OPTIMAX 2018

a focus on Education in Radiology

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Foreword

This year, OPTIMAX was warmly welcomed by University College Dublin. For the sixth time students and teachers from Europe, South Africa, South America and Canada have come together enthusiastically to do research in the Radiography domain. As in previous years, there were several research groups consisting of PhD-, MSc- and BSc students and tutors from the OPTIMAX partner Universities or on invitation by partner Universities. OPTIMAX 2018 was partly funded by the partner Universities and partly by the participants.

This year, five research projects were performed with a focus on education on dose- and image quality optimization.

De research projects were:

- CT Simulation as an Active learning tool
- Redesigning a Radiography Practical Active Learning Space
- Does Radiographer Training Across Europe Alter Image Viewing Patterns and Decisions?
- An Investigation into the Use of Lead Shielding Protection in Abdominal Radiography
- Inter-user Variability in DXA Scanning and Analysis

The summer school was concluded with a poster session and a conference, where the research teams presented their results. All five abstracts were submitted to the European congress of Radiology (ECR) and, when accepted, will be presented by the students as posters, or oral presentations.

This book comprises of two sections, the first section contains several chapters about new educational applications for Radiology Education. The second section contains the research papers of the five research projects.

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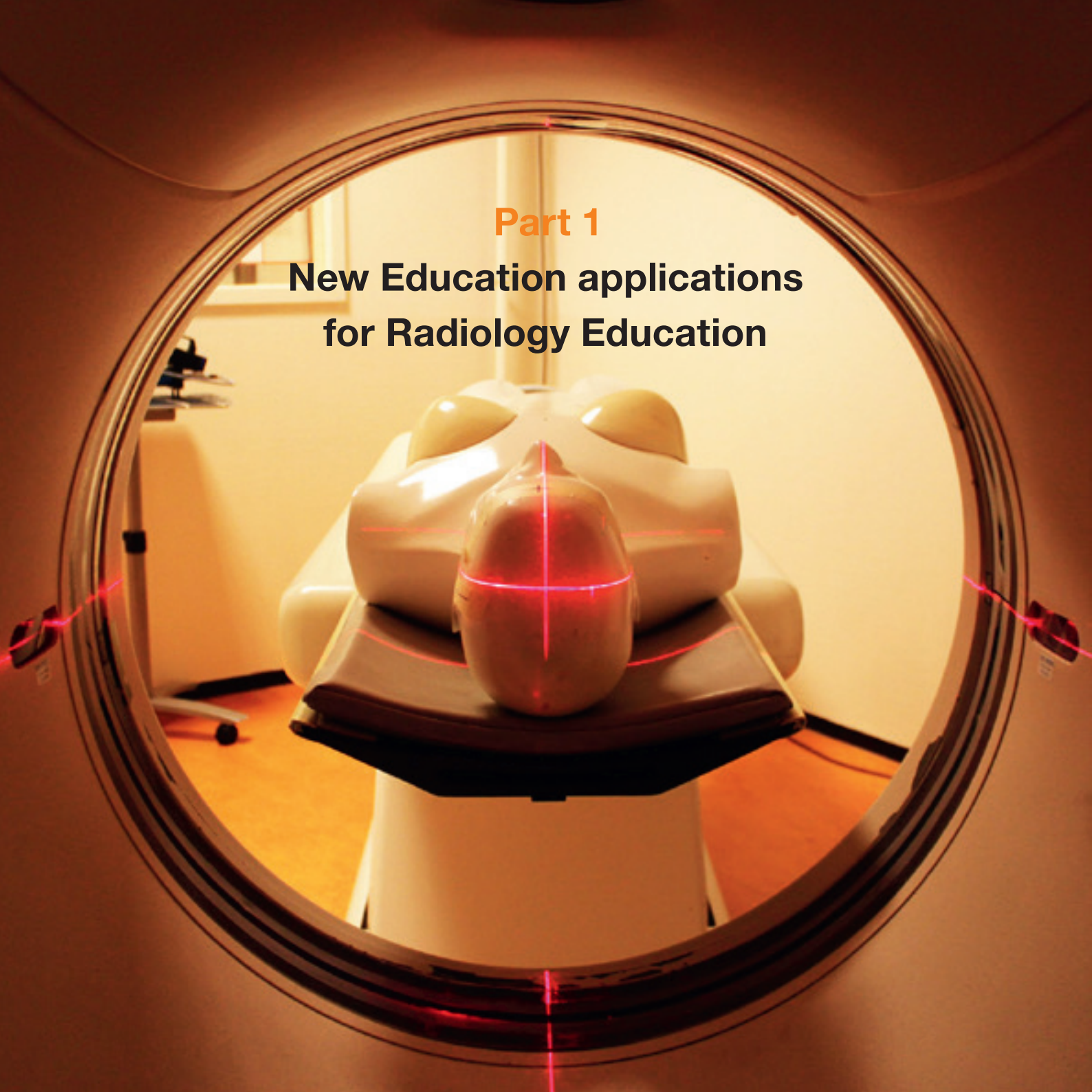

Part 1

New Education applications for Radiology Education

Clinical Simulation in Radiography Education

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Introduction

Demands on radiographer training are continually expanding. Following graduation, like other healthcare professionals, radiographers are required to solve complex clinical problems in real-life situations with multiple conflicting requirements. However, radiography education primarily focuses on classroom lectures and clinical instruction but with the goal of promoting application of theoretical knowledge into clinical practice. Within this context, radiography educators need to provide students with an acceptable level of clinical experience. This is commonly achieved within a balanced educational programme, split between the academic and clinical environments (typically hospital-based placements). This was evident in a recent European Federation of Radiographers Societies (EFRS) report where clinical placements form the basis of radiography education in over 21 European countries (England, et al., 2017). Clinical placements are not the total solution, and, in the same EFRS report, alternative strategies were evident. It is well accepted that clinical placements for all professions have limitations (Yuan, William, Fang, & Ye, 2012). There can be problems with case-mixes, availability of imaging equipment and differences in supervision to name but a few. Radiography educators are aware of this shortfall and strive to promote skills such as critical thinking, reflection and confidence through different learning approaches as they cannot prepare students for all clinical eventualities. Fortunately, technological advances such as simulation, are currently being developed within radiography education. Simulation provides an opportunity for students to learn in realistic clinical simulations and allows them to practise and learn in a safe environment (Shin, Park, & Kim, 2015).

Clinical simulation is a modern day and widely accepted pedagogical approach for training healthcare professions, using advanced educational technology. Put simply, clinical simulation is the experiential learning that every healthcare professional will need but cannot always engage with during real-life patient care. Within healthcare, a variety of simulators are commonly utilised, such as anatomical models of the human body to perform a simple technique, for example intravenous cannulation. Recently, human patient (integrated)

simulators have been found to lead to more realistic experiences and have the ability to offer the students the opportunity to assess, intervene and evaluate patient outcomes (Lee, Eom, & Lee, 2007). More complex systems also have the option of providing an objective assessment of student performance and can form part of assessments.

Traditionally simulation in medicine has been divided into low- and high-fidelity systems, definitions are based on the level of realism and the dynamic nature of the models or scenarios used (Wang, 2011). Healthcare literature suggests the term simulation is linked to a wider use of methods, for example role play, part task trainers, integrated simulators, computer-based systems, virtual reality, simulated patients and simulated environments (Bethea et al., 2014). There has been a huge increase in the utilisation of high-fidelity simulation (HFS) in healthcare education over the past two decades (Crytzer, 2011). HFS refers to the use of a computer-controlled full-size 'integrated' manikin to demonstrate realistic clinical manifestations and scenarios (Au et al., 2016). HFS can also provide an opportunity to communicate and interact with learners (Arthur et al., 2013, Gates et al., 2012). All of the above types of simulation will be explored now in greater detail, together with examples of their applications in radiography education.

Simulated patients (SP)

A SP is usually a professionally trained actor who is directed to present a history and sometimes mimic physical signs, or a patient who has received training to present his or her history in a standardised, reliable manner. Within radiography training, SPs are often used in assessments, for example Objective Structured Clinical Examinations (OSCEs) assessing basic radiographic technique. Occasionally, the learners themselves may act as SPs through role-play. Within radiography education there is huge overlap between SPs and role-play (discussed later within this chapter). SPs provide one option for simulating a number of tasks within radiographic practice. They do, however, fall sort of being fully able to replicate actual clinical scenarios due to the risks from repeat exposure to ionising radiation. SPs are also not fully able to simulate the range of clinical scenarios commonly encountered during radiographic practice, for example cardiac arrests and major trauma. As a result, SPs are often used in combination with other teaching and learning techniques to provide exposure to tasks that students may face within the clinical environment.

Simulated environments (SE)

The re-creation of the environment in which the activity is going to take place is common in simulation and clinical skills centres. Within Higher Education it is common to have rooms on campus which represent

X-ray, CT and ultrasound clinical facilities. In a number these centres these facilitates may be used for clinical work, but this often generates significant logistical and regulatory issues. Within reason, the ability to situate the activity in a realistic environment would be expected to increase the learner's engagement with the simulation and to enhance the suspension of disbelief. Although, for team training, it might be argued that training *in situ,* within the normal clinical environment, can provide individuals with real experience upon which to reflect. Undertaking training in clinical practice may, due to the impact of clinical activity and the distraction of ongoing work, create too much peripheral distraction to learning.

Role-play

Role-play is a widely used educational method for learning about communication. Although educational theory provides a sound rationale for using this form of simulation, as Nestel and Tierney state there is little published evidence on its effectiveness (Nestel & Tierney, 2007). Nestel and Tierney further state that students' prior experiences of role-play may influence the way in which they engage within this method. Role-play can be fully scripted (all players act from verbatim scripts) or partially scripted (players have certain prompts – often an opening line). Alternatively, one player (e.g. patient) is given a description of their role while the other (e.g. student) is provided with their

Figure 1. Example of a radiography technique being simulated using role-play with a fellow student performing the role of the patient (*image courtesy of the University of Salford*).

task. Players can rotate through roles within a single role-play (switching) with the intention of gaining insight into other roles or perspectives or players can be substituted at various points in the role-play by observers. Some role-play activities use role cards as a way of inserting new information into a role-play. Examples of role-play within radiography education include the positive identification of patients, dealing with challenging patients, for example those who are intoxicated or severely confused and when gaining consent for imaging examinations. Role-play can also extend into the practising of radiographic technique (Figure 1) and include radiation protection, moving and handling and infection control skills. Such scenarios are often limited in that the entire examination cannot be simulated (due to the use of ionising radiation) and that replicating complex features of the scenario, for example pain and loss of movement of a limb cannot necessarily be achieved. As previously stated, the reproducibility / success of the role-play scenarios will often depend on the acting skills of the simulated patient and the level of engagement / believe of the student performing the task.

Part-task trainers

These models are meant to represent only one part of a real scenario. Such simulators will often comprise of a single limb or body part (Figure 2). They are generally used to aid in the acquisition of technical, procedural or psychomotor skills such as intravenous cannulation or cardiopulmonary resuscitation (CPR). These simulators allow the learner to focus on an isolated task but are occasionally used in combination to enhance the learning opportunity, for example an anatomical model of the veins of the arm together with an intravenous access upper limb simulator. Some part-task trainers provide feedback to the learner on the quality of their performance (e.g. simple clicking to represent the adequate depth of chest compressions during CPR, the rising of the chest to confirm adequate ventilation and an airway seal). Within radiography training, part-task trainers can be used alongside other educational methods to make a scenario more realistic (Figure 3). For example, during a simulated CT examination an actor can provide verbal feedback to confirm identification, justification of the examination and contrast media safety checks. An upper arm intravenous cannulation phantom can be used to simulate cannulation and contrast administration whilst an anthropomorphic phantom can be scanned to safely simulate the imaging component (Figure 4). Switching between simulators can affect the fidelity of the task under simulation and has led to the development of more complex technologies e.g. HFS.

Computer-based systems

A number of computer-based systems are available for radiography education. Such systems are

Figure 2. A head phantom being used to simulate the performance of an orthopantomogram (OPG) examination as part of a radiography for dental nurses' course (*image courtesy of the University of Salford*).

Figure 3. The PIXY whole-body anthropomorphic phantom being used to simulate the learning of a common radiographic technique among 2nd year diagnostic radiography students (*image courtesy of the University of Salford*).

Figure 4. A head phantom being positioned as part of a simulated CT brain examination. This is a further example of a part-task trainer (*image courtesy of the University of Salford*).

likely to be internet based and form only part of the intended curriculum. These systems are often interactive and provide the user with an interface that represents variables that can be manipulated through the user's actions, providing feedback on the decisions made and the actions taken. The computer-based simulation packages from Shaderware are examples of this technology in radiographic practice. Shaderware currently provides the following computer-based simulation options:-

Within the Shaderware suite of software solutions it is possible, using any Windows PC, to position a simulated patient for either a general radiography examination or CT scan and manipulate the acquisition parameters and see the resultant images. Such systems provide an opportunity to teach practical radiography within the classroom and is highly useful for institutions without direct access to clinical imaging equipment. Radiography is a very hands-on professional and tactile cue are often required in order to ensure correct radiographic technique. Systems like ProjectionVR™ are limited in that they do not provide options for the direct positioning of patients. Such systems also limit the options for teaching and assessing moving and handling, infection control and radiation protection aspects of care. Other systems in addition to Shaderware are available and are either specifically focused on radiography training or more general

Table 1. Overview of computer-based virtual reality simulator systems from Shaderware Ltd.

Software name	Description
TomoVR™	CT simulator with the ability to gain experience and confidence in the positioning of patients and driving the CT operator's console.
ProjectionVR™	Provides a complete virtual X-ray room within a computer environment.
TechnicVR™	Provides an opportunity to support the learning of physics concepts. Within TechnicVR™ a computer model for heat and X-ray production exists with the opportunity to calculate real dosimetric quantities.
LectureVR™	Is an animated and interactive method for presenting model X-ray images to students while teaching image critique. Technology embedded within LectureVR™ also the tutor to alter the image in such a way as to demonstrate the boundary between acceptable and unacceptable.

Information sourced from www.shaderware.com

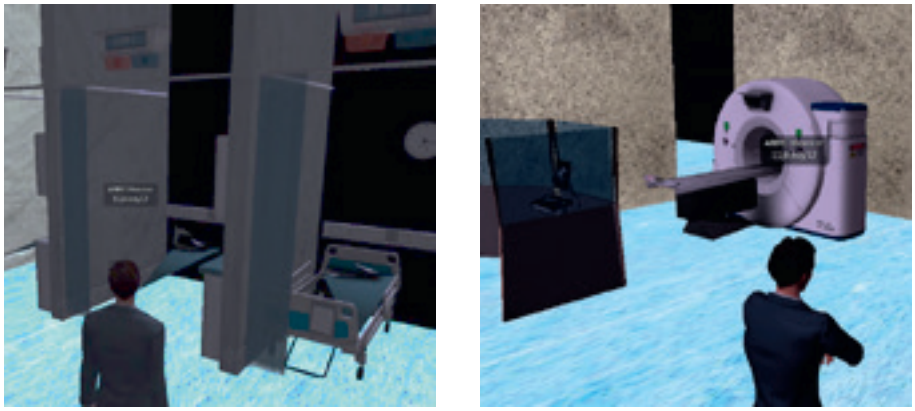

Figure 3. A screenshot from the Second Life computer programme showing an avatar present in a virtual hospital (left image) and CT suite (right image).

aspects of health care. The computer-based simulation software Second Life (Figure 3) provides an opportunity to explore virtual worlds. Within this system there is the option of visiting a hospital and in particular a Radiology Department. Scenarios can be built into Second Life in order to test a variety of skills, such as the management of patients and department design.

Virtual reality and haptic systems

A more sophisticated application of computer technology is encountered in truly virtual reality (VR) and haptic systems. Virtual reality refers to the recreation of environments or objects as a complex, computer-generated image; haptic systems refer to those replicating the kinaesthetic and tactile perception. Often VR and haptic systems are combined with some form of part-task trainer; the products that are currently available support vascular access training, endoscopy, laparoscopic surgical techniques and ultrasound examinations (Medaphor Scantrainer; Figure 4). Some of the applications provided by Shaderware and Second Life, for radiography, will also have overlap into the virtual reality domain.

Within radiotherapy training, VR systems have been well established in training curricula for many years (VERT). VERT is a virtual reality radiotherapy treatment room which allows the illustration of theoretical concepts right through to the acquisition of clinical skills in a safe environment. Being a virtual environment, VERT has the advantage of being able to respond to changes in radiotherapy treatment technology. With developments in radiotherapy, for example proton beam therapy, it will be possible

Figure 4. Medaphor Scantrainer® being used to train a sonography as part of a postgraduate abdominal ultrasound module (*image courtesy of the University of Salford*).

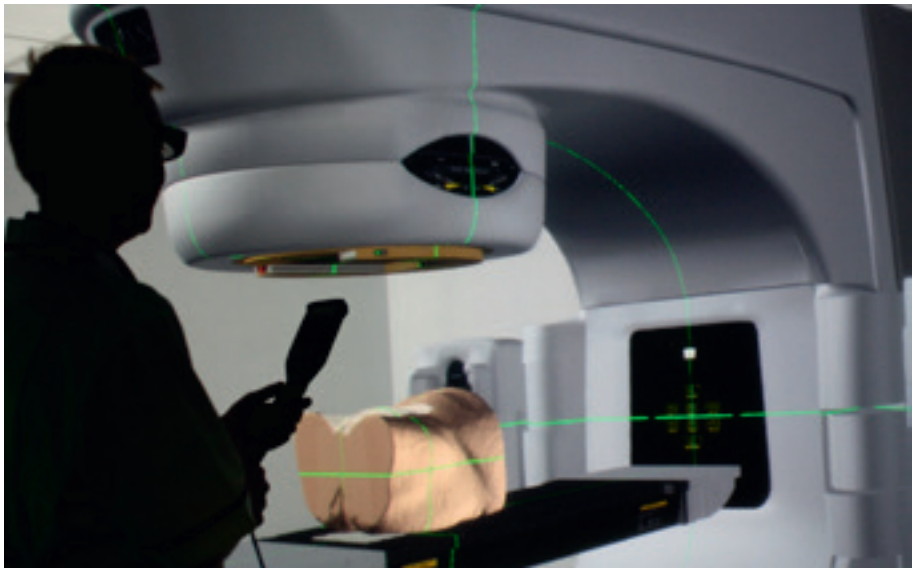

Figure 5. An example of the immersive VERT environment with a student positioning a section of a patient for a simulated radiotherapy treatment (picture courtesy of Vertual).

to simulate treatments without any major physical upgrades to equipment. This will allow both academic and clinical departments to remain clinically current but without the expense of acquiring new treatment units. VERT systems are available as immersive (fully virtual reality environments; Figure 5) or seminar (standard projector) based with the latter coming at a reduced cost. Both systems offer the same overall functionality but the immersive environment provides an added level of realism.

Integrated simulators

Integrated simulators are whole body mannequins (adult, child or infant) that are capable of responding to a variety of situations (Figure 6a). These can be the introduction of certain medications (Figure 6b), chest compressions, chest tube placement, urinary catheterisation and other physiological interventions and responses. Integrated simulators are known by a variety of names including human patient simulators or high-fidelity simulators (HFS). Due to their complexity they help suspend disbelief during a simulated scenario due to the integral computer technology housed inside the mannequin which allows the mannequin to respond in real-time to specific clinical interventions. Such systems are highly appealing to both educators and students because of their ability to contribute to very high

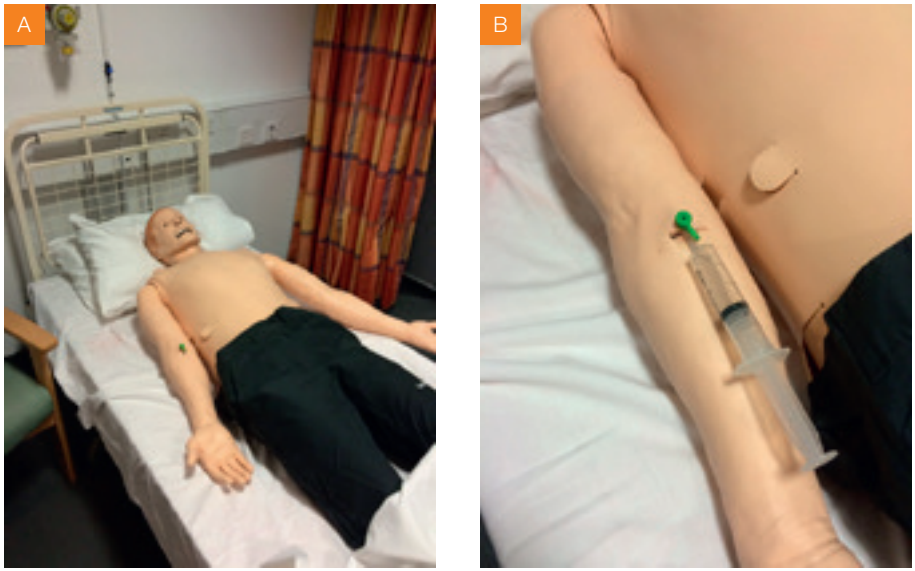

Figure 6. An example of an adult SimMan 3G integrated simulator (**A**) with the option of directly administrating intravenous pharmaceuticals (**B**) (*image courtesy of the University of Salford*).

degrees of realism (fidelity) within the simulated scenario.

As stated, HFS simulators combine a mannequin (usually a whole-body adult, child or baby) with sophisticated computer controls that can be manipulated to provide various physiological parameter outputs that can be physical (such as a pulse rate or respiratory movements) or electrical (presented as monitor readouts; Figure 7). These parameters may be automatically controlled by a physiological and pharmacological model incorporated within the software or may respond to instructor inventions in response to the actions of learners. The sophistication of these simulators and their costs vary. The METI and Medsim are HFS that have been at the forefront of work in anaesthetic simulation. More recently, SimMan (Figure 6a), a moderate-fidelity simulator, has become available at a much lower cost enabling an unprecedented growth in the use of this level of simulation.

Within radiography curricula at the University of Salford, HFS are used throughout all years of study. Within the second year, students are faced with a simulated anaphylactic reaction in which they must assess the patient and manage the reaction (Figure 8). In order to make the scenario more realistic careful planning and preparation are required. Successful simulations required that the scenario is broken down into a series of steps, these must list all cues and actions possible, both from the simulator and also the students (Figure 9). In order to create an added level of realism an actor's voice is relayed directly from a speaker in the mouth of the mannequin. Using this the actor can respond directly to verbal cues by the students. Microphones are also present within the mannequin and allow both the actor and the simulator supervisor to modify the scenario in real-time. More sophisticated systems provide the option of producing feedback on the scenario, this can be both objective (Figure 10) and subjective and can be printed out or emailed at the end of the scenario to the participating students. Since the simulated tasks are delivered in a safe and secure environment there is also the possibility of video recording the scenario. This provides additional possibilities in terms of students' reflecting on their performances and also through class observations or peer-review. Such endeavours require the appropriate physical resources to be available and the careful planning of facilities.

Summary

Simulation has come a long way, but there are still many barriers to its widespread use in radiography education. Fidelity, validity and cost issues still justify the delay in implementation. Equipment costs, skilled personnel and simulation programs have, however, improved over recent years. These

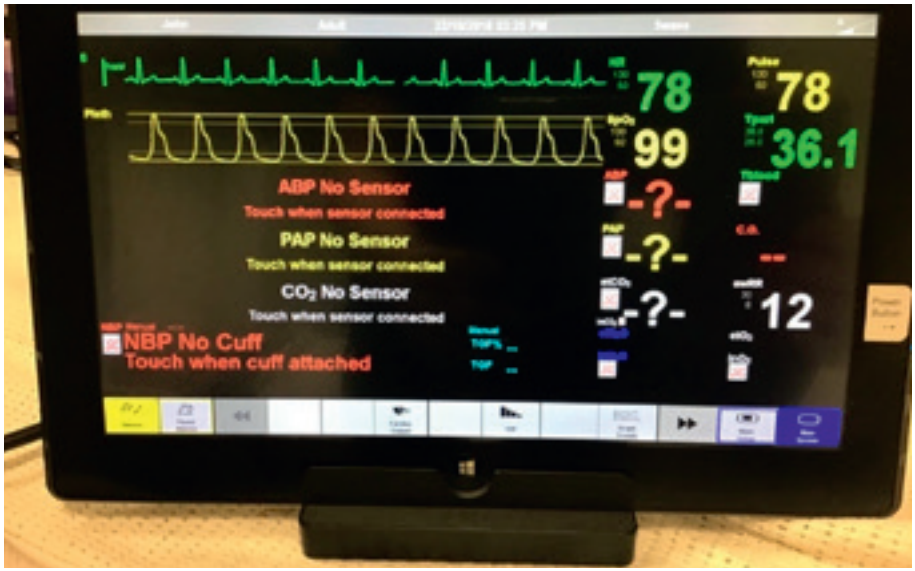

Figure 7. A physiological monitor display linked to the SimMan 3G simulator. This provides students with electronic simulations of vital signs from which the students are expected to make decisions about patient care. Such readouts can be adjusted in real-time by a computer linked directly to the simulator (*image courtesy of the University of Salford*).

Figure 8. An example of a high-fidelity simulated scenario using the SimMan 3G simulator. Within this scenario students are faced with a patient going into anaphylactic shock following the injection of iodinated contrast media as a part of a CT examination (*image courtesy of the University of Salford*).

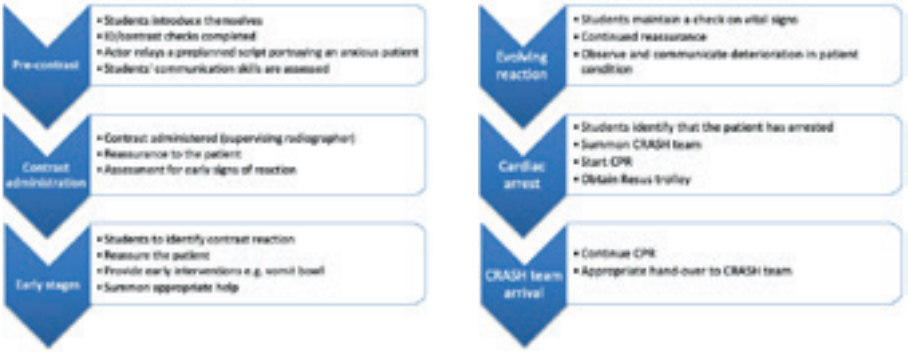

Figure 9. Example of the planning of a CT based contrast anaphylaxis scenario undertaken by 2nd year radiography students.

Figure 10. Within HFS simulation it is possible to acquire and provide students with objective assessments of their performance. On the left-hand image, the simulator is displaying normal vital signs whereas on the right-hand image the patient is in cardiac arrest. Feedback is being provided on the location, depth and rate of chest compressions (*image courtesy of the University of Salford*).

partnerships support the projection of increases in multidisciplinary, interprofessional, and multimodal simulation training. Worldwide acceptance of simulation is growing. The debate over the use of mannequin-based simulation for competency testing still remains controversial. Within radiography the need to produce images using ionising radiation and the tactile nature of the profession place further demands on simulator design. As within other professions, simulation is likely to progress into postgraduate training and possibly the maintenance of state registration. Simulation is not the only answer, it is likely that there are many skills which can be taught and assessed using simpler pedagogical approaches. Any radiography training curricula must be diverse in its approach to teaching and learning. It

must also factor in the needs of the learners and also the demands of the profession. A balanced curriculum is likely to include a component of simulation, this is likely to increase over the coming years with growing demands placed on training and further advances in digital imaging technology.

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Human tissue radio sensitivity, a review of literature and BEIR

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University of Salford

Introduction

We are exposed daily to ionising radiation, mainly from natural sources found in the environment, in our food and water. Additional exposure comes from unnatural sources including medical imaging or treatment using electromagnetic radiation or particulate radiation (3). The interactions of ionising radiation with biological cells occurs at the atomic level and it is the change in the atomic structure that can lead to cellular damage. The type of radiation influences its biological effectiveness with X-ray and gamma ray photons and beta particles the least damaging and alpha particles and other heavy nuclei are the most damaging.

Different tissues within the body have been shown to have different sensitivities to ionising radiation. The sensitivity is proportional to the rate of cell

Relative Radiosensitivity	Tissues (examples)
High	Lymphnoid tissue Bone Marrow Blood Intestines
Fairly High	Skin and other organs with epithelial cell lining (cornea, oral cavity, oesophagus, rectum, bladder, vagina, uterine cervix, ureters)
Moderate	Optic lens, stomach, growing cartilage, fine vasculature, growing bone
Fairly Low	Mature cartilage or bones, salivary glands, respiratory organs, kidney, liver, pancreas, thyroid, adrenal and pituitary gland
Low	Muscle, brain and spinal cord

Table 1 *NDT Resource Center (3) Citing Rubin and Casarett (2).*

division and inversely proportional to the degree of cell differentiation. This means that cells that are undergoing division or maturation processes are the most sensitive to ionising radiation. As far back as 1968, Rubin and Casarett presented data listing various tissues and their relative radiosensitivities (4) (Table 1).

Interaction of Ionising Radiation with Biological Matter

The damage to the cell is caused through direct or indirect action on the DNA molecules found within every cell of the body. The DNA molecule is composed of two strands which curl around each other to form the familiar 'twisted ladder' of the double helix. The 'rungs' are made of two bases, namely cytosine [C], guanine [G], adenine [A] or thymine [T] and connect in the middle in a specific pattern. 'A' only pairs with 'T' and 'C' only pairs with 'G'. These bases are always fixed in pairs, but they can appear in any order (eg A-T or T-A, C-G or G-C) which acts as a 'code' for the production of specific proteins. The 'legs' of the ladder are referred to as the backbone of the molecule and are composed of alternating sugar (deoxyribose) and phosphate molecules (5,6).

When cells are exposed to radiation, the radiation may pass directly through without causing any damage or interact at the atomic level within the DNA causing damage. This DNA-damage can be repaired, affect the cell's ability to reproduce itself correctly (i.e. mutation), or result in cell death through apoptosis.

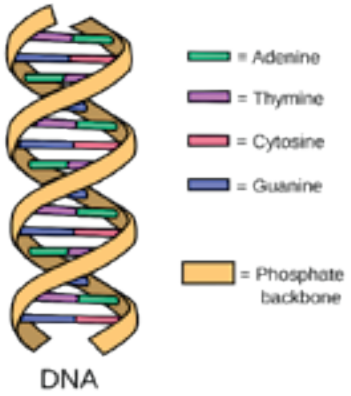

Figure 1 Illustration of the double helix DNA molecule made up of the four nuclea-bases and the sugar-phosphate backbone (7)

Direct action involves the photon (or alpha or beta particle) physically breaking one or both sugar-phosphate backbones or break the base pairs. Double backbone breaks are more difficult to repair and are more likely to result in apoptosis or cell mutation. Indirect damage is caused through the creation of free radicals (an uncharged molecule having an unpaired valency electron) which are highly reactive and cause chemical reactions within the cell leading to altered function or cell death. Radiation that deposits a large amount of radiation in a short linear distance (eg alpha particles) predominantly cause direct damage where X-ray and gamma ray photons predominantly cause indirect damage (8).

Effects of Ionising Radiation

The effects of ionising radiation are classed as deterministic (non-stochastic) or stochastic. Deterministic effects, also referred to as tissue reactions (9), occur after a threshold radiation dose has been breached and, on further exposure, worsens. Deterministic effects are a consequence of a sufficiently large number of cells being damaged in a period of time that the body is unable to replace them (10). Radiation protection of patients, members of the public, carers and comforters and radiation workers aim to prevent these deterministic effects occurring. To this end, for radiation workers and the public, the ICRP set dose limits below which tissue reactions should not occur (Table 2)

Type of limit	Occupational	Public
Effective dose	20mSv per year (averaged over defined periods of 5 years with provision that the effective dose should not exceed 50mSv in any single year)	1 mSv
Annual equivalent dose		
Lens of the eye[1]	20 mSv (averaged over defined periods of 5 years, with no single year exceeding 50 mSv)	15 mSv
Skin (averaged over 1 cm^2 regardless of area)	500 mSv	50 mSv
Hands and Feet	500 mSv	-

Table 2 *Dose limits as quoted by ICRP in reports ICRP 118[1] and ICRP 103* (9,11)*.The lower lens dose limit was published following review in 2012.*

It is essential to note that dose limits do not apply to medical exposures, ie patients. Provided the exposure is justifiable it can proceed as the effectiveness of diagnosis could be reduced and do more harm than good.

Stochastic can be considered as a "chance effect" and only the *probability* of an effect increases with radiation dose, the effect does not get worse. The widely accepted model used to set regulatory limits of radiation exposure is the linear non-threshold dose model (LNT). This model involves the scaling of the recorded effects of higher doses of radiation to low dose scenarios. Other models have been proposed as described by Hendee and O'Connor (12) and illustrated in Figure 2. This model is chosen due to its simplicity and its conservative approach. Quoting Scott (13), "if it is not correct then it is likely that the approach overestimates the risk of cancer induction at low doses". The linear non-threshold model is the "worst case scenario" where any exposure to ionising radiation carries a risk and it could be argued that this is erring too much on the side of caution and could impact on uptake of radiological procedures due to perceived risks.

Estimating Risk from Ionising radiation

The conventional way of reporting dosimetry is to use effective dose, which can be used in the comparison between imaging techniques and between different imaging modalities that use ionising radiation. Effective dose is the sum of the weighted organ doses. The tissue weightings are defined in the ICRP report 103 (11) and represent the relative sensitivities of the tissues and organs. A criticism levelled at effective dose is its inability to account for the age of an exposed individual and its limited approach to differences in radio-sensitivities between genders.

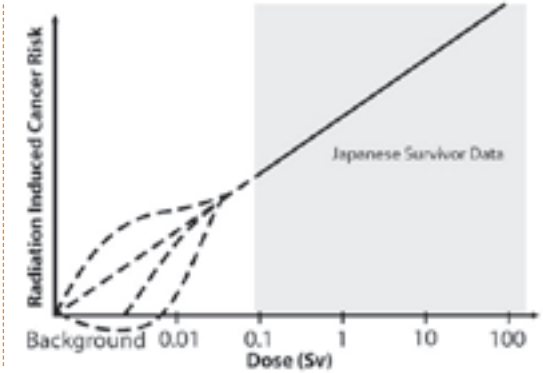

Figure 2 Models for extrapolating radiation-induced cancer risk to low doses (dashed line and curves) (12). Linear no-threshold (LNT) model = dashed straight line

An alternative is to use the available dosimetry data to calculate an estimation of the risk from an exposure to ionising radiation. Available data accounts for the age and gender of the individual and provides a less generic figure that can be used in the decision-making process.

Estimating the risk from an exposure to ionising radiation, especially low-dose exposures, is full of uncertainties. There are many publications available that will allow researchers to use measured or estimated dosimetry data to calculate the probability of the exposed individual from developing cancer in their lifetime (2) The most commonly used method is provided in the report Biological Effects of Ionising Radiation (BIER VII Phase 2). Published by Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, part of the Board on Radiation Effects Research Division on Earth and Life Studies who in turn are part of the National Research Council of the National Academies, the report uses data from epidemiologic and experimental research to determine how regulatory bodies should best characterise risks at low radiation dose level and rates.

The report explains that competing models of risk exist and are termed Excess Relative Risk (ERR) and Excess Absolute Risk (EAR). ERR is the rate of disease in an exposed population divided by the rate of disease in an unexposed population, minus 1.0. This method assumes that the there is a proportional relationship between the excess risk of cancer to the baseline cancer incidence. The EAR model is the rate of disease in an exposed population minus the rate of disease in an unexposed population and is more suited if there are significant differences between the reference population and the population under investigation (eg ethnicity). It is assumed that the baseline cancer incidence does not influence the rate of radiation induced cancers. Both models permit the calculation of the risk of cancer at a specified time post exposure.

To allow the calculation of the lifetime risk of cancer, a third method was developed. The Lifetime Attributable Risk (LAR) is the sum of ERR and EAR for each year after exposure out to a specified lifespan of approximately 80 years (14). In the development of this method the authoring committee of the Biological Effects of Ionising Radiation VII report were confronted with a decision as to which method to use to calculate LAR as there was poor correlation between EAR and ERR models and the large discrepancy between risk coefficients from medical studies and the atomic bomb survivor studies. To combine the several sources of uncertainty and generate a single estimate of LAR the BEIR VII committee created the final risk model by using a variable between 0 and 1 that reflected the relative strength of belief in the two models (15).

TABLE 12D-1 Lifetime Attributable Risk of Cancer Incidence[a]

Cancer Site	Age at Exposure (years) 0	5	10	15	20	30	40	50	60	70	80
Males											
Stomach	76	65	55	46	40	28	27	25	20	14	7
Colon	336	285	241	204	173	125	122	113	94	65	30
Liver	61	50	43	36	30	22	21	19	14	8	3
Lung	314	261	216	180	149	105	104	101	89	65	34
Prostate	93	80	67	57	48	35	35	33	26	14	5
Bladder	209	177	150	127	108	79	79	76	66	47	23
Other	1123	672	503	394	312	198	172	140	98	57	25
Thyroid	115	76	50	33	21	9	3	1	0.3	0.1	0.0
All solid	2326	1667	1325	1076	881	602	564	507	407	270	126
Leukemia	237	149	120	105	96	84	84	84	82	73	48
All cancers	2563	1816	1445	1182	977	686	648	591	489	343	174
Females											
Stomach	101	85	72	61	52	36	35	32	27	19	11
Colon	220	187	158	134	114	82	79	73	62	45	23
Liver	28	23	20	16	14	10	10	9	7	5	2
Lung	733	608	504	417	346	242	240	230	201	147	77
Breast	1171	914	712	553	429	253	141	70	31	12	4
Uterus	50	42	36	30	26	18	16	13	9	5	2
Ovary	104	87	73	60	50	34	31	25	18	11	5
Bladder	212	180	152	129	109	79	78	74	64	47	24
Other	1339	779	523	409	323	207	181	148	109	68	30
Thyroid	634	419	275	178	113	41	14	4	1	0.3	0.0
All solid	4592	3265	2525	1988	1575	1002	824	678	529	358	177
Leukemia	185	112	86	76	71	63	62	62	57	51	37
All cancers	4777	3377	2611	2064	1646	1065	886	740	586	409	214

NOTE: Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.

[a]These estimates are obtained as combined estimates based on relative and absolute risk transport and have been adjusted by a DDREF of 1.5, except for leukemia, which is based on a linear-quadratic model.

TABLE 12D-2 Lifetime Attributable Risk of Cancer Mortality[a]

Cancer Site	Age at Exposure (years) 0	5	10	15	20	30	40	50	60	70	80
Males											
Stomach	41	34	30	25	21	16	15	13	11	8	4
Colon	163	139	117	99	84	61	60	57	49	36	21
Liver	44	37	31	27	23	16	16	14	12	8	4
Lung	318	264	219	182	151	107	107	104	93	71	42
Prostate	17	15	12	10	9	7	6	7	7	7	5
Bladder	45	38	32	27	23	17	17	17	17	15	10
Other	400	255	200	162	134	94	88	77	58	36	17
All solid	1028	781	641	533	444	317	310	289	246	181	102
Leukemia	71	71	71	70	67	64	67	71	73	69	51
All cancers	1099	852	712	603	511	381	377	360	319	250	153
Females											
Stomach	57	48	41	34	29	21	20	19	16	13	8
Colon	102	86	73	62	53	38	37	35	31	25	15
Liver	24	20	17	14	12	9	8	8	7	5	3
Lung	643	534	442	367	305	213	212	204	183	140	81
Breast	274	214	167	130	101	61	35	19	9	5	2
Uterus	11	10	8	7	6	4	4	3	3	2	1
Ovary	55	47	39	34	28	20	20	18	15	10	5
Bladder	39	51	43	36	31	23	23	22	22	19	13
Other	491	287	220	179	147	103	97	86	69	47	24
All solid	1717	1295	1051	862	711	491	455	415	354	265	152
Leukemia	53	52	53	52	51	51	52	54	55	52	38
All cancers	1770	1347	1104	914	762	542	507	469	409	317	190

NOTE: Number of deaths per 100,000 persons exposed to a single dose of 0.1 Gy.

[a]These estimates are obtained as combined estimates based on relative and absolute risk transport and have been adjusted by a DDREF of 1.5, except for leukemia, which is based on a linear-quadratic model.

Figure 3 *Tables from BEIR VII stating the number of cancer cases (12D-1) and number of deaths (12D-2) per 100 000 persons exposed to 0.1Gy* (15)

Data presented in BEIR VII is easy to interpret with tabulated data stating the risk of cancer induction per unit dose in the often quoted “Table 12D-1 and 12D-2” Figure 3.

It is essential to note however, that there is a significant degree of uncertainty in the estimations due to the limitations of the epidemiological data which are generated from high dose atomic bomb survivor studies and clinical studies. It is argued that the cancer estimates should not be quoted as scientific fact and researchers should be aware of the uncertainty in the figures (16,17). However, there is a requirement that patients are made aware of the level of risk from any investigation or procedure (11,18,19). How this should be done is subject to much debate, for example should patients be presented with the absolute statistical risk (eg 1 in 1 000 000 chance of cancer induction), relative risk (eg compared to everyday activities) or a categorical risk as suggested by Wall et al (20) and presented in Table 3.

Using the life time attributable risk data can be used to obtain estimates for exposure scenarios. However, risk estimates should not be considered in isolation and with due regard to the uncertainty in their calculation. They should be considered alongside any dosimetry measurements or estimates.

Conclusion

Arguably, providing an indication of the level of risk is a better approach than a patient specific risk value as the statistics that sit behind the Figure 3 are subject to uncertainty due to the reasons described above. However, to aid the contextualisation of a dose the figures do provide researchers with an indication of the effect an intervention or alternative method of acquisition had. Using Quoting the figures as scientific fact does go against the BEIR VII statement of regarding estimates of LAR should be regarded…

“…with a healthy scepticism, placing more faith in a range of possible values” (Nations Scientific Committee on the Effects of Atomic Radiation, 2000).

Table 3 *The four broad risk categories relevant to diagnostic imaging* (20)

Category	Life time cancer risk		
Negligible	< 1/1 000 000		
Minimal	1/1 000 000	to	10/1 000 000
Very Low	10 / 1 000 000	to	100 / 1 000 000
Low	100 / 1 000 000	to	1 000 / 1 000 000

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The value of effective risk to decision making in radiographic practice

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This chapter considers communicating radiation risk to patients/clients, with Effective Risk in mind. Effective Risk takes into account the quantity of radiation received, which organs are exposed to radiation together with their tissue specific lifetime cancer risks per unit of equivalent dose. This data is specific to gender and age. Effective Risk is normally expressed as the number of cancers likely to be induced from the exposure, typically being expressed as 'the number of cancers induced per million [similar] people exposed to that radiation dose'. This data can then be presented in other simpler ways, perhaps being conveyed in one word, such as the risk of cancer induction could be considered as 'negligible' or 'minimal' – as would be the case for many diagnostic imaging procedures.

Effective Risk is considered to be a helpful way in which to convey radiation risk information to patient/clients as it is in an understandable form, unlike concepts such as Effective Dose (Sv), Absorbed Dose (Gy), Surface Entrance Dose (ESD (Gy)) and so on. Let us now consider perspectives from Referrer, Practitioner, Operator and of course, the Patient/Client.

The Referrer (e.g. physician, dentist or other authorised healthcare professional), as the name suggests, is the person who, after clinical examination, refers their patient/client to the medical imaging department for radiological opinion. At this stage the Referrer should explain to the patient examination benefits in relation to determining normality and/or whether an abnormality might be detected. This explanation should also outline the general risks of the examination and this should consider radiation risks. Sadly, despite a legal requirement for Referrers to be aware of the biological effects of radiation and risks, a substantial body of literature suggests this discussion, between Referrer and patient/client, is devoid or limited in information about the radiation risks. Research following on from this, in analyses of Referrer knowledge about radiation risks from medical imaging, has established that

Referrer knowledge is often limited. This reduces the value of such conversations. This problem has been explained by some in terms of the limited coverage of ionizing radiation and its detrimental effects within formative medical or dental practitioner (i.e. 'doctor') education. Similar to Practitioners and Operators, Referrers often use relative concepts that are general in nature and not overly specific to the case in hand, but perhaps they are more easily understood and remembered by patient/clients and clinicians alike because they are not laden with complicated physics concepts and terminology. For example,

A chest x-ray is about the same radiation dose, and therefore radiation risk, as a trans-Atlantic flight

Obviously the above does not indicate what the actual risk is as nothing is quantified, however it does translate into everyday language which helps to start a meaningful conversation with the patient/client about risk. If translated into Effective Risk parlance, the flight statement could be modified, for example

For a 50 year old male, a typical trans-Atlantic flight might have a cancer induction rate of ONE in ONE MILLION and this is consistent with the radiation associated with one chest x-ray. Therefore the radiation risk is negligible1

Taking a slightly different example

For a 10 year old female, a typical trans-Atlantic flight might have a cancer induction rate of FIVE in ONE MILLION and this is consistent with the radiation associated with one chest x-ray. Therefore the radiation risk is negligible[1]

In each of the above cases, risk is expressed in an individualised fashion which uses lay language and both are likely to be understood by the recipient. Individualisation relates to appropriate information which takes account age and gender, thereby separating out the different probabilities of ONE versus FIVE in ONE MILLION; however the outcome for both is the same in that each has a *negligible* radiation risk. From patient/client and healthcare professional's perspective the availability of a mobile phone app based on Diagnostic Reference Levels for all medical imaging procedures that use ionizing radiation could be a valuable asset to facilitate radiation risk conversations with patients/clients. Such an app would make available Effective Risk data for each examination along with an indication of

1 The data used in this example are fictitious and should not be quoted in clinical practice

whether the risk would be considered as ‘negligible’, ‘minimal’ and so on. With dynamic linking to organ risk factors, any changes over time could be captured within the app through automatic updates. Further research and development work is needed to create the underlying data to populate this app along with the creation of the app itself.

A key issue that must be considered when informing patients/ clients about radiation risk is to present a balanced argument, such that they can relate benefits and limitations of choosing to undergo or not undergo the imaging procedure, making an informed decision. With the concept of Effective Risk in mind, which can be used to convey risk in terms of cancer induction probability using terms such as ‘negligible’ or ‘minimal’ (etc), further research is needed to understand how patients/clients interpret these terms. A key issue to be explored will be to understand whether ‘cancer induction probability’ adversely affects their decision; if this is the case then strategies will need developing to help patients/clients cope with this type of information as they reach a decision on whether or not to have the imaging procedure.

After the Practitioner has considered the benefits and the risks of the examination and has justified the procedure, the Operator is then responsible for performing the procedure. This should be performed in a manner such that the amount of radiation used is As Low As Reasonably Practicable. As part of the decision-making process the Operator can vary a wide range of acquisition conditions and factors, these include: kVp, mAs, respective distaces between the source, patient and image receptor, filtration, grid / no grid, PA versus AP; and in CT examinations additional factors such as pitch and slice thickness etc. The problem faced by an Operator is, at the time of setting acquisition factors / conditions, they are not fully aware of the potential detriment (risk) to the patient/client when these are altered. Effective Risk can play a part here, by ‘individualising’ the risk by taking account of age / gender along with all acquisition variables through effective use of, for example, Monte Carlo [predictive] modelling. In this scenario the actual probability of cancer induction risk for the patient under investigation, expressed as ‘n’ per million, can be conveyed to the Operator on the acquisition console as they manipulate conditions and factors. With Effective Risk information available at point of care the Operator can then make truly informed decisions about the consequences of the factors / conditions as they manipulate them and this should lead to better optimisation practice as the Operator can experiment with different combinations in a time efficient fashion. For example, children have a higher radiation risk than adults and the Operator may spend more time optimising because of this. Knowing that increasing SID and kVp can reduce Effective Dose (and Effective Risk) even when using

the AEC to ensure noise / image quality is controlled, it seems sensible that an increase of 10-20cm to SID and 10kVp could make an important reduction in Effective Risk and this could be done in an informed fashion at the point of clinical care. Balanced against this is the need to be aware of how these changes will affect the quality of examination.

Suggested Reading

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Technology Enhanced RIS/PACS education yields extra benefits

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Abstract

Evidence has shown that employers want higher education to place more emphasis on helping students to develop five key learning outcomes including critical thinking, complex problem-solving, written and oral communication and applied knowledge in real-world settings. They consistently rank outcomes and practices that involve application of these skills over acquisition of discrete bodies of knowledge. It was only fitting then as University College Dublin School of Medicine redesigned the delivery of its RIS/PACS module for student Radiographers that these tenets were used to guide the evolution of the module from a knowledge-based didactic model to a true competency-based practice module.

Introduction

The Radiology Information System/Picture Archiving and Communications System or RIS/PACS module of the BSc Radiography programme at University College Dublin, was traditionally a largely didactic module that relied heavily on assessment of what was essentially rote learning. Indeed, this kind of delivery is quite prevalent in the vast majority of Health Sciences schools (Roth et al., 2014). The scope of the module encompassed general computer knowledge, Healthcare Information Technology (HCIT) architecture and systems, Standards, Legislation, Security and clinical workflows. It had a mid-semester task which resulted in an essay report and an end of semester examination. Students valued the mid-semester assessment but while the module reported good grades in comparison to other semester modules, the end of semester exam was seen by

students as the most stressful due to the left-field nature of the subject and the disproportionate amount of revision time it demanded. Undergraduate feedback showed little appreciation of the relevance of the subject and even post graduate feedback showed that it was several years before the importance of the subject material became apparent.

However, this was a Practice of Radiography module and by that definition, success in the module was supposed to confer clinical competence in this topic. The existing assessment structure did attempt to measure knowledge and the grades for this module were consistently good. But what did this really tell the educators or indeed the students involved in this module. Were the students trained to an adequate level? The answer would be 'yes', looking at the learning outcomes and the grades but the students themselves disagreed. The following student comment supports our understanding that rote learning style modules are not effective in the long term (Weinstein et al., 1988) and lead to a "Learn & Forget" culture.

Were they competent? Competence was inferred based on the fact that the knowledge was demonstrably present in the traditional didactic model used. The Oxford dictionary defines competence

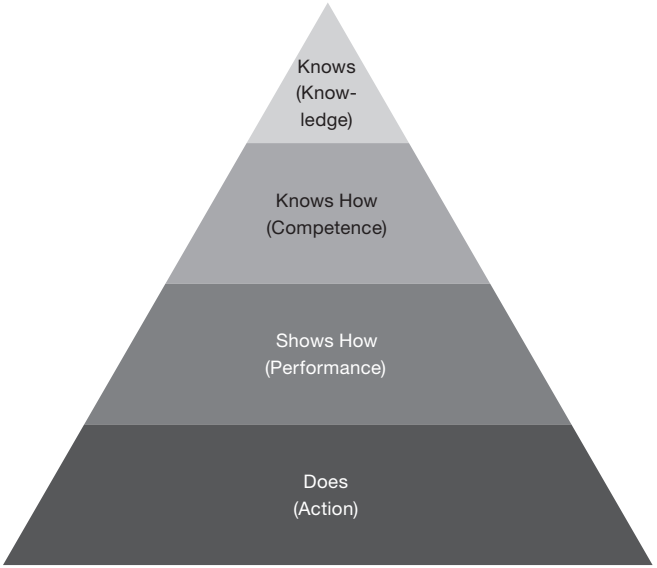

Figure 1: Miller's Framework for clinical/professional competence (Miller, 1990)

as “the ability to do something successfully or efficiently”. When the module was considered in the context of Miller’s framework for clinical/professional assessment (Miller, 1990) it was clear that it was definitely not achieving its designated goal of assessing practice competence but merely testing knowledge, a common enough trap (See figure 1).

Assessment has the ability to do more than simply act as a score or measure and indeed Gibbs and Simpson (2004) suggested “we should design assessment, first, to support worthwhile learning”. Bloxham and Boyd (2007) also make reference to the effectiveness of assessment activities saying they “should be designed to encourage good quality ‘deep’ approaches to learning in the students”. Indeed as far back as 1992, Conway et al. found that coursework as opposed to end of semester examinations were a better predictor of long term learning bringing into question even the reliability of end of semester examinations. It was clear that the entirety of the historical assessment plan was summative or assessment of learning with no formative features or feedback to influence change whatsoever (Hattie and Timperley, 2007), or in other words, no assessment for Learning or as learning as recommended by the National Forum for the Enhancement of Teaching and Learning in Higher Education (NF, 2017a).

The Diagnostic Imaging team therefore set about updating the module delivery based on evidence based best practice in education, student feedback from undergraduate surveys, discussion sessions and also from discussions with graduates who were able to place the education delivery and utility in the context of their subsequent professional experience.

Technological Resources

Before the discussion of the actual delivery, the technological resources available will be outlined.

University College Dublin already had a sophisticated Virtual Learning Environment (VLE) infrastructure which hosts all modules within the BSc programme. Not only does this allow tracked delivery of learning materials but also provides sophisticated material, release controls and a Grade Centre tool for managing in-module assessment. The Grade Centre is also SCORM compliant allowing the integration of third party developed assessment materials through a standards-based interface.

Online material Content Design Technology is also employed at University College Dublin. This is utilised for the development of eLearning packages for remote education, interactive study materials for use both remotely and on-site and also digital assessment packages.

The university has an advanced Diagnostic Imaging Department equipped with Digital X-ray equipment, both DR & CR, together with Ultrasound systems, Ultrasound simulators and a plethora of advanced post processing and imaging workstations. The Republic of Ireland is currently rolling out a national implementation of Radiology Information System (RIS) coupled with Picture Archiving and Communications System (PACS) entitled NIMIS. University College Dublin in cooperation with the NIMIS team and the vendor supplying the system installed a full clone of the system with mirrored functionality (i.e. the same 'look & feel') but without exposing the sensitive national patient database itself. The clone system has been populated with anonymised images from teaching and industry sources to maintain the appearance of a real-life image database.

Evolved Delivery Model

University College Dublin was aware from feedback of an element of technophobia in the previous radiography cohorts who felt the topic too great to grasp. Clearly the challenge lay with improving the perception of relevance of the material by establishing it in the context of the professional role the students were embarking upon. There was a need to make it manageable for the students to tackle this seemingly huge topic. A map of the radiographer role was therefore created within an overall diagnostic imaging workflow (See figure 2).

However, this localized workflow perspective was also perhaps part of the problem. Radiographers work as part of a delivery chain and they are dependent on what happens beforehand and their actions can have consequences to the subsequent work to be performed. When we consider the larger workflow picture (See figure 3) then perhaps the larger view of the infrastructure, the systems, the standards, the legislation etc. or in other words the learning objectives themselves; all becomes more relevant.

Not only the larger view but there are many other roles at play here and by having our own RIS/PACS system, we were in a unique position to help Radiographers understand the consequences of errors at any part of the chain. We communicated with the national teams to find out what the most common errors were in practice and unsurprisingly, we found that these were born from users not understanding the way the whole system worked and what the consequences of seemingly small mistakes were.

Simulation, both technological (Shanahan, 2016) and patient-based (Lewis et al., 2013) have demonstrated positive results in the education of clinical students. With our systems we could allow the Radiography student to participate in every step of the simulated delivery and allow them to execute roles they would not be permitted to do on a full live system. They could be prescriber to request an examination, clerical

Figure 2: Workflow model

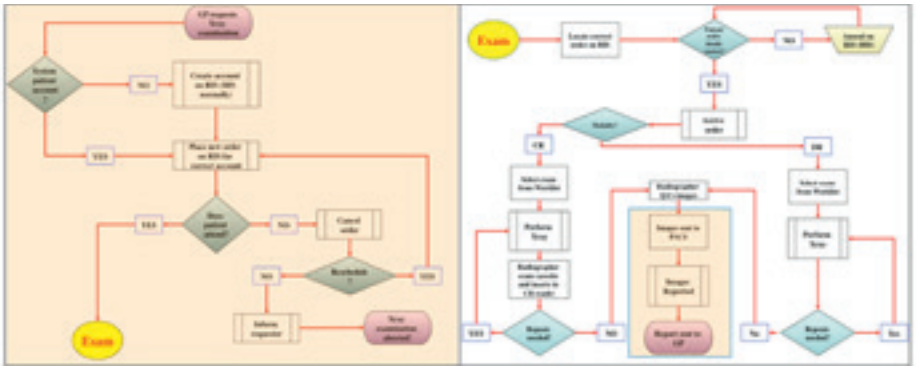

Figure 3: Expanded Workflow model

team member to create the patient, scheduler to create the order, vetting specialist to approve the order or not, performing Radiographer and then reporting (Radiologist) roles. This was huge in addition to the already great size of the legacy theoretical topic itself. How to 'eat the elephant' then? This segmenting of the workflow gave us the opportunity to break down the theory learning into bite size chunks and align the theory to practical lessons along the way. Thus, the design of the evolved model started to take shape.

The evolved model has five distinct elements of teaching/assessment/feedback in order to align with the required module and programme level outcomes (NF, 2017b). In an effort to make the module a more engaging and effective learning process, each week was broken into a structured weekly content package which was a manageable fragment of the whole. The first four combine on a weekly basis to deliver a 'weekly learning package' whereas the fifth acts as a useful capstone for the module.

The module opens with a discussion of the new module structure with the students and a negotiation of the learning contract in the form of "the good, the bad & the ugly". This was done to ensure the students knew what they could expect from the instructor and what was expected of them (NF, 2017b). The 'good' being that there will be no end of semester examination is a perfect opening gambit as students tend to find the end of semester grouped exam period very stressful so any module that departs from this traditional model tends to be favoured. Next comes the discussion of the 'bad' which is that there will be weekly assessment components in its place as the students develop a practice portfolio over the period. Academics and employers alike value electronic portfolios as evidence of knowledge and skills attained (AACU/Hart, 2013). The last piece of the discussion is the 'ugly' and this stems from experiential techniques to drive up attendance in lectures. The students will receive advance copies of the lecture notes so long as the class maintains >75% attendance at lectures. While we have had the debates of who does this actually penalise, we have also found that the class cohort can exert greater influence than any attempts by module coordinators. Historically we have had great success with this approach. As class participation is a key element in changing the perception and utility of the lecture, attendance is a critical element in the success of the model. Most students tend to be happy to agree to this with the last point being the only one of contention however, as will be demonstrated later, this tends to end up being a moot point.

The weekly package is broken down into a directed student learning activity in advance of a new style interactive lecture followed by a quiz component and finishes with a 'lab' component (See figure 4).

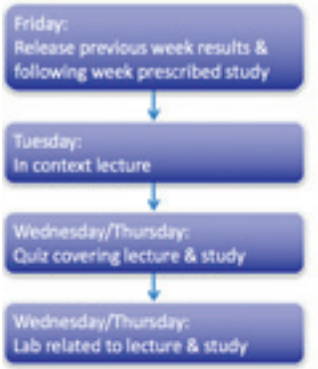

Figure 4: Weekly Learning Package structure

The student directed learning is the first component of the weekly learning package and follows the tried and tested flipped classroom model which, although challenging for some students, does drive engagement with the right framework (McNally et al., 2017). This empowered the student (NF, 2017b) to not only engage in the topic and see the context in advance of the lecture, but also enabled a preparedness assessment to be incorporated to validate the student effort and progress on a continuous basis. It allows the student to prepare themselves for the work following that week and allowed the student to tackle the seemingly huge topic in structured segments.

Time management is a self-regulation skill for undergraduates for good academic practice (NF, 2015)and is also a key principle in the National Forum Enhancement Theme 2016-18 (NF, 2017b). This is something we try to instil in our students for good learning practice. However, we have found that students still follow a module indoctrinated behaviour of leaving all the work to the end exam study period as they fail to grasp even the context of this basic skill. This changed in the new module. It seems Time Management can be taught after all.

The lectures that followed were redesigned to capitalise on the preparation the students did. Quizzes, polls, class discussions on key points before delivering the answer, all contributed to engaging the students in the topic rather than simply dictating the concepts. The attendance issue became a moot point as students will show up if they perceive a value in their attendance.

Next followed the quizzes which were delivered using the content design technology and integrated to the

VLE Grade Centre using the Sharable Content Object Reference Model (SCORM) standard. They were designed to take less than the first 10 minutes of the Quiz/Lab time slot with less than the remaining 50 minutes required for the practical work. The quizzes were focused on the factual/theoretical content from the prescribed study material and the lecture. The ultimate irony of the redesign was that the quizzes provided a more in-depth assessment of the module material knowledge than an end of semester examination ever did as there was no selection of topics for an exam paper but in fact every topic was assessed. Student preparedness is often assessed before progressing with training (Moye et al., 2012) and this is accomplished via the quiz before releasing the practical 'lab' element of the work. If the student did not pass the quiz the VLE would not release the lab content. The students could use the remaining lab time to study the material again (and in many instances, they confessed it was the first time they had visited the material). The students would get the opportunity to remediate the quiz/lab in an early morning slot the start of the following week. By week 5 of 12 typically there is no more quiz remediation and even in the first 5 weeks they tended to be minimal as most students quickly saw the value of this approach and engaged with it. Also, all students have visibility of the aggregated cohort performance statistics for each session as this lets them see how well they are performing compared to their peers. They report that they like this as they feel even though the work is hard at times, they are still performing to an acceptable level in their professional development and in comparison to their peers.

The quiz is also essential as the labs are the key to the ongoing practice portfolio. As RIS/PACS manager for the facility as well as being a full-time undergraduate and postgraduate lecturer, there is not enough time to create multiple patients, schedule multiple examinations, carry out the vetting, execute the reporting etc. Due to this unmanageable load (NF, 2017b), it is necessary that students themselves create the material they need in later weeks through each lab. The students execute tasks and create a lab report which again is submitted through the VLE Grade Centre system. The tasks are aligned with the student directed learning material and the lecture. While students had to act autonomously for the quizzes to assess personal preparedness, they were encouraged to support each other through the practical tasks as this would be typical behaviour in clinical practice. This also addressed a missing teamwork component noted in the legacy module.

The lab reports are assessed using a scoring rubric designed for each task and feedback was also managed through the VLE and was always given in terms of real-world consequences of failures to execute tasks correctly rather than simply describing

the work as incorrect (i.e. any errors are always reported back in the context of how they would affect patient care.). Positive feedback was also always included with additional reminders of the risks/situation avoided. In this way students were encouraged to engage with their tutors to not only learn but also to remediate their mistakes and use those opportunities also to enhance their learning in partnership (NF, 2017b). As with the quiz component, the visibility of the cohort statistics acts as a gatekeeper in encouraging the students to stay on top of the material and also acts as a reminder to them if they are lagging behind the class in general or if they have mistakenly assumed they had mastered the material to the required level.

There is plentiful evidence that the repeated spaced use (Carpenter et al., 2012) of the knowledge, both in repeated assessment of the theory (Rawson and Dunlosky, 2012) and in practice are known to improve long term retention of learning. The optimal period of spacing is subject of much discussion with figures ranging from 3 to 14 days (Bird, 2010) and with our spacing actions taking place over a 7 day period, the model is designed to enhance longer term retention. Also we cannot assume that students have effective learning strategies therefore including them as part of the design of the course is the best way to add this extra teaching element and skill transfer (Weinstein et al., 1988).

The diversity of assessments (NF, 2017b) is further complimented by the capstone reflections final assessment. Students are given guidance on reflection and then are required to provide two 30 minute reflections. The first is phrased to get them to consider the importance of what they learned and the second is to consider how they learned.

While our practice modules are designed to confer competence, there is a danger that practice assessed modules, just like end of semester exams, could fall victim to surface rote learning type behaviors. While practice exams may demonstrate surface competence, a healthcare professional must be adaptable and have the ability to problem solve when variables change. Indeed when assessing the value of simulation in education Söderström's team (Söderström et al., 2014) discovered that simulation students focused on visual information for their choices but only by reflecting on their choices were they able to transcend process and be able to problem-solve. Therefore including reflection is critical so that we can move beyond mere competence and achieve true capability (Fraser and Greenhalgh, 2001).

Conclusion

Many of the challenges around modern professional under and indeed post-graduate modules are not simply around grade performance but also in terms

of attendance, engagement, the conferring of clinical competence and enhancing professional conduct.

The module certainly delivered in terms of grade performance. The 2015 term saw a mean class module score of 70% as opposed to 58% in 2014 and 63% in 2013. While the overall module assessment had changed, the complex mid semester assessment component was retained and analysis of this component also saw a marked improvement in 2015 (65%) when compared with 2014 (59%) and 2013 (58%). This demonstrates an extra level of engagement and performance over previous years. However there were additional benefits noted…

In terms of attendance, while quiz and lab attendance were compulsory and therefore achieved 100% (allowing for remediation attendance), lecture attendance was in excess of 90% for the entire semester with 100% attendance at over 50% of lectures. Indeed, another module lecturer whose lectures preceded the weekly one for this module also commented on a dramatic rise in attendance that was, on discussion with the students, down to this one being next.

Each cycle, a class poll is taken at the start and the end of the module on the level of comfort with computer technology. This semester saw no change in the circa 25% of the class declaring being comfortable with the technology at the outset however typically in previous years we have a transition to a circa 75% class comfort level by the end whereas this year 100% of the class declared themselves comfortable with the technology.

A new final session discussed the complete diagnostic imaging workflow and the students demonstrated not only a clear understanding of the workflow but also had a clear understanding of the consequences of failures in the workflow, the actions these would necessitate and the clearest method of avoidance.

Reports from practice tutors indicate a new confidence in clinical placement by the students and them actively supporting and even instructing line staff on effective use of RIS/PACS. The results are that ALL the learning outcomes are now validly assessed in the module. The module has received a great deal of internal praise at school and university level presentations and has also been positively received at the European Congress of Radiology conference in Vienna in March 2016. The BSc Radiography programme of the School of Medicine in University College Dublin, has taken a leap into the 21st century by means of leveraging both educational technology and actual clinical systems technology. However, being cognisant of educational best practice has also kept pedagogy before technology.

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Research-informed Teaching: Unlocking Student Research and Learning Potential

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1. Introduction

Undergraduate education has historically been seen in conflict with the research and teaching agendas of academics [1,2]. However, the linking of research and teaching is attracting significant international attention from both policy makers and academics with research and teaching no longer being seen in opposition, but inextricably linked to one another [3,4]. Jenkins and Healy [5], also state that all undergraduate students in higher education should experience learning about research. Although they recognise that there are other goals to student learning such as employability, they maintain that students learning in "research mode" should be central to the curriculum as this provides students with vital transferable skills that may be useful for subsequent career development and helps to foster student appreciation of the role of research.

Research-informed Teaching (RiT) refers to this educational paradigm shift that places the emphasis on linking teaching with the learner undertaking some form of research [6]. However, the pedagogic language associated with linking research and teaching activities can cause confusion, as Healey (p.188) [7] noted that '*the protagonists are often using the terms of the debate in different ways*'. A lack of consensus in the literature as to what is meant by RiT has led to various terms being used to describe the link between research and teaching as the '*teaching – research relationship*' [8] or the '*teaching – research nexus'* [9]. Consequently, academics may have different interpretations of RiT, related to distinct, discipline-specific approaches to research and/or teaching. As a result, it can be difficult to identify the objectives of RiT and provide strategies that can support its development and delivery. Another issue is that some students may see 'research' to be the preserve of academics and consequently irrelevant to their needs for applied, practical knowledge required with employability [10].

RiT has been defined as taking many different forms, but it is generally accepted that this includes activities that are either *research-led*, *research-based*,

research oriented or *research-tutored.* Jenkins and Healey's [12] framework of four quadrants represent these different forms of RiT and are based upon the degree to which students are actively engaged with the research process. They use two axes, one that takes account of the extent to which students are treated as the audience or participants and the other classifies the approach emphasising research content or process and problems (Figure 1).

It has also been suggested that the four teaching activities in Figure 1 could be further subdivided. For example, there might be more types of research-led teaching according to whether academics use current or past research in their teaching and whether that research was carried out by themselves or by others [7]. Similar arguments also exist about the extent to which teachers facilitating research-based or research-tutored approaches need to be active or experienced researchers [13].

Brew & Boud [14] state that the key link between research and teaching students to see research as a process of enquiry into how knowledge is generated and communicated. However, an academic's understanding of RiT is likely to be dependent upon

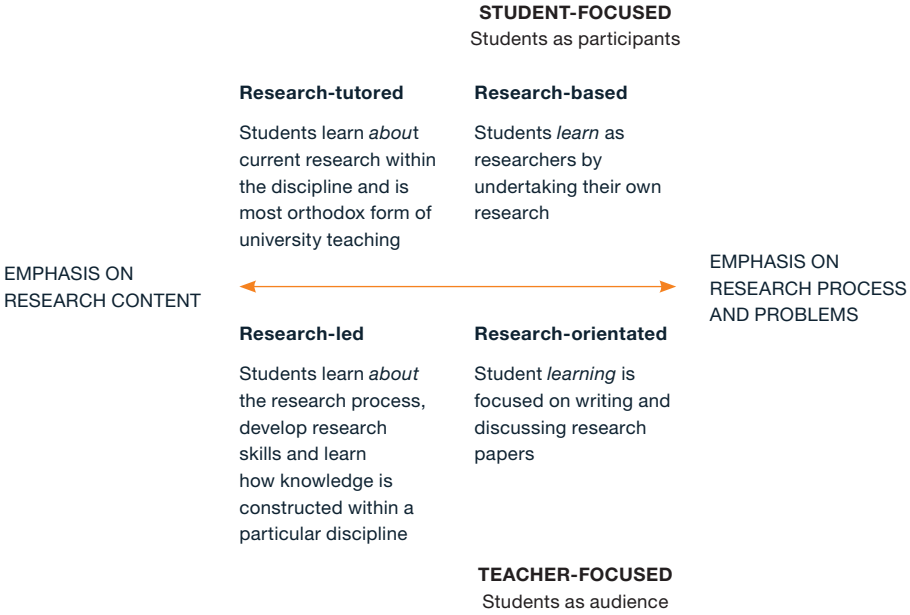

Figure 1: Framework of Definitions and Characteristics of the Four Forms of Research-informed Teaching [10, 12]

his or her own professional biases or departmental culture. A research-focused academic may favour research-led teaching, whilst a teacher focused academic may favour research-based teaching. Therefore, RiT can be considered as a broad, all-encompassing term which covers a diverse range of characteristics and activities [10]. However, RiT should not only be considered as a way to expose students to research but can play a wider role within the development of the curriculum by transforming teaching and learning practices (scholarship), as well as equipping students with skills, knowledge and attributes that will make them more likely to gain employment [10, 12].

Trowler & Wareham [15] analysed a range of case studies regarding the depiction of RiT in the literature and noted there are "*multiple sorts of linkages and relationships being referred to*". However, all definitions of RiT reflect learning where student engagement with research falls somewhere along a continuum with students as participants at one end and audience at the othe**r.** For the remainder of this chapter, 'Research-informed Teaching' will be used as an 'umbrella' term which follows the work of Jenkins and Healey [12] and encompasses the different types of research-teaching activities and characteristics in depicted in Figure 1. It will also be considered as a process that imparts knowledge, learning and research skills within the students' discipline.

2. Undergraduate research and teaching

Although a complex relationship exists between teaching and learning, there are two opposing viewpoints which identify either a 'trade-off' between research and teaching or a symbiotic relationship between the two [16, 17]. Both quantitative and qualitative research has established that there is no automatic link between research and teaching, but rather these two activities are loosely linked [18]. However, it has been argued that good researchers are not necessarily good teachers and good teachers are not necessarily active researchers [19]. There are also tensions amongst academics due to inequity in funding and rewards for research as research may be positioned higher to teaching by research-intensive institutions due to financial rewards [20]. Academics therefore may focus more on research excellence for their career development, resulting in research and teaching being seen in conflict with one another [17, 21]. Factors associated with this include pressures to compartmentalise teaching and research through accountability and funding mechanisms and management strategies of the academics' time that treat teaching and research separately [22].

Nonetheless, by introducing tighter links with research and teaching through formal strategies such as RiT, a productive relationship between research and teaching can be created [16]. Jenkins & Zetter [18] state that by establishing this link between research

and teaching there are three main advantages - *experientially* (both students and academics benefit with greater student understanding or knowledge through research); *conceptually* (benefits from development and co-production of knowledge) and *operationally* (benefits from reciprocity and economics of combining research and teaching as learning activities).

3. Adopting Research-informed Teaching Strategies

Engaging students with RiT is advantageous to deepening their knowledge base and development of key skills such as communication, critical thinking, problem solving and team working [23]. By involving undergraduates with research, they can demonstrate expertise within their own discipline which is key to gaining employment [3, 24]. However, the degree of participation by students with research can vary depending on which approach is used. For example, a research-based approach to learning, where students actively undertake research, will help them make sense of the new knowledge about their own discipline as opposed to a more research-led approach where students only learn about current research within their own discipline. Research-led and research-oriented approaches are considered as '*teacher-focused*' with the emphasis being placed on the dissemination of information by a teacher. Research-based and research-tutored approaches are the opposite of this and are more '*student-focused*' with the emphasis on learning by doing [10].

Teacher-focused approaches emphasise the transmission of research knowledge to a student audience, whereas student-focused approaches emphasise students constructing their own knowledge through active participation. This is seen as a more effective way for students to benefit from academic staff research [25] as it encourages a deep approach to learning [14, 26, 27]. However, teacher-focused approaches still have an important role in supporting students along their journey of learning and it has been argued that the combination of both approaches encompasses many benefits including subject expertise by the teacher and active learning by the student [10]. From an employability perspective these skills and experiences could be viewed as being more important than just knowledge acquisition [28]. However, these teaching-research links with Research-informed Teaching are not automatic and need to be constructed by academics and departments [29].

In 2009, at the University of Salford, UK we proposed altering the existing BSc (hons) undergraduate diagnostic radiography curriculum to expose our students to more research as part of their teaching and learning experience. This intervention was the Research-informed Teaching experience (RiTe) and

was integrated into undergraduate curriculum in 2012. RiTe incorporated a number of key learning outcomes to encourage students to undertake systematic inquiry into key areas of practice (image quality and dose optimisation) using an experimental science approach. It was hoped that this would lead to the early development of research skills (year 1 onward), enable students to link theory with practice to facilitate learning and/or translate research into practice, and lead to the creation of a community of undergraduate students and academic staff who would have commitment, purpose, and meaning with regard to radiography research. The introduction of RiTe has not only helped with student learning and research skill development but is seen by both students and academics as a way to help develop a culture of valuing research and students as co-producers of research. RiTe has led to a number of undergraduate research outputs from our department as consequence with students presenting posters and oral presentations at major conferences [30].

4. Research-informed Teaching and Healthcare Education

Current frameworks of RiT may not facilitate reflection or innovation in health and social care teaching, because they do not encompass the notion of student as practitioner. Dey *et al.* [31] suggest a complementary framework which explicitly acknowledges the student as both researcher and practitioner and which highlights the dynamic interaction between research, teaching and practice:

- *Integrating teaching and research*: Emphasises the interaction between students, lecturers and research active staff during the learning experience to enhance an understanding of research and develop research skills. Examples include use of current research evidence within teaching materials, developing students research skills, using staff research to inform students about the professional knowledge-base and discussion of evidence-base to stimulate the development of student research.
- *Developing students' skills in critical enquiry*: Emphasises the development of students as researchers. The consequent development of critical thinking and reasoning skills underpins decision-making in practice. Examples include enhancing students' ability to integrate and interpret evidence to inform decisions about practice, enhancing students' ability to identify gaps in knowledge and developing students' skills in identifying evidence.
- *Highlighting links between research and practice*: Emphasises the role of the student as 'knowledge-broker' within the workplace, as appropriate to their occupational level. Examples include promoting collaboration between academia and stakeholder organisations to develop research-aware cultures, students

conducting practice-informed research and developing students' skills to facilitate the adoption of evidence-based practice in the workplace.

- *Evaluating and monitoring teaching methods*: Relates to the modification of teaching content consequent on reflection and/or feedback, and the formal consideration of competences for practice within curriculum content. Examples include course team review of curriculum against current occupational competences and formal evaluation of teaching tools and innovations.

Early on in their careers, students may need to question the knowledge-base about a topic in order to make decisions about their own practice. Academic programmes that integrate RiT are an ideal opportunity not only to foster knowledge and understanding about research methods, but also to develop students' skills in identifying and critically appraising research and their understanding of the link between research and practice [32].

Conclusion

The introduction of activities that incorporate RiT can have a positive impact on student learning. RiT not only enhances learning and research skill development, but by involving students in the process of research they are provided with vital transferable skills which are useful for subsequent career development [3].

Student engagement in research is often expressed as a high-impact learning experience, and there is an extensive array of literature on combining research with teaching and the benefits of this [32, 33]. However, RiT is not only concerned with exposing students to research as part of their teaching and learning curriculum and engaging students in research processes and skills, it can also play a wider role within the development of the student and curriculum (e.g. employability and personal development planning) and develop an understanding of the history and role of research in their discipline [12].

However, not only do students benefit from being immersed in an environment where research is encouraged, promoted and valued (research culture), but professions or disciples as a whole also benefit from a commitment to establish a research culture that recognises there is always something within the current practice that can be improved, rather than adopting a complacent attitude that there is nothing more to learn [20].

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The European Federation of Radiographer Societies (EFRS) Educational Wing

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Introduction

The European Federation of Radiographer Societies (EFRS) was founded in 2008 by 27 professional societies of radiographers. The role of the EFRS as specified on its website:

"to represent, promote and develop the profession of radiography in Europe, within the whole range of medical imaging, nuclear medicine and radiotherapy and moreover everything that is directly or indirectly related or beneficial to this role, everything in the broadest meaning". [EFRS, 2018]

The EFRS is legally established in the Netherlands as a non-profit organisation. The role and aims of the EFRS and the requirements from the Dutch laws are reported in the **EFRS Constitution** which resulted from a meeting in Prague on the 17th November 2007. The federation defined the following aims to fulfil its role:

a. Undertaking all actions to generate influence on European policies and negotiating with European bodies about all issues that may be of relevance for the profession;
b. Stimulating inter-state professional cooperation throughout Europe in scientific, technical, ethical, organisational and labour areas by facilitating the exchange of information between member societies;
c. Promoting patient safety and radiation protection;

d. Promoting the use of the EFRS reference code of ethics;
e. Developing European standards of professional practice;
f. Promoting evidence-based practice and the principle of 'science in society';
g. Promoting harmonisation of initial and post-graduate education;
h. Facilitating free movement of radiographers;
i. Cooperation with other organisations with similar objectives;

One of the first documents developed after establishing the EFRS was the "EFRS Radiographer Code of Ethics". This document has been adopted by many member societies and is used together with their own national code of ethics, if available. In addition to English, this document has been translated into Hungarian, Spanish, Italian, German and Lithuanian.

As the result of differences in educational programmes and national requirements, the content of the radiography profession varies across Europe. Therefore, the EFRS General Assembly agreed on a clear and concise definition of a "Radiographer" who are medical imaging and radiotherapy experts. These professionals are accountable to the patients' physical and psychosocial wellbeing, prior to, during and following the examination or therapy. They take an active role in justifying and optimising medical imaging and radiotherapy procedures. They are key-persons in the radiation safety of patients and third persons in accordance with the "As Low as Reasonably Achievable (ALARA)" principle and relevant legislation. The EFRS recommends that official European bodies and authorities use the single title "Radiographer" in all of their documents and correspondence at the European level.

The EFRS is committed to raising the profile of radiographers across Europe. As a profession, we must make sure that radiographers raise their profile, and have a stronger voice, in healthcare circles, in education, in research, with national policies, and, most importantly, with patients and the general public. This is the focus of the recent EFRS public awareness campaign (#Radiographer2018). We want radiographers everywhere to be proud of their profession, to make sure that they always tell people that they are a radiographer, and also explain to people the importance of our profession. Think of the very important #HelloMyNameIs campaign and remember that:

"Together everything is possible"

"Be involved and make a difference"

Role of the Educational Wing

Historically, from 2002 until 2008 a number of educational institutions and professional societies had been actively involved in the Higher Education Network for Radiography in Europe (HENRE). HENRE as an EU funded network no longer exists and in 2010 the creation of the EFRS Educational Wing was agreed by the EFRS General Assembly to safeguard the important work being undertaken around radiography education.

Since 2008, the number of collaborating educational institutions in the EFRS Educational Wing has grown from 21 founding institutions (13 countries) to 62 institutions (25 countries) in 2018. The Educational Wing of the EFRS meets annually in March at the European Congress of Radiology (ECR). Since 2011, there has been concurrent EFRS seminars at ECR for radiography educational institutions and students. European educational institutions which offer radiography education are always warmly invited to join the EFRS as an *affiliate member* and collaborate with the Educational Wing.

The EFRS Educational Wing together with the EFRS has worked tirelessly to develop educational standards for radiography across Europe. One of the more recent publications is the EFRS European Qualifications Framework (EQF) Level 6 (Bachelors) Benchmarking Document for Radiographers.

Previously the EFRS have produced a EFRS EQF Level 7 (Masters) Benchmarking Document for Radiographers. The EQF acts as a translation device to make national qualifications more readable across Europe, promoting workers' and learners' mobility between countries and facilitating their lifelong learning. The overarching aim of the EQF is to develop a European-wide workforce that is mobile and flexible. The second edition of the EFRS European Qualification Framework Level 6 Benchmark Document for Radiographers (EFRS EQF Level 6) was drafted by a group of experts with input from the EFRS expert committees for Medical Imaging, Nuclear Medicine and Radiotherapy. This revision document was sent to all member organisations for comments in September 2017 and was discussed and approved by the EFRS General Assembly in November 2017.

Opportunities within the EFRS

Educational institutions

Numerous opportunities for educational institutions (EI) exist within the EFRS. Worthy of mention are some of these which include opportunities to collaborate on Europe-wide projects relating to radiography education. By way of an example, many of the partners on the European E-Breast project are all EFRS affiliate members. This is a ERASMUS+ funded project which ultimately seeks to improve mammography training across Europe.

The E-Breast project is also a further example of a collaborative research project involving members. Further examples include the just launched 'Safe and Free Exchange of EU Radiography Professionals across Europe' (SAFE Radiography) an Erasmus+ Sector Skills Alliance project involving three affiliate members (EIs) from the Educational Wing (EW) as well as the EFRS as a lead partner. EFRS EIs are also involved in the Dose Optimisation Summer School (OPTIMAX). EIs also benefit from access to EFRS webinars, for 2018 these will include presentations on the latest Membership Survey, Radiography Journal and Radiographers Research Network. EIs can also benefit from becoming directly involved in the Annual Meeting of the EFRS Educational Wing and the concurrent EFRS Educational Wing Workshop at ECR, Vienna, Austria. Previous workshops have discussed topics including innovative assessment strategies, managing clinical placements and the European Diploma in Radiography. EIs alongside full members have the option of attending the EFRS Annual General Meeting. In 2018, this was held at the birthplace of Wilhelm Conrad Röntgen in Remscheid, Germany. EIs being an extremely valuable source of educational expertise are also invited to participate in the production of EFRS statements, guidance documents and surveys. The following are recent examples of EFRS documents in which EIs have been involved in the production of:

EFRS EQF Level 6 Benchmarking Document for Radiographers – Second Edition

EFRS EQF Level 7 Benchmarking Document for Radiographers

EFRS Statement on Radiographer Research

EFRS Radiographer CPD Recommendations and Guidance Notes

EFRS Statement on Radiography Education

EIs also benefit from membership of the EFRS with the ability to nominate members to join the EFRS expert network. Working within the Educational Wing Management Team is also an option for any affiliate member. Currently, there are four elected members of the EFRS Educational Wing Management Team from a range of countries across Europe (Netherlands, Malta, Estonia and the UK). Within the EFRS, EIs are further eligible for discounted rates in terms of advertising related courses, events or jobs via the EFRS website.

For the future the EFRS are planning on launching a series of EFRS Research Awards and new in 2019 will be the European Diploma in Radiography. Two versions of the European Diploma will be piloted at ECR 2019: a European Diploma in Radiography (Medical Imaging) and a European Diploma in

Radiography (Combined Medical Imaging and Radiotherapy). A further European Diploma in Radiography (Radiotherapy) will also be offered after ECR.

Students

Students also receive many benefits from the EFRS. These include networking opportunities and access to the EFRS Student Session at ECR. The EFRS Board have worked extremely hard with the European Society of Radiology to develop a series of initiatives to increase the student contribution at ECR. These include the 'MyT3' and 'Invest in Youth' initiatives which allow students the opportunity to summarise their thesis in three minutes and received free registration and accommodation vouchers if they have an abstract accepted for the ECR meeting. Students can join the European Society of Radiology for free as 'ESR Friends' which will allow them to apply for the Invest in the Youth initiative and will also provide access to hundreds of online lectures through the Education on Demand platform which the EFRS has been working on, with the ESR, to improve accessibility for radiographers and radiography students. Education is at the forefront of EFRS activities and EFRS statements, guidance documents and Member Survey's all seek to help develop the landscape of radiography education across Europe. A large proportion of the EFRS Website is public facing and this provides a wealth of information for students, potentially facilitating access to international placement opportunities and networking opportunities.

Clinical / Academic staff

Clinical and academic radiographers have access to the EFRS Website and a series of documents and recorded webinars. Clinical and academic staff benefit from the networking opportunities that arise from the EFRS and are also represented within the EFRS through their professional societies. Within the EFRS website there will be a wealth of publications of interest to radiographers in both clinical and academic practice. Ultimately, a key strength of the EFRS is that they provide a strong and growing voice for radiographers across Europe. Relationships are growing and the EFRS has a voice with organisations such as the European Society of Radiology, European Institute of Biomedical Imaging Research, European Federation of Organisations for Medical Physics, Cardiovascular and Interventional Radiology Society of Europe and the European Association of Nuclear Medicine.

Summary

The EFRS recently celebrated its 10th anniversary at its Annual General Meeting in Remscheid, Germany. Over the past 10 years the EFRS has been highly successful in developing and promoting the role of radiographers in Europe. The rapid evolution and

The EFRS Executive Board and CEO participating in the EFRS public awareness campaign during the 2018 EFRS AGM in Remscheid, Germany. Pictured left to right: Anke Ohmstede *(Board Member, Germany),* Diego Catania *(Board Member, Italy),* Vasilis Syrgiamiotis *(Treasurer, Greece),* Charlotte Graungaard *(Board Member, Denmark),* Jonathan McNulty *(President, Ireland),* Charlotte Beardmore *(Vice-President, UK),* Dorien Pronk-Larive *(CEO, the Netherlands).*

The EFRS General Assembly, members of the Educational Wing, and Board participating in the EFRS public awareness campaign during the EFRS 2018 AGM in Remscheid, Germany.

success of the EFRS has brought huge benefits, especially within education and for radiography students. Radiography students now have a growing voice across Europe and one that is similar to fellow health care professions. Students are now better represented on international stages such as at ECR. As a result of the endeavours of the EFRS and its members the radiography profession is stronger and has a bright future.

Part 2

Research conducted during OPTIMAX 2018

Impact of a CT scan simulator on student learning

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Keywords:
Computed Tomography, Patient Dose, Image Quality, Simulation, Active Learning.

Abstract

Introduction: Computed Tomography (CT) largely contributes to the public's radiation dose and is an increasingly prevalent imaging modality with widespread use in diagnostic radiology. Radiographers who have a satisfactory understanding of scan parameters positively impact patient dose and image quality. An interactive CT simulation tool has the potential to assist in the learning of CT principles to facilitate optimization in CT practice. This study aims to assess the effectiveness of a CT simulation tool on student radiographer learning, with specific regard to the relationship between CT scan parameters, patient dose, and image quality.

Methods: The sample population (n=30) was chosen from a group of European radiography students. This population was divided evenly into a quality control and intervention group. Every participant from each group was administered a questionnaire, designed to measure understanding of different scan parameters' effects on image quality and radiation dose. The intervention group underwent interactive CT training using a CT simulation tool; the quality control group was a baseline and did not receive any teaching. The next day, the questionnaire was re-administered to each participant. Results from each questionnaire were calculated and compared.

Results: The results show that there was significant improvement in questionnaire scores for the intervention group and no improvement for the quality control group. The mean questionnaire score of the intervention group increased from 58% to 68% (P=0.0000617), while the quality control group's mean score did not change from 62% (P=1.00).

Conclusion: The CT simulation tool demonstrates improved student understanding on how CT scan parameters affect patient dose and image quality.

Introduction

Computed Tomography (CT) is an increasingly prevalent imaging modality with widespread use in diagnostic radiology (DDM2, 2014). The number of CT scans performed each year is increasing; according to a recent report, the number of CT examinations has increased by 57% between 2005 and 2012 in Canada (HC, 2016). Increases were also observed in European countries such as Switzerland (OFSP, 2018), Ireland (RPII, 2008 and 2012), the Netherlands (MVWS, 2013) and Nordic Countries (NRPA, 2012). Experimental and epidemiological evidence has linked CT associated radiation exposure to carcinogenesis (Power et al. 2016) and has thus amassed public concern (Freudenberg & Beyer, 2011). Considering this information, it is crucial to keep the public's ionising radiation dose "as low as reasonably achievable" (ALARA). Despite advances in dose-reduction technology and emphasis on ALARA, Berrington et al. (2009) and Mahesh (2013) found that

radiation exposure can vary significantly for the same CT examination. In a more recent study by Glazer et al. (2018), it was shown that significant CT protocol variation still persists to this date.

Radiographers are the health care professionals responsible for administering CT radiation dose to the public; they must possess sufficient knowledge on how specific scan parameters affect patient dose and image quality. Radiographer education is thus paramount in the optimization of CT imaging. CT parameters and their effect on dose and image quality can be difficult for radiography students to comprehend. Furthermore, it can prove difficult to teach these principles since, for radiation protection reasons, manipulating scan parameters on real patients for teaching purposes is not feasible. Phantoms may be utilized to demonstrate the effect of changing parameters, however, not every institution has access to CT equipment for training purposes. To assist radiography students' understanding of the aforementioned key CT principles and facilitate optimization in CT practice, an interactive CT simulation tool was developed in 2016 from a collaboration between University College Dublin and the then University of Bergen (Healy et al., 2017), now Western Norway University of Applied Sciences.

According to Anderson (2016), an "in-depth approach" to learning is when emphasis is placed on understanding and practical application helps learners to use and adapt knowledge in a clinical setting. This "in-depth" learning is vital in healthcare education and includes a range of learning styles. Learning styles can be loosely defined as "an individual's natural, habitual and preferred way of absorbing, processing and retaining new information and skills" (Reid, 1995). A combination of active learning and self-directed learning is believed to improve student's understanding (Edwards, 2015). When applying this concept to learning about CT scan parameters, as with the CT simulation tool, radiography students might be capable of benefiting.

The aim of this study was to determine if radiography students better understand how specific CT scan parameters affect patient dose and image quality by using a CT simulation tool. Thus, the impact of CT simulation as an active learning tool for students was investigated with the goal of improving student insight into applied ALARA principles.

Methods and Materials

A test-retest quantitative design was executed in this research study. The sample population consisted of 30 radiography students (n=30) at the OPTIMAX Research Summer School, randomly and evenly divided into an intervention group (n=15) and a quality control group (n=15). Participants were from 6 different countries and had varying levels

of CT experience, ranging from no experience to comfortable with CT. Participation was voluntary and written consent was obtained from each participant. A research invitation stated what the study involved, its location and time, and disclosed that all data would be coded. Ethical approval was granted by the controlling institution for the study. Questionnaires were pseudonymised to protect the identity of participants while still allowing tracking throughout the data capture cycle.

A baseline assessment to determine participant knowledge of CT was carried out for both the intervention group and quality control group. This consisted of a CT questionnaire, "Questionnaire 1", (Appendix B) administered on day 1 (see Table 1 timeline). The questionnaire was designed to test participants' understanding of the effects of specific scan parameters on image quality and radiation dose.

The questionnaire was developed by the research team and underwent validity testing (Mackison, Wrieden & Anderson, 2010) in a pilot study, using two individuals with different levels of CT knowledge. Reliability of the questionnaire (Barton, Wrieden & Anderson, 2011) was tested with the quality control group's difference in answers over time. The questionnaire was composed of 30 multiple choice questions, each with 4 possible options to choose from. Both text and image-based questions were included.

Referred to as the "intervention task", an instructional guide (Appendix C) was developed for the CT simulation tool (Figure 1) so that it would be an integrated and active learning tool (Campbell & Cabrera, 2014; Edwards, 2015). Individual learning styles were not taken into consideration, since results on this type of education are inconclusive (Anderson,

Time	Quality Control group	Intervention group
Day 1 (10:00)	CT questionnaire administered (i.e. Questionnaire 1)	CT questionnaire administered (i.e. Questionnaire 1)
Day 1 (13:00)	No CT simulation tool; no learning experience	CT simulation tool; learning experience administered (45 min session)
Day 2 (10:00)	CT questionnaire re-administered (i.e. Questionnaire 2)	CT questionnaire re-administered (i.e. Questionnaire 2)

Table 1. Timeline for data collection.

2016). During the self-directed 45-minute session, the instructional guide initially explained the workings of the CT simulation tool followed by structured tasks utilising the simulator in conjunction with formative questions to stimulate active learning. The intervention task focused on the changes that could be observed in image quality and patient dose when changing scan parameters on the CT simulation tool.

The 45-minute time limit was established to simulate an educational setting. All participants were asked to give feedback on the allotted time they were given to complete the task. To ensure viewing conditions were the same, both the ambient light, adjusted in accordance with McEntee et al. (2006), and the screen contrast and brightness were optimized using the Unfors Luxi light meter (detector version 8202050-A). In hospitals, this would be done annually for medical grade displays (Silosky, Marsh & Scherzinger, 2016). All monitors had equal brightness and contrast; this was measured using an SMPTE-image (Wade & Brennan, 2004) in conjunction with a light meter (Wade & Brennan, 2004). Human eyes need to adjust to light conditions (Bierings et al., 2018), therefore the intervention group needed to be in the dimmed viewing room for ten minutes before starting the intervention task.

There was no learning experience provided for the quality control group. The intervention group was directed to not talk about the intervention task with the quality control group. After the intervention, all participants were re-assessed with the same questionnaire, "Questionnaire 2". Data from pre- and post-intervention questionnaires were compiled and analysed in an Excel worksheet (Microsoft Office Professional Plus 2013).

CT Simulation Tool

The CT simulation tool was developed so radiography students can adjust scan parameters without actually using ionising radiation or performing a scan. The scan parameters that are adjustable include kV, mAs, slice thickness and detector size. These scan parameters were chosen because they cannot be changed once the scan is complete, and they are what contribute to image quality and patient dose. Reconstruction kernel is also available as a supplemental variable. The effects of any parameter adjustments, in terms of visual image quality and calculated dose received, may be visualized immediately on the interactive display (Figure 1). Two different fixed window settings were applied on an abdomen phantom (Kyoto body phantom): soft tissue and bone tissue window settings. A contrast resolution phantom and a spatial resolution phantom (Catphan) were also scanned with the same parameters. Hounsfield Units were measured in regions of interest (ROI) placed in the liver, spleen, fat, cortical bone and trabecular bone. Dose indices

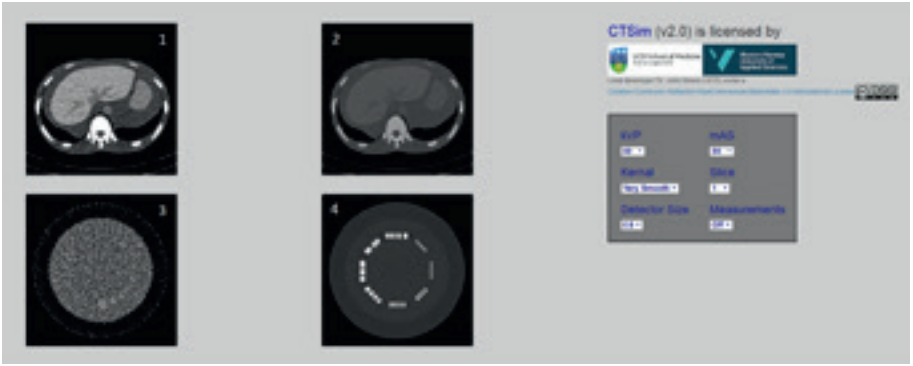

Figure 1. Screenshot of CT simulation tool's interactive display.

Computed Tomography Dose Index (CTDIvol) and Dose-Length Product (DLP) were also available for each scan parameter selection. Noise, defined as a standard deviation, was measured in the liver.

Statistical Analysis

The "Shapiro-Wilk Normality Test" was employed to verify data normality (Fiaz & Khan, 2015). Since the collected data was normally distributed, parametric tests such as paired and unpaired t-tests were utilized. All data are presented as mean ± Standard Error (SE). SE was used because it gives an indication of the uncertainty around the estimate of the mean measurement (Altman & Bland, 2005). Statistical analysis was performed using Microsoft Excel. Comparisons between results from the quality control and intervention groups were made by using a two-tailed, unpaired t-test. Comparisons between samples from the same group, pre- and post-intervention, were made by using a two-tailed, paired t-test. P-values of <0.05 (*) were determined to be statistically significant. With the Excel Analysis ToolPak, correlations were analysed for subjective experience with CT, country of university, time taken to complete the questionnaire, and time taken to complete the intervention task.

Results

Primary Analysis of the Intervention

To calculate the normality of the data, the "Shapiro-Wilk Normality Test" was used (Ahmad & Khan Sherwani, 2015). All data followed a normal distribution, with a rounded value of P=0.881.

Comparison of Pre-Intervention and Post-Intervention Scores

Using mean to compare measures of central tendency, the intervention group's mean score

increased by approximately 17% from pre-intervention ($\bar{x}$=58) to post-intervention ($\bar{x}$=68). Meanwhile, the quality control's mean score remained at $\bar{x}$=62 (Table 2). Because a comparison was made within each group, a paired t-test was chosen to see if the intervention had any effect. The paired t-test compared data for each group from questionnaire 1 and questionnaire 2. The quality control group acted as baseline for comparison. The paired t-test for the quality control group showed there is no statistically significant change in mean questionnaire score, with a value of P=1.00. The paired t-test for the intervention group displayed strong statistical significance at P=0.0000617 (P<0.05) (Table 2).

Comparison of Quality Control and Intervention Group Scores

Because a comparison was made between the quality control and intervention group, an unpaired t-test was chosen to see if any noted difference could be related to the intervention. Comparing the first questionnaire results between the control group ($\bar{x}$=62) and intervention group ($\bar{x}$=58), there is no statistical significance difference (P=0.512) (Table 3). There is also no statistical significance difference between the control group ($\bar{x}$=62) and the intervention group ($\bar{x}$=68) for the second questionnaire (P=0.226) (Table 3).

Table 2. Comparison of Pre-Intervention and Post-Intervention Scores. Descriptive statistics and results of paired t-test for both groups.

	Quality Control group		Intervention group	
	Questionnaire 1	Questionnaire 2	Questionnaire 1	Questionnaire 2
Mean	61.56	61.56	58.00	67.78
Std Dev.	17.04	12.40	11.81	15.00
Std Err.	4.40	3.20	3.05	3.87
Two-tailed, unpaired *t*-test P(T<=t)	1.00		0.0000617*	

Table 3. Results of unpaired t-test for pre-intervention and post-intervention.

	Questionnaire 1		Questionnaire 2	
	Quality Control	Intervention	Quality Control	Intervention
Two-tailed, unpaired *t*-test P(T<=t)	0.512		0.226	

Comparison of the mean change in questionnaire scores of the quality control group to the intervention group

Results from the unpaired t-test in Table 4 compare the mean change in questionnaire scores of the quality control group to those of the intervention group. The intervention group improved their test score with ~ $\bar{x}$=10, while the quality control group did not. This questionnaire score difference is statistically significant, as P=0.00119.

This finding is visually supported by Figure 2. In this graph, the standard error bars do not overlap, further indicating statistical significance in the intervention group's increase in mean score.

	Difference in Questionnaire Scores by Group	
	Quality Control	Intervention
Mean	0.00	9.78
Std Dev.	8.07	6.72
Std Err.	2.08	1.74
Two-tailed, unpaired *t*-test P(T<=t)	0.00119*	

Table 4. Descriptive statistics and results of unpaired t-test for difference in questionnaire scores for each group.

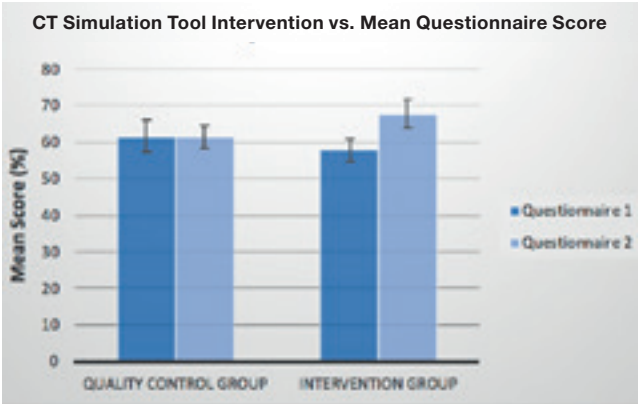

Figure 2. Questionnaire 1 and 2 scores for quality control and intervention groups.

Statistical Analysis of Dose and Image Quality Understanding

It is of interest to further analyse data based on the type of questions in the CT questionnaire. There were 10 questions relating to radiation dose and 18 questions relating to image quality. The following statistical analysis for dose and image quality concepts is based on these questions, respectively.

When the intervention was used, the scores for CT concepts relating to dose (+19%) significantly increased ($P<0.05$). Meanwhile, the quality control group showed no increase in scores on dose concepts ($P=1.00$) (Table 5).

This finding is supported by Figure 3 in which the different scores for the dose questions are shown.

	Quality Control group		Intervention group	
	Questionnaire 1	Questionnaire 2	Questionnaire 1	Questionnaire 2
Mean	56.67	56.67	54.67	64.67
Std Dev.	19.52	20.24	14.07	15.98
Std Err.	5.04	5.23	3.63	4.13
Two-tailed, unpaired *t*-test P(T<=t)	1.00		0.00593*	

Table 5. Descriptive statistics and paired t-test for questions on dose.

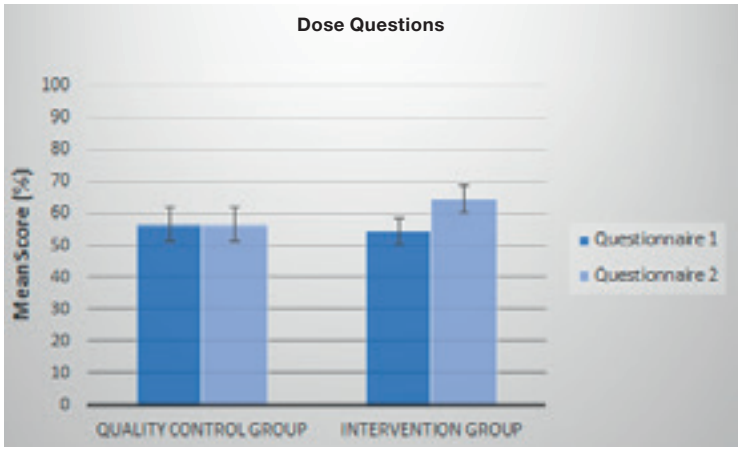

Figure 3. Mean scores of dose questions for questionnaire 1 and 2 for the quality control and intervention groups.

When the intervention was employed, the increase in scores for CT concepts relating to image quality (+19%) is statistically significant (P<0.05) with over 99.7% confidence (Table 6).

In contrast, the quality control group's mean increase in score (+3.06%) is not statistically significant. These results are also supported by Figure 4.

Correlation and regression analysis

"Delta" is defined as the difference in each participant's score between questionnaires (Questionnaire 2 score – Questionnaire 1 score).

As shown in Table 7, there was a very weak positive correlation between CT comfort and delta (r=0.01), time taken to complete questionnaire 1 and questionnaire 1 score (r=0.16), and time taken to

	Quality Control group		Intervention group	
	Questionnaire 1	Questionnaire 2	Questionnaire 1	Questionnaire 2
Mean	60.37	62.22	58.89	70.00
Std Dev.	19.34	12.81	13.90	15.82
Std Err.	4.99	3.31	3.59	4.09
Two-tailed, unpaired *t*-test P(T<=t)	0.553		0.00109*	

Table 6. Descriptive statistics and paired t-test for questions on image quality.

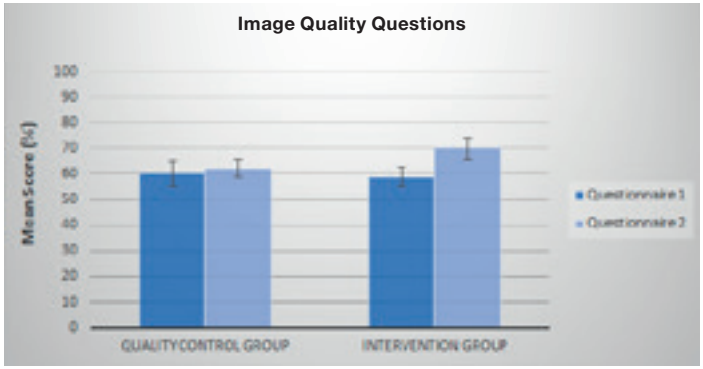

Figure 4. Mean scores of the image quality questions for questionnaire 1 and 2 for the quality control and intervention groups.

complete questionnaire 2 and questionnaire 2 score (r=0.07). A weak positive correlation (r=0.32) was observed between the time taken to complete the intervention task and Delta, as seen in Figure 5.

Regression analysis was carried out using country of university, CT experience, and the first questionnaire score to determine if these impacted the results. No statistical significance was found.

Discussion

The aim of this study was to determine if students better understand how specific CT scan parameters affect patient dose and image quality by learning using a CT simulation tool. One group experienced an interactive learning session with a CT simulation tool; the other group was a quality control group and received no teaching.

Table 7. Correlation scores.

Variable 1	Variable 2	Correlation Score
Intervention task time taken	Delta	0.32
CT comfort	Delta	0.01
Questionnaire 1 time taken	Score	0.16
Questionnaire 2 time taken	Score	0.07

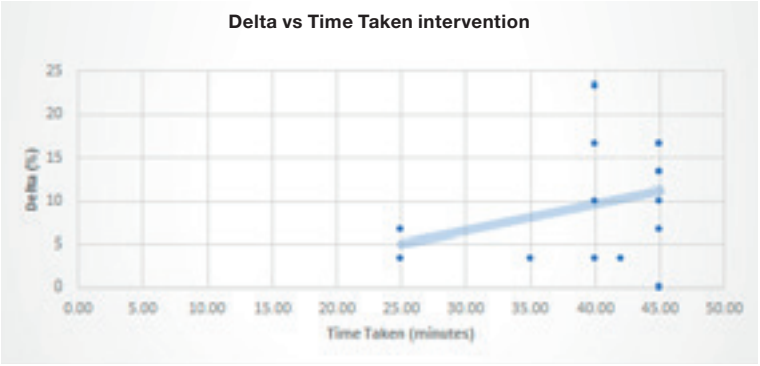

Figure 5. Scatter plot of Delta and the time taken to undergo the intervention (with trendline).

For the intervention group, the results revealed an statistically significant improvement in questionnaire scores following the CT simulation tool, representing better understanding of concepts relating to both image quality and patient dose. There was no statistically significant change in the quality control group's performance in either category of questions. Therefore, it can be concluded that the CT simulation tool promotes learning.

The groups remained constant throughout the study because there were no participant dropouts. Data was collected from all CT questionnaires in the population sample and no questionnaires were lost, damaged or made invalid. However, the population sample was small (n=30) and each group had n=15 participants. This introduces larger standard deviations and standard errors in data; despite this, there was still a significant improvement in the intervention group's scores.

Furthermore, the CT questionnaires' questions were not evenly distributed between questions concerning image quality (18 questions) and patient dose (10 questions) due to time constraints in the questionnaire design phase. This is a limitation in terms of statistical analysis, and ideally the number of questions for both categories would be at least 15. However, a statistically significant difference was still detected both categories.

A potential limitation to the study was the possibility for retention of knowledge based on the first questionnaire (a learning effect). However, since the quality control group performed the same in both questionnaires, retention of knowledge and a learning effect of the questionnaire can be excluded. This is also an indication of the reliability of the questionnaire: it shows that the questionnaire is consistent over time (Barton et al. 2011). In addition, the validity of the questionnaire (Mackison et al. 2010) was tested in a pilot study on two individuals with different levels of CT experience.

Participants had signed an agreement of participation, but the time needed to complete the study was limited and thus variable performance is a possible confounder. However, the largest correlation (r=0.32) was found between time used to complete the intervention task and questionnaire performance. Also, each participant had the potential to study before taking the second questionnaire; this was not controlled for, but was determined to be unlikely due to participants' other obligations as part of the research school at this time.

In this study, the intervention group was compared to a quality control group that did not undergo any teaching. Therefore, no comparison to another teaching method was made. Further research should measure the CT simulation tool's effectiveness relative

to a standard method of teaching. For example, this could be implemented in future research with the addition of a third group that is taught by a 45-minute university-based lecture. In addition, a large amount of data was collected but not analysed due to time constraints. Such extraneous data includes the participant's country of origin, year of study, level of experience, and intervention task feedback from the intervention group. Including these variables in a future study would be beneficial.

Conclusion

It was found that students who used a CT simulation tool improved their knowledge and understanding of how specific scan parameters affect both patient dose and image quality; this improvement was significant. It is proposed that the CT simulation tool is effective in teaching dose and image quality concepts; the tool may have utility in facilitating CT optimization. For future studies, it would be of value to perform a comparative analysis of the CT tool against a traditional approach to teaching this subject within a university.

Acknowledgements

We thank UCD, OPTIMAX and all participants for their support.

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Appendix A: Ethics Approval

UCD School of Medicine - UREC-SM

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25th June 2018

John Stowe

Dear Dr Stowe,

The UREC-SM Committee recently reviewed your application which was recently approved.

Your UREC-SM number is UREC-SM-2018-27.

Yours sincerely,

Dr Kathleen Curran
Chair, UREC-SM

Figure 6. Screenshot of e-mail received granting ethical approval.

Appendix B: CT Questionnaire

Name:

University:

How many years is your program?

What year of study have you most recently completed?

How much CT experience do you have?
Please circle one:

○ No experience
○ Some experience Comfortable with CT
○ Expert with CT

The following is a questionnaire of 30 questions on Computed Tomography (CT).
Please answer each question by circling your answer *and* writing your selection on the rightmost line. Results will be graded, but all scores will remain anonymous.

QUESTIONS/ANSWER:

1. If kVp is reduced (⇓) while mAs is held constant:
   a. Patient dose is increased (⇑)
   b. Patient dose is decreased (⇓)
   c. Patient dose remains the same
   d. Image quality increases (⇑)

---

2. In CT, does image quality change if mAs is doubled?
   a. Yes; it increases subjectively (⇑)
   b. Yes; it decreases subjectively (⇓)
   c. No; it stays the same
   d. Yes; the image quality is doubled

---

3. What is DLP?
   a. Dose rate
   b. Patient exposure
   c. Dose rate and patient exposure
   d. Noise index

---

4. What is spatial resolution in CT?
   a. Ability to differentiate objects from background
   b. Ability to record events occurring within a short duration
   c. Ability to resolve or distinguish objects of a certain size placed near each other
   d. Ability to detect or use all x-ray photons exiting the patient

---

5. Which factor does not affect contrast resolution?
   a. Slice thickness
   b. mA
   c. Kernals
   d. Anatomical plane

6. With slice thickness constant, which image acquired has reduced noise, and why?
   a. Image 1; due to decreased mAs (↓)
   b. Image 1; due to increased kVp (↑)
   c. Image 2; due to increased mAs (↑)
   d. Image 2; due to decreased kVp (↓)

7. While using sharp kernels allows for better spatial resolution, a disadvantage is:
   a. Increased patient dose (↑)
   b. Increased image noise (↑)
   c. A brighter image
   d. A darker image

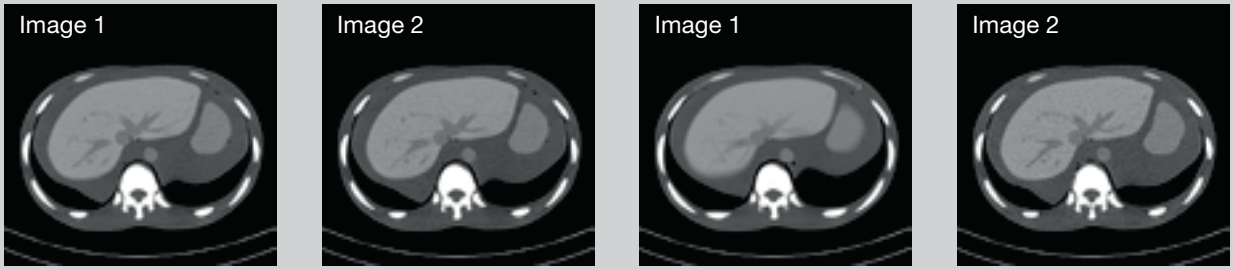
8. Image 2 has a higher CTDIvol dose in mGy. What change in scan parameters could account for this difference?
   a. Decreased mAs (↓)
   b. Increased slice thickness (↑)
   c. Using a higher resolution reconstruction filter
   d. Increased kVp (↑)

9. Which of the following results from increasing slice thickness (↑)?
   a. Decreased noise (↓) in the liver
   b. Increased noise (↑) in the spleen
   c. A more “grainy” image
   d. Increased noise (↑) in fat tissue

10. Decreasing kVp (↓) in CT is advantageous because:
   a. X-ray penetration improves
   b. Increased tissue contrast (↑)
   c. Less noticeable metal artefacts
   d. Scan times are reduced

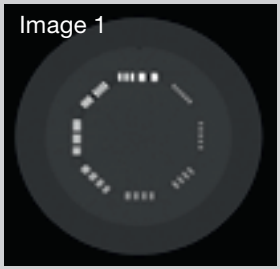
11. The CT number (Hounsfield Unit) of fat depends on:
   a. kV
   b. mAs
   c. Reconstructive algorithm
   d. Nothing, it is constant

12. Which of the following images features the largest slice thickness?
   a. Image 1
   b. Image 2
   c. Image 3
   d. Image 4

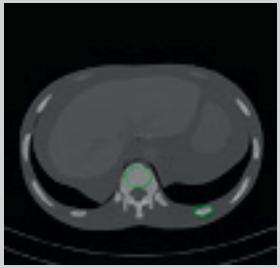


13. What is CTDIvol?
    a. Dose rate and patient exposure
    b. Patient exposure
    c. Dose rate
    d. Noise index

14. Why does Image 2 of the CT test tool have increased spatial resolution (↑)?
    a. Very sharp kernel reconstruction applied
    b. Very smooth kernel reconstruction applied
    c. Increase in kVp (↑)
    d. Increase in mAs (↑)

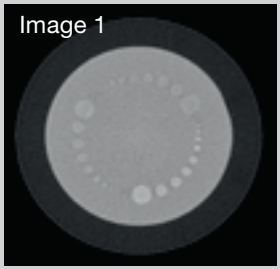


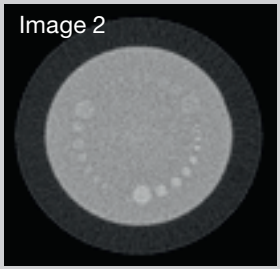
15. What is the most likely measurement for Hounsfield Units of cortical bone in the following image?
    a. 1000 HU
    b. 200 HU
    c. 0 HU
    d. -1000 HU



16. What is the reason for improved contrast resolution in Image 2?

a. Increased mAs (↑)
b. Decreased mAs (↓)
c. Thinner slice thickness applied
d. Decreased radiation dose (↓)





17. What is the most likely set of technical factors applied in the following image?

a. 30 kVp, 15 mAs
b. 80 kVp, 50 mAs
c. 130 kVp, 200 mAs
d. 150 kVp, 500 mAs

18. What kernel reconstruction was applied to Image 1?

a. Very smooth reconstruction
b. Standard reconstruction
c. Very sharp reconstruction
d. None

19. What technical factors would result in the highest patient dose (mGy)?

a. 80 kVp, 50 mAs
b. 110 kVp, 100 mAs
c. 130 kVp, 200 mAs
d. 110 kVp, 400 mAs

20. Which of the following is the most likely Hounsfield Unit of fat tissue?

a. -500 HU
b. -20 HU
c. 500 HU
d. 1000 HU

21. Does the application of a reconstructive filter (post-scan) affect dose?

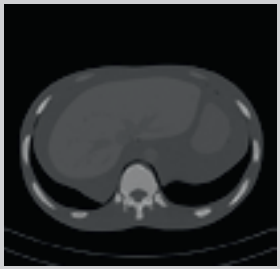
a. Always
b. Never
c. Only with a smooth kernel
d. Only with a very sharp kernel

22. For a CT scan, factors such as kV, mAs, and acquisition slice thickness are selected:
    a. Before the scan
    b. After the scan
    c. During the scan
    d. Never; these factors are always constant

23. Which of the following is not a primary scan parameter?
    a. Tube voltage
    b. Tube current
    c. Scan time
    d. Kernels

24. Which of the following is true?
    a. Image noise decreases (↓) with increasing kVp (↑)
    b. Image noise increases (↑) with increasing kVp (↑)
    c. Radiation dose decreases (↓) with increasing kVp and mAs (↑)
    d. Radiation dose is constant with increasing kVp and mAs (↑)

25. What parameters were likely selected for the following image?
    a. 30 kV, 50 mAs
    b. 110 kV, 200 mAs
    c. 250 kV, 500 mAs
    d. 400 kV, 400 mAs



26. Which of the following is true?
    a. Radiation dose increases linearly (↑) with scan time.
    b. There is a simple relationship between voltage and radiation dose.
    c. Radiation dose decreases (↓) when thinner acquisition slices are selected.
    d. Radiation dose decreases linearly (↓) with increasing mA value (↑).

---

27. The following abdomen CT slice features what window setting?
    a. Water window setting
    b. Soft tissue window setting
    c. Bone window setting
    d. Air window setting

---

28. Which factor does not affect spatial resolution?
    a. Kernals
    b. mA
    c. Slice thickness
    d. Patient motion

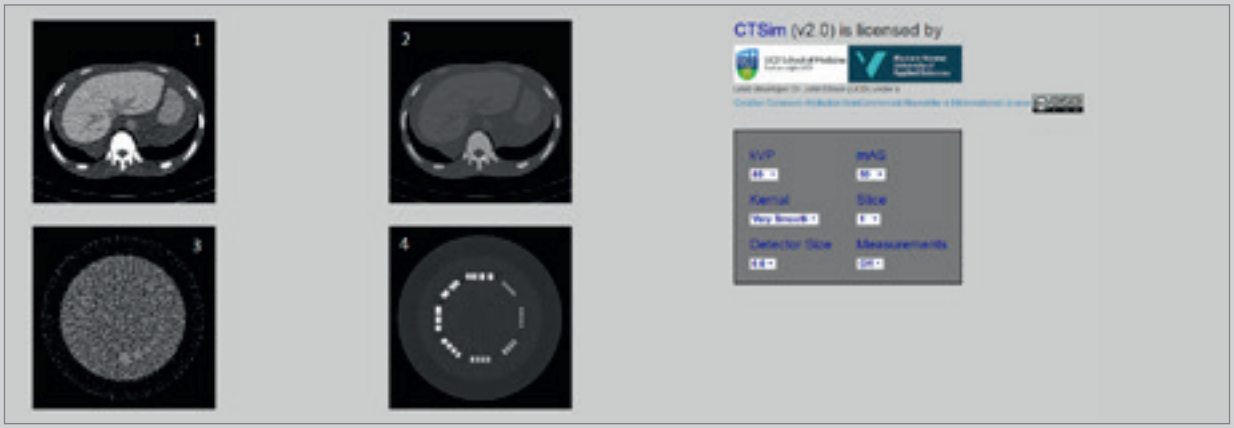
29. Which image has decreased detail (⇓) and why?
    a. Image 1; due to smaller acquisition slice thickness
    b. Image 1; due to larger acquisition slice thickness
    c. Image 2; due to smaller acquisition slice thickness
    d. Image 2; due to larger acquisition slice thickness

30. CT image enhancement is used to:
    a. Enhance shape and edge for improved image quality
    b. Reduce image noise
    c. All of the above
    d. None of the above

Appendix C: Intervention Task

How to use the CT simulation tool

Basics about the tool:



You can see four pictures on the screen.

1. Top left: CT slice of an abdomen phantom with a soft tissue window setting
2. Top right: CT slice of an abdomen phantom with a bone tissue window setting
3. Bottom left: CT slice of a contrast resolution phantom
4. Bottom right: CT slice of a spatial resolution phantom

On the right part of the screen, you can see adjustable parameters.

- kVP: it is a scan parameter, only adjustable prior to scan.
- mAS: it is a scan parameter, only adjustable prior to scan.
- Kernal: it is a reconstruction parameter, it sharpens or smooth out edges.
- Slice: it is the acquisition slice thickness in millimetres. It must be chosen before scan and can then only be made thicker in post-processing.

- Detector size: not part of the lesson. Just note that the slice thickness has to be bigger than the detector size.
- Measurements:
  if you switch them on, you can see:
  - HU in different regions of interests (RoI). Zero is water.
  - The **CTDIvol** in mGy represents the dose received in 1 centimetre (i.e. **dose rate**).
  - **DLP** in mGy.cm which is the dose received by the patient (i.e. **patient exposure**).
  - Noise, defined as standard deviation, only measured in the liver. The bigger it is, the more noise there is.

Using the Tool:

First, keep the measurements switched off.

Start parameters are at kVP: 80, mAS: 50, kernal: very smooth, slice: 1

1. If you increase the kVP and keep the rest of the parameters the same. What changes do you see in the pictures? Can you explain the changes?
2. Put kVP back at 80 and start changing the mAS. What are the changes now? Can you explain what you see?
3. Put mAS back at 50 and change the kernel. What can you see now? Explain what you see.
4. Set the kernal back to very smooth and start changing the slice thickness. Do you see any differences?

Image Quality:

Contrast resolution is the ability to distinguish two shades of grey that are similar but not the same. In the contrast resolution phantom (image 3) you can count the circles you see.

1. Looking at the pictures and changing the parameters, what combination gives the best contrast resolution?
   Try to explain what you see, write this down and write down what parameters you used.

kVP	mAS	kernal	slice

Spatial resolution is the ability to distinguish very small objects that are close to each other, in the spatial resolution phantom (image 4) you can count the lines you see.

2. Still looking at the pictures and changing the parameters, what combination gives the best spatial resolution?
   Try to explain what you see, write this down and write down what parameters you used.

kVP	mAS	kernal	slice

Now turn on the measurements. During the next steps, take a look at how the HU change.

3. Play with the parameters. How does the noise affect what you see?
   How does it affect contrast resolution?
   How does it affect spatial resolution?
   How does it affect the picture of the abdomen?

Dose:

Look at the dose in DLP.

Go back to the parameters you found for the best contrast resolution.

1. How do the parameters affect the dose compared to the start parameters (kVp:80, mAs: 50, kernal: very smooth, slice: 1)?
2. Was this what you expected?
   ○ yes ○ no
   Why?
3. Can you adjust the best parameters for contrast resolution you found so the contrast resolution stays the same, but the dose decreases?

Now use the parameters for the best spatial resolution you found.

1. How do the parameters affect the dose compared to the start parameters (kVp:80, mAs: 50, kernal: very smooth, slice: 1)?
2. Was this what you expected?
   ○ yes ○ no
   Why?
3. Can you adjust the best parameters for spatial resolution you found so the spatial resolution stays the same, but the dose decreases?

Dose and Image Quality:

Try to reduce both the noise and the dose in the best image for contrast resolution you found.

1. Were you able to do it?
   ○ yes ○ no

Use these parameters: kVP: 110, mAS: 250, kernal: standard, Slice: 4

DLP= 7.81 mGy.cm

Now try to reduce the noise and keep the dose close to this DLP. Write down what parameters you found.

kVP	mAS	kernal	slice

Use these parameters: kVP: 110, mAS: 250, kernal: standard, Slice: 4

SD = 8.6

Now try to reduce the dose and keep the noise close to this SD. Write down what parameters you found.

kVP	mAS	kernal	slice

Conclusion:

What are your conclusions about scan parameters and the influence on image quality and patient dose?

Comments:

How much time did you use to complete this?

……..minutes

Was it enough?

○ yes ○ no

Would you have liked to have more time?

○ yes ○ no

Did you find the task easy, normal, or difficult?

○ easy

○ normal

○ difficult

Do you have any comments to help us improve?

PLEASE DO NOT TALK ABOUT THIS TASK WITH OTHER GROUPS!

Mapping University Skills labs in Radiography: Students' Perspectives

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Keywords

Radiography, Skills Lab, Clinical placement, Equipment.

Abstract

Background: Establishing an effective theory and practice relationship is necessary for every radiography student. The effectiveness of a Skills Lab is paramount to ensure that student radiographers are prepared for Clinical Placement (CP). The aim of this study is to map the perspectives of radiography students regarding the university Skills Lab.

Methods: This study is mainly quantitative, with one qualitative element. A paper-based questionnaire was administered to 26 radiography students from seven different countries that were participating in the Optimax summer school. The questionnaire comprised 3 closed questions concerning demographics, 6 closed questions regarding the SL of their university, 3 of which were Likert Scale questions, and 1 open question about how SL could be enhanced, according to the students.

Results: Students indicated a competent lab tutor, smaller group size and simulated patient interaction to be important factors in the SL. In addition, environmental factors (light, temperature) were less important. Students mentioned that their equipment is of a lower standard than CP, but they also said that they feel well prepared for CP. Students found modern equipment not hugely important.

Conclusion: Students indicate that theoretical and practical skills labs prepare them well for CP. However, they suggest that a competent lab tutor and additional time are important factors in the SL.

Introduction

The role of the radiographer, from its genesis over 100 years ago, has changed constantly. The same can be said about radiographic education[1]. While teaching practices vary between universities in different countries, they each possess the fundamental system of combining theoretical and practical components[1]. Radiography universities across Europe operate on the assumption that a Skills Lab is an intermediate step in closing the gap between theory and practice[2]. Establishing an effective theory and practice relationship is important for every radiography student[1]. The effectiveness of practical sessions in an active learning environment is paramount to ensure student radiographers are prepared for clinical placement[3].

In the literature, several criteria were identified as possible conditions to maximize learning in a Skills Lab. A Skills Lab should be designed in a way that most accurately portrays a genuine hospital environment[4]. A study conducted by C. Haraldseid et al[4] noted that nursing students seemed to be practicing with outdated equipment, which created a Skills Lab not on par with genuine working conditions in a hospital. With regards to radiographers specifically, insufficiencies in the quality or lack of updated equipment being used were noted in the practical learning rooms for students[1]. These studies may suggest that modern, hospital relevant equipment would certainly benefit (radiography) students learning in a Skills Lab.

Group size certainly has an effect on the educational benefits of the Skills Lab[1]. J. Monks et al[5] claim that with larger student to teacher ratios, problems arise such as lack of clarity, less preparation, on top of less effective teaching methods and also less enthusiasm.

This study indicates that smaller group sizes may be more beneficial to student learning. This is further compounded by R. Pal[6], as his study indicates that smaller group sizes are considered more effective, as the material is covered more comprehensively.

Conditions that affect a learning environment include temperature and brightness of the Skills Lab, time of practical session and size of the learning group[7]. Temperature (20 degrees Celsius approx.) has a positive impact on students' academic performance[1]. C. Barkmann et al[8] noted that cool lights also improved concentration levels in students[15].

Problem Based Learning (PBL), which includes simulation-based learning experiences, is defined as a teaching method that is based on the idea of learning from cognitive and social interactions in a problem-centred environment and is effectively utilised by medical schools[1]. Noted benefits include students feel this technique better prepares them for the clinical environment.[4] A realistic learning environment inspires students to work harder, as they receive a real insight into the working world of their profession, something which this teaching technique can provide, as long as the simulated scenario is an accurate representation of a genuine clinical occurrence[8].

According to A.Kong et al[11], tutors are a vital component of simulated learning activities, as they may add to the fidelity of the scenario, as well as provide instant feedback. This adds to the aforementioned benefits of a realistic simulated environment. Furthermore, skills labs can provide a reflective component via recorded lab sessions allowing students to obtain instant feedback. This is something which students appreciate[11].

As described above, several factors have been described that could possibly enhance a Skills Lab for various disciplines such as medicine. However, whether these factors also account for the ideal Skills Lab for radiography students, remains unclear. The aim of this study is to identify what radiography students believe to be an effective Skills Lab.

Method

A study using a multi-item closed-response questionnaire with one open-response question (Appendix A) was used to ask radiography students attending an international summer school (Optimax) about their opinion of a Skills Lab. Students from a cohort of countries including Ireland, The Netherlands, Switzerland, Norway, South Africa, Canada and Brazil were involved.

The questionnaire design was based on themes found in a literature review.

- Part A of the questionnaire elucidated demographic data from the participants.

- Part B sought student opinion on various aspects of a Skills Lab detailing student experience, important teaching aspects and how well these prepared students for CP.
- Part C was an open-ended question where the students gave qualitative free text comments on how to improve the Skills Lab.

To optimize the quality of the questionnaire, a pilot study was conducted by surveying five randomly chosen Optimax students. Based on the pilot, no alterations were needed to adjust the questionnaire before the main study and thus, the results from the pilot were included in the main study. The questionnaire was distributed to the remaining Optimax students. At the beginning of the questionnaire, there was text explaining the aim of the study including a definition of a Skills Lab. The term PLE (Practical Learning Environment) was used in the questionnaire; this term is interchangeable with Skills Lab. No identifiable information was obtained from the students. The data collected from the survey was compiled in an Excel spreadsheet. The students' suggestions gathered from the open-ended question were compared to find common themes. Excel, together with OneDrive, was chosen for its ease of cooperation.

Ethical exemption was granted for the study by the Undergraduate Research Ethical Committee (UREC) at UCD.

Results

Twenty-six students of 7 different nationalities were given the questionnaire, with a response rate of 100% (Table 1).

Country of study		
	Ireland	6 (23.1)
	Switzerland	5 (19.2)
	The Netherlands	5 (19.2)
	Norway	6 (23.1)
	Canada	1 (3.9)
	South Africa	2 (7.7)
	Brazil	1 (3.9)
Year of study	First year	3 (11.5)
	Second year	10 (38.5)
	Third year	11 (42.3)
	Fourth year	2 (7.7)
Duration of study		
	3 years	11 (42.3)
	4 years	15 (57.7)

Table 1 *Demographics*

The Skills Lab is part of all participating student's radiographic education. 16 students (61%) found that the theory covered before their Skills Lab sessions was appropriate.

38.5% of students believe the Skills Lab does not prepare them well for the use of RIS/PACS/ Administration in clinical and only 3.9% of students believe the training they received in regards to RIS/ PACS/Administration use prepared them very well (Figure 1). The data was further analysed and it was discovered that students from particular countries had different opinions on positioning patients, occupational hazards, communication with patients and use of RIS/PACS. Students from Ireland and Switzerland regarded their work with positioning patients in the Skills Lab quite effective responding with "very well" and "well" respectively, while students from Norway considered their work only "adequate". Yet overall, students were of the opinion that positioning patients in the Skills Lab served them well for CP, with 65.4% responding with "well" and "very well" (Figure 2).

Fig. 1 student perception of preparation by Skills Lab (SL)

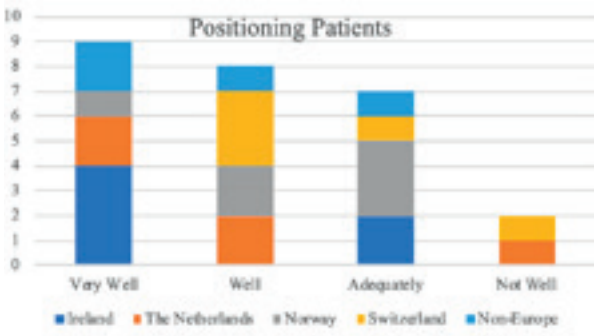

Fig. 2 Country-specific preparion by the Skills Lab on positioning patients

Furthermore, with regard to occupational risk hazards students from both Ireland and Norway agreed that they felt "well" equipped by the Skills Lab, but students from Switzerland believed that they were "not well" prepared by the Skills Lab. Furthermore, students from South-Africa felt the most prepared concerning occupational risk hazards, responding "very well" to this question. Moreover, both students from Norway and Switzerland felt that they were "not well" prepared for the use of RIS/PACS/Administration in CP by the Skills Lab. This data corresponds with the 38.5% of overall students (See Figure 1).

14 students (53.9%) answered that the equipment in the Skills Lab was of a lower standard than that found in their CP and 9 students (34.6%) found the standard was equal in both situations. Students from Ireland, Norway and Non-European countries were of the opinion that their Skills Lab was of a lower standard than their CP, while students from The Netherlands and Switzerland observed that their Skills Lab was equal to that of their CP.

Figure 3 shows what students consider to be important factors in the Skills Lab. Their answers varied with regards to the standard of the equipment and the gap in content between lecture and lab material. However, students reached more of a consensus on the issue of the Skills Lab environment and the competency of the lab tutor. Again, further analysis of the data further showed that students from Norway felt that modern equipment was quite necessary for the Skills Lab, while students from Switzerland did not see this to be relevantly important. Similarly, students from Ireland and the Netherlands disagreed with students from Norway

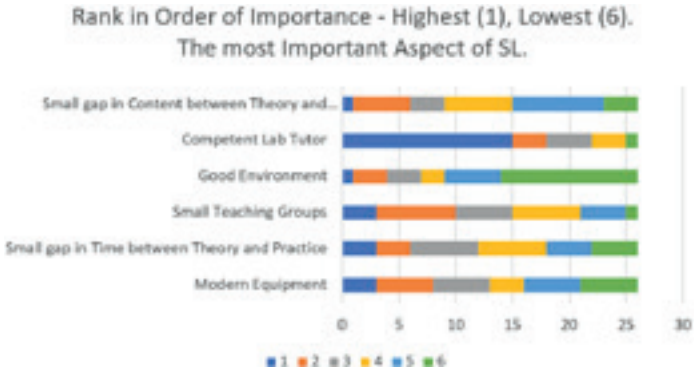

Fig. 3 Most important aspect of the Skills Lab (SL)

and Switzerland on the significance of the content gap between lecture and lab material. Conversely, students from Ireland, Norway and non-European countries agreed that a good environment was not the most important aspect of the Skills Lab. The environmental factors affecting the lab were ranked the lowest with 19 (65.2%) (Figure 3). Students from Ireland, Norway and Switzerland agreed that a competent lab tutor was the most essential aspect of the Skills Lab with 15 (57.7%).

Self-study, a competent lab tutor and filming labs for feedback findings were substantial teaching aspects (Figure 4). On closer examination it was identified that students from the Netherlands rated self-study more necessary than students from Norway and Switzerland. Yet, students from The Netherlands rated a competent lab tutor equally necessary for an effective Skills Lab. The majority of students (53.9%) believe a competent lab tutor is the most important aspect of the Skills Lab (Figure 4). Having a simulated patient interaction was found to be the second most important aspect of teaching in the Skills Lab by most students (30.8%) (Figure 4). Students from all 7 countries reported filming labs for feedback inessential, with 61.5% rating it lowest in importance for effective teaching.

Students were asked to suggest ways they wished to enhance their Skills Lab, through an open question which solicited free text remarks. Results stated that 8 students (30.9%) would like to have better equipment, 7 students (26.9%) would like to receive more time practicing in labs and 4 students (15.4%) proposed that small groups would be beneficial. The remaining 7 students gave no feedback.

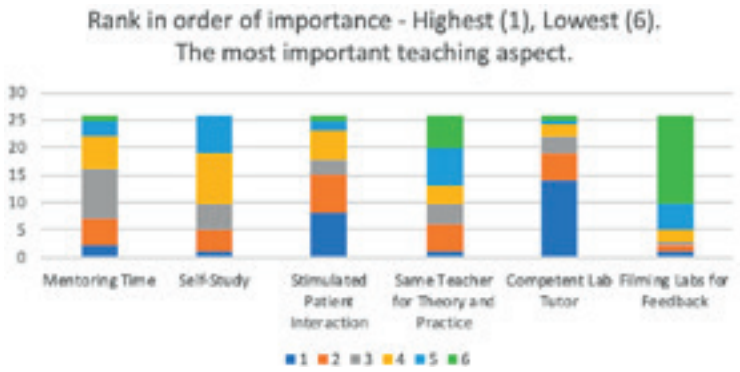

Fig. 4 Most important teaching aspect

Discussion

This study examined radiography students' perception of a radiography Skills Lab. 26 radiography students, all participating in the Optimax Summer school, answered a questionnaire and the resulting data was compiled and analysed. As suggested by K. Kyei et al[2], the Skills Lab is an effective way to reduce the gap between theory and practical learning and it was found that according to the students, the main factors that influence learning in the Skills Lab are reduced group sizes, competent teacher and simulation.

15 (57%) students agreed that a competent lab tutor is the most important part of a Skills Lab and 14 (53%) ranked a competent lab tutor as the most important teaching aspect. These findings are vital as it demonstrated that having a competent lab tutor could enhance the Skills Lab and perhaps help reduce the theory and practice gap[11]. According to Almohiy et al[11], competent tutors who are comfortable clinically are necessary to allow students to practise radiography skills and hence foster a deeper understanding of the topic. This draws parallels with the results regarding students from all countries, including The Netherlands who believe that a competent lab tutor is just as important as self-study.

Students indicated that they wanted to spend more time in the Skills Lab. Yet, as there are differences in radiography education programmes[1] and our students are at different stages of their bachelor or master programs, it was difficult to quantify this aspect. However, it must be considered that additional time is desired. It is possible that students need extra time in the Skills Lab because their program contains large numbers of students and so an individual's time to learn skills is reduced[3]. According to Kyei et al[2], a combination of limited resources and an overabundance of students contributes to an ineffective Skills Lab. This study is consistent with our results detailing the need for smaller groups in the Skills Lab. Our results showed that small student groups (less than 6 students) in labs was identified as the second most important aspect of an enhanced learning experience in the Skills Lab with 7 out of 26 students (26%). This agrees with the literature, where a smaller teacher-to-student ratio enhances the Skills Lab[5]. According to Monks et al[5], a larger group size leads to a lack of clarity from the tutor, a lack of enthusiasm from students and a reduced completion of course outcomes. Hence, students may need small numbers in their Skills Lab for lessons to be effective.

Our study showed that most students found the equipment in their Skills Lab of a lower standard compared to the equipment in the clinical environment. This finding involves students from Ireland, Norway and non-European countries. Students from Ireland, Norway, Switzerland and

Non-European countries (38.5%) also answered that better equipment would enhance the Skills Lab. These opinions support the Haraldseid et al[5] view concluding that old or outdated equipment results in an inadequate training situation. However, the data collected was not overwhelmingly substantial which suggests the standard equipment is not the first priority of students. Students seem to be more concerned with the availability of equipment relative to group size rather than the standard[3]. This aligns with both results from our and other studies[2,4.]

Our study shows that students are of the opinion that simulated patient interaction is one of the most important aspects of the Skills Lab. According to Bate et al[8], a simulation allows students to activate their knowledge and reflect on their task which in turn fosters a deeper understanding of the topic. This simulation can encompass communication with the patient, use of the equipment and positioning the patient. The majority of students indicated that their Skills Lab prepared them well for the clinical placement, concerning the communication with patient and patient positioning. However, with regards to the use of the software equipment (RIS/PACS/ADMIN), 10 students believe that they were not very well prepared for the clinical environment by their Skills Lab. It was found that students from Norway and Switzerland in particular did not feel well prepared with using software technology. This is an important finding as part of our research and would suggest improvements must take place concerning the practical application of software manipulation in preparation for CP. It must be noted, however, that software technology differs from site to site, from location to location and hence formalised training in relation to software technology might be hard to standardise.

Most students were of the opinion that the Skills Lab prepares them best for positioning patients. This implies that most time spent in the Skills Lab is focused on technique rather than the simulation of a real clinical experience, which would include communication with patients and use of software. This relates to the results concerning students from Ireland, who felt very prepared for clinical placement concerning patient positioning, but did not feel as prepared for the other aspects of the Skills Lab. Hence, a PBL approach may work at incorporating all elements of simulation and better prepare students for CP. Overall, PBL students prove to be more efficient, more prepared with regards to their interpersonal skills as better problem solvers, according to the literature reviewed[8,9,10]. This agrees with the results of our study suggesting that simulation of the clinical setting such as PBL is needed to give students a heightened sense of self-efficacy and improves their attitude towards clinical placement[9].

Despite the benefits of filmed lab sessions recorded in our reviewed literature[3], 61.5% of Optimax students listed filmed labs the least important option in comparison to the other mentioned teaching aspects. This may indicate that students would prefer sacrificing reflective and critical thinking skills in favour of traditional teaching aspects.

Within the literature[11], it was found that temperature (approx. 20 degrees Celsius) may have a positive impact on the performance of students. Our study showed that the environment was the least important aspect in the Skills Lab. However, students nowadays may expect a certain standard from their Skills Lab and hence have taken for granted the role environmental factors play on their learning ability.

There are some limitations to our study. These include the small number of students (n=26), the fact that some countries were represented by 5-6 students and others by just 1 or 2 students and how the CP experience of the students was difficult to compare. Possibly, if more open questions were used, answers would allow a better understanding of student choices.

Conclusion

There were a number of notable findings in our study. Firstly, students believe that a competent lab tutor and additional hours in the Skills Lab are some of the most important aspects of a useful Skills Lab. Furthermore, we deduced that students are more concerned with the availability of equipment relative to group size rather than the standard of the equipment. We also noted the need for simulated scenarios in the Skills Lab and how this better prepares students for CP. Lastly, we discovered how the training of RIS/PACS/Admin for CP is insufficient for students, observing a high percentage of students from most participating countries highlighting a lack of knowledge in this area. However, students respond that overall theoretical classes and SL sessions prepare them well for CP.

Recommendations

We wish to encourage more research based on the Skills Lab in radiography. Our findings can be the basis for further investigation and elaboration concerning the radiography Skills Lab where a more in-depth analysis can be performed about students from different countries. We hope that further research could eventually lead to a framework of an ideal effective standard of a Skills Lab, which can be used universally. Other potential studies could be conducted on the opinions of lab tutor and their perception of the radiography Skills Lab.

Acknowledgement

We would like to thank Prof. Peter Hogg, Dr. Annemieke van der Heij-Meijer and Dr. Jonathan McNulty for their insight and expertise. We thank University College Dublin for all their facilities.

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Appendix A: Enhancing a radiography practical learning environment

Our study aims to observe how the practical learning environment (lab sessions) for radiography students are designed and what are the possibilities to improve them. Practical learning environment is a practical lab session, where time is dedicated to learn practical skills, such as manipulating x-ray tube, practicing radiography positioning and exposing phantoms.

The questionnaire is composed of 3 parts.

Ethical exemption was granted for the study by the Undergraduate Research Ethical Committee (UREC) and by the Dean of Diagnostic Imaging at UCD.

Participation is voluntary and anonymous, therefore by participating you grant consent for the data to be used in the study.

Thank you for your help.

Part A:

1. **In which country are you studying your Radiography degree?**
   - ○ Ireland
   - ○ Switzerland
   - ○ The Netherlands
   - ○ Norway
   - ○ Canada
   - ○ South Africa
   - ○ Brazil

2. **What year are you currently in your radiography study?**
   - ○ First year
   - ○ Second year
   - ○ Third year
   - ○ Fourth year
   - ○ Post-graduated

3. **What is the duration of your study?**
   - ○ 2 years
   - ○ 3 years
   - ○ 4 years
   - ○ 5 years

Part B:

4. **Is practical learning environment part of your radiography education program?**
   - ○ Yes
   - ○ No

5. **Do the theoretical materials taught in lectures prepare you for practical learning environment sessions?**
   - ○ Very well
   - ○ Well
   - ○ Adequately
   - ○ Not well
   - ○ No opinion

6. **Does the practical learning environment prepare you well for:**

	Very well	Well	Adequately	Not well	No opinion
Equipment use					
Positioning patients					
Occupational risk hazards (needle sticks, infection)					
Communication with patients					
RIS/PACS/ administration					

7. **Is the equipment in your practice learning environment of the same standard seen in your clinical placement?**
   - ○ Higher standard
   - ○ Equal standard
   - ○ Lower standard
   - ○ No opinion

8. **Rank in order of importance (1) strongest, (6) lowest. The most important aspect to practical learning environment.**
   - ○ Modern equipment (x-ray tube, detectors, phantoms etc.)
   - ○ Small gap of time from theoretical lecture to practical learning session
   - ○ Small teaching groups (less than 6)
   - ○ Good environment (Temperature, light)
   - ○ Competent lab tutor
   - ○ Small gap in content between lecture material an lab material

9. **Rank in order of importance (1) strongest, (6) lowest.**

   The most important teaching aspects.

   ○ Mentoring time
   ○ Self-study
   ○ Simulated patient interaction
   ○ Same teacher for lectures as well as labs
   ○ Competent lab tutors
   ○ Filming labs for feedback

Part C:

10. **In the space provided please suggest some ways you wish your practical learning environment was enhanced.**

Does Training Have An Impact on Radiography Students' Approach to Chest X-Ray Image Quality Assessment?

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Abstract

Introduction: Radiography is evolving, and education must evolve with it. Radiography training mainly consists of theory-centred classes and clinical practice; however, this varies from country to country. Image quality assessment is a critical part of radiography. This study examines how aspects of training influence student radiographers' decision making.

Aim: To investigate whether training (academic study, clinical experience and country of education) received by undergraduate radiography students in four European countries influences their assessment of image acceptability/quality.

Materials and Methods: 23 radiography students from four European countries completed the task of accepting or rejecting 30 chest radiographs on the basis of image quality. Each participant gave reasons for any rejections. The total time taken, reject rate and reasons for rejection were compared between students in earlier/later stages of their degrees, those with more/less clinical experience, and those from different countries.

Results: Clinical experience, academic experience or country of education did not influence time taken by participants to view images. Participants with more clinical experience rejected more images than those with less. Clinical experience and country of education also influenced reasons for image rejection; participants with more clinical experience rejected significantly more images for absence of a lead marker, while Irish and Norwegian students rejected more images based on exposure than Swiss students.

Conclusion: Clinical experience had an influence on student radiographers' assessment of chest x-ray image quality in terms of both rejection rates and reasons for rejecting images. Country of education also influenced reasons for rejection.

Introduction

Radiography education programmes are constantly changing and evolving across the world in academic and clinical content. Radiography education consists of theory-centred classes in universities and clinical practice in hospitals (1). It is anticipated that the differences in education between countries is likely influenced by different roles of the radiographer in different cultures and healthcare settings (2). In Europe, most of the universities have the freedom to frame their curricula, which leads to variation between and within countries (3). Harmonisation of radiography education has been suggested by England et al. (4) and is promoted by the European Federation of Radiographer Societies (5), with the goal of producing radiography graduates educated to a more similar standard. This would also allow greater mobility of radiographers between European

countries (3). For example, students participating in this study from the institution in the Netherlands do not undertake any clinical practice until the third year; until then, students are taught mainly in skills labs and 3D simulations. Norwegian students begin clinical practice from year one. Switzerland has a small portion of its clinical practice concentrated on projection radiography, but Irish students are exposed to clinical practice from early in the first year, focusing on projection radiography.

High rates of image rejection have implications for 'management, training, education, as well as for quality' (6), and previous authors have highlighted the need to understand the "inter-subjectivity of radiographers' perception of, and attitude towards, both clinical and technical image quality criteria" (7). Therefore understanding how different training methods impact radiographer behaviour may inform recommendations for radiography education.

This study aimed to investigate whether the experience received in clinical practice and radiography education in four European countries (Ireland, Netherlands, Norway and Switzerland) influences how radiographers assess images for quality and the differences between them. Radiography training is very broad but for the purposes of this study we have chosen to investigate the influence of 1) percentage of degree completed 2) the amount of time spent in a clinical setting 3) the country of education on the time taken to assess image quality, rejection rates, and reasons chosen for image rejection.

Materials and Methods

In this study, radiography students were asked to accept or reject chest radiographs on the basis of image quality.

Ethics

The study was reviewed by the UCD Institutional Research Ethics Committee and granted exemption from full ethical review (Ethics reference number: UREC-SM-2018-26). Prior to beginning the study, written informed consent was obtained from each participant, after a description of the experiment. Participants were informed that the results of the study will remain anonymous. The images used were completely anonymised and used with permission from clinical sites from which they were sourced.

Pilot Study

A pilot study was conducted to identify potential issues with the research method and to modify it accordingly (8). A pilot study was performed with two participants from non-European countries. The data collection from the pilot study was analysed and the method was altered (adjusting the criteria used to

categorise reasons for rejection and the provision of a more informative instruction leaflet).

Images

A total of 28 anterior-posterior (AP) and postero-anterior (PA) chest x-ray images were selected from a collection of chest images from a previous study with permission from the clinical sites where they were generated. Two of the images were replicated within the test set to determine participant response consistency. The images were not selected on the basis of normality / pathology and represented a range of technical qualities. Each chest radiograph was converted from Digital Imaging Communication in Medicine (DICOM) to lossless Joint Photographic Experts Group (JPEG) file format.

Equipment and Environment

The images were displayed at 1920 x 1080 resolution on a 23" Thin-Film Transistor (TFT) Liquid Crystal Display (LCD) monitor. Environmental lighting conditions were representative of radiographers' / bedside clinical conditions at 378.85 lux and were consistent throughout the study (9).

Participants' eye movements were recorded using a Tobii TX300 eye tracker (Bildal, Sweden); however, the results of this eye tracking are not presented in this paper and may be used in a further study. Calibration was performed for all participants prior to viewing images. The eye tracking did not require any immobilisation and should not impact participants viewing behaviour.

Participants

Radiography students from four different European third-level educational institutions were invited to participate in this study. Each participant had completed at least one year of a diagnostic radiography degree and was attending the 2018 OPTIMAX Research Summer School. Basic demographic data collected included: country of education, course duration, most recent year of study completed and number of weeks spent in radiographic clinical practice to date. Table 1 demonstrates participant demographics according to country of education, course duration, mean level of study and mean number of weeks spent in clinical practice. The participants were grouped in two further categories for analysis for the effects of academic and clinical experience (Table 2).

Task

Participants were informed of the total number of images in the study and that there was no right or wrong answer. Participants assessed a total 28 of chest x-ray images and accepted or rejected them on the basis of image quality. When the participant had made a decision on each image, he/she pressed the spacebar to advance to a multiple choice

Country	Number of Participants	Total Course Duration (years)	Median Years of Study Completed	Mean Weeks of Clinical Experience
Ireland	7	4	2(1-2)	10.0
Netherlands	5	4	2(1-2)	0.0
Norway	5	3	2(1-2)	16.8
Switzerland	6	3	2(2)	8.0

Table 1: Participant demographics. Range is shown in parentheses where applicable.

Grouped by clinical experience		Number of participants
Group 1	≤ 10 weeks spent in a clinical setting	14
Group 2	> 10 weeks spent in a clinical setting	9
Grouped by academic experience		
Group A	< 50% of degree completed	13
Group B	> 50% of degree completed	10

Table 2: Participant groups used to test for the effects of clinical and academic experience

questionnaire allowing him/her to record their decision to accept or reject the image. Participants could not go back in the image viewing task. There was no time limit placed on the image viewing session. Figure 1 shows an example of how the images and questions were presented.

The total time taken to complete the image viewing task was measured using Tobii Studio Software (Bildal, Sweden), which indicated the initial time the participant started the task and their time of completion.

After the participant finished the image viewing session, they were brought into another room by a researcher. Here they were presented with each of the images they had chosen to reject as a reminder, and they were asked why they had rejected the image. Participants' responses were categorised in groups based on image quality criteria (Table 3) listed in the European Guidelines (10). No medical justification for the images was provided other than they were chest x-ray images that they should be evaluated for general radiographic image quality.

Data Analysis

The quantitative data was recorded into an Excel spreadsheet and imported to the IBM SPSS 24 program for analysis.

All hypotheses were tested using non-parametric tests because the data did not have normal distribution. The Mann-Whitney U test was used for comparisons of two groups and the Kruskal Wallis test were performed to test for differences between countries of education, with post-hoc testing completed using Mann-Whitney U tests. The level of significance was set at $p \leq 0.05$.

Results

Intra-observer variability

The decisions made by participants on the repeated images were compared and 22 out of 23 participants gave the same response for both repeated images, indicating good consistency.

Figure 1 Presentation of the task

Image quality criteria	Example of reasons for rejection in this criterion
Exposure	Overexposure/underexposure
Positioning	Rotation, tilt
Structures included	Anatomy cut-off
Patient motion	Blurring
Inspiration/expiration	Number of ribs visible
Centring	Direction of central ray
Lead markers	Absent/incorrect
Artefacts	Detector/ preventable/foreign object
Others	

Table 3: Criteria under which participants' reasons for rejection were categorised

Total time

The mean time (s) spend on the task was increased in group 2 (more clinical experience) as compared to group 1 (less clinical experience). However, the Mann-Whitney U test showed that the increase from 398 s to 506 s was not statistically significant. The test was also applied to groups A (less academic experience) and B (more academic experience) and showed no statistically significant difference between the two groups (Table 4). The Kruskal-Wallis test has shown that there is no statistical significant difference between the four European countries (Table 4).

Rejection rates

Students with more clinical experience (Group 2) had a statistically significantly higher rejection rate (50.2%) than those with less clinical exposure (Group 1) (36.2%). Students with more academic experience (Group B) had a similar rejection rate (42.14%) than those with less experience (Group A) (42.58%). Irish students had the highest rate of image rejection while Dutch students had the lowest.

Clinical experience					
	Group 1 <10 weeks	Group 2 >10 weeks			*p-value*
Mean time (s)	474.00	435.78			*0.88*
Rejection rate (%)	36.22	50.20			*0.03**
Academic experience					
	Group A <50%	Group B >50%			*p-value*
Mean time (s)	398.40	505.69			*0.12*
Rejection rate (%)	42.58	42.14			*0.88*
Country of education					
	Ire	Neth	Nor	Swi	*p-value*
Mean time (s)	491.00	519.40	420.20	403.83	*0.54*
Rejection rate (%)	51.53	31.43	47.14	36.90	*0.11*

Table 4: Results for total mean time(s), rejection rates (%) and p value for the clinical experience, academic experience and countries of education.

*statistically significant difference; p≤0.05

Reasons	Country				
	Ireland	Netherland	Norway	Switzerland	*p-value*
Exposure	16.67%	3.17%	10.68%	0.00%	*0.02**
Collimation	18.33%	28.57%	23.30%	13.92%	*0.52*
Positioning	22.78%	14.29%	11.65%	15.19%	*0.07*
Centering	3.33%	6.35%	1.94%	6.33%	*0.72*
Lead markers	1.67%	0.00%	9.71%	0.00%	*0.06*
All structures included	7.22%	15.87%	15.53%	16.46%	*0.71*
Patient's motion	3.89%	1.59%	0.97%	1.27%	*0.08*
Inspiration/expiration	10.00%	1.59%	7.77%	10.13%	*0.34*
Artefacts	14.44%	23.81%	16.50%	34.18%	*0.68*
Others	1.67%	4.76%	1.94%	2.53%	*0.88*

Table 5: Participant results from reasons for rejection divided by country of education

*statistically significant difference; p≤0.05

Reasons for rejection	Results and static significance					
	Clinical experience			Academic experience		
	Group 1 <10 wks	Group 2 >10wks	*P-value*	Group A <50%	Group B >50%	*p-value*
Exposure	6.28%	9.82%	*.096*	13.23%	5.95%	*0.26*
Collimation	19.37%	21.88%	*.369*	21.40%	18.45%	*0.12*
Positioning	17.80%	17.86%	*.141*	21.01%	11.90%	*0.19*
Centering	4.71%	3.57%	*1.00*	3.89%	4.17%	*0.74*
Lead markers	0.00%	5.36%	*.028*	1.17%	5.36%	*0.52*
All structures included	14.14%	11.16%	*.305*	8.95%	17.26%	*0.26*
Patient's motion	2.09%	2.68%	*.403*	3.50%	0.60%	*0.07*
Inspiration/expiration	5.76%	10.71%	*.083*	7.39%	9.52%	*0.93*
Artefacts	27.23%	14.73%	*.026*	17.12%	24.40%	*0.52*
Others	2.62%	2.23%	*.516*	2.33%	2.38%	*0.69*

Table 6: Results from reasons for rejection based on clinical experience and academic experience

Reasons for rejection

Reasons for rejection were compared between students training in different countries. No significant differences were found except for “exposure”, where students trained in Ireland and Norway both rejected more images than students trained in Switzerland.

A statistically significant difference in ‘lead markers’ being cited as a reason for rejecting images also existed between students with less (Group 1) and more (Group 2) clinical experience. Finally, there is no statistically significant difference for reasons for rejection between students with less (Group A) and more (Group B) academic experience. Full analysis of reasons for rejection may be found in Tables 5 and 6.

Discussion

The aim of this study was to investigate if clinical experience, academic study and country of education influenced student radiographers’ decision making when accepting or rejecting images on the basis of image quality.

The results of this study could help to inform standardisation of education of radiography students across the Europe. Indeed, the comparison in X-ray image quality assessment pointed out some differences between categories of clinical experience, academic experience and counties of education. Those differences could help the European universities to improve education and move towards standardization. Also, education standardisation could reduce time of adaptation in new employment, generating less stress and greater productivity. In addition, more uniform European curricula could increase labour demand and labour supply through countries.

Total time

None of clinical experience, education experience or country of education had a statistically significant influence on the total time taken to view all the images. This lack of difference in time taken could possibly be associated with participants having a similar viewing pattern, but further research would be necessary to confirm this assumption. Further research could also perhaps evaluate the scrutiny time per image to investigate whether images accepted or rejected for certain criteria require more time.

One study has shown that radiologists and experienced radiographers had a relatively shorter scrutiny time compared to students when searching for pathology (11). Contrary to the above findings, the current study has found that students with more clinical experience took on average over 100 seconds longer than those with less experience. Although this was not statistically significant, it may be due to a small sample size reducing the statistical power of the study.

Rejection rate

The results showed that participants with more clinical experience participants had statistically significantly higher rejection rates than those with less clinical experience. This could be explained by differences in perceptions of image quality. According to Mount, more radiologists accept poor (43%) and unacceptable (73%) images compared to radiographers (13%), and this could lead to unnecessary repeats (12). Furthermore, this study found that radiologists and radiographers use conflicting evaluation criteria, in which the radiologists focus on the diagnostic value of the images whereas radiographers consider closely the technical factors of the images. Therefore, the current study might indicate that the more clinically experienced radiography students were behaving in a way more similar to graduate radiographers, who appear to be very critical of image quality. The implications of excessively high reject rates may translate to higher patient dose, higher number of repeats, less waiting times, departmental costs and lower patient satisfaction (12).

Reasons for rejection

The participants with more clinical experience rejected significantly more images than those with less clinical experience because of the absence of lead markers on some of the chest radiographs. This could be related to those with less clinical experience either a) not noticing the lack of a marker, b) not believing lead markers are necessary or c) being more prepared to use only digital markers. For instance, a Maltese study revealed that most radiographers preferred to apply digital markers post-exposure because it was quicker than using pre-exposure lead markers (13). While different sites may have different protocols, and images may not require repeating solely on the basis of absent lead markers, the different approach taken by more clinically experienced students was interesting. Lead marker placement is important and should be done before taking an x-ray image especially in cases of possible anatomical situs invertus (reversal of major organs from their original position), and the European Society of Radiology has established a fundamental protocol of placing a lead marker before taking an x-ray of the patient (14). Therefore, theoretical teaching should emphasise the importance of lead maker placement before taking the x-ray image(s) so that students are aware of the importance of markers before starting clinical placement.

There was a significant difference in reasons for rejection between countries in terms of exposure. The difference was particularly noted between Ireland and Switzerland, and between Norway and Switzerland. This could be related to the differences in theoretical teaching or perhaps cultural differences, although further research is needed to

confirm this. Notwithstanding that previous studies have highlighted factors such as exposure, patient positioning, patient motion, artefacts and processing errors as the main cause of rejection—to some degree, exposure and processing errors continue to affect departmental performance regardless of recent digital advancements (12). Another study has shown that Belgian radiographers were more critical of image quality than Irish radiographers (15), and it is possible that those findings are similar to those of the current study, which may show that cultural or teaching differences according to countries or individual institutions influence rejection criteria.

Limitations of the study

The study had a limited sample size with only volunteer participants from the OPTIMAX program readily available to participate. Therefore, differences may relate to institutions rather than to countries as only single institutions from each country were represented. Also, it is possible that the effects of country and clinical experience may be linked in this study as some groups had very different mean clinical exposure (for instance, none of the Dutch students had yet undertaken clinical placement as their practical education in the earlier part of their qualification is lab based). Further analysis and study may help to differentiate between these factors

Conclusion

Students' exposure to clinical placement influenced student radiographers' assessment of chest x-ray image quality both in terms of time taken, rejection rate and rejection based on absence of a lead marker. Cultural or educational differences between countries / institutions also appears to influence rejection based on exposure. Even with a small sample size, this study indicates that clinical experience has an influence on the way student radiographers accept or reject chest images. It appears that percentage of degree completed did not have any influence.

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An Analysis of Breast and Gonad Lead Shielding Effectiveness in Abdominal AP Radiography: A Phantom Study

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A phantom-based study to determine the impact of lead shielding on radiation dose to breast and gonads located peripheral to the primary beam during antero-posterior abdominal X-ray examinations.

Abstract

Purpose

Lead shielding can be applied to radiosensitive organs to minimise radiation dose and therefore the risk of stochastic effects. Gonads and breast are key examples of radiosensitive organs on which shielding can be used. Using a phantom-based approach, this study assessed whether lead shielding for breast and gonads influences dose in abdominal radiography.

Method

AP abdominal X-ray examinations were performed on six different phantoms; a neonate, 1-year old, 5-year old, 10-year old, 15-year old and adult male phantom. Breast attachments were added to the 15-year old and adult phantom to mimic a female patient. The radiation dose to the breasts and male gonads, shielded (lead equivalent 0.5mm thickness) and unshielded was measured using a RADCAL dosimeter. Five dose measurements were taken and then averaged for each protocol. Descriptive statistics were used to describe mean dose, standard deviation and percentage dose reduction with shielding. Wilcoxon signed rank tests were used to test significance of differences in organ doses with and without leads. A friedman test was used to detect differences in organ dose across multiple lead shielding combinations in the adult male phantom.

Results

Radiation dose to the breast tissue was reduced by 46 - 93% across all age groups, with the greatest reduction to breast dose found in the 15-year old and adult phantoms. A lesser dose reduction of 13 - 50% to the male gonads was achieved with shielding. The dose reduction observed with shielding in each age group was statistically significant ($p<0.05$). During AP abdominal X-ray examinations, sheilding of the breasts and male gonads is recommended to reduce radiation to these radiosensitive regions.

Conclusions

For AP abdominal radiography, lead shielding of breasts and male gonads has potential clinical utility.

Introduction

Diagnostic imaging has revolutionised healthcare since its introduction at the end of the 19th century. Conventional X-ray examinations remain a vital diagnostic tool in modern medicine today. In a recent survey of 36 European countries, conventional X-ray examinations made up approximately 87% of all imaging examinations involving ionising radiation.[1] While the diagnostic benefits of X-ray examinations are extensive, one must consider the potential stochastic effects associated with ionising radiation, such as radiation induced cancer or other genetic effects.[2] The probability of these stochastic effects occurring is proportional to the dose and there is no dose threshold below which the effects do not occur,[3,4] therefore radiation protection and dose optimisation is of utmost importance.[5]

An abdominal X-ray is considered a relatively high dose projection radiography X-ray examination with an effective dose of 0.4 mSv [6] accounting for 4.42% of the population collective dose in the UK.[7] The ICRP recommend exam justification and optimisation as key radiation protection principles.[2] Optimisation is defined as maintaining diagnostic image quality while reducing dose As Low As Reasonably Achievable (ALARA) so the benefits outweigh the risks associated with the medical exposure. There are many tools radiographers can employ to optimise X-ray examinations such as appropriate selection of imaging parameters, collimation and protective shielding.[8] Protective shielding, such as lead, may be used to protect radiosensitive organs such as the breast, gonads and thyroid.[4]

According to ICRP publication 34 [9] "gonads should be shielded when, of necessity, they are directly in the x-ray beam or within 5 cm of it, unless such shielding excludes or degrades important diagnostic information".[2,10] There are a variety of shields available including wraparound shields, aprons, gonad and thyroid shields, etc. with a minimum lead equivalent of 0.25mm for secondary radiation. If the kVp exceeds 100 kVp, shields greater than 0.5mm lead equivalent should be used for primary and secondary radiation. [11] Most commercially available half aprons designed for gonad protection are 0.5mm lead equivalent. Flat gender-specific gonadal contact shields may be used for patients in the supine or recumbent position.[12]

Despite the benefits of lead shielding, the clinical necessity of lead remains controversial in dose optimisation studies, with some studies [13,14] discouraging the use of gonad shielding, particularly within the primary beam due to the risk of obscuring anatomy of interest which may result in repeat exposures. Many studies on pelvic radiography [3] have demonstrated a substantial dose reduction of 50-95% to male gonads [2,13] and female breasts dose reduction of 50%, with the use of gonadal shielding

within the primary beam, as defined by current recommendations.[7] On the contrary, female gonad shielding is not recommended in pelvic radiography due to the variable location of the female gonads within the pelvic inlet, risk of obscuring anatomy of interest, body habitus and risk of patient movement. Issues with malpositioning the shields can lead to repeats i.e. double exposures if relevant anatomy is obscured.[2,3,11,12,14-17]

The majority of dose studies [13,14,16,18,19] focus on shielding of the gonads without consideration of the breast tissue which is considered more radiosensitive. Tissue weighting factors proposed by the ICRP 103 [2,4] stipulate that the radio-sensitivity of the breasts has increased from 0.05mSv to 0.12mSv and gonad radio-sensitivity decreased from 0.2mSv to 0.08mSv indicating the need for radiation protection.

Shanley et al. investigated radiography educator's opinions on the use of lead for gonad and breast finding that only 44% advocate breast shielding outside the beam, compared to 63% advocating gonad shielding, within the primary beam for gonads. [8] Moreover, a dose study for AP and lateral thoracic spine projections with breast shielding shows that there is an 35% reduction and a 24% reduction to the breasts, respectively.[17,20] A similar study of AP lumbar spine projections and breast shielding found an 80% reduction in the breast radiation dose when lead of 0.5mm was applied, over the breasts, outside the primary beam.[17]

It is worth noting that paediatric patients are a special case and require additional thought for radiation protection. They are more radiosensitive than adults due to rapidly growing cells and their longer life expectancy [2,14,18]; research shows that paediatrics have a higher lifetime risk of radiation induced cancer with the risk increasing in younger children.[21] Furthermore, paediatrics can pose a challenge when it comes to using lead protection, as they tend to move a lot and may cause the lead shield to obscure anatomy causing repeated images or inadequate protection, thus precautions should be taken to reduce patient movement.[22]

Literature on the use of lead shielding in paediatrics has been published in recent years.[14,18] *Warlow et al.* [18] found that incorrect positioning of paediatric gonadal shielding was an issue in 32% of male pelvic radiographs and 75% of female pelvic radiographs, thus female gonad shielding should be omitted.[14] Breast tissue is not yet present in female paediatrics, although, the youngest age in which breast development is visible is at the age of 8 years, according to a study done by *H. Ma et al.*[23] The risk of breast cancer increases with exposure to radiation at younger ages.[21] Many research studies, which assessed the impact of lead shielding on

spine, chest and pelvis radiography, have produced conflicting recommendations; lead shielding was generally recommended if placed outside the primary beam and contraindicated for use within the primary beam i.e. female gonad shields. The degree of dose savings varied depending on X-ray projection and technical factors.[13-15,17,19] The drawbacks of lead shielding included infection control and risk of malpositioning, obscuring relative anatomy and repeated unnecessary exposure. The impact of lead shielding on dose reduction in abdominal radiography has not yet been investigated. Thus, the aim of this study was to determine whether lead shielding should be placed over the breast tissue and/or male gonads to reduce dose to these radiosensitive regions during AP abdominal radiography.

The aims of this research were as follows:

1) To investigate the impact of lead shielding on radiation dose to the male gonads for the AP abdominal radiography in paediatric and adult patients.
2) To investigate the impact of lead shielding on radiation dose to the breasts for the AP abdominal radiography in paediatric and adult patients.

Method

An experimental study was performed on paediatric and adult anthropomorphic phantoms to investigate the impact of protective lead shielding for female breast and male gonads. Both of these tissues are located close to the primary beam for the AP abdomen radiograph and considered radiosensitive according to the ICRP [2] with a tissue weighting factor of 0.12 for the breast and 0.08 for the male gonads.

Materials

For this study two different brands of dosimetry phantoms were used to simulate patients. Atom dosimetry anthropomorphic phantoms were used to simulate neonate, 1-, 5-, 10- and 15-year old patients (figure 1).[24,25] The atom adult female was used to simulate a 15-year old. The specifications of the atom phantoms are described in table 1. An adult RANDO anthropomorphic phantom was used to simulate an adult sized patient (figure 2).[26] The RANDO phantom used is model ART-211X, ART-212X and is manufactured by RSD. Its height is 175 cm, its weight is 73.5 kg and it was used with a breast attachment of 600 ml (C-cup).[26]

The experiments were performed in the X-ray lab of the University College Dublin, using a GE model 2291655-5 DR X-ray tube with integrated image receptor (Revolution XR/D) (see tables 2.2 and 2.3). In accordance with Report 91[27], prior to commencing experimental work, quality assurance tests were performed. These tests included beam centring and alignment, output consistency and output reproducibility (see QA results in appendix A). The results fell within expected tolerance limits.

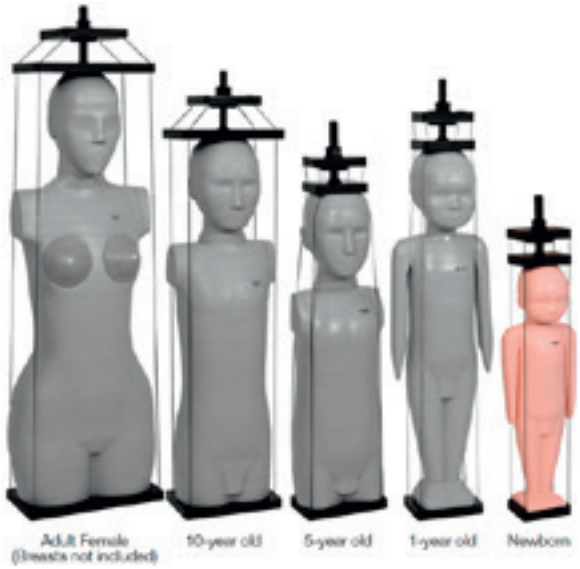

Figure 1: Atom Dosimetry Anthropomorphic Neonate, 1-, 5-, 10- and 15-years old Phantoms

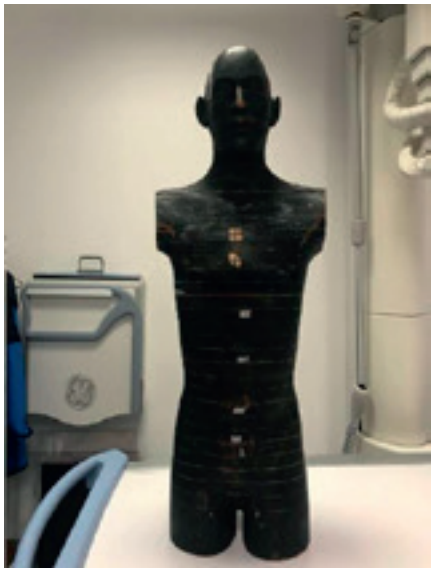

Figure 2: Rando Dosimetry Anthropomorphic Adult Male Phantom

Phantoms	Neonate	1-year	5-year	10-year	15-year
Model nr.	703	704	705	706	702
Height (cm)	51	75	110	140	155
Weight (kg)	3.5	10	19	32	50
Breast attachment	None	None	None	None	400ml (B-cup)
Physical Density, G/CC	1,41	1,45	1,52	1,56	1,6
Electron Density, 1/CC	4.498·1023	4.606·1023	4.801·1023	4.878·1023	5.030·1023
Manufacturer	ATOM CIRS [24,25]	ATOM CIRS [24,25]	ATOM CIRS [24,25]	ATOM CIRS [24,25]	ATOM CIRS [24,25]

Table 1: Specifications of CIRS Anthropomorphic Phantoms [24,25]

Parameter	Specifications
Peak Power	80 Kw
Minimum kVp change	1 kVp
kVp Accuracy	+/- 10%
mAs Range	0.25 mAs to 630 mAs
Minimum change	Variable
mA Accuracy	+/- 20%
Output	Switched variable frequency design

Table 2: Specifications of JEDI 80RD IT Performance Generator

Feature	Specification
Anode angle	12,5°
Anode heat dissipation	75,000 heat units
Total filtration	3,6mm/Al
Anode material	Polyrhenium
Anode heat storage capacity	350,000 heat units
Focal spot sizes	0.6mm and 1.25mm
DAP accuracy	+/- 10%

Table 3: Specifications of GE MAXIRAY 100 Tube

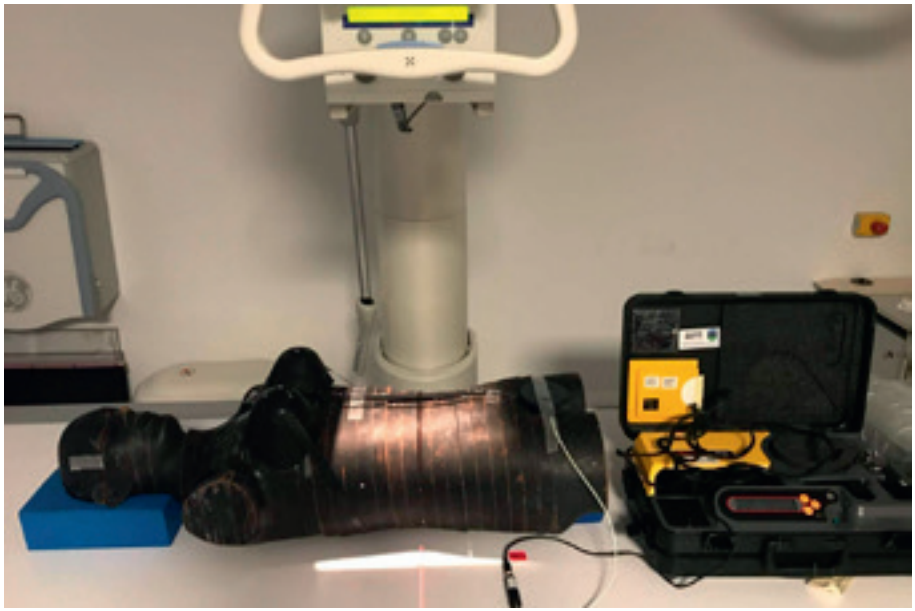

Figure 3: Scatter Probe Placement for Male Gonad Dose Measurement on Adult RANDO Phantom

Figure 4: Scatter Probe Placement for Breast Dose Measurement on Adult RANDO Phantom

Dose measurements, in Gray (Gy), were performed using a RADCAL dosimeter, model XLPRO-4083, with the scatter probe attachment.[28] The scatter probe was placed parallel to the coronal plane on the surface of each phantom in two locations; (1) over the male gonads and (2) over the breast tissue (Figures 3 and 4). The exact location of the scatter probe was marked on each phantom to ensure that it was placed in the same location for all exposures for the range of lead shielding positions. The RADCAL had been calibrated to national standards for the X-ray radiation qualities produced to IEC and ISO standards.[28,29] Five exposures were generated with the RADCAL in a single position for each imaging protocol and then averaged to minimise random error. [28]

Imaging Protocol

Antero-posterior (AP) abdominal exposures were performed on each phantom positioned supine on the X-ray table. A vertical central ray was directed to the median sagittal plane at the level of the iliac crests. [30] The X-ray beam was collimated to the skin borders laterally, diaphragm superiorly and symphysis pubis inferiorly.[30] Measurements of the resultant collimation field were recorded during the pilot study and used in the main study. Resultant images were assessed visually for evidence of under- (noise) or over-exposure (saturation).

A pilot study was carried out to assess the feasibility of the experiment and to determine appropriate exposure factors for the AP projections on each of the phantoms. A paediatric X-ray exposure chart published by Knight et al. in 2013 [31] was used as a baseline from which parameters were modified. The mAs given by the AEC were closely matched (within 2mAs for neonate, 1-, 5-, and 10-year old and within 5mAs for 15-year old) to the prescribed exposure chart, therefore the AEC recommended mAs was used (table 4). DAP measurements recorded were below national DRLs.[32] All paediatric exposures were obtained at a source-to-image distance (SID) of

Table 4: Exposure Parameters used for each Anthropomorphic Phantom

	Neonate	1-year	5-year	10-year	15-year	Adult male
kV	63	66	70	73	77	75
mAs	2	2	4	5	10	20
Collimation (cm)	13 * 11,6	17,3 * 17,8	26,0 * 20,4	33,2 * 21,8	36,7 * 25,6	36,6 * 28,7
Grid ratio	No grid	No grid	13:1	13:1	13:1	13:1
SID (cm)	110	110	110	110	110	120

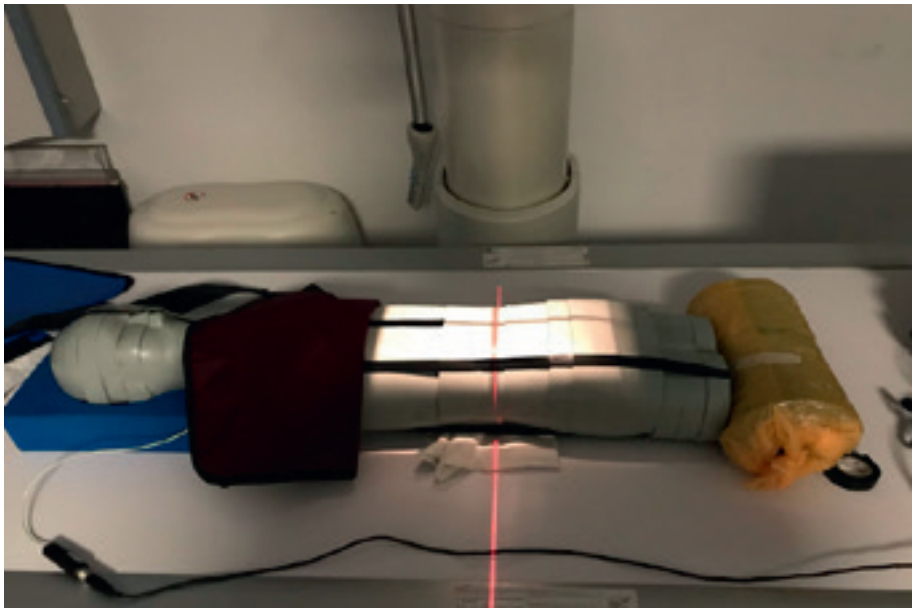

Figure 5: Position of half apron over breast tissue on Atom paediatric phantoms

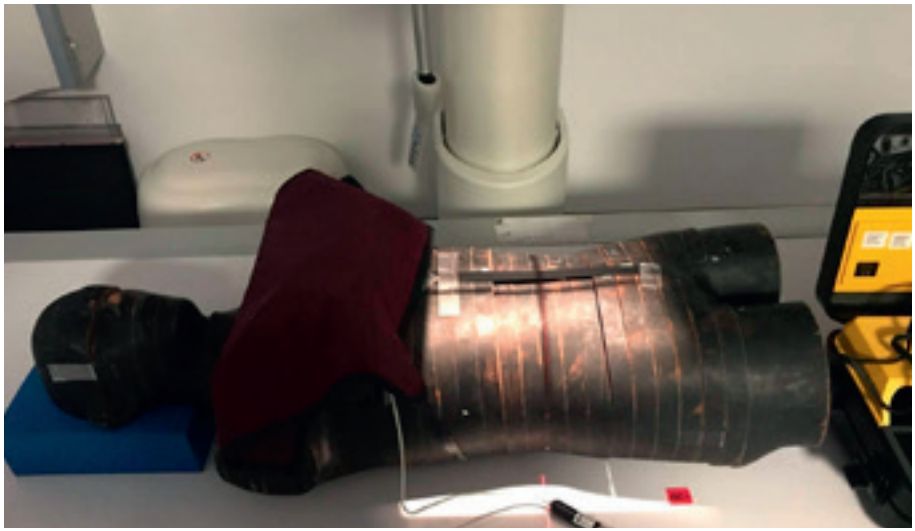

Figure 6: Position of half Apron over Breast Tissue on Adult RANDO Phantom

110cm in line with literature.[30] The SID was increased to 120cm for the adult phantom to include the relevant anatomy.[30] The grid, when used, had a grid ratio 13:1. Based on the SID and the phantom thickness [12,30] the decision was made to use a grid on the 5-year old, 10-year old, 15-year old and the adult phantom.[24-26]

Protective Shielding

Half apron protective shielding was used in this experiment, 0.5mm lead equivalent thickness, to imitate clinical scenarios. The lead shield was exposed to assess for cracks for quality assurance. The following lead shielding combinations were tested:

1. No lead aprons (control group)
2. Lead apron over the breast tissue only
3. Lead apron over the male gonads only
4. Lead aprons over both the breast tissue and the male gonads

For all the phantoms, except for the neonate, both female breasts and male gonad doses were measured. Various combinations of lead were tested. Because of the size of the neonate the decision was made to only use lead on the gonads and therefore only measure the dose to the gonads.

Protective lead aprons were positioned 1 cm outside the collimated light beam to avoid artefacts on the image, either inferior to the symphysis pubis or over the breast. When placed over the breasts in paediatric patients, the apron was folded to avoid contact with patient's neck and face (see positioning in figure 5). This resulted in Pb equivalent of 1.0mm thickness protection over the breasts in paediatric patients. Positioning of the lead apron draped over adult breast tissue is demonstrated in figure 6.

Statistical Analysis

Descriptive statistics were used to describe the dose reductions achieved for each protocol. Normality of data was assessed using the Shapiro Wilks test and visual histogram analysis. Wilcoxon signed rank tests were used to assess the statistical significance ($p<0.05$) of organ dose reduction with and without lead shielding. The Friedman test was used to assess whether multiple lead combinations resulted in statistically significant ($p<0.05$) dose reduction in the adult phantom.

Results

The mean dose measurements for each imaging protocol are detailed in table 5. No shielding was used for the control protocol.

For the 1-, 5-, 15-year old and adult phantoms, dose reduction to male gonads using male gonad shielding compared to control measures ranged between 12.65% to 22.68%. A greater dose reduction was observed to the gonads for the 10-year old at 32.52% and to the neonate at 50.08% (see figure 7).

	Breast dose measurement (μGy)				Male Gonads dose measurement (μGy)			
Age	Control	Breast Shield	Male Gonad Shield	Both Shields	Control	Breast Shield	Male Gonad Shield	Both Shields
Neonate					1.29 (+/-0.02)		0.64 (+/-0.01)	
1 year old	3.26 (+/-0.01)	1.27 (+/-0.03)	3.25 (+/-0.03)	0.98 (+/-0.01)	2.02 (+/-0.02)	2.00 (+/-0.03)	1.77 (+/-0.01)	1.76 (+/-0.01)
5 year old	9.30 (+/-0.09)	5.02 (+/-0.04)	9.27 (+/-0.08)	5.01 (+/-0.05)	5.49 (+/-0.02)	5.81 (+/-0.02)	4.25 (+/-0.05)	4.23 (+/-0.03)
10 year old	9.63 (+/-0.05)	4.53 (+/-0.03)	9.38 (+/-0.06)	4.52 (+/-0.02)	4.58 (+/-0.02)	4.50 (+/-0.04)	3.09 (+/-0.02)	3.05 (+/-0.03)
15 year old	17.88 (+/-0.05)	5.11 (+/-0.01)	17.86 (+/-0.04)	5.78 (+/-0.02)	17.89 (+/-0.01)	17.72 (+/-0.02)	14.63 (+/-0.01)	15.27 (+/-0.04)
Adult	50.33 (+/-0.13)	3.28 (+/-0.01)	50.41 (+/-0.03)	3.29 (+/-0.02)	58.31 (+/-0.33)	61.89 (+/-0.04)	50.61 (+/-0.41)	52.29 (+/-0.06)

Table 5: Meaa (+/- SD) Dose Measurements to Breast and Male Gonads for each Combination of Shielding (μGy)

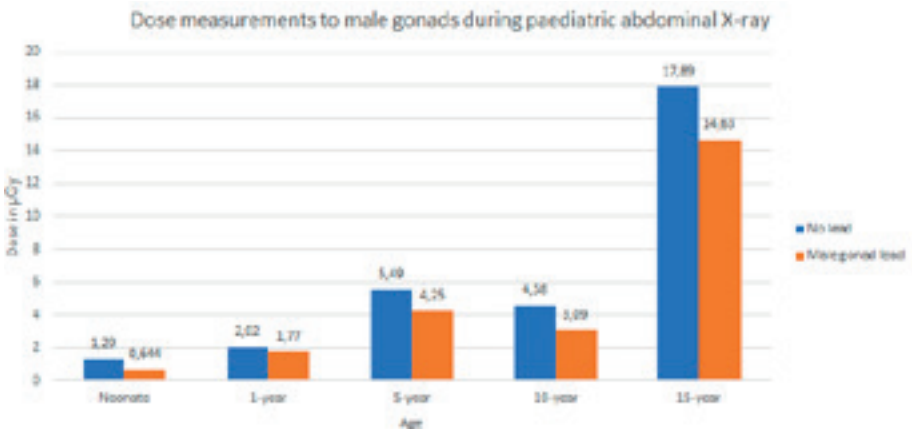

Figure 7: Dose Measurements to Male Gonads during Paediatric Abdominal X-ray Examinations

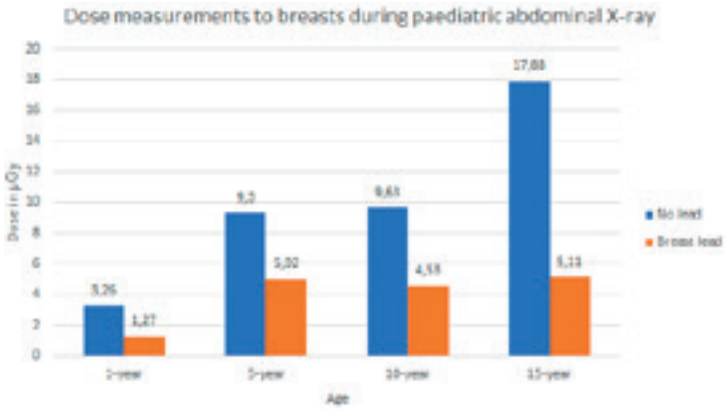

Figure 8: Dose Measurements to Breasts during Paediatric Abdominal X-ray

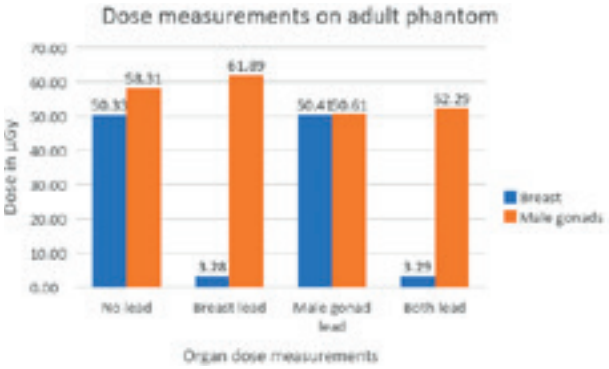

Figure 9: Dose Measurements on Adult Phantom

Wilcoxon signed-rank test indicated dose reduction to the male gonads achieved with lead use in neonate and paediatric phantoms (1-, 5-, 10-, and 15- year old) was statistically significant ($Z = -2.032$, $p < 0.05$). Gonad dose measurements in the adult male differed significantly with varying combinations of lead shielding ($X2(3) = 15.0$, $p < 0.05$) as seen in figure 9.

Shielding resulted in a 46.03%-71.39% dose reduction to the breasts in 1-, 5-, 10- and 15- year old phantoms ($Z = -2.032$, $p < 0.05$) compared to unshielded breast dose measurements. The 5- and 10-year old phantoms have the lowest reduction values at 46.03% and 52.94% respectively, followed by the 15-year old at 71.39% and one year old, 60.98% (see figure 8).

Radiosensitive organ	No lead	Breast Lead	Gonad Lead	Both Lead
Breast dose	6.04	0.39	6.05	0.39
Gonad dose	4.66	4.95	4.05	4.18
Total	10.7	5.34	10.1	4.57

Table 6: Effective Dose for Adult Phantom (in μSv)

A substantial dose reduction of 93.48% was achieved in the adult breast with shielding ($X2(3) = 12.75$, $p < 0.05$).

For the adult sized phantom, organ specific doses were calculated using weighting factors (wT) for breast tissue and male gonads (gender not specified by ICRP, assume the wT is an average for both genders). This shows a major dose reduction for the breast tissue when protective shielding is used and amplifies the importance of shielding breasts compared to male gonads.

Discussion

This research investigated the effectiveness of lead shielding for radiation protection of the breasts and male gonads during AP abdominal radiography. Although the breasts and male gonads are located peripheral to the primary beam, this study demonstrated significant dose reductions (12.65% - 93.48%) to these radiosensitive regions with the use of lead shielding in both adult and paediatric phantoms ($p<0.05$).

Interestingly, the greatest dose reduction was achieved in the adult and 15-year old phantoms with female breast attachments. The application of lead shielding over the breast tissue was effective in reducing the dose to the breast by 93.48% to the adult phantom ($p<0.05$) and 71.39% to the 15-year-old ($p<0.05$). This finding reflects the importance of breast shielding which is greatly underrated by many radiography educators, despite increased tissue weighting factor with 56% of the educators reported it as irrelevant after being surveyed.[8] The greater effectiveness of breast shielding in the larger phantoms could be attributed to the lead shield folding entirely over the breasts i.e. greater coverage of the breast and the breasts being further from the collimation field than in paediatric phantoms (due to smaller patient size and lack of tissue/ difference in breast morphology). With the known radio sensitivity of the breasts[2,21], it is imperative that every effort is made to protect the breast tissue from radiation and reduce the risk of patients developing radiation-induced breast cancer. Our study suggests that lead shielding is an effective method to protect breast tissue during AP abdominal radiography. This finding

concurs with other studies which have assessed the effectiveness of lead shielding in lumbar spine radiography and found a large dose reduction of 80% with the use of breast shielding.[17] Slight differences in the degree of dose reduction to the breast between our study and that of *Mekis et al* may be due to differences in the thickness of lead shielding (0.5mm was used by Mekis compared to a folded 0.50mm lead apron thus equal to 1.00mm for our study), area under examination, exposure factors used and sensitivity of TLDs versus RADCAL scatter probe dosimeter [28] .

Breast dose was reduced by 60.98% in the one-year old phantom when a 0.5mm Pb equivalent half lead apron was folded and placed flat on top of the breast tissue ($p<0.05$). Dose reduction to the breasts in the 5-, and 10-year old phantoms with shielding compared to non-shielded control measurements was 46.03% and 52.94% respectively ($p<0.05$). While the dose reduction with breast shielding was not as impressive as in the adult phantom (93.48%), it is worthwhile when considering current literature on radiation-induced cancer risks. According to the BEIR-VII report, the risk of radiation-induced cancer to the breast tissue is highest in youngest female children and decreases with age; radiation-induced breast cancer risk in 15-year olds is half that to a neonate.[21] Therefore keeping the dose to the breast as low as reasonably achievable (ALARA) is particularly pertinent in paediatric radiography. Other factors to consider, which could not be accounted for in this research study, include shielding effectiveness at breast morphology and development, the size of commercially available shields relative to paediatric patients, risk of patient movement and risk of infection control.

A dose reduction to the gonads was also achieved through lead shielding in this study, although not to as great an extent as the breasts. The neonate phantom had the highest gonad dose reduction of 50.08%. In the rest of the paediatric age groups and in the adult male phantom, a dose reduction of 12.65% - 32.52% was attained through the application of lead shielding over male gonad area. Thus, still a significant reduction in the gonadal radiation dose for all male age groups. Historically, the gonads were considered more radiosensitive than the breast until approximately 2007 [2] when updated radiation sensitivity tissue weighting factors were amended based on scientific literature which emerged. There is a lot of controversy in clinical practice regarding the usefulness of gonad shielding. Many studies [13,14,18] have rejected the use of female gonad shields within the primary beam due to the risk of obscuring anatomy which may warrant a repeat exposure to the patient. As the lead is placed 1 cm below the symphysis pubis in this study, the risk of obscuring abdominal anatomy of interest is very low. This

research indicates that lead shielding of the male gonads can significantly reduce radiation dose during abdominal radiography, therefore should be implemented in clinical practice for both paediatric and adult patients.

Recommendation for further research

Further investigations should be done to assess the effectiveness of breast shielding in other general radiography examinations. Translation of our research into clinical practice and follow-up research into the ease of application of lead shielding, particularly in breast shielding during paediatric radiography, is recommended. Design of protective shielding for breasts in terms of shape and lead equivalent is another avenue for further exploration. The impact of shielding on scatter to other internal organs could also be researched through placement of dosimeters within organs of anthropomorphic phantoms.

Limitations of the study

Firstly, the tests were performed on phantoms which means that patient movement did not affect the measurements or the positioning of the lead shields. In the 15-year old adult phantom with breast attachments, the phantom design appears to replicate a female with a bra on, which is not realistic compared to clinical practice. No breast specific lead shields were available, only the half lead apron. It is possible that different values could have been obtained if using breast specific shielding.

Conclusion

This study has confirmed that dose is significantly reduced when lead shielding is applied for an AP abdominal radiograph outside the collimation field over the male gonads and breast tissue thus contributing to good practice and patient radiation protection. Shielding of these radiosensitive areas is of paramount importance and should be applied in clinical practice for AP abdominal radiography.

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The impact of operator training on the accuracy of DXA lumbar spine analysis

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Keywords:
DXA, osteoporosis, training, x-ray.

ABSTRACT

Introduction

This study involving Dual-energy X-ray Absorptiometry (DXA) spine images investigated the effectiveness of an additional training session compared to basic instruction provided by the scanner manufacturer (by video) on student radiographers' ability to make appropriate DXA analysis decisions. Lack of operator training can potentially lead to technical errors and inaccurate patient diagnosis which may be detrimental to their bone health and put them at risk of a fragility fracture in the future.

Methods

Radiography students (n=24) attending the OPTIMAX research summer school in University College Dublin (UCD) participated. The students first watched a video that was provided with the DXA scanner software. This video explained the basic process of analysing a DXA spine image. Participant knowledge of understanding how to analyse a DXA spine image was then assessed by questionnaire. Immediately after the completion of the first questionnaire , an expert DXA radiographer (16 years experience) provided a training session on DXA lumbar spine analysis, giving a more in-depth, comprehensive and step-by step tutorial on how best to analyse DXA spine images and common pit-falls to be aware of. Lecture notes and a set of DXA guidelines (based on international best practice and on which the lesson was designed) were distributed during the training session. The participants repeated the questionnaire, with access to the tutorial notes and guidelines.

Results

The results of the questionnaire responses pre- and post-training were calculated and demonstrated an improvement in the questionnaire scores post additional training. Data normality was checked by Shapiro-Wilks test and was shown to be parametric. The mean questionnaire score of the post-training group increased by 13.7%, and was shown to be statistically significant with a p value of. 0.002.

Conclusion

The additional DXA training provided positively affected the student radiographers' understanding on how to analyse DXA images.

Introduction

Osteoporosis is a bone disease that occurs when the body loses too much bone, makes too little bone, or a combination of both processes occurring simultaneously. As a result, bones become weak, and are susceptible to fracturing as a result of minor injuries [1]. Due to bone loss caused by osteoporosis and osteopenia, peri- and postmenopausal women above the age of 50 are more likely to fracture bones than premenopausal women [2]. Dual-energy X-ray absorptiometry (DXA) is the 'gold standard' for measuring bone mineral density (BMD), diagnosing osteoporosis, and monitoring changes in BMD over time [1]. The BMD calculated from the DXA scan is converted to a T- and a Z-score (based on World Health Organisation guidelines) and it is from these scores that a diagnosis can be made, and treatment started, if necessary. Therefore, it is essential that these BMD scores are accurate, reliable and reproducible.

Various studies have reported that, for DXA images to be analyzed correctly, the operator should be competent [3,4]. DXA operators are not required to have a formal background education in any healthcare profession, such as nursing or physiotherapy. In some countries (e.g. Ireland), operators are only required to complete a radiation protection course in order to operate a DXA scanner – no formal training in any patient positioning or scanning and analysis techniques is required [5]. Operators are then legally allowed to scan patients using DXA [6].

Due to operator variability and various technical errors, the analysis of DXA exams can be inaccurate [4]. Some of the inaccuracies may be due to precision errors of the machine, but also due to incorrect positioning of the patient, inaccuracy of image analysis during the post-processing stage and variability in the skills of the operators [3]. The aim of this study was to investigate whether training specifically in the area of DXA spine image analysis would improve the operator's ability to analyze the images.

Methods and Materials

A test-retest quantitative method was carried out in this study. The sample population consisted of 24 student radiographers attending the OPTIMAX research summer school in UCD. The students were from seven different countries: Ireland, The Netherlands, Switzerland, Norway, South Africa, Canada and Brazil. They were at various stages of their studies, some in 3 and some in 4-year programmes, with various amounts of time spent on clinical placement. Participants had varying levels of knowledge of DXA scanning ranging from no knowledge of DXA at all to having a basic understanding of what DXA was. It was decided not to include OPTIMAX tutors in the study, due to the

possibility of their having experience working in DXA introducing a bias.

Due to the limited numbers of participants available, it was decided not to have a control group and to use all available participants for the study to increase the validity of the results. Participants signed a consent form, their participation was voluntary, and they were free to withdraw from the study at any time. All the images used in the study were anonymised to avoid any possible identification. Ethical exemption was granted by the UCD Research Ethical Committee for the study .

The DXA training and the time intervals of when the data was collected is presented in Table 1.

In step one of the study, all the participants simultaneously watched a 4-minute video produced by the manufacturer of the DXA scanner. This video is provided as a training aid and shows the step by step process of how to analyse a DXA spine image. It did not, however, give any theoretical background on the subject, or discuss the analysis in the context of providing best practice guidelines on the analysis of DXA spine images. This provided the participants with a very basic level of understanding of DXA spine analysis. It was chosen to give the participants an introduction to DXA spine analysis as it mimics what is available to DXA operators in a clinical setting, where no formal training in DXA scanning is offered or available.

Immediately after watching the video, each participant had 25 minutes to complete a questionnaire (step 2, 'Questionnaire 1') with 20 questions. This was in order to establish their baseline understanding of how to analyse a DXA spine images following the training video provided by the manufacturer.

Directly after the questionnaires were completed and returned, the participants were given a training session by an experienced DXA radiographer (step 3). DXA analysis software was used in the training session to demonstrate not only the basics of how to analyse DXA spine images, but also to show examples of the nuances of DXA spine analysis, and the limitations of the software. During this training session, participants also received a handout which outlined the DXA best practice guidelines as produced by the International Society for Clinical Densitometry (ISCD)[7] as well as a copy of the lecture notes. The level of training provided aligned to that currently given within Irish clinical centres as part of "in house" DXA training (verified by personal contact with university teaching centres affiliated with Radiography degree participation).

In step 4 and the final part of the study, the participants completed the initial questionnaire a

second time, renamed Questionnaire 2. Participants were permitted to refer to the protocols and notes provided on DXA while answering the questions in this stage of the study.

Questionnaire Design and Image Selection

An online questionnaire website called Socrative [8] was used to create and administer the questionnaire which consisted of 20 multiple choice questions (MCQs) each with a choice of answers, with only one correct choice. In addition, demographic information such as gender, country of participant study, years of training in radiography, and how much time they had spent in clinical placement were asked.

The remainder of the questions related to images which represented different scenarios which commonly presented during the analysis stages of DXA. Images from the internet [9] were used as well as images from the GE Lunar Prodigy iDXA with software version 8.8 [10]. The images were selected to represent typical DXA spine images which operators routinely analyse, including images which tested the operators' decisions as to whether or not to include a vertebra in the DXA analysis. If the vertebrae are not suitable to be included in the analysis, then leaving the vertebrae in would lead to an erroneous result. It is in these situations that the correct training and expertise that the operator has, directly affects the overall results of a DXA scan.

Questions answered by the participants focused on four main aspects of DXA spine analysis, namely in relation to:

- The repositioning of inter-vertebral lines;
- The inclusion or exclusion of vertebra/e in the overall analysis;
- The acceptance of the Region of Interest;
- The requirement to potentially repeat the DXA scan.

Table 1. Outline of training and date collection

Step	Action
Step 1	Participants watch the manufacturers training video
Step 2	The DXA questionnaire administered (Questionnaire 1)
Step 3	Participant underwent a training session (30 min session)
Step 4	The DXA questionnaire re-administered

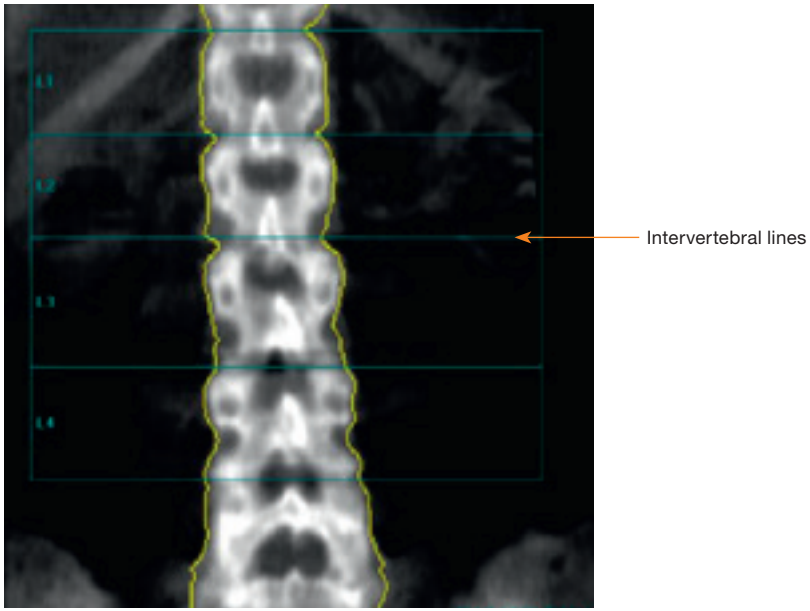

Figure 1. Example of a DXA image (GE Lunar Prodigy iDXA with software version 8.8 [9])

Figure 1 shows a DXA spine image and the arrow points to the intervertebral lines, which may be moved, or angled, as needed.

All questions asked in the questionnaire were based on the difficult aspects and most common mistakes made in DXA analysis [11]. During the image analysis sessions, the images were displayed on the participants laptops via BlackBoard, (the online learning environment used in UCD) and they were also projected onto a large screen within the participant viewing room. Ambient lighting was kept low to mimic clinical reporting rooms and this remained constant throughout the study during image review periods.

A pilot study was performed which involved three participants to test the study instructions. Some wording was adapted to accommodate the different levels of English of the participants to minimise the risk of misunderstanding, however the core questions remained unchanged.

Statistical Analysis

Statistical analysis was performed using SPSS Software Version 24.00[12]. A normality test was

performed. The significance value (p=0.573), on the Shapiro-Wilk scale, showed that the data was normally distributed and therefore a paired two-tailed t-test could be performed with accuracy. An ANOVA test which is an analysis of variance, assessed the potential differences between the scale-level variables and the nominal-level variables, such as gender and country. The reference cut-off value of significance used was ($p \leq 0.05$). The paired two-tailed t-test was chosen to determine if there was a statistically significant difference between the two questionnaires before and after the additional DXA training once it was established that the data was normally distributed.

Results

The sample population consisted of 24 radiography students attending a three-week research summer school in UCD. The sample comprised of 37.5% male and 62.5% female students. They had various years of studying completed and studied in five different countries, as presented in Table2.

The results showed an increase of 13.9% in the mean score of correct responses between the post training group (61.9%) vs. the pre-training group (48%), with a p-value of 0.002. As this p-value is <0.05, this improvement has been shown to be statistically significant. A paired T-test was then carried out on the

Table 2. Participant demographics

	Years of Study Completed						
	1		2		3		4
No. of Students (n=24)	5 (20%)		14 (58%)		3 (12%)		2 (8.3%)
	Country of Study						
	Ireland	Nether-lands	Norway	Switzer-land	Canada	Brazil	South Africa
	5 (20%)	5 (20%)	5 (20%	5 (20%)	1 (4%)	1 (4%)	2 (8.3%)

Table 4. The mean difference in correct responses post additional DXA training.

	Mean	Std. Dev.	Std. Error Mean	Sig. (2-tailed)
Intervertebral Lines	0.333	2.082	1.202	0.808
Exclude Vertebrae	3.800	2.864	1.281	0.041
Regions of Interest	8.667	4.726	2.728	0.086
Repeat Scan	0.500	1.915	0.957	0.638

participant responses when categorised into the four groups of typical types of analysis carried out on DXA spine images, outlined in the methods. The results are presented in Table 4.

The correct responses pre- and post-training session were identified and an increase of 15.84% in the number of correct responses in the category of ‘’excluding vertebrae’’ was found to be statistically significant with a p-value of p=0.041. However, in relation to the other three categories labelled; ‘Intervertebral lines’, ‘regions of interest’, and ‘repeat scan’ none were deemed, statistically significant, with p-values of 0.808, .086 and 0.638 respectively.

An ANOVA test was applied to elements of the demographic data and is the statistical technique that was employed to assesses potential differences in scale-level dependent (e.g. exam scores) variables by a nominal-level variable (e.g. years of study) having 2 or more categories. Gender, clinical experience, year of study or country of study were investigated, however they were found not to statistically significantly influence the increase in correct answers findings were as follows: participants clinical experience (p=0.110), gender (p=0.635), years of radiography study (p=0.927) and their country of origin (p=0.194). These categories, therefore cannot be assumed to have influenced the participants’ ability to answer the questions correctly for either questionnaire one or questionnaire two.

Discussion

The aim of the study was to determine whether training in DXA spine analysis would impact the operator’s ability to analyse DXA spine scan more accurately. The accuracy of the participants in analysing DXA scans pre- and post-training with an experienced DXA radiographer was tested. The correct questionnaire responses pre- and post-training were analysed and compared, and it was found that the total of correct answers in the post-training questionnaire had increased by 13.7%. This positive change in knowledge, with respondents answering more questions correctly post training, was shown to be statistically significant with a p-value 0.002, suggesting that the training had a positive impact on the participants ability to make better decisions on how to correctly analyse DXA spine images. It also suggests that the ‘training’ video supplied by the DXA manufacturer independantly, may not give operators comprehensive training in the analysis of DXA spine images. The study has demonstrated that the participants responded well to the training provided and they were able to apply their new knowlege and understanding to the analysis questions post training.

The training provided by the expert DXA radiographer (16 years DXA training) was based on the key-points of DXA lumbar spine analysis as well as the most common mistakes made by DXA operators [1]. Emphasis was placed on excluding unsuitable vertebrae, the placement of vertebral body lines and border and the importance of understanding when this was necessary. This aspect of the analysis was not discussed in detail in the training video provided by the DXA manufacturer. The study incorporated four key aspects of DXA scan analysis labelled 'intervertebral lines', 'excluding vertebrae', 'region of interest' and 'repeat the exam or not'. The category of 'excluding vertebrae' resulted in substantial differences in correct responses post-training compared to the pre-training responses ($p=0.041$). Whilst the remaining three categories were not statistically significant. It is difficult to predict why one area of analysis in particular appeared to illicit more correct responses than the others. It could possibly be due to a language barrier which may have caused a lack of comprehension in some aspects of the training. The participants were from various countries and English was not the first language of many. Questions and answers were written in basic English to accommodate most levels of understanding and was tested by means of a pilot test and deemed appropriate.

The information in the questionnaire and the handout, however, may still have been interpreted incorrectly putting the non-native English speakers at a disadvantage, thus affecting the overall findings. The level and understanding of English of the participants was not measured prior to the study because of the limited time-frame in which the study had to be completed. Some questions were found to have a decrease in the amount of correct responses after the training, but it was not possible to determine if this was due to comprehension / level of English or reading ability, as no baseline had been established. It would have been interesting to see if a language barrier impeded the comprehension of the training, and thus the ability to understand the subtleties in DXA image analyses, thereby affecting the overall significance of the results.

The participants from the Netherlands showed a relatively large difference in the correct responses pre- and post-training in compared to participants from other countries. Whilst overall study findings did not identify the participants country of origin to be not significantly significant, the observation of improvement in this particular group may be due to a better level of English in these students or possibly the training method carried out in this study being a similar learning style that these participants are used to.

The participants in this study came from different educational backgrounds and therefore may have different learning styles and study preferences, which may have affected the results. This was not taken into consideration in this study. Passive learning, where the student does not interact with the content, but is merely present and lectured to, as was the method of 'training' in this study, is only one way in which students learn. Those learning in this way have been shown to only retain 10%-50% of the content [13]. However, active learning, which involves listening to a lecture and then interacting with the content for a short time directly after in smaller groups, has been shown to increase retention up to 90% [14]. This could be a possible limitation and reason to conduct further research to acknowledge different learning styles and recollection of information given which could include not only using a more active learning style during the training phase, but also to include a method in the data collection which captures the learning style the students participating in the study are used to. This may potentially assist in understanding why participants may or may not take in the information during the training and learning phase. The impact of training in this study is focused upon student radiographers who are novices in DXA, the inclusion of qualified radiographers may render different findings and requires investigation.

Factors such as number of years of radiography study or time spent on clinical placement were examined. It could have been assumed that these factors would have contributed to participant knowledge, as they are directly related to knowledge of anatomy and radiographic practice, though not specifically DXA experience. However, this was not shown to be the case when tested statistically ($p>0.05$), so therefore did not affect the outcome of the results. Other incidental factors, such as gender and country of origin were then considered and again were not shown to be significant ($p>0.05$),

Based on the study findings, training improved the ability of participants in making correct decisions regarding the analysis of DXA lumbar spine images. There is some evidence to suggest that placing emphasis on certain aspects of training significantly improves operator competency in those areas, as evidenced by the increase in the correct answers in the area of 'excluding vertebra'. Further research is recommended, using a larger cohort and including a control group without any training, with participants with the same level of English, which may reduce the adverse effect a language barrier may have on the responses. A more detailed questionnaire / method of collecting data may allow a better understanding of other factors that may have significant impact on an operator's ability to accurately analyse DXA lumbar

spine scans, thereby producing a more reliable result for patients.

Conclusion

The purpose of this study was to investigate if focused training for novices undertaking analysis of DXA lumbar spine images improved DXA operators' accuracy. The results identified that when training was provided by a radiographer experienced in DXA this positively impacted the participants' ability to make appropriate decisions, and correctly analyse DXA spine images.

The results also showed that clinical experience (as students) and number of years of completed study did not impact the study findings. The results demonstrated that the improvement post additional training was independent of country, gender, and years studied. This further demonstrates that correct training reduces the risk of errors in DXA analysis for a range of participant demographics, as no other factors were shown to be statistically significant.

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