP, lateral, or flexion-extension (functional) radiographs.[1,2]

Functional radiographs have long been used for measuring spinal movement and for diagnosing instability.[3] However, such measurements are unreliable due to errors from positioning, distortion and magnification, with mean test-retest errors of up to 4.9°.[4] By contrast, QF is reported to be accurate to 0.32° for coronal, and 0.52° for sagittal plane inter-vertebral rotation[5] with inter-observer errors below 1.5° for rotation and 1.5 mm for translation.[6–9]

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QF technology is mainly limited to research, although a new system for clinical use has recently gained 510(K) clearance from the United States Food and Drug Administration (KineGraph VMA, Ortho Kinematics, Austin, Texas, USA).[10] However, few authors have published radiation dose data and none have compared these to published data from radiographic images. The present study sought to provide this, with suggestions for further optimising radiation doses by analysis of the characteristics which contribute to dose.

The aim was to determine if quantitative fluoroscopic investigation of the lumbar spine imparts a similar dose-area product (DAP) and effective dose (ED) to lumbar spine radiographs .To determine this, published data for AP and lateral radiographs were interrogated. Because no published data exists for functional radiographs, local hospital data were used to represent this dose for comparison. A secondary aim was to determine which factors may contribute to a reduction of the dose from quantitative fluoroscopy.

Methods and materials

This was a retrospective study comparing the radiation dose from an on-going QF study with AP and lateral lumbar spine radiographs, functional radiographs, and other QF studies. The comparisons were Dose Area Product (DAP) measured in Gray multiplied by area (Gy cm^2) and the estimated effective dose (ED) measured in miliSievert (mSv).

Published dose data

National and international surveys,[11–15] and peer reviewed scientific literature reporting radiation doses of lumbar spine radiographs and quantitative fluoroscopy/cineradiography/videofluoroscopy were examined.[5,9,16–20] Literature was excluded if only entrance skin doses (ESD's) were reported leaving six references reporting DAP values and eight reporting effective dose. DAP and ED were extracted and compared to the dose from QF in this study.

Quantitative fluoroscopy

Ethical approval was obtained from the UK National Research Ethics Committee Southampton A (09/H0502/99). Recruitment of all participants and theirwritten informed consent were carried out by the principal researcher prior to screening. QF was undertaken in the recumbent coronal and sagittal planes, in a cross-sectional mixed gender study ($n = 74$) of in vivo lumbar spine biomechanics, and movement was controlled by a specially designed motorised motion table (Fig. 1). Data collection was undertaken by the principal researcher using a portable digital C-arm fluoroscope with a 30 cm Image Intensifier (Siemens Avantic, Germany), and a pulse rate of fifteen frames per second was selected to minimise movement blurring.

DAP, procedure time, age, gender, height and weight of the participants was obtained. DAP was then converted to ED using PCXMC v2 software(stuk.fi) and 2007 ICRP 103 tissue weighting factors.[21] For QF, The mean kVp was 67 for coronal and 79 for sagittal plane, and the mean focus skin distances (FSD) were 75 cm and 60 cm respectively.

Hospital radiographs

A local hospital database of referrals by spinal surgeons for functional radiographs was inspected. The search covered the previous 12-month period and the cumulative DAP was recorded for patients who had a four series examination (weight-bearing AP, lateral, flexion and extension) or a two series examination (weight-bearing flexion and extension). The collection of retrospective hospital dose data did not require ethical review; however hospital and radiology department R&D approvals were gained.

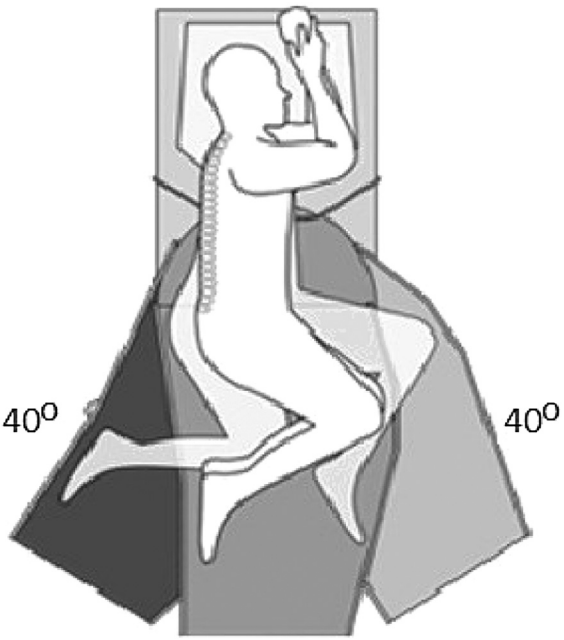

Figure 1. Diagram of the passive motion table for QF of the lumbar spine. Patients lie in either a supine or lateral decubitus position with L3 centred to the fulcrum with knees bent to flatten the lumbar lordosis. The table swings through an arc of 40° each way.

No identifying details were recorded and patients who had images that were repeated were excluded, as were those who only had supine AP and lateral lumbar radiographs. Examinations were undertaken by different practitioners using the same room equipped with a GE Medical Systems DEFINIUM 8000 System. ED was estimated using generalised conversion coefficients from the NRPB-R262 report[22] (see Table 2).

Statistical analysis

For QF, the relationships between DAP (outcome variable) and procedure time, age, gender, height, weight and body mass index (BMI) (predictor variables) were examined. A 2-sided 5% significance level was used. Initially, a least squares linear regression (IBM SPSS Statistics Version 19) of total dose was conducted to calculate unadjusted regression and correlation coefficients. Next, a multiple linear regression model including only height, weight and BMI determined whether all 3 variables independently predicted dose. Large changes in the standard errors of the regression coefficients

Table 1
Demographics of participants imaged with QF versus local hospital data of weight-bearing lumbar radiographs (2 or 4 series) for instability.

	This QF study	Local hospital
	$N = 74$	$N = 27$
Gender (%)	Male = 42 (57%) Female = 32 (43%)	Male = 11 (41%) Female = 16 (59%)
Age years. Mean (SD)	36.9 (8.49)	63.2 (17.2)
Weight Kg. Mean (SD)	74.97 (12.73)	–
Height m. mean (SD)	1.716 (0.127)	–
BMI mean (SD)	24.77 (2.57)	–

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