



# Digital imaging and radiographic practise in diagnostic radiography: An overview of current knowledge and practice in Europe

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## ABSTRACT

**Introduction:** Recent research has identified the issue of ‘dose creep’ in diagnostic radiography and claims it is due to the introduction of CR and DR technology. More recently radiographers have reported that they do not regularly manipulate exposure factors for different sized patients and rely on pre-set exposures. The aim of the study was to identify any variation in knowledge and radiographic practice across Europe when imaging the chest, abdomen and pelvis using digital imaging.

**Methods:** A random selection of 50% of educational institutes ( $n = 17$ ) which were affiliated members of the European Federation of Radiographer Societies (EFRS) were contacted via their contact details supplied on the EFRS website. Each of these institutes identified appropriate radiographic staff in their clinical network to complete an online survey via SurveyMonkey. Data was collected on exposures used for 3 common x-ray examinations using CR/DR, range of equipment in use, staff educational training and awareness of DRL. Descriptive statistics were performed with the aid of Excel and SPSS version 21.

**Results:** A response rate of 70% was achieved from the affiliated educational members of EFRS and a rate of 55% from the individual hospitals in 12 countries across Europe. Variation was identified in practice when imaging the chest, abdomen and pelvis using both CR and DR digital systems. There is wide variation in radiographer training/education across countries.

**Conclusion:** There is a need for standardisation of education and training including protocols and exposure parameters to ensure that there is continued adherence to the ALARA principle.

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## Introduction

The digital imaging techniques of computed radiography (CR) and digital radiography (DR) have made a significant impact on imaging departments and has led to the potential for reductions in radiation doses for standard imaging examinations.<sup>1</sup> However, current research suggests that the radiation dose has actually increased due to the wide exposure latitude of digital systems. Great variations in practice have been identified by recent authors<sup>2</sup>

which results in a large range in radiation doses for similar examinations and has resulted in “dose creep”.<sup>3–5</sup> Dose creep is a phenomenon whereby radiation doses have crept upwards due to imaging staff sometimes opting to use higher exposure factors which results in a higher signal to noise ratio (SNR), producing a higher quality image with less noise. Staff can then post process the digital image to produce a better quality image.<sup>4</sup>

It is well recognised that the three most important factors to consider when producing good image quality in digital imaging include appropriate selection of (i) tube voltage (ii) tube current (iii) exposure time.<sup>6,7</sup> However, pre and post processing image manipulation is available for all digital radiography and enables manipulation of the resultant image hence, the selection of these technical factors may be perceived to play a less critical role in providing a good diagnostic image.<sup>8</sup> When compared to film screen radiography, both computed and digital image receptors respond to x-ray exposure and produce digital data over a wider range of

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exposure intensities i.e. wider dynamic range.<sup>9</sup> With conventional radiography the resultant radiograph reflects the quality and quantity of radiation interacting with the film as contrast and optical density. In CR and DR digital image processing takes place in the form of histogram analysis and look up tables. These processes adjust the raw linear data and amend the image contrast and brightness intensity, including those images that have been moderately under or over exposed. Therefore, diagnostic images can be obtained using a wider range of exposure factors as digital radiography is less mAs and kV dependent; this may reduce the need for repeat exposures however patients may be incurring higher radiation doses than are necessary.<sup>8,9</sup> Previous studies have highlighted the trend for staff to overexpose rather than underexpose patients as this reduces quantum mottle on the resultant image and improves image quality.<sup>5,10</sup> In light of this, more recent authors have highlighted the need to optimise the performance of the digital system by ensuring the appropriate selection of technical parameters.<sup>11–15</sup>

In compliance with article 56.2 of the European Directive 2013/59/Euratom (<https://ec.europa.eu/energy/sites/ener/files/documents/CELEX-32013L0059-EN-TXT.pdf>) employers in each EU Member State must ensure “the establishment, regular review and use of diagnostic reference levels for radiodiagnostic examinations, having regard to the recommended European diagnostic reference levels....”.<sup>16</sup> Diagnostic reference levels (DRL) are defined as radiation dose levels for typical x-ray examinations for standard sized patients using standard equipment. These levels help to highlight recurrent over or under exposures but they also allow for higher doses to account for such times when a higher dose is required for diagnosis. Use of DRL has been shown to reduce the overall radiation dose and the range of doses observed in clinical practice<sup>17</sup> however the ways DRL are being developed across Europe varies.<sup>3</sup> Data from 2014 highlights that DRL for adult x-ray examinations have been established in 72% of the 36 European countries, whilst only 39% of the countries have established DRL for paediatric x-ray examinations.<sup>3</sup> For adult DRL, 77% are based on national dose surveys in Europe while the rest are based on published values or recommendations e.g. EC recommendations. Similarly, 64% of paediatric DRL are based on national dose surveys while the rest are based on published European guidelines or other publications.<sup>3</sup>

The respective DRL for a variety of hospitals are discussed by the European Commission Radiation Protection N° 180<sup>3</sup> and highlight a wide variation in practice across Europe. Standard exposure techniques currently used internationally are determined in the individual imaging departments and variation exists between departments. Therefore, a standard adult radiation dose for a particular examination can vary depending on which hospital/department they are examined in. This variation has previously been identified, at both national and international levels by several authors.<sup>18–20</sup>

A report of ‘dose creep’ in American hospitals<sup>21</sup> states that between 20% and 35% of patients in the US are overexposed by at least a factor of two and claim that this is due to the introduction of CR and DR technology. In addition to this, research of digital imaging systems from five different suppliers performed with the aid of phantoms<sup>9</sup> concluded that it was technically possible to both, under and over expose the imaging plates and still be able to process the data to produce an acceptable image quality. Results concluded<sup>9</sup> that radiographers need to become more knowledgeable about the digital imaging systems to ensure that they produce high quality images with the least amount of exposure to patients. More recently, it has been reported<sup>4</sup> that radiographers are not manipulating exposure factors for different sized patients and rely on pre-set exposures with staff openly admitting to “bumping up” their x-

ray exposure to ensure a diagnostic image. As identified recently<sup>22</sup> staff selecting the most appropriate exposure factors at the time of x-ray exposure is the simplest and most effective way to ensure adherence to the As Low As Reasonably Achievable (ALARA) principle.

## Aim and objectives

The aim of the study was to identify any variation in radiographic practice across Europe when imaging commonly performed examinations of the chest, abdomen and pelvis. The objectives of the study included exploring

1. the standard operating parameters used across departments,
2. the range of imaging equipment currently used in hospitals,
3. levels of awareness and use of DRL in the different countries
4. the education and qualification level of radiography staff employed in the imaging departments.

## Methods

Ethical permission was sought and granted from Ulster University in Northern Ireland. The research design was an online survey using a questionnaire designed via SURVEYMONKEY. The survey was sent as a link embedded in an e-mail and the focus of the questionnaire was current practice when using digital imaging in clinical departments. The questionnaire consisted of 30 questions in total with 15 open-ended questions allowing respondents to provide their own answers combined with 15 closed questions requiring specific information on the use of CR and DR. To prevent irrelevant questions being asked, “questionnaire skip logic” was used to skip respondents to specific questions on a later page, based on their answer to a previous closed-ended question. The questionnaire consisted of two parts.

- (i) The first part focused on the characteristics of the department (hospital type, number of beds) and radiography staff (number, EQF level and years of experience), the type of x-ray equipment used (Film screen, CR or DR), equipment age and staff awareness of the existence of local or national DRLs.
- (ii) The second part of the questionnaire focused on the acquisition parameters for the three common examinations i.e. PA chest, AP abdomen and AP pelvis (the questionnaire asked respondents to supply average exposure data specifically for average sized male patients between 65 kg and 75 kg in weight to ensure results would be comparable across centres).

kVp, mAs, Source to Image receptor distance (SID) or Focus to Film Distance (FFD), anti-scatter grid use. Data was also collected on staff training on the use of CR and DR.

A pilot study was performed among a total of six radiographic staff in educational institutions in the UK, Ireland and the Netherlands to highlight any ambiguity in questions and test the validity and reliability of the questionnaire prior to use. This included native and non-native English speakers, who would not be included in the target distribution group. Following feedback from the pilot study, the questionnaire was revised to decrease ambiguity of questions for non-native English speakers and also decrease the length of time commitment required to complete the questionnaire. Inter-rater reliability was tested by inviting two staff members of the same institution to answer the questionnaire and a high correlation was noted between the two respondents in each institution. The respondents in the pilot study were then asked to

complete the questionnaire again on a second occasion 3 weeks later to test–retest reliability.

A random selection of 50% of countries ( $n = 17$ ) which were members of the European Federation of Radiographer Societies (EFRS) were selected from sealed envelopes. The educational institutions in each country who are affiliate members of the EFRS were contacted via their contact details supplied on the EFRS website. Each of these radiography educational institutes were asked to identify 3 radiographers in 3 different hospital networks (where possible) to complete a survey via SurveyMonkey. Cases of initial non-response were followed up by reminder emails.

Descriptive statistics were performed with the aid of Excel and SPSS version 21.

## Results

Completed questionnaires were returned from 12 out of the 17 different countries selected across Europe. A total of 51 survey responses were sought and 28 completed survey responses were received from Austria, Belgium, Denmark, Estonia, Finland, Hungary, Ireland, Italy, Latvia, Malta, Netherlands, Sweden. Incomplete questionnaire were not included in data analyses.

### Standard operating parameters used across departments

Exposure factors varied greatly for PA chests and AP abdomens using both CR and DR digital systems however exposures for AP pelvis was more comparable as illustrated in Table 1. This variation was noted across all parameters including kVp, mAs, SID and also included variation in the use of anti-scatter grids. Anti-scatter grids were used for all chest radiography in both DR and CR, however when imaging the abdomen and pelvis anti-scatter grids were more commonly used for DR than CR (100% & 92% for abdomen and 93% & 87% for pelvis respectively).

### The range of imaging equipment currently used in hospitals

Regarding the type of hospital involved in the study, hospital size was grouped as <100 beds, 100–500 beds or >500 beds; the majority of hospitals were large with more than 500 beds (54% of responses see Fig. 1). The type of equipment in clinical use varied to include 4% of departments using CR alone, 39% using DR solely and the vast majority use both DR and CR together (57%) (see Fig. 2). The equipment ranged in age from 2 to 25 years with an average age of 8.5 years. Staff training was delivered by the vendor specialists in the majority of hospitals (60%), whilst the remainder of training was cascaded down “in house” to other staff by more senior radiographic staff (40%). On average the majority of staff (60%) received 1–2 days training in the use of CR and DR equipment, with 25% and 15% of staff receiving 3–5 days and 6–10 days training respectively.

### Levels of awareness and use of DRL in the different countries

When asked if they were aware of the use of DRL in their departments 74% of respondents stated that they were using

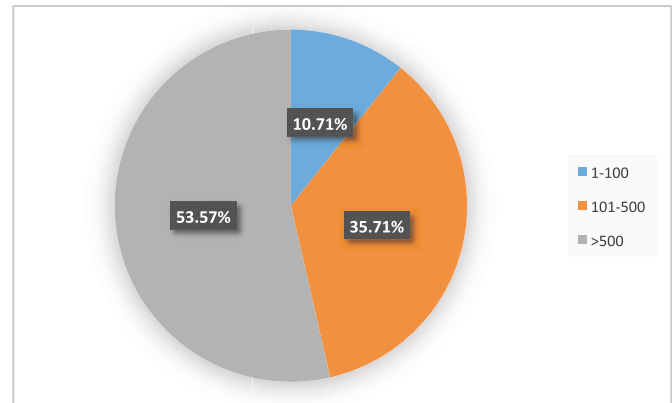


Figure 1. Range of beds in each hospital?

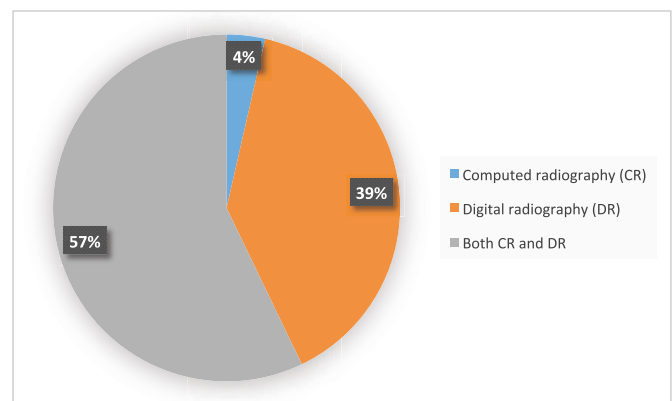


Figure 2. Range of x-ray equipment in use?

nationally established DRL, 13% were using LDRL and 13% reported they do not have DRL (see Fig. 3).

### The education and qualification level of radiography staff employed in the imaging departments

The number of staff in the radiology departments ranged from less than 20 to over 100 radiography staff with a modal response of 21–40 staff (31% of responses) and 54% of departments employing 41 or more staff (See Fig. 4). The European Qualifications Framework (EQF) level of qualifications possessed by the imaging staff varied from EQF level 5 (equivalent to a UK Diploma of Higher Education, or the first 2 years of a 3-year degree) to EQF level 7 (equivalent to a UK Master's degree). When looking at staff qualifications within the separate departments 4% of responding departments had all of the staff holding EQF level 5 qualifications only. A total of 29% had an unequal mixture of EQF level 5 and EQF level 6 with mainly level 5. A further 17% of departments had all of their staff holding qualifications at EQF level 6 and above only—equivalent to a UK Honours degree ± postgraduate study. In total 67% had a mixture of EQF level 5, 6 and 7 qualified staff (see Fig. 5).

Table 1

Standard operating parameters used for chest, abdomen and pelvis radiography.

	Chest CR	Chest DR	Abdomen CR	Abdomen DR	Pelvis CR	Pelvis DR
kVp	55–130	95–150	65–100	77–109	77–81	70–85
mAs	1–6	1–5	16–75	10–40	16–77	13–70
SID (cm)	150–200	150–200	90–180	90–180	90–150	90–150

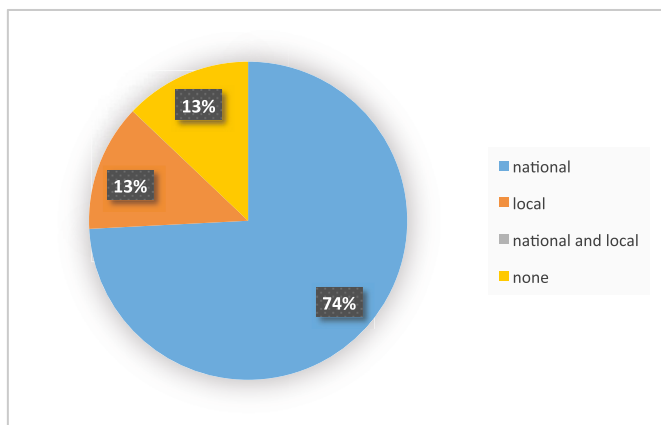


Figure 3. Awareness of DRL in imaging departments.

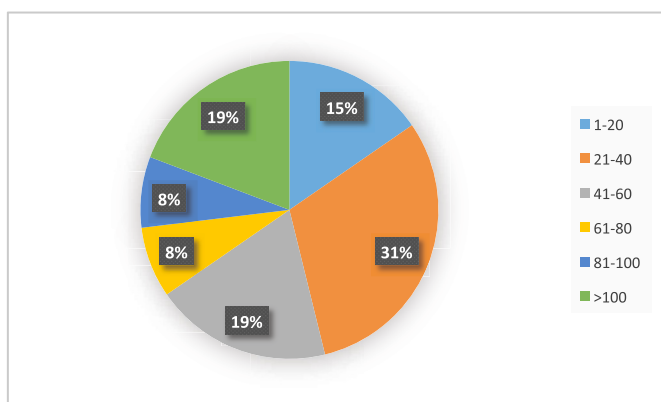


Figure 4. Number of radiography staff in each department?

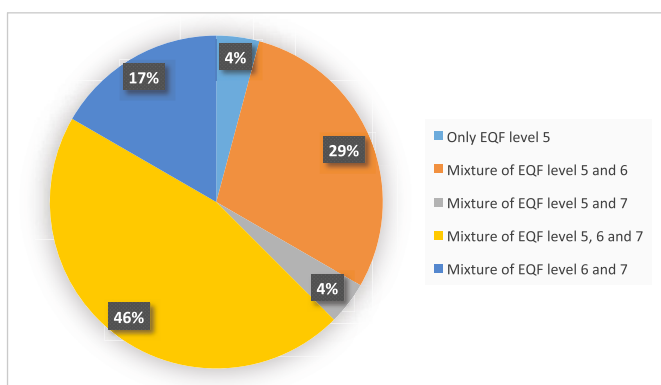


Figure 5. European Qualifications Framework level of qualifications held by staff in departments.

## Discussion

Within the survey, data was obtained from affiliate members of EFRS across 12 out of 17 European countries giving a response rate of 70% of those countries selected. A response rate of 55% was achieved from the individual hospitals which is lower than recent studies<sup>23,24</sup> but comparable with the average rate for online surveys of healthcare professionals.<sup>25</sup> As far as the authors are aware, this is the first survey of radiographer practice using digital radiography across a sample of European countries. Our study shows that across

Europe there is widespread use of CR and DR equipment for plain radiography and also different qualifications of staff operating it.

Variation was identified in the data collected on the standard operating parameters across the three common examinations. Some of this variation is easily explained as the chest kVp varies with some departments favouring low kVp techniques and others high kVp techniques. The majority of hospitals perform a high kVp technique for imaging the chest (85%). The variation in kVp used for abdomens was less easy to explain, with CR exposures ranging from 65 kVp to 100 kVp. This is important to note as Andria et al.,<sup>12</sup> identified that to obtain the best balance between image quality and dose to air, operators should use an average tube voltage value of 90–110 kV. Use of lower kVp settings may not fully optimise the sensitivity of the detector. A surprising variation was also recorded in the SID used for abdomen examinations in one hospital with distances varying between 90 cms and 180 cms (the remainder of hospitals used an average of 110 cm). No correlation was noted between SID used and use of anti-scatter grid. This variation will have a significant impact on the exposure parameters required to produce a diagnostic image, the type of grid used (if any), whether AEC can be utilised and the corresponding dose to the patient. This is of great concern when one considers that these departments were all using similar CR or DR equipment. Similar variation in practice has been reported recently by Bijwaard et al.<sup>26</sup> who highlighted the large variability in doses for the same examination in 21 different Dutch hospitals.

The type of equipment being used by departments to perform chest, abdomen and pelvis examinations was mainly a mixture of CR and DR with DR equipment being more prevalent than CR. 96% of responding departments were using DR equipment, either alongside CR equipment or in solely DR departments. Most staff training was delivered by the vendor specialist however, an additional 40% of training was cascaded down to staff “in-house” by more senior staff. This is usually performed as a cost saving exercise in most departments but may lead to information being misinterpreted or forgotten as it is passed from one member of staff to another. This in turn may lead to different practices among staff in departments.

Variation in many aspects of digital radiographic practice exists between countries – The majority of responding hospitals were large university hospitals who would be expected to keep up-to-date with, and conform to, European and International regulations governing radiological protection and the use of DRL. Although 20% of the departments were relatively small, with less than 20 staff employed, the majority of departments employed more than 40 staff, reflecting the size of the departments and the potential workload that this implies. The use and awareness of DRL was encouraging, with 74% of respondents using National DRL and a further 13% using LDRL, this equated to 87% using DRL. An additional 13% of respondents were not aware of any DRLs in use. The data collected are only for adult examinations and so DRL usage for paediatric examinations cannot be commented upon, however the data presented here agrees with the 2014 data that showed 72% of the 36 European countries were using adult DRL.<sup>3</sup>

The level of qualification held by radiographic staff shows some variation across the countries surveyed with 4% of departments employing imaging staff with EQF level 5 qualifications, the equivalent of a UK Diploma of Higher Education – the standard qualification of an assistant practitioner in the UK. The remaining hospitals employed staff with qualifications above EQF level 5 up to EQF level 7. 4% of departments employed mainly EQF level 5 employees and a mixture of EQF level 7. In total 67% of hospitals reported employees with level 7 qualifications (Masters level) alongside their level 5 and 6 staff. With the increasing complexity of imaging procedures now routinely undertaken in hospitals



world-wide and the widespread use of digital radiography the most appropriate level of qualification for radiographers should also be increasing. It could be argued that level 5 is not a sufficiently high level of qualification for imaging staff working in the modern imaging department – especially in those departments staffed entirely at this level. The European Federation of Radiographer Societies (EFRS) recommendation is that the level of knowledge, skills and competence of a radiographer should be at EQF level 6.<sup>27</sup> The wide variety in radiographic practice seen across the countries surveyed may have its origins in the varied level of educational qualifications held by the staff.

## Conclusions

The variation in education, training and practice would suggest that there is a need for standardisation of protocols and exposure parameters to ensure that there is continued adherence to the ALARA principle. It is essential that operators have a good knowledge of all technical factors in relation to patient dose and image quality in digital radiography.

## Recommendations

DRL should be revised in many hospitals in European countries to ensure they represent current national practices. Staff awareness of DRL needs to be increased to ensure DRL are adhered to both locally and nationally. The education/qualifications required by imaging staff at a European level should be standardised to ensure consistent and safe practise is maintained.

## Conflict of interest statement

None.

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