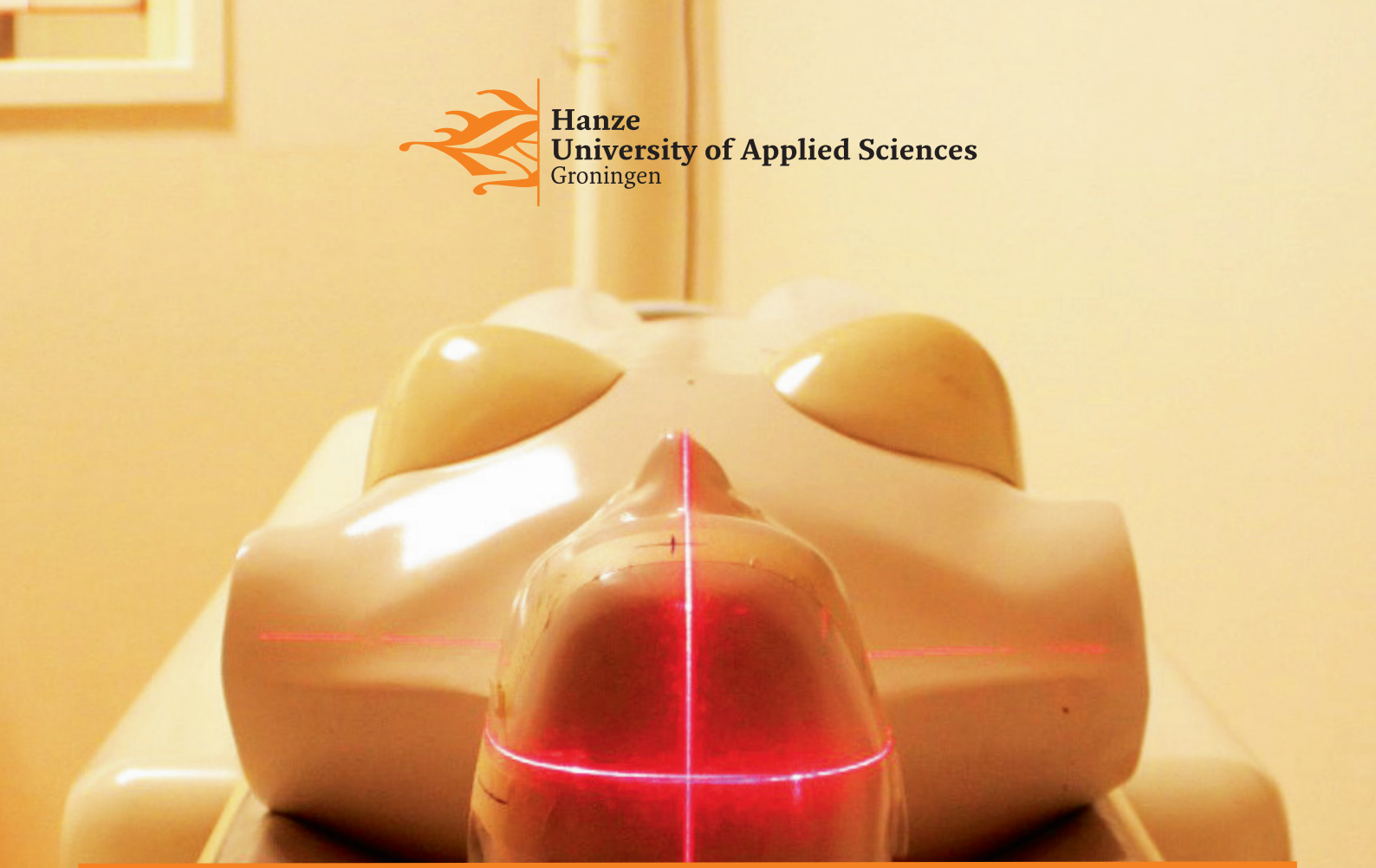


Hanze
University of Applied Sciences
Groningen

OPTIMAX 2015

Multicultural team-based research in radiography, a holistic educational approach.

Groningen, the Netherlands

Edited by: Peter Hogg, Christine Blakeley and Carst Buissink

Hanze
University of Applied Sciences
Groningen

OPTIMAX 2015

Multicultural team-based research in radiography, a holistic educational approach.

Groningen, the Netherlands

Edited by:

Peter Hogg, *Professor of Radiography, University of Salford, Machester UK*

Christine Blakeley, *lecturer, University of Salford and Central Manchester Foundation Trust*

Carst Buissink, *Coordinator OPTIMAX 2015 and Internationalisation MIRT, Hanze University of Applied Sciences, Groningen, NL*

Publishing information

Open source publisher

Attribution-NonCommercial-ShareAlike
CC BY-NC-SA
ISBN 978-1-907842-77-1

Acknowledgements

Martini Hospital, Groningen
For facilitating equipment and contribution to our students insight in radiology

Research and Innovation Group Healthy Ageing, Allied Health Care and Nursing.
For providing research equipment

University Medical Centre, Groningen
For contributing to our students insight in radiology

Hanze University of Applied Sciences, Groningen
For hosting OPTIMAX 2015

Acknowledgements

We would like to thank the following people:

Esther van Nieuwenhoven
Organization OPTIMAX 2015
Hanze University of Applied Sciences, Groningen

Leslie Robinson
Senior lecturer, School of Health Sciences
University of Salford, Manchester United Kingdom
for delivering essential lecturers on team theory and project management

Design by Canon
Staff Office Marketing and Communication,
Hanze UAS, Groningen
Josien Buikema, MA

Table of contents

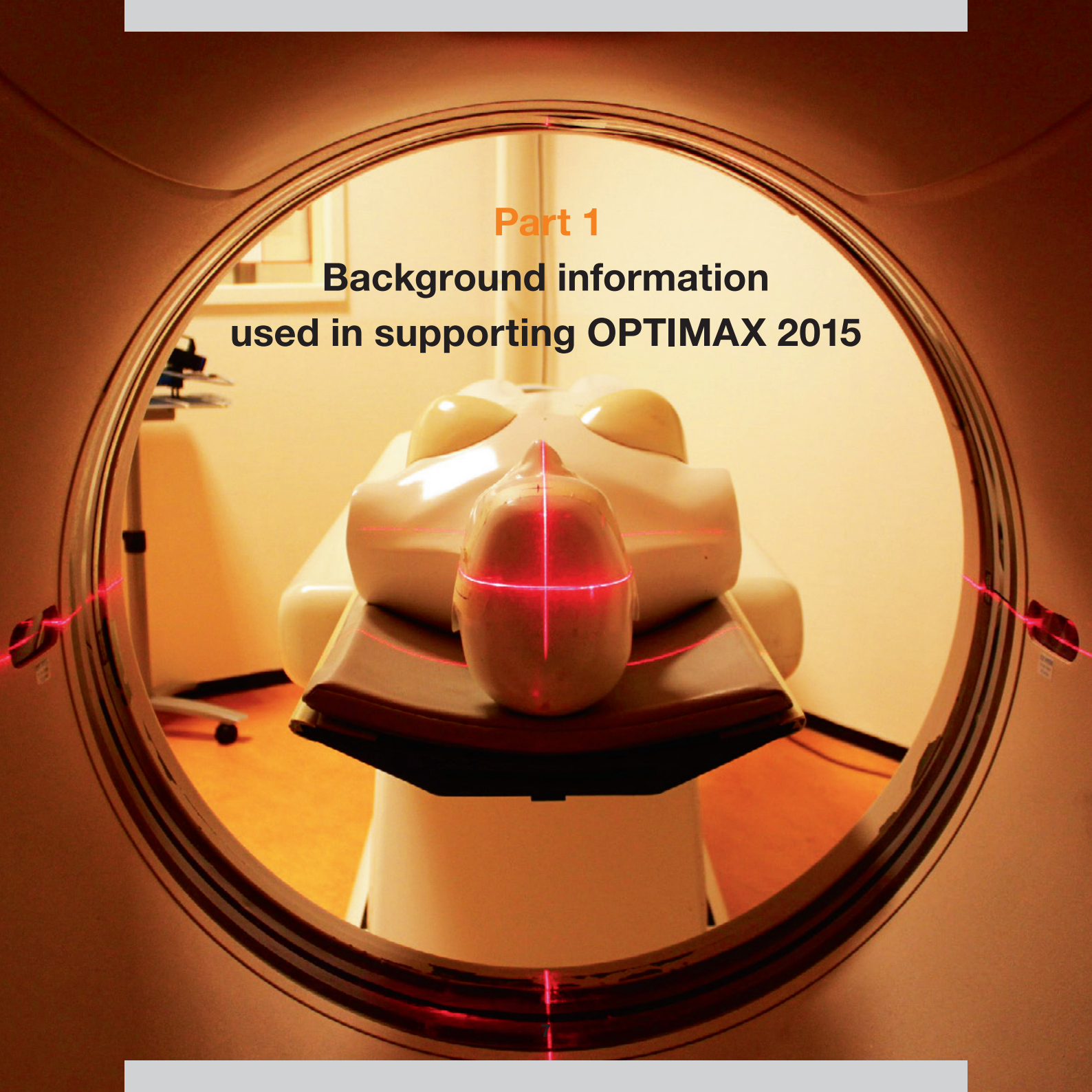
Foreword

Following the successful OPTIMAX summer school held in Salford, 2013 and Lisbon, 2014 we organized OPTIMAX2015 summer school in Groningen. Fifty three people participated, comprising PhD, MSc and BSc students as well as tutors from the five European partners. Professional mix was drawn from engineering, medical physics/ physics and radiography. This summer school was hosted by the Hanze University of Applied Sciences Groningen in the Netherlands. It was funded by the partners. Two students from South Africa were invited by the Hanze University and one additional student from the United Kingdom who was funded by Nuffield. The summer school comprised of lectures and group work in which experimental research projects were conducted in five teams. Team project focus varied, two concentrating on CT reconstruction techniques and image quality, one on image quality high and low noise levels on DR systems, one on reliability and validity of detecting low dose radiation when using radiation detection applications and devices for smartphones. And one about ultrasound validity and reliability measuring rectus femoris muscle size. The summer school culminated in a poster market and conference, in which each team presented a poster and oral presentation on the conference.

This book contains two parts, the first six chapters of this book shows the structure of organizing a summer school like OPTIMAX. The second part contains the oral papers in written format, in journal article style, and after editing they have been included within this book. At the time editing this book, several of the experimental papers has been commenced development work in order to make them fit for submission to conferences.

OPTIMAX 2015 Steering Committee

- Buissink C, Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, The Netherlands
- Hogg P, School of Health Sciences, University of Salford, Manchester, United Kingdom
- Lança L, Lisbon School of Health Technologie, Polytechnic Institute of Lisbon, Portugal
- Sanderud A, Department of Life Sciences and Health, Oslo and Akershus University College of Applied Sciences, Oslo, Norway
- Jorge J, Haute École de Santé Vaud – Filiè TRM, University of Applied Sciences and Arts of Western Switzerland, Lausanne, Switzerland



Part 1

Background information used in supporting OPTIMAX 2015

OPTIMAX: An overview

José Jorge[1]

1. Haute École de Santé Vaud – Filiè TRM, University of Applied Sciences and Arts of Western Switzerland, Lausanne, Switzerland

Radiography students and practitioners' skills in optimising x-radiation dose and image quality are a crucial scientific and professional aim for patients and the profession of radiography. Radiographers are on the front line where point-of-care-decisions are made about image quality and radiation dose in the attainment of images that are fit for purpose. With this in mind, the OPTIMAX summer school represents an innovative holistic educational experience to develop and use strategies to optimise dose and image quality within multicultural research teams.

OPTIMAX is the name of our three week residential research summer school. It was initially organized in 2013 in Manchester, United Kingdom and hosted by the University of Salford. Since then it has been successfully hosted in 2014 by the Escola Superior de Tecnologia da Saùde de Lisboa in Lisbon, Portugal and Hanzehogeschool in 2015, Groningen in the Netherlands. OPTIMAX was supported financially in Salford and Lisbon by a grant dedicated to Intensive Programs awarded by the British Council, United Kingdom, within the European Union mobility and long life learning program Erasmus.

OPTIMAX is open to BSc, MSc and PhD students and we try not to have more than 50 students in total. Typically at least seven tutors are full time within the summer school, and approximately 10-15 additional tutors are involved too. Between 55 and 70 students and tutors participate in OPTIMAX per annum. Despite OPTIMAX being aimed at optimising x-radiation dose and image quality, it has always been conceptualised in an interdisciplinary and multi professional environment. In this way, over the years, OPTIMAX has drawn tutors and students from several disciplines, including radiography, physics, engineering, ultrasound, nuclear medicine, psychology and occupational therapy.

Preparation for each summer school commences approximately 12 months before the residential component. On a monthly basis a steering committee, from each partner institution, meets by Skype to

prepare for the residential component. Preparation includes each partner university recruiting and preparing their own students and also recruiting and preparing their own tutors. Tutors and students need to know a lot of detail about the summer school in order to make a decision on whether they wish to attend, and having made that decision to prepare for the summer school itself. When student and tutor names are known from all partner universities they are assigned into multicultural teams (typically six). Each team has a permanently available tutor for the three week residential period and one permanently available tutor for the whole period oversees and organizes the event and acts as Principal Investigator for all pieces of research.

Socio-cultural events also need organizing and they tend to be organized by the host university. This consists of organising Welcome and Farewell Parties for all attendees, to schedule visits of cultural and/or professional interest according to local availability. Organisation of socio-cultural activities are highly time consuming on the host organization; also a lot of thought needs to be given to cost minimisation. As part of the cultural events, each country delivers a PowerPoint presentation about their own country, their university and also each tutor/student gives one slide about themselves (eg hobbies). Each talk is left to the Steering Committee member who brings along the students to organise. The socio-cultural programme is valuable to find out about other cultures; it also plays a crucial role in team building of each research groups and moreover in development of the OPTIMAX spirit.

Conceptualisation and implementation of research, teaching and learning activities needs organising well in advance of the residential component. Essentially this resembles the planning of any taught programme. Again this is a highly time consuming activity, particularly for the host organisation. Planning activities include:

- Booking laboratory and lecture rooms
- Booking tutorial rooms – each research team needs one of these, with internet access and a data projector/beamer
- Ensuring that catering is available, as often when the summer school is organised (August) university catering facilities might be closed
- Ensuring all laboratory equipment is fully quality controlled, compliant with current legislation and working within manufacturer specification
- Creating a suitable timetable, to include all activities
- Creating research questions and outline methods for the teams
- Updating the tutor and student handbooks, and an OPTIMAX visitor guide to the host city
- Creating computer accounts for students and tutors, and creating a virtual learning environment (eg Blackboard)
- Other tasks, as required

The work placed onto the host organisation is substantial and an organisation should not enter into hosting OPTIMAX without having though through the resource (time/equipment/human) implications. It is also worth noting that the host steering committee member must have the full support of their organisation and also they must have a team of supportive people from their organisation prior to and during the summer school. This team could comprise technicians, administrators and academics; typically 5-10 host tutors would provide specific help at various stages.

The residential component starts with a Welcome event, typically held on a Sunday evening. This is the first occasion that student and tutor group members meet each other. The lead tutor for each group should take on the responsibility of helping students get to know one another in this social event.

The residential programme commences with a welcome lecture, which includes an overview of the whole three weeks. Normally this is delivered by a staff member from the host organisation. This is followed by lectures and group exercises on team working and project management. This allows for each group member to get to know one other, to define the role each one plays within the team work as well as starting to plan the research tasks and activities they will eventually perform. Also, lectures on research methods and statistics are provided to all participants. Moreover and according to the research questions topics previously selected, some research content specific lectures are given to all students and tutors - for example, physics and visual measures of image quality. Also, training is given to students by host institutions' librarians on literature searching tools. Finally, tutor training on local radiation rules, equipment and software are provided.

In the second week, team work time increases and it is mainly dedicated to reviewing scientific literature by means of journal and data collection realised according to the method established in each group. In order to prepare for the last summer school week, lectures on scientific writing, scientific paper production and scientific poster/conference presentation is given. In week 2 all groups give an update presentation on progress of their research as an oral presentation. It is also important to highlight the role of the Principal Investigator too, as they review each groups progress on a very regular (eg 2-3 times a day) basis. Finally, statistical support is offered throughout weeks 2 and 3 on a one to one basis by an expert.

The third week is dedicated to completing data acquisition, performing data analysis, writing a draft scientific paper, creating a scientific poster and creating PowerPoint slides for the final conference

presentation. During the final Thursday assessment of the draft scientific papers performed is done by the tutors regarding the draft paper. An overall mark is assigned to each draft paper. Students also score one another for their contribution to team working. The peer assessment is used to moderate the scientific paper mark for each student, based upon the contribute they make.

A poster presentation session takes place on the final morning. In the final afternoon, the OPTIMAX conference takes place; here the PowerPoint presentations are presented by the students. A maximum of 30 minutes per paper is allocated, to include questions. All the conference papers are scored by one tutor, and straight after each paper this tutor presents to the other tutors what mark should be awarded and why. Seven ECTS is awarded to the participating students to OPTIMAX from the universities that use this system within their own radiography curriculums the European Credit Transfer System.

Finally a Highlights Lecture is given by the Principal Investigator and the Certificate of Attendance are awarded to all the participants. Those eligible for ECTS are awarded formal notification about this at this stage.

On completion of the residential component the Principal Investigator works with the first author tutor for each group to redraft/edit the articles and abstracts to stage where they would be ready for external review. Again this aspect of the work is substantial. All co-authors (eg students) receive copies of the final conference abstract submissions and final scientific papers and are encouraged to make comments. Once done the abstracts can be submitted to conferences and the scientific papers are sent out for external blinded peer review. The Principal Investigator and first author tutor for each group revise the work accordingly.

In 2014 we produced a special issue of the scientific journal Radiography [1] disseminating the research work done during OPTIMAX 2013 in Manchester. In this issue the steering committee wrote a Guest Editorial explaining the OPTIMAX concept. The first three articles [3, 4, and 5] are written by Salford University investigators involved in the residential component; these articles are based on lectures given within the first residential week. The next five articles [6, 7, 8, 9 and 10] communicate the experimental studies and main results conducted by each of the six research groups. The two last articles [11 and 12] ending this special issue assessed the educational and multicultural dimensions of this first edition of OPTIMAX.

Arising from OPTIMAX 2015 in Lisbon, we published a book as open source with ISBN, making it free to readers [2] in order to disseminate the research work. On this occasion, each research group produced two papers. The first paper focused on the literature review related to the research study [13, 15, 17, 19, 21 and 23]. The second paper concerned the research [14, 16, 18, 20, 22 and 24]. Five out of six of these papers are directly related to the optimisation of image quality and dose in X-ray medical imaging. The sixth paper compares the interface pressure between body and bed, for participants lying on two different imaging surfaces being so the first OPTIMAX research involving humans. [22].

For the three editions of OPTIMAX, abstracts were submitted to the Annual European Congress of Radiology in Vienna as well to national conferences such as the United Kingdom Radiology Conference or the Portuguese Radiographers Association Congress. Almost 40 papers/posters, arising from OPTIMAX, have been presented at these conferences over the last 3 years.

Last but not the least, a final component of the OPTIMAX summer school is marketing of the open source book we produce. This can be achieved in many ways, including encouraging journals to review the book and publish those reviews such that people are made aware of the book.

References

Manning, D., & Hogg, P. (Eds). (2015). Radiation Dose and Image Quality [special issue]. *Radiography*, *20*, 291-370. http://www.sciencedirect.com/science/journal/10788174

Hogg, P., & Lança, L. (Eds). *OPTIMAX 2014: Radiation dose and image quality optimisation in medical imaging*. Open Source, University of Salford: http://usir.salford.ac.uk/34439/1/Final%20complete%20version.pdf

Thompson JD, Manning DJ, Hogg P. Analysing data from observer studies in medical imaging research: an introductory guide to free-response techniques. Radiography 2014;20 (4):295-9.

Mraity H, England A, Hogg P. Developing and validating a psychometric scale for image quality assessment. Radiography 2014; 20(4):306-11.

Tootell A, Szczepura K, Hogg P. An overview of measuring and modelling dose and risk from ionising radiation for medical exposure. Radiography 2014; 20(4): 323-32.

Buissink C, Thompson JD, Voet M, Sanderud A, Kamping LV, Savary L, et al. The influence of experience and training in a group of novice observers: a jackknife alternative free-response receiver operating characteristic analysis. Radiography 2014; 20(4):300-5.

Mraity H, England A, Akhtar I, Aslam A, De Lange R, Momoniat H, et al. Development and validation of a psychometric scale for assessing PA chest image quality: a pilot study. Radiography 2014; 20(4):312-7.

Tugwell J, Everton C, Kingma A, Oomkens DM, Pereira GA, Pimentinha DB, et al. Increasing source to image distance for AP pelvis imaging e Impact on radiation dose and image quality. Radiography 2014; 20(4):351-5.

Lança L, Franco L, Ahmed A, Harderwijk M, Marti C, Nasir S, et al. 10 kVp rule an anthropomorphic pelvis phantom imaging study using a CR system: impact on image quality and effective dose using AEC and manual mode. Radiography2014;20 (4):333-8.

Reis C, Gonçalves J, Klompmaker C, Barbara AR, Bloor C, Hegarty R, et al. Image quality and dose analysis for a PA chest X-ray: comparison between AEC mode acquisition and manual mode using the 10 kVp 'rule'. Radiography 2014;20(4):339-45.

Higgins R, Robinson L, Hogg P. An evaluation of the student and tutor experience of a residential summer school event (OPTIMAX). Radiography 2014;20 (4):363-8.

Robinson L, Hogg P, Higgins R. An observational study of cross-cultural communication in short-term, diverse professional learning groups. Radiography 2014; 20(4):356-62.

Borge S., Campbell N., Gomes A., Raszkowski A., Rook J., Sanderud A., Vallinga A., Vouillamoz A., Buissink C., An evaluation of SAFIRE's potential to reduce the dose received by paediatric patients undergoing CT: a narrative review. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 9-13.

Borge S., Campbell N., Gomes A., Raszkowski A., Rook J., Sanderud A., Vallinga A., Vouillamoz A., Buissink C., Maintaining image quality for paediatric chest CTs while lowering dose: FBP versus SAFIRE. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 15-20.

Ahmed A., Garcia A., Bakker A., Tomkinson D., Salamin J., de Lange R., Buyvidovich S., Sohrabi T., Dominguez A., Campeanu C., Plasman P., The impact of Sinogram-Affirmed Iterative Reconstruction on patient dose and image quality compared to filtered back projection: a narrative review. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 21-26.

Ahmed A., Garcia A., Bakker A., Tomkinson D., Salamin J., de Lange R., Buyvidovich S., Sohrabi T., Dominguez A., Campeanu C., Plasman P., A comparison of Sinogram Affirmed Iterative Reconstruction and filtered back projection on image quality and dose reduction in paediatric head CT: a phantom study. In In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 27-36.

Reis C., Ndlovu J., Serrenho C., Akhtar I., de Haan S., Garcia J., de Linde D., Thorskog M., Franco L., Hogg P., Review article: Optimisation of exposure parameters for spinal curvature measurements in paediatric radiography. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 37-42.

Reis C., Ndlovu J., Serrenho C., Akhtar I., de Haan S., Garcia J., de Linde D., Thorskog M., Franco L., Lança C., Hogg P., Optimisation of paediatrics computed radiography for full spine curvature measurements using a phantom: a pilot study. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 43-51.

Jessop S., Hart G., Santiago A., Samara A., Markali B., Cottier Y., Guerreiro J., Normann E., Momoniat H., Jorge J., England A., X Radiation dose implications in screening patients with ferromagnetic IOFBs prior to MRI: a literary review. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 53-58.

Hart G., Jessop S., Santiago A., Samara A., Markali B., Cottier Y., Guerreiro J., Normann E., Momoniat H., Jorge J., England A., A balance between image quality and effective dose in orbital X-ray screening for ferromagnetic IOFBs: a pilot study. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 59-67.

Everton C., Bird S., Brito W., Collé P., Franco A., Lutjeber S., Nodeland K., Rième S., Siddika M., Webb J., Angmorterh S., The effects of clinical support surfaces on pressure as a risk factor in the development of pressure ulcers, from a radiographical perspective: a narrative literature review. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 69-74.

Everton C., Bird S., Brito W., Collé P., Franco A., Lutjeber S., Nodeland K., Rième S., Siddika M., Webb J., Angmorterh S., An experimental study to compare the interface pressure and experience of healthy participants when lying still for 20 minutes in a supine position on two different imaging surfaces. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 75-79.

Bloomfield C., Boavida F., Chabloz D., Crausaz E., Huizinga E., Hustveit H., Knight H., Pereira A., Harsaker V., Schaake W., Visser R., A narrative review on the reduction of effective dose to a paediatric patient by using different combinations of kVp, mAs and additional filtration whilst maintaining image quality. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 81-84.

Bloomfield C., Boavida F., Chabloz D., Crausaz E., Huizinga E., Hustveit H., Knight H., Pereira A., Harsaker V., Schaake W., Visser R., Reducing effective dose to a paediatric phantom by using different combinations of kVp, mAs and additional filtration whilst maintaining image quality. In Hogg, P and Lança, L 2015, *Radiation dose and image quality optimisation in medical imaging*, Open Source, University of Salford: 85-91.

Team and project management skills

Kitty Schillemans[1] and Leslie Robinson[2]

1. Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, The Netherlands
2. School of Health Sciences, University of Salford, Salford, UK

This chapter gives a description of the team and project management skills that were used during the OPTIMAX summer school of 2015. At the end of the 3 weeks the usefulness of these tools was evaluated by a questionnaire for all students and by a focus group discussion. The main results of this evaluation will be discussed. Finally, suggestions will be made for the 2016 OPTIMAX summer school.

Activities preparing to work in teams

At the beginning of the course all students started with teamwork sessions facilitated by one senior lecturer from a University in the UK. These sessions included diverse team-building activities, most of which were informed by the Myers-Briggs Type Indicator model (MBTI) (1). This model is based on Carl Jung's theory of personality types, which proposes that people have an innate preference for just one of the two dichotomous dimensions associated with each of four personality types. In combination, these four types provide 16 different personality types. By understanding one's own personality preferences and appreciating differences in the personality types of others, it is proposed individuals can become more accommodating to the different characters and perspectives in a team.

On day 1 of the summer school, the facilitator started with an introduction to the four MBTI personality dimensions of types: (1) Extraversion and Introversion (E-I), (2) Sensing and Intuition (S-N), (3) Thinking and Feeling (T-F), (4) Judging and Perceiving (J-P). Presentation of the theories and the associated exercises were taken from the slide share open source website and can be found here *http://www.slideshare.net/malpascoe/mbti-team-dynamics*

After the introduction, the students carried out exercises related to the four dimensions of the types. Within each group one student led the discussion and one observed the others. For determining the I-E split (i.e. the differences between types) within

each group, the students discussed the subject "How individual members preferred to relax at the end of a stressful week". Characteristics in behaviour of the E and I types were discussed afterwards. For the S-N type split, the students had to look at a picture and had to describe what they saw. Afterwards the interpretations and differences were discussed with the emphasis on the importance of looking from another's perspective. To split the T-F type, the students had to discuss what to say to their partner/friend dressed in clothing inappropriate to an occasion. The T's are direct and focussing on the outcome, while the F's have an indirect, tactful approach. For the splitting of the J-P type the students had to choose a spot between two extremes on a line: "I can play any time" and "I have to get my work done before I can play", showing that individuals had different priorities with regard to play and work.

In this first part the students found out their own personality type and in the second part they looked at the personality types in their own teams and considered what this might mean for how their team would develop and would work together. They had to make a type table of the different personality types in their team and had to note the team role for the different personality types. This exercise used the Management Team Roles indicator (MTR-i), proposed as an extension to the MBTI model to align personality to team roles labelled: coach, crusader, explorer, innovator, sculptor, curator, conductor or scientist. Descriptions can be found at *http://www.teamtechnology.co.uk/workingoutyourteamrole2.htm* (2)

Finally, students were asked to find out more about people within their own groups by drawing a flower; points of common interest between the group members were placed within the flower's centre whilst each individual had their own 'petal' in which an interest unique to them was written.

On the second day, the groups developed some strategies to cope with potential risks to their own group and project management skills. The session was about managing the project and their team from a global perspective, not the specifics of their research design. The students were asked to demonstrate their project management skills through the undertaking of a small but fun task; dropping an egg from a height without it cracking. The 5 stages of project management (initiate, plan, execute, monitor & control and close) where then given with reference to the egg task they had just completed. This is a standard model for project design from the Project Management Body of Knowledge (PMI 2008 4th edition) (3).

The *initiate* phase concerned defining scope: aims and objectives; specifying outputs, identifying team roles and responsibilities creating ground rules, and agreeing a work ethic.

To evaluate the group's potential the students undertook a SWOT analysis with strengths, weaknesses, opportunity's and threats. The importance of communication was emphasised as one of the most important factors to influence team effectiveness. Spencer-Oatey (2008) (4) suggests that communication can be influenced by cultural differences in *perceived* power/hierarchy and by *social distance* (in other words how friendly a person is) between the group members. These can be particularly difficult to negotiate in a cross-cultural team where language and differences in cultural understanding of power and position can cause misunderstandings to occur. These differences influence also whether one is true to their personality type. Spencer-Oatey suggests that these problems can be overcome by two processes: socialisation, because getting to know one another makes it "ok" to disagree and the setting of ground rules/contract, which establishes an expectation to disagree for learning. This theory has the assumption that "the team that plays together, stays together". This implies that challenging interactions are easier when your friendships are secure and it is much easier to ask a favour of a friend than a stranger.

The groups had to construct their own team's ground rules, which were informed by their SWOT analysis in which they should consider rights (what can everyone expect from others), obligations (what must everyone agree to do?) and processes (how will they conduct their business e.g. decision-making, expressing opinions). When the grounds rules were described the group had to choose a name for their team.

The *plan* stage was supported by asking the teams to complete a Project Gantt Chart. Resources, especially time, were limited so students had to identify exactly what would happen on each day of the three week project. A Gantt chart template was provided for the students and included the 5 phases: initiate, plan, execute, monitor & control and close.

The *monitor and control* phases were implemented through daily reflective team meetings, the outcome of which was captured on a reflective log sheet which linked back to the Gantt chart to ensure each day's set of activities had been carried out as per the plan. Reflection did not just emphasise tasks but also included a brief discussion about how well the team was working from an interactional perspective. A tutor was identified to oversee all teams to ensure they engaged in an effective and supportive manner. She undertook reflective discussions with the teams and facilitated a focus group discussion at the end of week 3. She was also there to support the groups' tutors in managing any team difficulties.

Evaluation of the activities

Questionnaire

A short evaluation questionnaire was designed to capture the students' opinions about their preparation for team working and project management. This was administered to the student on the final day via the Bristol Online Survey tool (©University of Bristol).

The questionnaire first listed all the team-building and project management activities and asked the students to identify which had been useful. A number of open questions were then asked to elicit suggestions to support team-work. These are captured in the table:

However, it was piloted on one of the other programme tutors for comprehensibility.

The questionnaire link was emailed to all 31 student participants of the summer school. Twenty six students completed the questionnaire (84%). Of the activities that were identified as useful for preparing students for working in teams the following were selected by more than 50% of the respondents: identifying their MBTI personality role (n=18): egg exercise (n=17); identifying a team name (n=16); allocating project roles to team members (n=14 and creating group ground rules (n=13).

Exercises that scored as less useful were exercises that required more critical and/or analytical skills: getting to know each other by drawing a flower (n=10); MBTI personality splitting exercise (n=9) team SWOT analysis and giving feedback (n=8); identifying ones and others team member MBTI-role (n=6); project planning using the GANTT chart (n=4).

Suggestions for better **preparation** for team-working were made by 4 students: teambuilding activities like trust exercises (named by 2 students); a meeting before Optimax starts and more activities like the egg exercise. Most of the other students stated that no more exercises were required. One respondent

What other activity or activities might we have included to help you prepare to work in teams on your project?
What other activity might we have included to help your team work during the summer school?
Do you think your teamwork was successful? (Students were asked to explain their answer)
Do you think your project was successful? (Students were asked to explain their answer)
Do you have any other comments about the activities we used to prepare and support you for your teamwork?

Table 1 Open questions about suggestions to support team-work

said that there were too many as these were time consuming and another felt that being a radiographer meant they were already equipped with team-working skills.

On the question, "which other activities might be included to help the teamwork **during** the summer school", 12 students added suggestions, while the majority found it sufficient. Nine students proposed more teambuilding like paintballing (2 students), dinner together, and hanging out together. Students therefore felt team-building was best fostered through socialisation. One student added this comment:

"The first evening when we had to go into the city with the groups was a really good start"

On the question "Do you think your teamwork was successful?" 20 students (76.9%) answered yes and 6 students (12.1%) answered no. Students who were positive generally gave responses which emphasised either the 'task':

"Good team spirit", "equal division of labour", "everybody did their part", "we finished our work in time", "we worked well and communicated well"

Or the social element of working together:

"We had a great time", "we had fun"

Other responses recognised the importance of both social interaction and getting the task done, identifying the interaction between both these elements:

"I think we had a good balance. We did not only work together but had fun together. We always supported one another"

Negative responses were about difficulties in communication or the lack of team spirit.

"Some of us weren't communicating well with high stress level"

"The language barrier was difficult to overcome"

"In smaller groups the group worked fine, but all together fronts formed between cliques"

Despite these reported difficulties by some team members, all 26 respondents felt their project had been successful. Many of the explanations for this referred to the team's successful research outputs, however other students acknowledged that working well together was a measure of the project's success

"I liked how we worked together and i think everyone is happy with our results"

In terms of final suggestions about the preparation activities, most students did not offer further comments and felt what had been provided was fun and sufficient. Three students thought they were time-consuming and unnecessary. None of these three students reported having communication or work problems in their teams.

Focus Group

At the end of the final day after the students had filled in the questionnaire, two students of each team were invited to join the focus group to discuss the topics of the questionnaire. Of each group the chairman and one other volunteer were invited to participate. In total, four students joined this discussion. Two teams were still busy with their project, while three teams were represented; two teams by the chairman and one team by the chairman and a volunteer. The four students consisted of two male and two female students. The focus group was led by the tutor who undertook the group observations during the summer school and who was available for students and tutors to talk about problems occurring in the group process. The focus group discussion lasted one hour, while notes were made by a student who participated in the organisation of Optimax. The data were frequency analysed so that the most frequently occurring comments comprised the discussion reported below.

The following points were mentioned which could be improved in the teamwork:

Group bonding

According to the students in the focus group, group bonding was not strong enough. They agreed that the group in general will work harder when group bonding is strong. The students in the focus group were positive about the possibility of learning more about oneself and others by the group work at the start, but they would have liked more social activities together, for instance every Friday when the work for that particular week had been done.

A strength of the summer school which motivates the students is the mix of nationalities. Students mentioned that they like to meet people from different countries. This could be promoted more according

to the students. The male students thought that promoting the "fun" aspect would attract more male students to follow the summer school. The female students had the impression that girls in general tend to put more effort in the group work than boys. They also supported a more relaxing environment.

They all were positive about having an evaluation every day, but this could have been more specific. A way to do this could be to specify the behaviour needed for good teamwork, like "listen carefully to the ideas of other group members", "talk in English all the time", "give enough information to the other subgroups about what you're working at", "follow the ground rules", "efficient working" etc. This could be added in terms of rubrics on the daily evaluation form.

Stress management

The male students would prefer to have more possibilities for physical exercises during the day in between the teamwork, like playing soccer or Frisbee outside or games inside like card games. Also other relaxing activities for groups and for individuals could help to diminish stress.

In particular, in the first week students would like to have had the method section ready as soon as possible, so they could have one day of fun to connect the group and release stress. Also more teamwork was important in the first week for a better work delivery. One suggestion was to do some communication exercises to support the communication within the group.

With regard to the MBTI personality types, a female student in the focus group was negative because she felt fixed by the choices she had to make.

"The character test didn't give the members of groups the chance to take the task they really wanted or was best for them. Every situation is different and personalities are also more than just one character introvert or extravert, people can be a little bit of both depending the situation".

She would prefer to use another way of getting to know each other. She didn't think that using the MBTI types were an effective way to divide the work in the team. It is uncertain if more students had the same opinion about the exercise with the MBTI personality types.

Lloyd concludes in his article (5) that the MBTI Psychological Type approach is found to be a

valuable aid to understanding self and others and thus enhancing effective team-working, but that one should abandon the insistence that every individual is constitutionally either, for example Extravert or Introvert. Furthermore one should emphasize that there is no moral evaluative stance that for example Extraversion is a desirable quality which Introverts sadly lack. Type theory sees the polar opposites as two complementary qualities, morally neutral, each with its innate strengths and vulnerabilities, and each with much intrinsic value. (5) The negative connotation of the student could be due to value judgements of the Five-Factor (or Big Five) Model, the model of personality still dominant in mainstream academic psychology. McCrea and Costa (1989) found a high level of correlation between the MBTI personality types and the Five-Factor model. The Five-Factor model contains four positive qualities (Extraversion, Openness, Agreeableness and Conscientiousness) and one negative quality (Neuroticism). (6) Therefore it is important to explain the model clearly to the students and to emphasize both advantages and disadvantages of each type and the influence of circumstances on the behaviour. As Lloyd describes: “Type theory has always spoken of its polarities as preferences, recognizing that the demands of an individual’s circumstances, responsibilities and moral convictions often modify behaviour from what is intrinsically preferred”. (5)

The focus group mentioned that the egg- experiment was a good way of getting to know each other, but more in the sense of playing together. The aim of the egg experiment itself, namely the insight that one should first discuss about the aim of the project before starting, wasn’t important for the students. Clearly the students themselves added more importance to its value in terms of getting to know each other in a playful way.

In addition to this activity another tool could be useful in the international context of the summer school, to get to know each other’s background by using the “Social Identity Pie”. (7) In this theory identity can be divided in 12 pieces of a pie, namely nationality, social class, personal history, economic status, gender, health/disabilities, religion, ethnicity, race, political view, age and sexual interests. In the exercise each individual draws his own pie and makes the parts that are important to himself bigger than the others. Afterwards the students can discuss in pairs the following questions: “Which aspects of your identity have the biggest meaning for you and why?”, “Which parts are in front and which more in the background?”, “Which aspects make you proud and which are a source of ambivalence?” “Which part comes alive in your study?” They also can ask questions about the specific beliefs and values that are typical for their nationality. This could be positive in the process of team working. A better

understanding of cultural values makes one more secure and empathetic to others, for instance the degree of politeness or directness in expressing one's feelings. Cultural differences may occur in the way students and tutors get along with problems in the group. It could be an advantage if students talk at the start about cultural differences in the approach to communication.

The students were positive about the possibility of having a person in the background they could consult and talk to when they had problems. This was also the case for some tutors, who talked about problems in their group and about the strategy that might be useful to solve the problem.

Although there were only four students attending the focus group they all agreed about the importance of group activities, exercises to get to know each other better and to reduce stress.

Conclusion

All students evaluated their project as successful. In terms of suggestions about the preparation activities, most students did not offer further comments and felt what had been provided was fun and sufficient, although three students thought they were time-consuming and unnecessary. To optimise communication between them, nine students would like to have had more exercises. Whilst exploring the MBTI personality types was useful for identifying potential differences, most students said they would prefer fun exercises to get to know each other better, and using personality data to inform team roles was generally not useful.

The motivation to participate in the summer school for most of the students is doing research, getting to know students from other countries and having a good time together. In general students would like to have more social activities during the weeks and in the evening, such as having dinner and hanging around. Also activities which release stress were proposed, both outdoor activities/games as well indoor activities/games.

Overall students admit and show that it is important to play together in order to be successful as a team:

"A team that plays together, stays together".

References

1. Malpascoe Team Dynamics using MBTI Leadership Development Series *http://www.slideshare.net/malpascoe/mbti-team-dynamics* [accessed 23/11/15]
2. 'Understanding Team Roles (the Essential Guide Series)' - Published by Team Focus Ltd. ISBN 978-0-9934169-2-7 published 2015; Team Technology (no date) Working out your team role [available at] *http://www.teamtechnology.co.uk/workingoutyourteamrole2.htm* [accessed 23/11/15]
3. Project Management Institute (2012), A Guide to the Project Management Body of Knowledge, 5th Ed.
4. Spencer-Oatey, H. (2008). Face, (Im) Politeness and Rapport. Culturally speaking; culture, communication and politeness theory, 2d ed. H. Spencer-Oatey. London, Continuum: 11-47.
5. John B. Lloyd (2012) The Myers-Briggs Type Indicator and mainstream psychology: analysis and evaluation of an unresolved hostility, Journal of Beliefs & Values: Studies in Religion & Education, 33:1, 23-34, DOI: 10.1080/13617672.2012.650028
6. McCrea, R.R., and P.T. Costa. 1989 Reinterpreting the Myers-Briggs Type Indicator from the perspective of the five-factor model of personality. *Journal of Personality* 57: 17-40.
7. Miller, J., & Donner, S. (2007) The complexity of multidimensional social identity development (Chapter 4). In S. Bormann, M. Klassen, & C. Spatscheck (Eds.) *International social work: Social problems, cultural issues and social work education.* Opladen, Farmington Hills: Barbara Budrich Pub.

Research Methods – how to write a research question

Annemieke Meijer and Ruurd Visser[1]

1. Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, The Netherlands

Introduction

Imagine that in your field of work technological developments have led to new insights. Whether these new insights improve patient examinations and diagnosis has not been investigated in your department. This raises a question you would like to answer. This chapter helps you to get started with writing a suitable research question.

As the research question defines the topic that will be addressed and delimits the variables that will be measured, formulating of a good research question is very important. As a consequence, it is quite difficult to formulate a good research question as the type of question that is asked has implications for the type of research that is performed and the development of the research project depends on the question that is asked to begin with.

This chapter provides helpful information to convert a research problem into a correct and researchable research question. The chapter comprises advice from the authors, based on their personal experiences regarding research methods. Two cases will be used to illustrate how research questions might be written.

Case 1: You are a medical imaging researcher. You want to know whether X-ray or MRI is better for detecting scaphoid fracture. Conventional X-ray is the current gold standard.

Case 2: You are a researcher in the field of oncology. A novel chemotherapy drug has been developed and you want to perform a clinical trial to assess the drug's efficacy in breast cancer patients.

Getting started

Before starting your research one has to write a research proposal. This proposal defines exactly what your research will be about, which problem(s) you will address, the research question, hypothesis and aim of the work, and a description of the methods that will be used to answer the research question. In the research proposal you begin with introducing the context of the research. In general you start with a broad scope of the context followed by a description of the research problem where you define the problem statement. It is very important to support your problem statement with up-to-date peer reviewed references, and possibly pilot data, in order to clarify the relevance of your research. Finally you end the introduction with the aim of the research. This results in a typical structure of an introduction; in general starting with a broad context and ending with a focussed aim (figure 1).

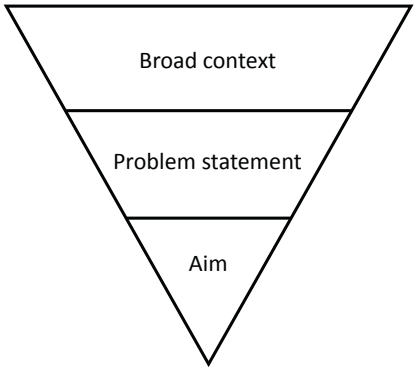


Figure 1 Typical structure of an introduction to your research.

Case 1:

Context: A short description of scaphoid fractures.
Scope: Methods to diagnose scaphoid fractures.
Problem statement: Unclear whether conventional X-ray or MRI is better in diagnosing scaphoid fractures.
Aim: Investigate the diagnostic value of conventional X-ray and MRI in diagnosing scaphoid fractures.

Case 2:

Context: The description and epidemiology of breast cancer.
Scope: The drug that is currently used to treat breast cancer.
Problem statement: The drug that is currently used shows severe side effects and/or is not effective enough.
Aim: To investigate the effect of a new drug for the treatment of breast cancer.

Conversion of problem into a research question

Next, the research question and possible sub questions are formulated. They should be logically deducted from the problem statement and research aim. In other words, the problem needs to be converted into a question. Formulating the research question is one of the most essential steps in your research; the question describes exactly what you want to investigate. The research aim and question are strongly related to each other. Acquirement of an answer to your research question implies that you reach the aim of your research.

By means of the formulation of your research question you define specifically what will be investigating. Consequently, you can ask various questions based on the same research aim.

Case 1: The aim was to investigate the diagnostic value of conventional X-ray and MRI in diagnosing scaphoid fractures.

Possible research questions:

- What is the difference in diagnostic value between conventional X-ray and MRI for patients suspected of a scaphoid fracture?
- What is the positive predictive value of conventional X-ray in comparison to MRI in diagnosing scaphoid fractures?
- What are the (dis)advantages of conventional X-ray in comparison to MRI in diagnosing scaphoid fractures?

Case 2: The aim was to investigate the effect of a new drug for the treatment of breast cancer.

Possible research questions:

- What is the effect of the new drug compared to chemotherapy on the 5-year overall survival of female breast cancer patients?
- What is the effect of the new drug in combination with chemotherapy compared to chemotherapy alone on the 5-year overall survival of female breast cancer patients?
- What is the effect of increasing the dose of the new drug for the treatment of breast cancer?

Types of research/ types of questions

The type of research question that you ask directly influences the methodology and method of the research. It will influence the paradigm you select (eg qualitative/quantitative). For quantitative studies it also determines the appropriate statistical analysis. Various types of questions and associated research types have been described. Below, some common types of questions in relation to the field of medical imaging are described using case 1.

Descriptive; the current situation regarding a subject (the dependent variable) is described.

Case 1: What does a scaphoid fracture look like on a conventional X-ray?

Comparative; Two or more techniques or interventions are compared. Most commonly a new technique is compared to a gold standard or to a placebo. Many different outcome measures are possible. In this case, the two techniques or interventions are the independent variables and the outcome measure is the dependent variable.

Case 1: What is the difference in diagnostic value of conventional X-ray in comparison to MRI in diagnosing scaphoid fractures?

Predictive; The effect of an intervention on the outcome/prognosis of/for the patient is investigated. In this case, the intervention is the independent variable and the outcome/prognosis is the dependent variable.

Case 1: What is the positive predictive value of conventional X-ray in comparison to MRI in diagnosing scaphoid fractures?

Evaluative; This type of question results in a retrospective research design. The effect of introducing a new intervention/technique/protocol is evaluated. In this case, the new intervention/ technique/ protocol is the independent variables and the effect is the dependent variable.

Case 1: What is the difference in image quality between conventional X-ray and MRI for patients diagnosed with a scaphoid fracture?

Criteria to formulate a research question/ checklist

A good research question has to measure up to the following criteria. You can use these criteria as a checklist while formulating your question.

Specific; your question needs to be clear to every reader; leave no room for any other interpretation than your own.

Measurable; the question needs to contain a variable that can be measured using a measuring tool. For example (*Case 1*) the question *'Which technique is the best in diagnosing the scaphoid fracture?'* is not measurable. Change the question into *'What is the positive predictive value of conventional X-ray compared to MRI in diagnosing scaphoid fractures?'* and you have formulated a question that is actually measurable. The measurable variable/outcome will be your dependent variable.

One fold; do not ask more than one question at the time.

Realistic; is it achievable to answer your research question in general and within the given timeframe?

Complete; your question needs to contain all the variables to be investigated

Open question; Do not formulate a closed question that can simply be answered with *'yes'* or *'no'*. The trick to generate an open question is by starting with *'What is the effect of…'* or *'to what extend…'*

Ethical; The research has to follow ethical guidelines. If necessary, ethical approval has to be obtained.

Tool to formulate an answerable research question

PICO (Patient, Intervention, Comparison, Outcome) is an acronym that can help you formulate a research question that meets the criteria described above.

P: Patient; describes the disease/type of patients that will be investigated

I: intervention; describes the intervention or E: Exposure; describes for example the diagnostic tool (imaging modality) to which the patients will be exposed.

C: Comparison; describes the gold standard, or reference test /placebo

O: Outcome; describes the outcome measure that is needed to answer your research question

The idea of this acronym is that you fill in the *P, I, C,* and *O* for your research. Subsequently, you use all the information in one grammatically correct sentence in order to generate a question. In general, you can complete the following sentence: 'What is the effect of *I* compared to *C* on *O* in/for *P*?'

Case 1:

P: Patient suspected of a scaphoid fracture
I: MRI
C: Conventional X-ray
O Diagnostic value

Question: What is the effect of MRI compared to conventional X-ray on the diagnostic value for patients suspected of a scaphoid fracture?

Case 2:

P: Breast cancer patients
I: Your new drug, let's call it Optimax
C: Chemotherapy
O: 5-year overall survival

Question: What is the effect of Optimax compared to chemotherapy on the 5-year overall survival of breast cancer patients.

This acronym is very helpful in case you plan to perform a comparison study. Unfortunately, this acronym is not applicable for all types of research. As you can imagine, the acronym is not appropriate for phantom studies. In addition, in case you plan to perform an observational study or a non-experimental study, *I* and *C* will not be described separately. NB You may notice that *O* describes the dependent variable and *I* and *C* the independent variables.

Sub questions

When the research question is too complex, sub questions are required to help answer the main research question. Using sub questions, specific aspects of the research question can be addressed in more detail. All sub questions need to be related to the main research question. Furthermore, the sub questions will be investigated separately. For each sub question a hypothesis can be formulated and if possible subsequently tested statistically.

Case 1: Research question: What is the effect of MRI compared to conventional X-ray on the diagnostic value for patients suspected of a scaphoid fracture?

Sub questions:

- What is the sensitivity of conventional X-ray in diagnosing a scaphoid fracture?
- What is the sensitivity of MRI in diagnosing a scaphoid fracture?

Case 2: Research question: What is the effect of increasing the dose of the new drug for the treatment of breast cancer?

Sub questions:

- What is the dose response curve of the new drug for the treatment of breast cancer?
- What are the side effects of the new drug for the treatment of breast cancer?

Visual image quality assessment methods

Hussien Abid Ali Mraity[1] and Maily Alrowily[2,3,4]

1. University of Kufa, Faculty of Science, Department of Physics, Najaf, Iraq
2. Ministry of Health, Saudi Arabia.
3. Ministry of Education, Saudi Arabia Cultural Bureau in London.
4. Health Sciences Research Centre, University of Salford, Salford, UK.

Medical imaging continues to provide a fundamental source of information that can help clinicians with diagnosis and management. Theoretically, diagnostic accuracy is dependent upon the quality of information within the image and subsequently the quality of an image may affect diagnosis and also how a patient will be managed (Mraity et al, 2014a). The assessment of image quality provides metrics which are essential for a wide range of medical imaging applications (Wang, Bovik, & Lu, 2002). First, they can be used as a quality assurance/control indicator of imaging system performance. Second, they can be used to optimise patient radiation dose during X-ray practice because dose reduction is limited by the quality of information provided (Jessen, 2004). Finally, they can be used as a benchmark for choosing the appropriate image processing algorithm by which one can obtain relevant radiographic information. Dose optimisation and image processing are essential for imaging systems which use ionising radiation, as they can minimise the need for repeat radiographic procedures, and optimise patient exposure thereby limiting unnecessary radiation (Sezdi, 2011).

Image optimisation generally concerns itself with creating an image which is *fit for purpose*. The term, *fit for purpose* is rarely defined adequately within journal papers (Shet et al, 2011). Generally speaking, the quality of an image involves visual analysis to determine visibility of data contained within it (Jessen, 2004). This should confirm that any image quality measure, other than those based on the eyes of an observer, could be regarded as a supportive or predictive measure (i.e. physical measure). This is because image perception is almost always based on the visualisation of anatomical features within an image (Mraity et al, 2014b); whereas physical measures relate to a measure of detectability of relevant features but do not directly measure the fidelity of those features. When defining the quality

of an image, the purpose of the image should be considered (Lemoigne, Caner, & Rahal, 2007). It is widely agreed that image quality can be defined in terms of its acceptability for answering the primary clinical question(s) (Sharp, 1990; Shet, Chen, & Siegel, 2011).

Image quality evaluation

There are several approaches that can be used to measure the quality of an image (Alsleem & Davidson, 2012). These are generally classified as physical (e.g. SNR), psychophysical (e.g. line pairs) and visual/clinical approaches. However, for this chapter the focus will be on those which are clinically relevant (visual approaches). In this context, literature review reveals that different methods were adopted under the class of the clinical assessment. This includes European Guidelines for quality criteria (CEC), visual grading analysis, two alternative forced choice, receiver operating analysis (ROC) and eye tracking methods.

European guidelines on quality criteria (1996)

In 1987, a team from the Commissions of European Communities/Radiation Protection Programme launched a project to identify radiographic criteria which could help medical imaging professionals make better informed judgements in evaluating image quality. These criteria included technical, physical and radiological parameters (Maccia, Ariche-Cohen, Nadeau, & Severo, 1995). Initially, six routine X-ray examinations were considered, including skull, chest, lumbar spine, pelvis, urinary tract and breast (EC, 1990). The reasons for selecting these radiographic examinations were due to their frequency of use and the radiation dose which they were administering to patients. The image quality criteria focused on how clearly anatomical structures are visualised within a specified radiographic image and how this aids in making an accurate diagnosis. Some of the criteria, however, rely on the correct positioning of the patient, whereas others are dependent on the technical performance of the imaging system (CEC, 1996). This is supported by providing a quantitative guide to explain the minimum size at which important anatomical structures should be visible on a radiograph. In addition to this, the degree of visibility of anatomical structures were categorised into three major definitions: 1) Visibility, *characteristic features are detectable but details are not fully reproduced; features just visible;* 2) Reproduction, *details of anatomical structures are visible but not necessarily clearly defined; details emerging;* 3) Visually *Sharp Reproduction, anatomical details are clearly defined; details clear* (Jessen, 2001). This CEC (1996) project is considered as the foundation on which further work on quality assessment criteria have been be built by the radiological community (CEC, 1996). Overall, the purpose behind the criteria was to standardise practice and reduce the variability in radiation dose,

and, most importantly, in the evaluation of image quality.

Visual Grading Analysis (VGA)

The visual grading of the visibility/reproduction of normal anatomy or pathology is a valid and commonly used approach to visually quantify the quality of an image in medical imaging (Seeram, Bushong, Davidson, & Swan, 2014). Its application is based on how clearly the anatomical structures are visualised by an observer, by asking the observer to rate the visibility and reproduction of detail in the [clinical] image. A human-based approach like this makes it a clinically relevant and preferred way to assess [clinical] image quality (Smedby & Fredrikson, 2010). Also, the relevance of the VGA for detectability of pathology has been investigated, and ultimately determined there to be a strong correlation between the visibility of normal anatomy and the detectability of pathological structures (Sund, M., Kheddache, & Månsson, 2004; Sund, Båth, Kheddache, Tylén', & Månsson, 2000; Morán et al., 2004).

Rationale for using VGA

Bath (2010) provides a number of reasons for using the visual grading approach, namely 1) validity of VGA studies can be assumed as high provided that the anatomical structures are chosen based on their clinical relevance; 2) in certain cases visual grading has been found to be in agreement with pathology detection studies using observers (Sund et al., 2000) and physical calculations of image quality (Sandborg et al, 2006); 3) in comparison to ROC (Receiver Operating Characteristic) studies, VGA experiments are relatively easy to undertake, particularly to optimise equipment locally; 4) time required to implement VGA studies is moderate when the observer's workload is taken into account meaning that it can be attempted in the hospital/clinic. There are two common types of VGA system which can be applied to assess the image: Absolute VGA and relative VGA.

Absolute VGA

In this approach the observer is asked to give his opinion on the visibility of anatomical structures in the image. The data from this method is then analysed to provide the overall visual grading analysis score ($VGAS_{abs}$) of an image using the following equation:

$$= 1 \quad = 1 \quad = 1 \quad = 1 \qquad x \; x$$

where Gabs represents the absolute rating for a given image (i), structure (s), and observer (O). The letters I, S and O refer to the number of images, structures and observers respectively.

Relative VGA

The relative VGA requires a rating of the visibility of anatomical structures against the same structures within a reference image. The observer should grade the visibility of the structure using a scale in which a value of 0, or equivalent, referring to visibility is equal to the reference image. Positive (eg +1) and negative (eg -1) values using this approach would indicate whether the structures' clarity in comparison to the reference image is better (eg +1) or worse (eg -1). Overall scores for an image can be derived using this expression:

$$= \quad = 1 \quad = 1 \quad = 1 \qquad x \quad x$$

where G_{rel} represents the absolute rating for a given image (I), criterion (C), and observer (O). The letters I, S and O refer to the number of images, structures and observers, respectively. It is suggested that two images should be displayed on side by side monitors with same brightness, and the reference image must include well defined landmarks (Månsson, 2000; Zarb, Rainford, & McEntee, 2010 & Seeram, Bushong, Davidson, & Swan, 2014).

2-AFC is a psychophysical method used to show how efficient an observer is in perceiving small differences among several visual/physical stimuli. In this context, the alternatives can be represented as different aspects of the stimuli (Cunningham and Wallraven, 2012). In medical imaging the stimulus could either be a lesion or a level of noise. The origins of 2AFC involved two separate stimuli, where one of them is blank and the other is not. The presentation of the stimuli is conducted randomly (Pelli & Farell, 1995). For image evaluation purposes, 2AFC could involve a number of images being assessed against a reference image; this means that the 'images to be evaluated' and reference image are displayed at the same time, side by side, on two separate monitors. By way of comparison, this method has been described as being less biased and very sensitive to subtle differences across different images. This is because the observer is forced to compare one stimulus of an image with the same stimulus in the reference image. This should contribute to lessen the subjective interference and therefore subjective bias. The performance of 2AFC was previously investigated in terms of how efficient it is for characterising observer performance and identifying the small changes of processed images (Gur et al, 1997 & Abbey & Eckstein, 2002).

Receiver operator characteristic (ROC)

This approach originated from the signal detection theory, in which a low-contrast signal should be identified in a noisy background. ROC analysis is widely used in radiology to visually assess the diagnostic images and the observer performance. In ROC an observer is asked to rate images with

suspected disease whereby diagnostic performance can be determined by the number of correct responses. (Zarb, Rainford, & McEntee, 2010). Observer performance is generally determined by the area under the ROC curve (Tingberg, 2000). This curve plots the true positive fraction as a function of the false positive fraction; a figure of merit can be obtained from the area under the curve (Chakraborty, D. P., 2006). However ROC has a major drawback in that it are highly dependent upon disease prevalence. Furthermore, the images have to be divided into normal and abnormal; consequently a large number of images are required. The ROC methodology does not work well for multiple lesions on same image; and finally localisation of lesion is not taken into account and therefore a case may be diagnosed as abnormal but the true lesion could be missed (Bath, 2010 & Zarab et al, 2010). In order to overcome the above limitations in ROC analysis, measures have been taken to improve its performance. Examples of these ROC include LROC, FROC, FFE and DRCO.

Eye tracking

This can be a helpful tool for the understanding of how an observer views images. Various commercial eye tracking systems exist. Such systems are capable of determining the line of gaze and assessing the dwell time while a subject observes an image on a computer screen. The system works by utilising infrared light from a diode on a headband, which is reflected from a reflective visor into the eye. Light is ultimately reflected to a camera which is recorded (Krupinski, Graham, & Weinstein, 2012). Eye positioning measurement equipment measures the visual dwell time and saccades. Dwell time is the time it takes an observer to look or fixate on a specific location. Saccades refer to the jumps between fixations. The latency period of saccades is between 100-150ms and the velocity is typically between 308 and 1008 visual angle per second. (Krupinski et al., 2006).

References

Abbey, C. K., Eckstein, M. P.(2002). Classification image analysis: Estimation and statistical inference for two-alternative forced-choice experiments. *Journal of Vision, 2*, 66-78.

Alsleem, H., & Davidson, R. (2012). Quality parameters and assessment methods of digital radiography images. *The radiographer*, 59(2), 46-55.

Båth, M. (2010). Evaluating imaging systems: Practical applications. *Radiation protection dosimetry*, 139(1-4), 26–36.

Chakraborty, D. P. (2006). ROC curves predicted by a model of visual search. Physics in Medicine and Biology, 51(14), 3463–3482. *http://doi.org/10.1088/0031-9155/51/14/013*

Commission of the European Communitie (CEC). (1996). European guidelines on quality criteria for diagnostic radiographic images: (EUR 16260 EN). Brussels: CEC.

Cunningham, D. W., & Wallraven, C. (2012). *Experimental Design From User Studies to Psychophysics*. Boca Raton: CRC Press.

European Commision (EC). (1990). CEC Quality Criteria for Diagnostic Radiographic Images and Patient Exposure Trial:, (Report EUR 12952), . Brussels:CEC.

Jessen, K. A. . (2001). The quality criteria concepts: An introduction and overview. Radiation protection dosimetry, 94(1-2), 29–32.

Jessen, K.A. (2004). Balancing image quality and dose in diagnostic radiology. European Radiology Supplements, 14(1), 9-18.

Krupinski, E. a., Graham, A. R., & Weinstein, R. S. (2012). Characterizing the development of visual search expertise in pathology residents viewing whole slide images. *Human Pathology*, 44(3), 357–364. http://doi.org/10.1016/j.humpath.2012.05.024.

Krupinski, E. a., Tillack, A. a., Richter, L., Henderson, J. T., Bhattacharyya, A. K., Scott, K. M., … Weinstein, R. S. (2006). Eye-movement study and human performance using telepathology

Lemoigne, Y., Caner, A., & Rahal, G. (2007). *Physics for medical imaging applications*. Amsterdam: IOS Press & Springer.

Maccia, C., Ariche-Cohen, M., Nadeau, X., & Severo, C. (1995). The 1991 CEC trial on quality criteria for diagnostic radiographic images. *Radiation protection dosimetry*, 57(1-4), 111-117.

Månsson, L.G. (2000). Methods for the evaluation of image quality. Radiation protection dosimetry, 90(1-2), 89–99.

Morán, L.M., Rodríguez, R, Calzado. A, Turrero, A, Arenas, A., Cuevas, A., . . . Morán, P. (2004). Image quality and dose evaluation in spiral chest CT examinations of patients with lung carcinoma. *British journal of radiology*, 77 (922), 839-846.

Mraity H, England A, Akhtar I, Aslam A, De Lange R, Momoniat H, et al. Development and validation of a psychometric scale for assessing PA chest image quality: A pilot study. *Radiography*. 2014a;20(4):312–7.

Mraity H, England A, Hogg P. Developing and validating a psychometric scale for image quality assessment. *Radiography*. 2014b;20(4):306–11.

Pelli, D. G., & Farell, B. (1995). Psychophysical methods. In M. Bass, E. W. Stryland, D. R. Williams & W. L. Wolfe (Eds.), Handbook of optics:Fundamentals , techniques , and design (2 ed., Vol. 1). New York: McGRAW-HILL , INC.

Sandborg, M., Tingberg, A., Ullman, G., Dance, D. R., & Alm Carlson, G. (2006). Comparison of clinical and physical measures of image quality in chest and pelvis computed radiography at different tube voltages. *Medical physics*, 33(11), 4169–4175.

Seeram, E., Bushong, S., Davidson, R., & Swan, H. (2014). Image quality assessment tools for radiation dose optimization in digital radiography: An overview. *Radiologic technology*, 85(5), 555-562.

Sezdi, M. (2011). Dose optimization for the quality control tests of X-ray equipment. In A. B. Eldin (Ed.), Modern approaches to quality control: InTech.

Sharp, F.P. (1990). Quantifying image quality. *Clinical physics and physiological measurement*, 11(Suppl. A), 21-26.

Shet, N., Chen, J., & Siegel, E.L. (2011). Continuing challenges in defining image quality. Paediatric radiology, 41(5), 582-587.

Smedby, O., & Fredrikson, M. (2010). Visual grading regression: analysing data from visual grading experiments with regression models. *British journal of radiology*, 83(993), 767-775.

Sund, P., Båth, M., Kheddache, S., & Månsson, L.G. (2004). Comparison of visual grading analysis and determination of detective quantum efficiency for evaluating system performance in digital chest radiography. *Euorpean radiology*, 14(1), 48-58.

Sund, P., Herrrnannb, C., Tingberg, A., Kheddached, S., Månsson, L. G., Almén, A., & Mattsson, S. (2000, February 12, 2000). Comparison of two methods for evaluating image quality of chest radiographs. Paper presented at the Image Perception and Performance, San Diego, CA.

Tingberg, A., Herrmann, C., Besjakov, J., Rodenacker, K., Almén, A., Sund, P., … Månsson, L. G. (2000). Evaluation of lumbar spine images with added pathology. Proc. SPIE, 3981, 34–42.

Wang, Z., Bovik, A. C., & Lu, L. (2002). Why is image quality assessment so difficult? *IEEE,* 4, 3313 -3316.

Zarb, F., Rainford, L., & McEntee, M. (2010). Image quality assessment tools for optimization of CT images. *Radiography,* 16(2), 147-153.

Scientific Poster Design

Louise Rainford[1]

1. University College Dublin

The dissemination of investigative findings is an important part of the research process. Radiography needs to continually update and build its professional practice evidence base and publish research findings. One way in which to share research findings in a relaxed and less formal setting than an oral presentation is a poster presentation [1]. Poster presentations at formal meetings such as local, national or international scientific congresses allow an audience of similar interest access research findings and have interaction with the researcher [2]. Posters when designed well can facilitate a concise overview of the research presented [3]. A poster forms a storyboard of information and its narrative requires careful consideration as the facts are presented differently to a full journal manuscript. This is largely due to word limit constraints and the nature of interaction of the audience with a poster, which may be limited to a few minutes at a conference proceedings, rather than being accessible for repeated referral as with journal articles. The potential for researchers to interact at poster discussions also offers the opportunity for researchers to enhance their reputation directly with colleagues and facilitates networking; therefore first impressions are critical [3]. Guidance on the practical aspects of how to design scientific posters to optimal visual effect however is limited [1]. As technologies for producing posters develop and gain complexity it is essential healthcare professional researchers ensure they possess a skills base which allows them to achieve high standards of visual scientific communications when representing professional societies or academic institutions [4].

The aim of this chapter is to deliver a step by step guide on the production of a scientific poster and include practical tips and provide examples in a visual format. The author's insight derived from personal experience of poster presentation production is offered to assist others to efficiently and effectively prepare scholarly posters. There are numerous methods by which posters can be developed, as an increasing number of software options are available, however this chapter will principally focus upon poster production using Microsoft PowerPoint which is software readily available and commonly used. The practical advice

provided is relevant when using other templates such as in Microsoft Word or Sway. Examples of poster guidelines from scientific meetings will be incorporated and sample marking criteria for poster presentations is discussed. The content of the chapter aims to provide students with practical advice for poster preparation and insight into the common aspects assessed with respect to posters produced either for scientific conferences or as part of education programmes.

PowerPoint Template

The first step of any poster production is to prepare the PowerPoint template by firstly selecting a blank PowerPoint slide. By selecting the Design Tab on the main tool bar and then slide size a pop up box will appear and then determining whether the orientation is to be portrait or landscape, followed by identification of slide dimension. The size of the PowerPoint slide will depend on institution or conference instructions if the poster is to be printed. Common paper sizes are A0 (841 x 1189 mm), A1 (594 x 841 mm) and A4 (210 x 297 mm).

Presentation Style

Once it is determined whether the poster is portrait or landscape format how the information which is to be displayed is arranged needs to be thought through by the presenter. Several authors recommend the use of mapping in sketch format in preparation and careful consideration of where figures and tables and other graphics will be interspersed on the template [4, 5]. A decision needs to be made on the layout of the poster, for example the number of main columns in the poster: two or three would normally be used as shown in Figure 2. In PowerPoint the insertion of text boxes to align vertically to the number of columns is the most commonly applied method. Balance of content, in the design phase should be planned so the content flows from top to bottom of each column and from right to left for the entire poster [6].

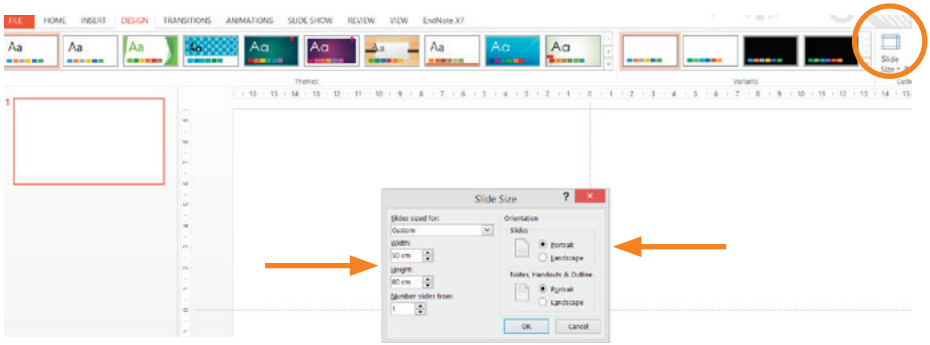


Figure 1 Screen shot of Microsoft PowerPoint interface for the selection of Slide Size (red circle), the red arrow pointing to portrait/landscape selection and the green arrow identifying the selection of poster size (relevant for posters printed for physical display).

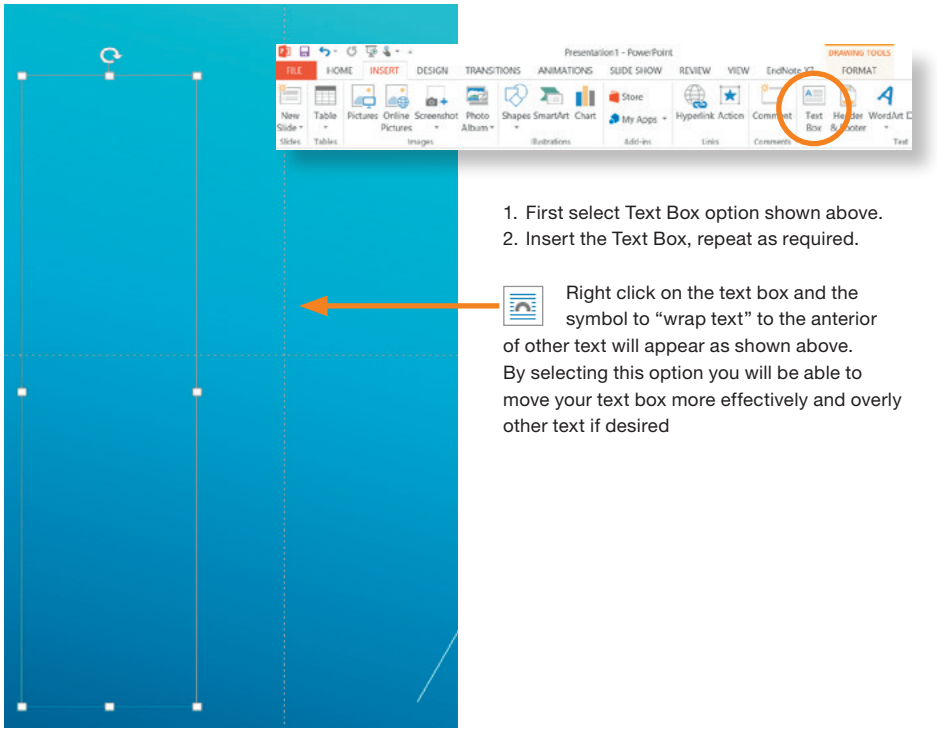


Figure 2 Inserting a text box

Next the background template for the poster needs to be selected and whilst this can alter as the poster design, it is wise to consider basic background details from the start. There are a number of different styles that can be applied as shown in figure 7 (a-c) and figure 8 (a-c). A fundamental question focusses upon what colour should be used during background formatting and this is a decision which should be made in conjunction with the figures and tables to be inserted and any other graphics.

The selection of colours used in a presentation will have an impact on the audience. Colours can convey warmth and tone. In healthcare scientific posters, the use of white conveys a clinical tone which is perceived as “clean and crisp” [6].

In selecting the background colour some literature would advise the avoidance of solid colours however these can work well depending upon the poster content (figure 4a). Textures however should be

Figure 3 Example of white template contrasted with bold colour applied effectively.

Figure 4
(a) Use of a bold background template
(b) Box format to differentiate each section

avoided [6] and it is advisable not to use too many colours for text, possibly use one colour for the title and to help draw the eye of the audience then for the principal sections of the poster use a different colour for section headings compared to section text, as shown in figure 4b.

It should be remembered that a proportion of the population are colour blind and the use of red should be kept to a minimum [5]. Additionally how we visualise colours is determined by our experience of colour and genetic deficiency; this can affect red/green and also blue/yellow differentiation [7]. The use of a colour wheel to select appropriate contrasting and complementary colours is an option (figure 6a) [6]. A high level of contrast between the background and text is preferable with the background lighter in colour tone. Complementary colours are ones which oppose each other on the wheel and using these colours can make a bold statement (figure 6b).

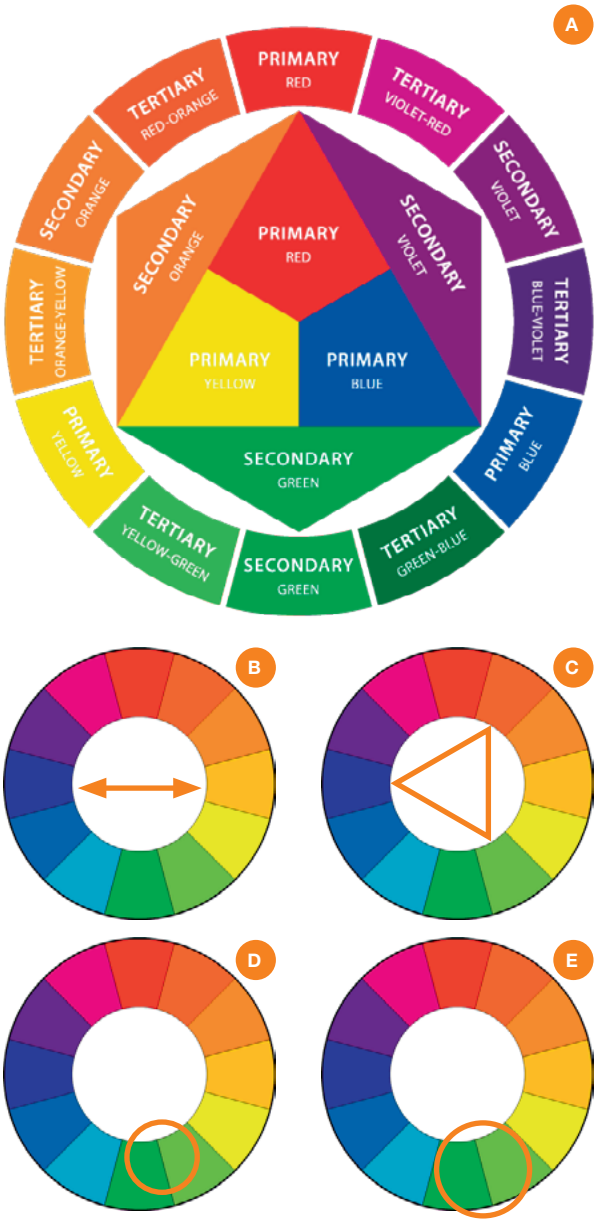


Figure 6
(a) Colour Theory Part 1 (www.pengadprinting.com)

Figures 6 (b) – (e)
Colour considerations
(b) Complementary Colours
(c) Triadic scheme
(d) Split complementary Scheme: Blue/Green
(e) Balanced scheme: Blue, Green, White

Figure 7 (a) (b) (c) Examples of colours used for poster backgrounds.

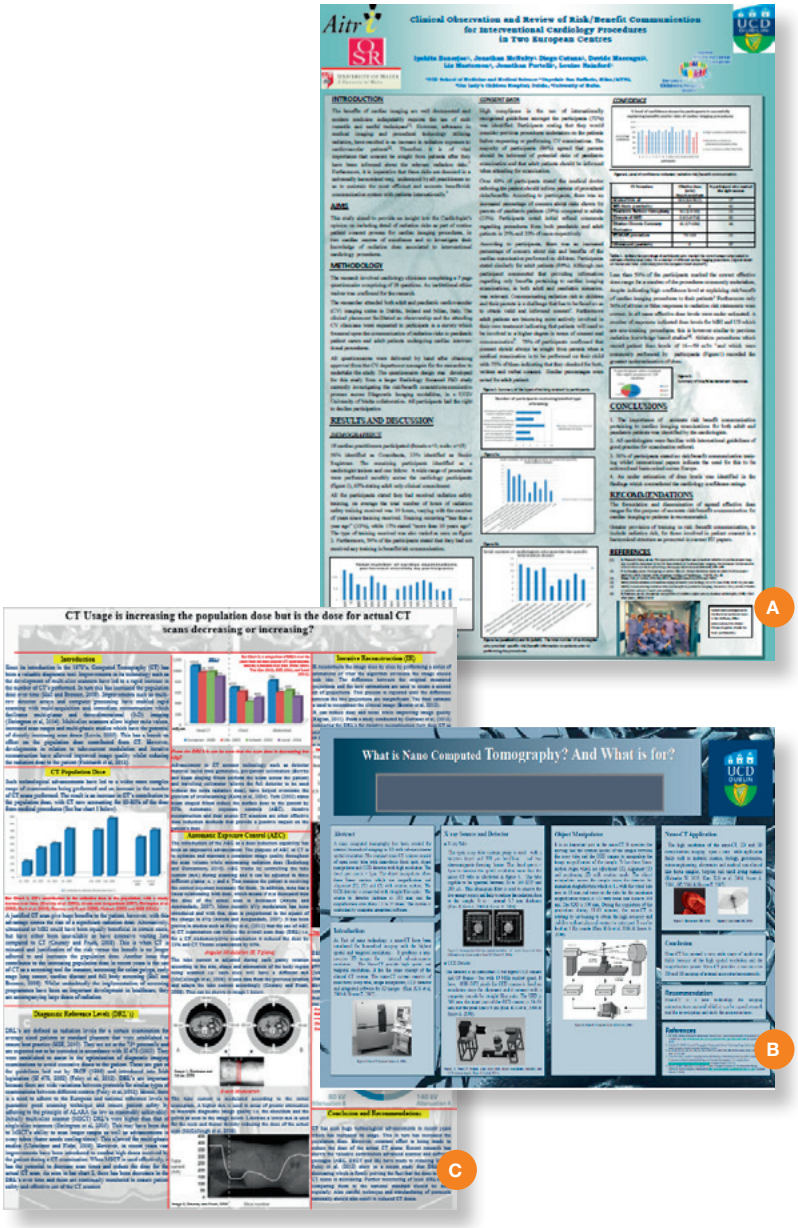


Figure 8

(a) Example of a relevant image forming a background visual and not distracting from the poster content;

(b) A bold background visual which whilst not scientifically relevant to the poster content adds visual impact to attract the audience;

(c) Example of an overcrowded poster which contains a relevant background visual but this clashes with the remainder of the poster design, creating a negative impact.

By drawing a triangle between three evenly dispersed colours on the wheel a triadic scheme is achieved (figure 6c). Split complementary colours can be derived from any colour combination, whereas two colours adjacent to each other is called a split – complementary scheme (figure 6d), a three colour scheme is indicative of balance (figure 6e) [7].

Varying shades of blue are perceived as “cool and calming” for readers and the use of blue is commonly seen in posters however other tones that do not distract from the text and figures/tables inserted are viable alternatives [7]. Care needs to be taken with respect to the contrast of colours between the main template and graphics included, below figure 7(a) demonstrates how a green template is successfully applied whilst figures 7(b) and (c) demonstrate the use of varying tones of blue based templates however the contrast of colours is suboptimal in 7(c) as the blue template is too dominant in the region of the title.

Solid colour fill, colour fill with a gradient applied or templates which incorporate a background design depicting a discrete image are all possible options in poster design. Background graphics may extend across the poster or part of the poster, behind any text or further images applied during poster design as shown in figure 8 (a -c). Inlay graphics should be relevant to work but not distracting from text. Examples of good and poor poster design are provided, both Figures 8 (a) and (b) demonstrate good use of background design whereas the design in 8 (c) whilst appropriate to the subject matter distracts from the text. The poster shown in figure 8 (c) would have benefited from a reduced amount of text, of a greater font size and a background template in an alternative colour tone, these factors would have facilitated a more positive impact.

Use of Logos

Professional affiliations are important and must be included as appropriate. When selecting these logos it is crucial that only official logos are used. These are often sourced on a white background which is fine if the background colour for your poster is white, however if you are using a coloured background you may want to remove any white aspects surrounding your logo as demonstrated in Figure 9(a).

Affiliations

Scientific presentations require all authors to be included and details of their affiliation(s). There is a set protocol which needs to be respected and which is often misunderstood by both students and novice researchers. The primary author is listed first, the secondary author is listed last at the end of the author list. Then then the third most significant author is placed directly after the first author, after this the remaining authors are placed between the third and last author as appropriate.

Figure 9

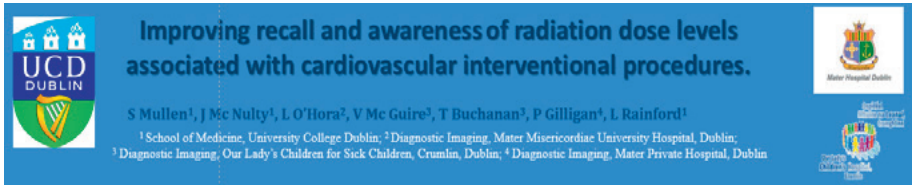
(a) Visual depiction of the effect of removing the white surround on logos.

(b) The white background surrounding all four logos is appropriate in this poster as without the contrast to the dark blue template selected the logos, particularly the more delicate in design would become less visible if the contrasting white mount had been removed.

(c) In this poster the *AITRI* logo is presented without the white surround and it is appropriate as the dark text in the logo contrasts well with the overall poste template. Likewise the *Mater Hospital Dublin* logo presents well however possibly one enhancement to this poster header would be to remove the white surround for the UCD logo so its dark colours can contrast optimally with the poster template.

To identify their professional affiliation the authors are numbered, this text is formatted as superscript ad below the authors list a "key" of the numbered affiliations is provided as seen in in figure 10.

Figure 10 In this example S Mullen is the lead author affiliated to the School of Medicine UCD, L Rainford is the second author, J McNulty the third. The superscript notations are aligned to the professional affiliation not to the position in the author listing.



It is essential that the authors listed have opportunity to review and comment on a poster prior to submission and that confirmation is received that they are satisfied to have their name on the work. This is extremely important matter, as once accepted for presentation the work will be deemed to have incorporated their involvement. Additionally the detail of affiliations needs to be confirmed by authors to ensure their professional allegiance is correctly displayed.

Title

The title of the poster is often the first aspect reviewed and is a focal point therefore its content and format needs to be succinct whilst written in a manner to promote interest, colourful, clear and **LARGE**; at least five times larger in size than formatting within the main content sections [5, 8]. The title should draw the audience in and capture the scope of the work being presented.

Poster Content

Whether the poster is for internal assessment on an academic programme of study or an original research study submitted for a conference presentation the poster guidelines may include word limits, formatting and reference guidelines and in each case these must be adhered to and applied to the poster content which is captured within the sections expected within scientific posters, namely:

- Aims and Objectives (Introduction)
- Materials and Methods (Methodology)
- Results; Conclusions and References

The content of written text should follow a logical sequence as the reader passes from section to section. Normally for scientific posters the path for readers to follow is determined by the established sections listed above, however if the poster design veers from traditional sections then the use of numbers and colour coding or symbols such as arrows can be utilised to map the pathway. Appropriate images should be used where possible to illustrate the work as images will attract attention for the brief time the audience has to view the poster whilst long paragraphs of text have a negative effect upon poster impact [9-11].

The content in each section should capture the attention of the reader and the key points are delivered in an interesting and clear manner [9, 11]. Sentences need to be constructed carefully so that complex research items are filtered and the essential information is delivered. All non-essential text should be removed so the style of presentation is direct and delivers clearly written prose [4].

Keywords

Keywords at the start of sentences will strengthen the "take home message" for example: "*CT dose*

modulation resulted in …." rather than "*The findings identified that CT Dose modulation…..*" [4]. If the audience viewing the poster is international in constitution additional consideration needs to be given to language applied. Language needs to be clear and precise with wording that will be easily and universally understood across nationalities.

Grammar

Either the use of English or American English should be used with no crossover of the two styles in one poster. A common error is the use a mix of "z" rather than "s" in words, for example: The **Optimisation** process was **recognized** as important. Either American English and the use of "z" or English and the use of "s" should be applied. A further example of other words which are commonly seen are miss-spelt due to American English or English wording confusion are **pediatric/paediatric** and **center/centre**. The use of abbreviated words such as **won't** rather than **would not** is not acceptable and all abbreviations and acronyms must be defined at first mention in the text. Quantitative measurements should be included in International system of units (SI) [12]. Finally with respect to general points on poster content: do not overcrowd a poster. Try to maintain the focus upon one main theme. The original research performed may be extensive but a poster should focus in on the principal findings being presented and relate directly to the title of the poster. Too much text is distracting and weakens the impact of the work as previously shown in figure 8(c) [9, 10]. The next step in poster design is to ensure the required sections are present and effectively written.

Aims and objectives (Introduction)

This section provides the justification for the study, the key aims and the research question to be investigated and/or the hypotheses of the work. The audience needs to understand why the research was performed and what was aimed to be achieved so they can cross reference to the findings and conclusions in later sections. An introduction also allows for succinct information to be provided for any key definitions or technologies, disease descriptions or pathophysiology relevant to the work of the chosen topic and a brief summary of referenced work on the topic under investigation.

Methods and materials

Detail of how the study was performed needs to be included with sufficient clarity to permit repetition of the work. The key elements of the method need to be presented for example: what patient group was investigated and what inclusion criteria defined the group. What equipment was employed and which experimental metrics were tested, over what period and by whom. Additionally were ethics requirements adhered to.

Figure 10 Extracts from the poster previously shown in figure 7(b) show an initial introductory section in two parts: INTRODUCTION and AIM: this is acceptable. The introduction outlines the radiation dose associated with EVAR procedures and the topic of Diagnostic Reference Levels with references; this provides the justification for the study. The AIM of the work is then clearly described for the audience.

INTRODUCTION: Endovascular Aneurysm Repair (EVAR) has become the treatment of choice for patients with abdominal aortic aneurysms with suitable anatomy[1]. The EVAR-1 trial[2] showed that EVAR has a reduced mortality (1.8%) compared with open repair (4.3%), as well as reduced morbidity [3,4]. However, concerns exist regarding the radiation exposure during fluoroscopically based interventional procedures.[5,6] EVAR procedures have become increasingly complex and are therefore associated with an increased radiation burden.[7] Reference Levels have been introduced in clinical practice as a tool for monitoring patient dose exposure. Reference levels are a radiation dose exposure level, set at the 75th percentile, for radiological examinations/procedures for average-sized patients and are used to identify unusually high patient radiation exposures.

AIM: This study aimed to establish local Reference Levels for EVAR and recommend a European Reference Level for EVAR procedures based on data from all five centres, such Reference Levels are currently not established.

Figure 11 In this example the confirmation of ethical approval is provided and a clear method is described in a manner that would facilitate repeat studies. The description includes detail of the data collected in each participating centre. The method also clearly identifies the type of centres which participated indicating the centres had to have had a history of 10 years or more offering EVAR procedures

METHOD: Institutional permission to collate data was attained from each clinical centre. Retrospective dose data was collected for 178 standard EVARs performed between January 2014 – July 2015 from five specialist centres in Ireland (n =2) and Italy (n=3). Standard non-fenestrated EVAR procedures only were included. Centres offering specialised services to regions of similar size were included and who had experience of EVAR of over a decade. Patient BMI and gender demographics were reviewed: Ireland vs Italy. *Collected data included:*

P_{KA} - kerma-area product
$K_{a,r}$ - total air kerma/ reference point
FT - fluoroscopic time
Number of Acquisitions
Frame Rate of Acquisition
Type of Acquisition
Operator experience
Patient Height/Weight
Equipment specifications

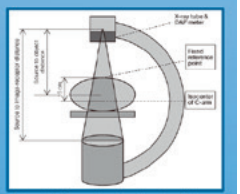


Figure 3. Schematic of key imaging features

Results

The principal findings of the study are presented in this section, as concisely as possible, in the form of tables or figures (where applicable). The findings outlined need to offer sufficient detail for the conclusions which follow and address the research question posed by the initial aim of the study.

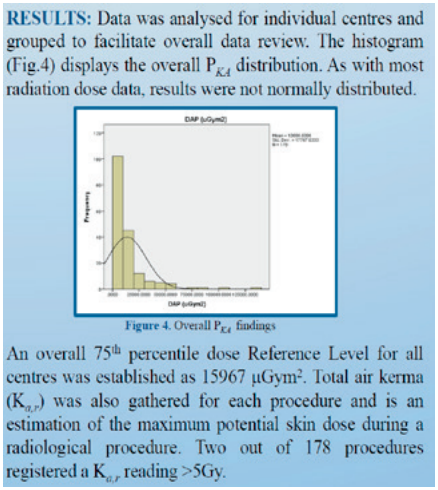
On average audience members will spend around 5 minutes looking at a poster so the key findings need to be clearly displayed demonstrating your desired "take home message" [13]

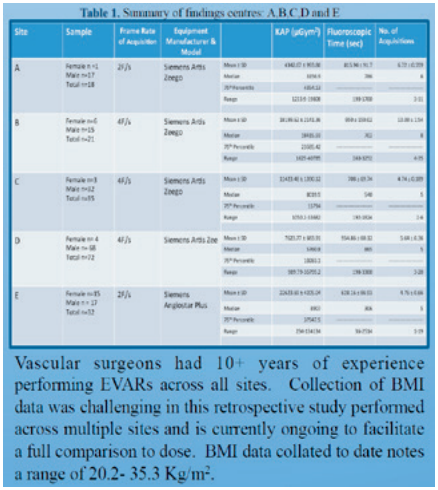
Conclusion (Discussion and Conclusion)

A succinct discussion of the findings identified in the Results Section and their significance, with reference to other cited work and clinical importance where relevant needs to be included. The final paragraph should include a concise, succinct statement which can be cross referenced back to the initial research question posed or aim of the study.

In the "Conclusion Section" example provided the variance in findings between X-ray units, despite employing the same equipment and parameters is noted and further research is recommended as to why this variance is seen. The importance of patient weight details is reiterated following comment in the results section that this was difficult to source but

Figure 12 The principal findings of the study are described in two graphics and several sentences. The study set out to establish DRLs and states these in this section for a cohort of patients with a specific weight range. The inclusion of information that two of the 178 procedures registered dose readings above 5Gy is of clinical relevance to professionals in this field which is reiterated in the Conclusions section figure 13.





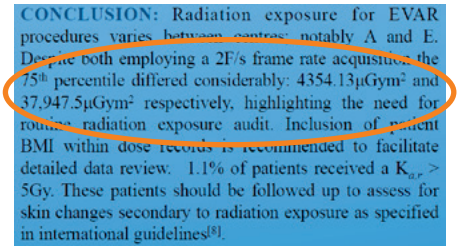

CONCLUSION: Radiation exposure for EVAR procedures varies between centres notably A and E. Despite both employing a 2F/s frame rate acquisition the 75th percentile differed considerably: 4354.13µGym² and 37,947.5µGym² respectively, highlighting the need for routine radiation exposure audit. Inclusion of patient BMI within dose records is recommended to facilitate detailed data review. 1.1% of patients received a $K_{a,r}$ > 5Gy. These patients should be followed up to assess for skin changes secondary to radiation exposure as specified in international guidelines[8].

Figure 13 The principal findings are reiterated and conclusions stated to align with the research aim stated in figure 10.

is required for DRL data. Finally a key point is made with regard to the patient management of cases that exceed radiation dose Trigger Levels.

The key aspects, "take home messages" of the poster are concluded: Establishment of DRLs, consideration of difficulty attaining the dose data, the need to identify why differences in dose occur across centres for the same examination and the clinical consequence and frequency of high doses which exceed recommended "Trigger Levels", thus fulfilling the poster title: "Investigation of Reference Levels and radiation dose associated with abdominal EVAR (Endovascular Aneurysm Repair) procedures across several European centres".

References

Statements made in the text of the poster need to be supported by referenced bibliographical work which is cited to support the research. Recent literature should be cited in the introduction in particular and other sections where relevant to support the presented material, recommendations made upon review of the data collected. Many scientific committees with oversight of poster submissions proffer recommendations for reference volume for example European Congress of Radiology conference presentation guidelines (ECR 2016) states up to a maximum of 20 references [12]. This however may not be possible if posters are to be physically displayed space which the poster template can be restrictive and requires consideration, for electronic posters this is less of an issue. Often the text size of the References Section is smaller than other sections, mainly due to space issues. It is critical the references are written accurately and without spelling mistakes etc. When printed errors in formatting will be obvious and for electronic posters the view mode can be zoomed in on substantially and thus the detail must be correct. This is often a section completed poorly by students and as it is the last section to be confirmed possibly this is due to time constraints or "poster fatigue".

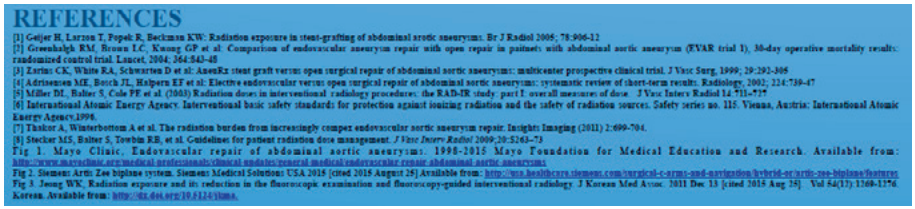


Figure 14 Fourteen references were included for the poster example provided

Harvard	Vancouver
Smith, D. and Wolf, J. (2014). Drug therapy optimisation in breast cancer. J Pharmacol Exp Ther 122:19-29.	Smith, D. and Wolf, J. Drug therapy optimisation in breast cancer. J Pharmacol Exp Ther. 2014; 122:19-29.

Table1 Example of the subtle difference in text presentation Harvard vs Vancouver referencing

The majority of poster guidelines request citations in the text to be in Arabic numerals in square brackets, e.g. [2-4, 11]. The list of references that are included should only include those that are cited in the text and that have been published [12]. Those presenting need to understand if they are referencing using Vancouver or Harvard styles and refer to documents to ensure the referencing text applied is appropriate for the scope of material referenced e.g. journal articles, book chapters, internet references and so on [14]. The style of referencing needs to be consistent. Table 1 demonstrates the subtle difference between referencing an article using the Harvard versus the Vancouver style. The scope of this chapter does not extend to detail the intricate requirements of Referencing styles and institution guidelines should be available to students or multiple guidance options can be found on the internet.

Formatting Content

Text

A poster should be readable at a distance of approximately 2 metres [5, 9]. The choice of text for both the title section of a poster and the main content is subjective in nature and will naturally vary between authors. A rough guide is that font height on a printed poster should be no less than 5mm in height, with taller font sizes used for headings (2cm) and the main title (3cm) [5, 9]. Examples of a range of font types are provided in table 2, with inclusion of how these fonts appear once in bold format and with shadow affect applied as commonly seen for poster titles. A spell check should be made in addition to a visual inspection of the text and formatting as some spelling and formatting errors may not necessarily be identified by software.

The text in each section of the poster content should preferably be in a justified format to add balance and symmetry to the poster. The visual impact of not justifying paragraphs is depicted in figure 15.

The Microsoft function for achieving text justification can be located as identified in figure 16.

Tahoma	Investigation into the impact of	**Investigation**
Verdana	Investigation into the impact of	**Investigation**
Palantino	Investigation into the impact of	**Investigation**
Calibri	Investigation into the impact of	**Investigation**
Times New Roman	Investigation into the impact of	**Investigation**
Arial	Investigation into the impact of	**Investigation**

Table 2 Examples of commonly employed font types and their appearance when "bold" is applied and a "shadow effect".

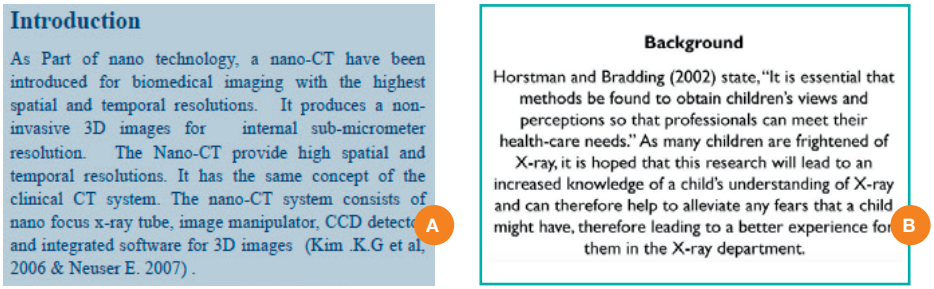


Figure 15 Example of prose to demonstrate how justification of text enhances the written work.

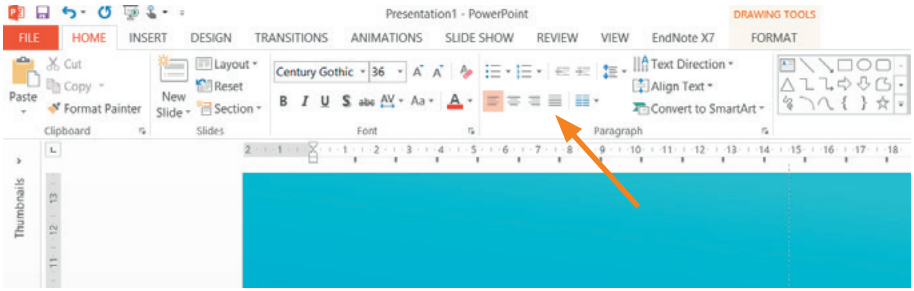


Figure 16 Location (red arrow) of the icon to facilitate the formatting of text to justification mode.

It is recommended that line spacing should be slightly greater than single spacing to improve readability [4, 15]. The colour applied for text is important and needs to be seen clearly against background colours and graphics, figure 15 (a) demonstrates a use of colour tones to differentiate between a heading and the text in the section. Section headers need to provide a key point of focus.

The poster layout will benefit from symmetry which is more visually attractive and the use of less text and more graphics. A poster is a visual display and whilst you may be wish to capture great detail from your research do not be afraid to edit out large amounts of text and consider how a graphic or chart may convey the same content. Graphics will draw the attention of the audience and often aid in remembering the actual poster/abstract on display, graphics when included appropriately can also support the explanation of what may be a complicated process or concept [6, 11 15].

Figures, Tables and Graphics

An audience is not likely to spend much time on a poster that does not have a sufficient number of graphics to support the text therefore the inclusion or images in the form of images, tables and/or histograms is essential. The graphics need to be relevant and clearly linked to the text. Clearly presented graphics can have significant impact on an audience if applied and referenced appropriately. Keep tables simple as complicated tables can make the research message harder to comprehend [9, 11, 13]. The use of a focal point is also of benefit, in Figure as the audiences eye will first be attracted by the image of a happy child and then drawn to the children's art, this type of focal point attracts attention effectively [4].

A further item to consider in poster design is the "mounting" or "framing of figures or graphics". Shown below in figure 19 is an example of how by adding a dark blue border to the image the figure stands out more effectively on the pale blue background of the poster. Such border effects are highly advised.

Word limits

Within each section of the poster there needs to be sufficient information to provide the reader with an understanding of why the study was performed how it was undertaken and what the principal findings were. Some poster guidelines will include minimum word content requirements [12]. A balance is required between under and overcrowding of text.

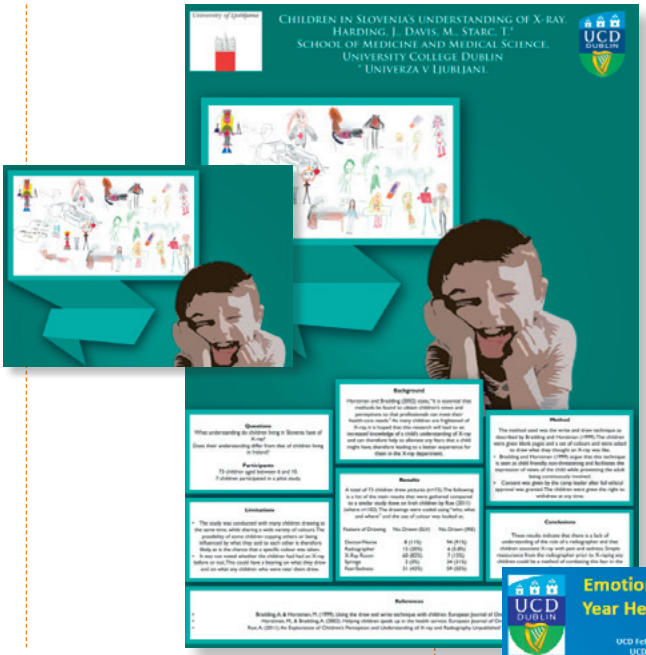


Figure 17 Demonstrates and example of strong graphics in poster design. Whilst the poster contains a limited word presence the images leave a lasting impact upon audience members.

Figure 18 The use of a graphic (indicated by the red arrow) which clearly indicates the subject covered in the poster at "first glance".

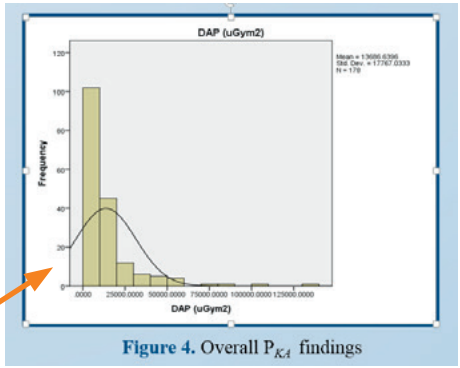


Figure 19 Example of mounting an image at the image/template interface identified by the red arrow.

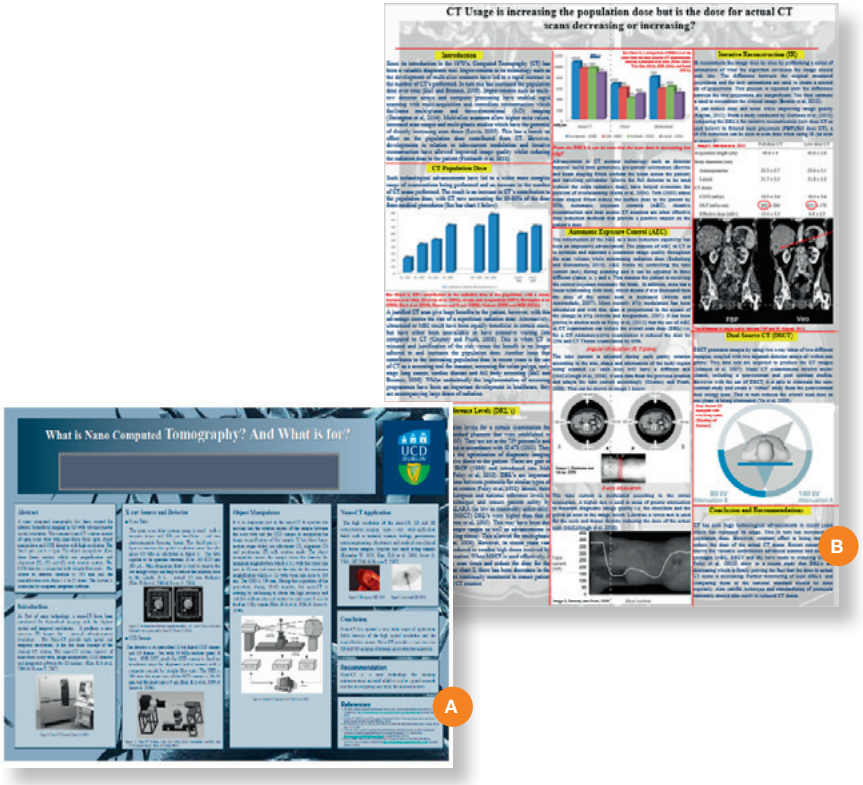


Figure 20
(a) An example of borderline too few words
(b) An example of word overcrowding.

Copyright

Copyright can be defined as "the exclusive and assignable legal right, given to the originator for a fixed number of years, to print, publish, perform, film, or record literary, artistic, or musical material" [18]. Permission must be sought to use images, graphics etc. which have a copyright status. Many large publishing houses have dedicated customer help links to support authors wishing to reuse previously published material. For example Elsevier Publications are partnered with the Copyright Clearance Center's Rightslink service which offers a weblink to attain permission to use and republish material from Elsevier, similar systems exist across publishing groups. To include material without the appropriate permissions is unacceptable and is a difficult area for students but regulations on copyright are clear and must be adhered to.

Whilst copyright protects creative and/or artistic artworks including photographs and can only be used with the copyright owner's permission you can use images you have drawn or photographed yourself. The origin and property of images must be clearly stated e.g. © "Department of St Elsewhere" Chicago Medical Centre/ USA 2014 or for images already published, the full journal citation must be given ©"Mc Nulty J et al. (2010) MRI of Brain. Radiography. Vol 11: 5-15". Any unreferenced image will be assumed to be the property of the authors. [12].

Product and company names

Many scientific committees in their instructions to authors will ask for posters to be non-promotional and non-commercial in nature with manufacturers named only if essential for example it is sufficient to state that images were acquired "at 1.5 T" or "using a 64-slice CT scanner" without mentioning the manufacturer [12]. Once a company is named the product must be appropriately referenced and trademark stamps be used as appropriate.

Ethical standard

Research with human and animal subjects requires either ethical approval or an ethical waiver, once the methodology meets the criteria for a waiver, from an appropriate ethics committee prior to commencement of the study. The poster submission must acknowledge such compliance [12]. Posters reporting the results of experimental studies on human subjects must include a statement to the effect that informed consent was obtained from participants [17-21].

Patient confidentiality

In all instances patient confidentiality must be protected. No names, hospital identifiers or any other information that allow the patient to be identified should appear in illustrations, images, videos, or texts. Authors also need to remember that in cases of rare or specific diseases, patients can potentially be identified by descriptions if the work place of the

authors is mentioned therefore particular caution is required [17-21].

Assessment Criteria for Poster Presentations

There are numerous considerations that require attention when designing a poster, all matters previously discussed are key elements to success. Attention to detail is essential so avoidable errors do not negatively impact upon the finished product. In the final section of this chapter a brief outline of criteria commonly used in the assessment of posters is given. Poster evaluation is commonly split into criteria related to the poster content and design (table 3), the second evaluation criteria focusses upon how the presenter can defend their poster (table 4).

A number of tips when attending a poster defense include: arrive on time; dress professionally; smile and welcome interaction from audience members who have given time to listen to the defense and shown an interest in the work; have business cards at hand or handouts of the poster with contact details.

The criteria outlined are not exhaustive and would alter for individual poster submissions however student awareness of how an evaluator may view the poster they design is aimed at supporting authors in preparation of their work.

Content	Scientific content of poster, analysis, quality and relevance of supporting images
	Integration of theory and practice
	Critical discussion and awareness of professional, social and ethical issues.
Accuracy	Accuracy of images, statements, facts presented etc.
Information Literacy	Correct use of the stipulated referencing system in text and reference list
	Quality, quantity and relevance of references
	References used appropriately
	Complete reference list
Presentation	Visual impact of the poster
	Choice of font style, size, colour, spacing
	Use of headings, captions, figure legends
	Clarity and accuracy of grammar and spelling, fluency of expression
	Relevance to target audience

Table 3 Example of criteria which may be applied to evaluate a poster presentation

Communication: Oral Presentation	Verbal and non-verbal communication skills Ability to explain aims, objectives, findings and conclusions drawn in a clear/concise manner Accuracy of oral presentation vis a vis poster Use of graphics/text to summerise key ideas.
Communication: Defense of Poster	Familiarity with case/topic chosen Ability to answer all questions in a professional, clear and confident manner

Table 4 Example of criteria which may be applied to evaluate a poster defense

Summary

The prospect of preparing a poster can seem daunting to a novice researcher. Allow adequate time for preparation and when reviewing the final product for errors do not perform this task when fatigued. Attention to detail is important as posters are visual displays which when printed for presentation or presented in an electronic format are seen in a magnified manner and small errors become far more visible. The process of visual perception and how the audience reviews a poster is complex however a useful diagram demonstrating the development of perception when an observer is given an image or in this case a poster to look at is shown in figure 21, adapted from work by leading vision scientists [22].

The diagram outlines the time taken for an audience member to view your presentation findings and demonstrates the importance of having focal points and key headings which you want your audience to fixate upon.

This chapter has aimed to provide a step by step guide on aspects of poster design presenters need to be aware of and consider when preparing scientific submissions. The practical tips given apply regardless of the technology used to prepare the poster, whilst it is acknowledged some technical points included will vary with technology. Good quality poster presentations are essential and “first authors” need to respect that they are representing their own work but also the reputation of their co-authors and their associated professional affiliations.

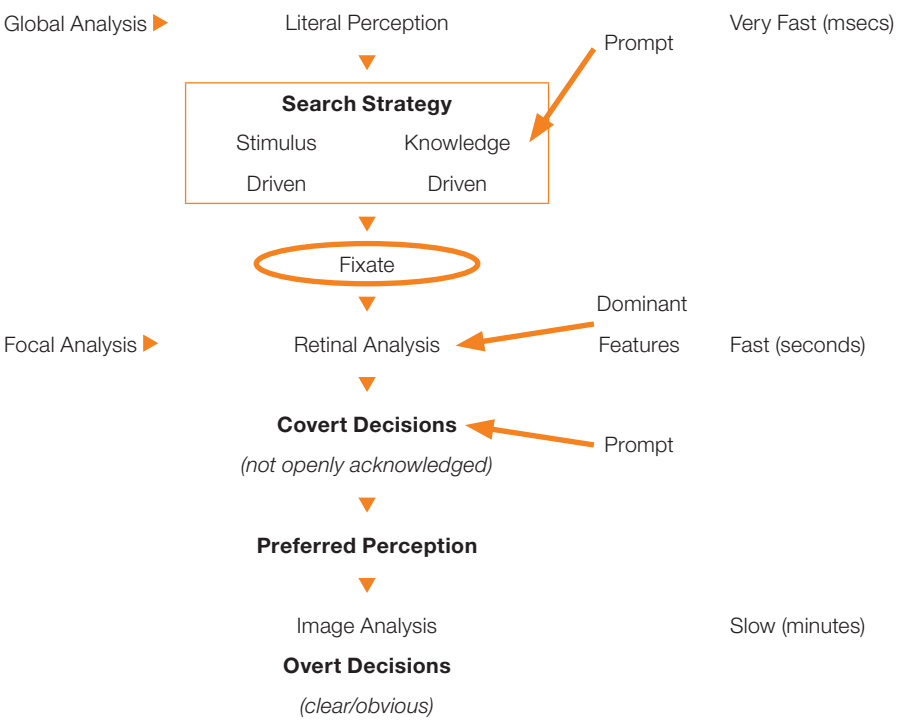


Figure 21 A schematic diagram of the development of perception (22)

References

Taggart HM, Arslanian C (2000). Creating an effective poster presentation. Orthop Nurs. 2000 May-Jun; 19(3):47-9, 52.

Sherbinski LA, Stroup DR (1992). Developing a poster for disseminating research findings. AANA J 1992 Dec; 60(6):567-72.

Moore LW, Augspurger P, King MO, Proffitt C (2001). Insights on the poster preparation and presentation process. Appl Nurs Res. Vol 14 (2): 100-4.

Murray R, Thow M, Strachan R (1998). Visual Literacy: Designing and Presenting a Poster. Physiotherapy: Volume 84 (7), 319-327.

Jennings D (2012). Assessment: An introduction to effective poster design and construction. UCD Teaching and Learning/Resources. *www.ucd.ie/teaching*

Ellerbee S (2009). An artistic View of Posters. Newborn and Infant Nursing Reviews (www.nainr.com): Volume 9 (2): 109-110.

Hoffman D (2000). Visual intelligence. Chapter 5: The day colour drained away, 107-138. W.W. Norton & Company, Inc: New York.

Harms M (1995) How to …prepare a poster presentation. Physiotherapy: Vol 81, 276-277.

Brown BS (1996). Communicate your science!...Super seminar slides. Trends in Cell Biology: Vol 6(2): 74-76.

Brown BS (1996). Communicate your science!...Writing research reports. Trends in Cell Biology: Vol 6 (4): 158-160.

Brown BS (1997). Poster Design – Six points to ponder. Biochemical Education: Vol 25 (3): 136-137.

European Society of Radiology (2016). *https://www.myesr.org*

Wipke-Trevis D, Williams D (2002). Preparing and presenting a research paper. J Vasc Nurs Vol 20: 138-143.

Dwyer M (1995). A guide to the Harvard referencing system. British Journal of Nursing: Vol 4 (10): 599–602.

Rupnow J, King JW (1995). A primer on preparing posters for technical presentations. Food Technology. Nov: 93-102.

Oxford English Dictionary: *http://www.oxforddictionaries.com/definition/english/copyright*

European Commission (2010). European Textbook on Ethics in Research. *http://ec.europa.eu/research/science-society/document_library/pdf_06/textbook-on-ethics-report_en.pdf*

World Health Organisation (2011). Standards and Operational Guidance for Ethics Review of Health-Related Research with Human Participants. *http://apps.who.int/iris/bitstream/10665/44783/1/9789241502948_eng.pdf*

European Commission: EURAXESS Researchers in motion. European Charter for Researchers *http://ec.europa.eu/euraxess/index.cfm/rights/europeanCharter*

U.S. Department of Health and Social Services. HHS.gov: Nuremborg Code. *http://www.hhs.gov/ohrp/archive/nurcode.html*

United Nations Educational, Scientific and Cultural Organisation. Universal Declaration on Bioethics and Human Rights (UNESCO, 2006). *http://unesdoc.unesco.org/images/0014/001461/146180E.pdf*

Beutel J, Kundel H, Van Metter R (2000). Handbook of Medical Imaging.Vol.1 Physics and Psychophysics, Chapter 18: Visual Search in Medical Images, 837-855. SPIE: Washington: USA.

Presenting at Conferences

Peter Hogg[1], Andrew England[1] and John Thompson[1,2]

1. School of Health Sciences, University of Salford, Salford, UK
2. University Hospitals of Morecambe Bay NHS Foundation Trust, UK

Introduction

This chapter helps you prepare for presenting work at a conference. It comprises of hints and tips from the authors, based on their personal experiences.

A conference is a meeting of people to discuss a topic of common interest. Medical imaging conferences cover a broad range of topics; including political, technical and scientific. It is also an opportunity to showcase new techniques, new methods or unusual findings. Specific to medical imaging there are numerous conferences throughout the world ranging from small (eg several hundred delegates) to large (tens of thousands of delegates). The largest in Europe is the European Congress of Radiology (ECR, *https://www.myesr.org/*) and the largest in the world is the Radiological Society of North America (RSNA, *http://www.rsna.org/*).

Medical imaging conferences have various components that usually include an exhibition by industry, interactive poster sessions and oral papers. The exhibition is where the manufacturers display their new products, and for large conferences fully assembled state of the art machines are available for your inspection. Manufacturers often have lots of staff available to help with technical and sales questions. They are a valuable source of information for students and clinical staff. The poster sessions come in two forms, electronic and physical. Electronic posters (computer/web-based) have gained much more prominence in recent years, not least because often after the conference they remain available for all to access. A digital object identifier can be an added bonus of an electronic poster. A traditional poster session comprises physical print outs of the posters which are pinned to poster display boards. Please see the chapter on how to create these. This chapter is concerned with oral papers. Typically there are many oral papers, and each sits within a specific theme, for instance an imaging modality (eg PET/CT), body part (brain) or pathology (thyroid cancer). In some conferences there can be over a thousand oral presentations, and this means that there will have

to be many parallel oral papers sessions, forcing the delegate to decide which they wish to attend. It is important that the delegate has decided what oral sessions they wish to attend prior to arriving at the conference; otherwise they can become overwhelmed by the choice, leading to precious time being lost reading the conference booklets while trying to decide what to see. Normally the conference booklets, which list all sessions, poster/paper titles, times and venues, are available as PDF downloads well in advance of the conference to allow for planning. For some conferences there are applications that delegates can use to download this information onto their mobile phones, to carefully plan which session they want to see and allow for easy reference throughout the conference itself.

Different people want different things from a conference. Manufacturers want to promote and sell their products, encourage customer loyalty through pre and after sales support and provide benevolent services too (eg free education). These activities manifest themselves in many ways. For instance, within the exhibition itself their staff will offer technical information about their products; they also provide lectures which go well beyond the sales pitch. Manufacturers are at the cutting edge of technical innovation and they place significant financial investment into future products. Whilst their research and development work is a closely guarded secret they do share information about discoveries and give insights into what might be over the horizon, through lectures for all to attend. Also, for their current and potential customers, they provide activities and sessions just for them. These come in various forms, including whole evening events of oral papers, discussion forums and food. Often these are referred to as ‘user groups’.

Aside the technical exhibition there is the scientific session, comprising posters and oral sessions. Both of these allow researchers to share their work and receive feedback on it. The purpose of sharing work is to influence others, such they might adopt some of the ideas into their [clinical] practice. Receiving feedback on your research is important, as it allows for experts in the field to comment on your work when it is presented. Whilst this process can be challenging, or even intimidating, it can help with identifying errors in the work which might be corrected before the work is published into a journal. It can also give you ideas for future research projects. Good work should not stop at being presented in a conference; it should be written up and submitted to a journal as a paper. Journals have a much greater reach than conferences; consequently work in journals is more likely to influence change.

Conferences are excellent for professional networking. They allow those with common interests to come together to discuss common problems and solutions. Networks can be formal or informal. Formal would typically involve a professional/ scientific body or manufacturer providing a forum for debate, sharing of research and sharing of practice. Normally these events would be organised by a committee, the composition of which would have the common interest at its heart. Often such forums and committees produce guidelines, which can inform practice. An informal network would involve people coming together without the need of committee structures, but the purpose is the same.

Preparing to present at a conference

If you have not presented at a conference before then it is worth your while to take advice and support from somebody who has. They will help you identify the things that need to be done, when and how. They will help you avoid problems and probably speed up the process. In doing so their input will make the whole process run more smoothly and this should result in a better experience for you.

If you wish to take study leave to attend and/or seek financial support from your employer then at the onset you should seek permission from your employer. Your line manager should be able to advise on what process you must engage with to seek permission and support. Internal processes for granting permission and support vary greatly between institutions, but broadly they fall into two categories – formal and informal. The formal option normally involves completing paperwork, to explain what you want, why you want it, and what the cost is. The paperwork is often scrutinized by a committee who decide whether or not to support you, in full or in part. The informal option is becoming less common, and this happens at local/department level. Here your department or an individual in that department decides, and the decision making process might not involve completing paperwork. If you use holidays and your own finances to attend then employer permission will not be necessary. Many conferences have 'early bird' fees, which can offer a good reduction on the conference fee. You also need to consider whether you want or need to attend the whole conference. In many cases, you may only need to be there on a single day to deliver your oral presentation or defend your poster, but for an international conference, anything other than a full attendance may be impractical.

At the onset it is important that you know what you want to present at the conference. Most people who present for the first time typically do a single poster or single oral paper. If it is your first time then don't overstretch yourself by committing to several. Posters and oral papers can be mentally demanding and

some people find them stressful. See how the first one goes, and if you enjoy it then do more than one next time. In many conferences you will see certain 'names' crop up many times in the oral and poster sessions. They may do several, possibly in excess of ten. Typically these are experienced researchers and presenters and they have been doing this for many years.

It is important that you allow plenty of time to prepare for a conference presentation, poster or oral. Research work takes a lot of preparation time, as you will have conducted the research, analysed the data and understood what it means well in advance of the conference. Depending upon the rigour of the research it would typically mean the work would have commenced at least 12 months prior to the conference. If there are several co-authors working on the same presentation, it can also take extra time to come to a mutual agreement of the content. This will be discussed further in the next section. Some oral presentations (eg 'review and invited' papers) require a lot less time. Here experts outline key issues in a particular area, using already published material, often along with some of their own observations. The people who deliver these are usually at the leading edge of their subject, and they can put together their presentation in a fairly short time, perhaps within a few months. Review/invited papers will be explained in detail later in this chapter.

Coming back to what you wish to present at the conference, it is important that you know the topic area(s) well. You should have read widely about that topic; you should be aware of work similar to yours and be familiar with it. You should build on that work and have a clear idea where your work fits within what we know already and what is already published. Unless your presentation is 'political', you should minimise anecdote and personal opinion. For scientific presentations you can make yourself look silly and poorly informed if you do not do this. If you use somebody's research findings or ideas within your own presentation you must acknowledge them formally (use references, ideally at the bottom of the slide, but avoid cluttering this with too much reference information). It is also a good idea to anticipate the questions or comments that may arise – what are the limitations of your work; can you justify your methodological choices?

Co-author and acknowledgements

Co-authorship can be a major source of tension, particularly when people are excluded. They may feel aggrieved and even allege academic misconduct. To minimise the chance of this occurring you should agree the authorship at the onset. First let's consider acknowledgments. People are acknowledged for helping out, for instance helping with data collection, typing results into a computer and maybe helping to identify volunteers for research studies. Strictly

speaking they make no intellectual contribution to the work and are easily differentiated on this basis. By contrast co-authors do make an intellectual contribution, and this can come in many forms. For instance they may have: made a substantial contribution to conception and design, acquisition of data, or analysis and interpretation of data; drafted the work or revised it critically for important intellectual content; whatever their involvement they should have seen the final version of the work and approved it. All authors should have ownership of the work and all of them should be able to deliver the conference presentation or defend the conference poster. It is equally bad academic conduct to have a co-author on a paper that is not deserving of authorship.

Full paper or abstract?

When you know what you wish to present at the conference the next thing to find out is what do the conference organisers need from you in order to decide whether your work is good enough or not? Typically an abstract is needed; occasionally a full paper is required. An abstract is a short summary of your work, normally 250 words or less. It captures in a concise fashion the key elements of your work. For research the typical abstract structure would be: purpose, method, results, conclusion. If you wish to present a review paper (see later in this chapter) then you must create the structure yourself. For abstracts you must select your words very carefully, as 250 or less isn't much to convey what your work is about in order to convince the panel who will judge it and decide on whether it should be presented. Your abstract should describe what your work is about. It would use accepted abbreviations and ideally use the controlled vocabulary of the Medical Subject Headings (MeSH)1. Full papers are not common, but if they are required they could be in the region of 2500-5000 words; they would be like a journal article. Whatever the format, you should look at the conference web site and find the instructions that are set out for would-be presenters. Follow that advice to the letter.

Once the abstract/full paper has been written it must be submitted to the conference; this is normally done through a web-based submission system. As part of the submission process you would normally be expected to tick boxes about ethical compliance and also the transference of copyright in the event of your work being accepted. Since there are often many categories (eg brain) for posters and oral sessions, when you submit your work for consideration you should also tick the box for which category it fits within. Finally, many conferences require you to declare any conflict of interest. An example of a conflict could be that your work is financially supported by a company that has a vested interest in your work. Ensure that you are aware of the abstract

submission deadline, and also make a note of any future deadlines – some conferences require you to upload a poster or oral presentation in advance of the conference.

If you are submitting an abstract for invited, keynote or eponymous lectures you might also be required to submit a short biography about yourself. More information about these sorts of lectures are given later in this chapter.

Once your abstract or full paper has been submitted it will be judged, usually on a double blind basis, by two of more members of the conference scientific committee. Double blind means the judges will not know who you are and you will not know who they are. Often the judges use a numeric scoring system and also free text comments. It normally takes 2-3 months to find out whether your work has been accepted or rejected. The outcome of this process is as follows: oral paper – accept, reject or offer as a poster; Poster (electronic or physical) – accept or reject. If your paper is rejected as an oral paper and accepted as a poster do not be too upset as posters are excellent ways to communicate your findings, they appear in the abstract books and unlike oral papers, an electronic poster has the benefit of being available for others to see after the conference and a physical poster can be displayed in your place of work. Confirmation (accept or reject) comes as an email. In some cases you have to acknowledge that you will present the poster/oral paper. Also there is normally a requirement that you register as a delegate for the conference by a specific date. Failure to do so could mean that your poster/oral presentation is automatically withdrawn.

English

The official language of many conferences is English. Whether you are an indigenous English speaker or not you should consider getting help with written and spoken English. Meanings can get lost through poor use of English, the abstract might be rejected and/or your oral/poster presentation might be misunderstood.

Which conference should you attend?

You must first make a decision on which conference to attend. First and foremost the conference must be relevant to your work. Audience size might be important too, as there is nothing more disheartening than presenting your work to small numbers of people. Audience size at the European Congress of Radiology can be quite large, often being in the low hundreds. Citation is important too, and this often comes with conferences that publish the abstracts (or full papers) and where a conferences abstracts book is available with ISBN; better still that the abstracts (or full papers) are published within a peer review journal. In both instances your work is available

beyond the conference itself, and possibly searchable through databases such as Medline, consequently your work stands a better chance of getting cited. Other factors to bear in mind are cost and location; some conferences can be cheap to attend and the registration fee for the European Congress of Radiology for students can be around 50 Euros. By contrast other conferences can be several hundred Euros. The cost of getting to the conference venue obviously depends upon location and transport options to get there. Most people present at a national conference before presenting at an international one.

Types of oral presentation

So far this chapter has considered general information about conferences and presenting posters/oral paper at them, from here we shall only consider oral papers.

There are many types of oral paper within a conference: examples include proffered, invited, keynote, eponymous, highlights and debate. Proffered is the most common by far; these comprise the presentations given by those people who submitted their abstracts/full papers. Their length varies from 5-6 minutes to 12-15 minutes. Time is also allowed for questions. The other papers are by invitation. Here the conference committee select topics and people to give them. Normally all of these would be given by individuals who are well known scientists/clinicians in their field. Invited papers are typically associated with a set of proffered papers; if the theme for the session is brain (perhaps focused to one pathology) then the invited paper will be about that. The invited paper will summarise the literature in a highly specific field and the presenter will usually use examples from their research too. Their length varies from 20-30 minutes. Debate papers come in two forms, for and against. These tend to be short (eg 5-15 minutes) and they present key arguments about the positives or negatives of a contentious point. After the papers have been given the audience and a panel of experts cross examine the people who gave the two papers and at the end there can be a vote, to decide who won. The voting is usually light hearted, however the cross examination after the for/against papers have been given can be intense. Eponymous lectures are named after people (eg Marie Curie Lecture) or places, and typically they can be up to 1 hour duration. They are big invited presentations and follow the same format; they are given by well know people. They can also be an incentive for delegates to attend a conference. There are not usually more than a few eponymous lectures in a conference, typically 5 or less depending upon the size of a conference. Keynote lectures are usually given by world leading figures and again follow a similar format to invited and eponymous presentations, being up to 1 hour duration. Depending upon conference size there might be one or more key notes. The final type of presentation is highlights. This is the final

presentation of the conference and everybody is invited to attend this. Normally they occur just prior to the conference closing ceremony. They tend to be delivered by people well known within the conference, for instance these people would have published a fair number of journal papers and have presented a fair number of posters and oral papers (various types) at the conference you are attending. They will be well known and respected in that conference and will likely be a member of the conference organising/scientific committee.

Visual aids

Most people use visual aids to help deliver their presentation and you would be well advised to do the same. You will need to use some form of generic presentation software (eg PowerPoint) and the conference itself will likely inform you what that will be. Do use what they say, do not use something else as they might not be able to accommodate you. Be mindful of the colours you select when creating your slides, as some of your audience might be colour blind or have dyslexia.[2,3] There is lots of online help for tips on how to make good PowerPoint presentations.[4]

When you have created your slides you might be able to submit them over the internet prior to attending the conference. If this is not the case then do carry copies of the slides in multiple forms (2 or more memory sticks and email them to yourself) – just in case. On arrival at the conference you will need to check them in, if you have not done so already over the internet. When checking them in (this tends to occur in a place called the 'speaker ready room') do review them on a conference computer to make sure that no formatting errors have occurred.

Try to avoid having more than 2 slides per minute. The first slide should be the title slide; it will include the title of the presentation and indicate the authors and their affiliations/institutions. It is a good idea to follow this with an 'overview' slide; this would simply and concisely outline the main headings within your talk and its structure. If you use animations (within a slide) do not use overly elaborate ones or they might be distracting to your audience. For each slide it is a good idea to reveal 'a bit at a time', rather to show everything at once. This helps your audience assimilate the information in a fashion which you think is logical. Choose the words you use on your slides carefully: rule of thumb – keep them simple and specific to the subject at hand. Technical words are fine, so long as they are commonly used in that field. Avoid having too many words on a slide and use acronyms/abbreviations with caution. Pictures paint a thousand words, so consider using photographs and diagrams. Charts are a valuable way to explain quantitative data.

The inclusion of video and sound into a presentation can be useful and powerful, however on occasion they might not work. So make sure you have tried them in the lecture theatre the day before and if necessary consider alerting the technician at the back of the room about this. Charts/graphs should be clear, they should be large enough to be seen from anywhere in the lecture theatre and they should be labelled adequately. When using a graph/chart in your presentation you should explain what it is about, explain the axes and finally point out clearly what your audience should be looking at in the chart/graph. If you do not have the time to do all of this in your presentation then ask yourself, 'do I really need this graph/chart in my talk as it might not mean anything to my audience'. Flow charts can be helpful to explain the order in which things occurred in your research, they can be much better than chunks of text.

Check the data in your slides. If you have a table then make sure the numbers add up. If you have percentages make sure the numbers add up to 100. Keep your data simple. Do not include spread sheet dumps comprising large amounts numbers. Your main ambition is to convey understanding and information. Keep your data (and storyline) as simple as possible.

Structuring your presentation

The easiest structure is for proffered papers for research – introduction including rationale, method, results, discussion and conclusion. Do you not use anecdotes; do not use personal opinion. Invited, keynote and eponymous lectures need to have a structure imposed into them, and they logically comprise beginning, middle and end. The beginning gives background to the topic and purpose of the presentation, typically it would justify why this is the right time for this presentation to be given. The middle would comprise a set of important issues to be explored; the issues would unfold in a logical and progressive order. The end would summarise the key points raised and also, if required, explain what recommendations could arise.

Rehearsing your presentation

It is highly recommended that you do this. First do it by yourself, in front of your computer. Speak aloud. Get used to the sound of your voice. Then, if available, do it in a classroom or similar. Project your slides, use a pointer and again talk aloud through your presentation. If there is a microphone use it, get a feel for it. Then try it in front of your colleagues and ask for feedback. This should also tell you whether or not your presentation is the right length: being nervous can cause you to involuntarily speed up, so the more practice you have, especially in front of others, the better your final presentation will be.

Your audience

Prior to attending the conference find out as much as you can about the audience, as you do not want any surprises on the day. What language will you be expected to talk in? What do they know about your topic – are they novice, intermediate, expert or a mixture. A mixture is always a challenge because it is difficult where to pitch the level of the presentation – too high and the novices will get confused, to low and the experts will get bored. What are their professional backgrounds? How many will likely be in your audience? Incidentally large audiences can be easier than small ones, because in large audiences people feel intimidated and don't want to ask questions of you after your talk. How will your audience be seated – traditional lecture theatre style or something else? Finally, it might be worth finding out whether there will be formal evaluation of your presentation. At some conferences the audience use their mobile phones to rate your presentation, at the end of the session and the results are projected to the screen – this can be intimidating.

The lecture theatre

Know which room you are to present your work within and ideally check your slides in that room the day before. Try everything out. See whether they have an electronic pointer and become familiar with it. Do not hold pointers at arm's length because nerves make your hands and the pointer shake. Many lecture theatres have a system of coloured lights that only you can see when you are presenting; an amber light means you have a short time left in which to finish; a red light means stop right now as you have reached the end of your allotted time. If there is a microphone try it out and get used to it. Work out where your mouth should be to get maximum audibility. On the day you present it is advisable to go to the room 15-20 minutes before your session starts. Tell the chairman you are there. They may ask you a couple of questions about you, and if you are lucky you might get a 10 second introduction before you start your presentation.

If the room is a traditional lecture theatre then you will likely have a lectern to present from. This might be on a stage. Typically people stand behind the lectern and present from there. Occasionally people stand right at the front of the stage and even within the audience to present; for this you will need a roving/ clip on microphone and you will be experienced and confident.

Speaking

Talking to an audience can be frightening. If you are frightened your voice may change, you might find it hard to think and communicate. You might fidget. All of this distracts your audience and it can have a negative impact on you. You need to develop a strategy to deal with nerves, in order to minimise them

and also minimise their effect on the quality of your presentation.

For your first few presentations you will hear your own voice for the first time whilst speaking. It can be an unusual experience at first, so do try out a microphone somewhere else before doing the presentation. When talking making sure your voice is audible. Don't mumble. Don't talk too fast. Don't talk in a monotonic tone, add intonation where appropriate. Don't feel you need to talk all the time, use silence from time to time. Silence is a powerful way of communicating sometimes. Importantly, believe in yourself and your work and let this show through to your audience.

Humour can be good, if done well, however humour can be difficult and also culturally specific. If you are not a born comedian then avoid humour, or your jokes might not attract laughs and you could make yourself look silly. As your experience of doing conference presentations grows, you may gain the confidence to introduce humour.

Let your personality show through, be yourself and relax. As appropriate within your presentation, smile, frown, look sad, etc. Have an open posture, don't present with your arms folded. Where you look is important too. If you look at your slides and point at your slides with the pointer your audience will look where you are looking. If you want to talk to your audience then look directly at them, look them in the eye, and they will likely look at you and not your slides. If you are at a lectern on a stage you will probably have a light on you, so they will be able to see you. Engage your audience. Entertain your audience. Your presentation is a performance. Your intention is to interest them in what you have to say. Your intention is to make them remember what you talked about a long time after your presentation is finished.

It is a good idea to have a drink with you when you are doing a talk. A small disposable plastic water bottle with the easy to drink non spill option is ideal. If it's your first conference presentation then make friends with the audio visual technician, as they will probably give you tips and look after you. Tell the session chairman this is your first presentation and they might look after you too.

Finally, have a strategy for how to answer the audience questions which come at the end of your presentation. If you are new to conference presenting then try to head off the unexpected – you don't want a tricky question. So tell the chairman to ask specific questions. Also ask your friends/colleagues to do the same. It is important that co-authors are in the conference room for your presentation and if you have a tricky question then pass the question to

one of them. Your co-authors should be prepared to defend the presentation if required. If you don't know the answer to a question then thank the person for the question and apologise that you do not know the answer.

Dress for the conference. Typically those who present will dress smart casual or business style (eg suit). Be sensitive to cultural differences, particularly when abroad.

Jet lag

Presenting at conferences isn't easy; it can be tiring and stressful. If you are to present in another time zone you might find you are to present when you would normally be asleep. Therefore, consider arriving *at least* 1-2 days early and don't party all night before your presentation.

After the conference

Reflect on your presentation and the conference as a whole. What went right – amplify this. What could be done better and how? What did you observe in another presenter that you liked? Consider adopting some of their presentation methods for the next time you do a presentation. Also, do develop your own style.

Finally update your CV, to include the conference presentation. Then write the presentation up for a journal and submit it. Journal papers have much more reach and value than conference presentations.

(Endnotes)

1 *http://www.nlm.nih.gov/mesh/*
2 *http://www.bdadyslexia.org.uk/*
3 *http://www.colourblindawareness.org/*
4 *http://www.makeuseof.com/tag/10-tips-for-preparing-a-professional-presentation*

Part 2

Empirical research conducted during OPTIMAX 2015

An analysis of the validity and reliability of a handheld ultrasound device for measuring rectus femoris muscle size.

Willemke Nijholt[a], Astrid Bakker[a], Alicia C. Bennett[b], Morten H. Borgen[c], Anne Ellermann[a], Peter Hogg[b], Patrícia T. Gamboa[d], Martine Thorskog[c], Liesl Vorster[e], Ingrid J. Aandahl[c]

a) Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, the Netherlands.
b) School of Health Sciences, University of Salford, Manchester, United Kingdom.
c) Oslo and Akershus University College of Applied Sciences, Oslo, Norway.
d) Escola Superior de Tecnologia da Saúde de Lisboa, Lisbon, Portugal.
e) Department of Clinical Sciences, Radiography, Central University of Technology, Bloemfontein, South Africa.

Keywords

Rectus Femoris
Reliability
Ultrasound
Validity
Handheld

Abstract

Background: Previous studies show that ultrasound is valid and reliable when measuring muscle size. A Philips handheld ultrasound device was released in April 2015. The aim of this study was to investigate the validity and reliability of the handheld ultrasound device compared to a conventional ultrasound device, when measuring the size of the rectus femoris (RF).

Methods: Two sonographers scanned 39 volunteers (mean age=29.3y, 26 female), once with the Toshiba SSA-660A (regular) ultrasound device and twice with the Philips hand held VISIQ device. The size of the RF (expressed in cross sectional area (CSA) was measured two ways; using the trackball on the Toshiba device and an automatic region of interest on the VISIQ device (method 1), and an ellipse on both devices using the formula π*half width*half length (method 2).

Results: Method 1 resulted in an intraclass correlation coefficient (ICC) of .811 with a 95% (confidence interval) CI of .773-.837 (inter-rater reliability) and .907 with a 95% CI of .822-.951 (validity). The ICCs of method 2 were .787 with a 95% CI of .593-.888 (inter-rater reliability) and .867 with a 95 % CI of .746-.930 (validity).
Conclusion: VISIQ is a valid and reliable device for measuring RF-CSA. In clinical practice VISIQ could be used for measuring RF-CSA, consequently it could be an economical and easily portable technology for use in both clinical and residential settings

Introduction

According to the profile of ageing by the United Nations (UN) the percentage of the worldwide population over the age of 65 in 1980 was 6.0%, and by 2013 had risen to 8.0%. The UN predicts that this percentage will increase to 15.6% by 2050. (1) A condition of ageing is sarcopenia. The term sarcopenia was first used by Rosenberg in 1989 and literally means poverty of flesh.(2) Sarcopenia is now defined as a geriatric syndrome, related to the decline of muscle mass and muscle function.(3) In the study that Cruz-Jentoft (2014) conducted on adults over the age of 50; 1-29% living in community dwelling populations, 14-33% in long term-care populations and 10% in acute hospital care population, developed sarcopenia.(4) Early life developmental influences, poor diet, ageing, sedentary lifestyle, chronic diseases and certain drug treatments are all contributing factors to the development of sarcopenia. An impaired state of health is common amongst people with sarcopenia, the increased risk of falls and fractures, disabilities, loss of independence and mobility disorders all increase the risk of death. Through the measurement of muscle size the risk of falls and injury can be determined early.(4)

Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are considered to be the "gold standard" for measuring muscle size. However, high costs, long scanning times and restricted accessibility of MRI, as well as the ionizing radiation dose caused by CT, are some drawbacks of these techniques.(3) Ultrasound does not use ionizing radiation, is relatively inexpensive, and allows for a faster diagnosis, in comparison to CT and MRI. Literature shows that ultrasound is another valid and reliable scan method for measuring muscle size. (6) Giles et al. (2015) determined that ultrasound is strongly correlated to MRI when measuring the rectus femoris (RF) thickness.(7) They found that the

intraclass correlation coefficient (ICC) of the mean difference between ultrasound and MRI for measuring the RF is 0.858.

A new mobile ultrasound device (VISIQ Philips medical) was released by Philips in April 2015. The VISIQ Ultrasound device is mobile, meaning the ultrasound device can be used in general health care, for example, at nursing homes and in Intensive Care Units. The VISIQ is more practical and convenient to use than the conventional Toshiba SSA-660A Xario ultrasound device because of its level of mobility. Due to the often limited mobility of the elderly, visits to health centres for imaging such as MRI and CT can be difficult. The mobility of the VISIQ means that examinations can be carried out in the homes of elderly patients. The VISIQ is more affordable when compared to the Toshiba SSA-660A. Despite the high expectations of the VISIQ, information about the validity and reliability of VISIQ in measuring muscle size is lacking.

The aim of this study, therefore, is to investigate the validity and reliability of VISIQ ultrasound device compared to the Toshiba SSA-660A Xario ultrasound device, when measuring the size of the Rectus Femoris (RF) in healthy adults.

Methodology

Study population

In this quasi-experimental study, healthy adults who took part in OPTIMAX 2015 were invited to volunteer in the study. Volunteers were selected if they met the inclusion criteria; they had to be over the age of 18 and in good general health. The volunteers were fully informed about the study procedures, the aim of the study and gave written informed consent before participation. This study was carried out over 3 weeks, at the Hanze University of Applied Sciences, Groningen, Netherlands. Before ultrasonography measurements were taken, age, height and weight were collected of all participants, and the BMI calculated. Ethical approval for the study was granted by The Medical Ethical Committee, of The University Medical Centre, Groningen (reference number: METc 2015/305).

Ultrasonography measurement

Measurements of the RF were obtained using a Toshiba SSA-660A Xario ultrasound device (Toshiba Medical Systems Corporation, Tochigi-Ken, Japan) and a Philips VISIQ ultrasound device (Philips Healthcare, Bothell, United States).(8)assessing its concordance with dual energy X-ray densitometry (DEXA The transducers used were a curved array transducer, type C5-2 on the VISIQ and a curved array transducer, type PVT375BT on the Toshiba SSA-660A. A fixed scanning protocol was used on both devices; frequency 11Hz, gain 64 dB and a depth of 8 cm.

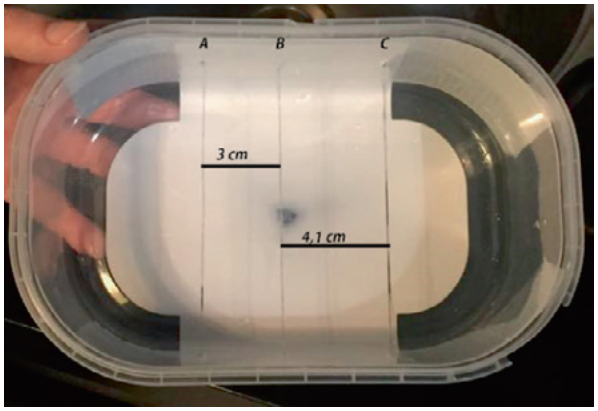


Fig 1. Phantom measurements

Measurements were acquired individually by two trained sonographers, blinded to each other's measurements. In order to investigate the inter-rater reliability and the validity, both sonographers scanned each volunteer three times, once with the Toshiba SSA-660A and twice with the VISIQ.

Operator Measurement Accuracy test

Before any study data was collected, a phantom was used to determine the accuracy of both sonographers in taking measurements from the screen data. Test scans were carried out twice, on two different days, using the Toshiba SSA-660A. The phantom contained three lines of fishing wire, placed at varying distances within gel.(9) The distance from line A to B was 3 cm, and the distance from line B to C was 4.1 cm *(fig.1)*. Both sonographers were unaware of the distances during the tests. Individually, the sonographers were tasked with measuring the distances between the lines using the Toshiba SSA-660A. While carrying out the tests, the previous measurements on the ultrasound screen were covered, making it impossible for the sonographers to see the results until all of the tests had been completed.

Table 1a and 1b show the accuracy test results from both sonographers. The results gained from the phantom show that the accuracy of both the sonographers was high as their measurements were close to the actual distances of the phantom. These results show that both sonographers had a 3% error when measuring distance A-B, and sonographer 1 had a 1% error when measuring distance B-C, whereas sonographer 2 had a 2% error. The level of error was low for both sonographers indicating their high level of accuracy.

Table 1a. Results accuracy test A-B

	Actual distance = 3 cm	
	Sonographer 1	Sonographer 2
T_0 *Measured*	3.10	3.17
T_1 *Measured*	3.09	3.10

Measured= measured distance between A-B in cm

Table 1b. Results accuracy test B-C

	Actual distance= 4.1 cm	
	Sonographer 1	Sonographer 2
T_0 *Measured*	4.23	4.21
T_1 *Measured*	4.12	4.20

Measured= measured distance between B-C in cm

Measurements of RF muscle

Imaging was conducted with the volunteer lying supine with a rested extended leg. The cross sectional area (CSA) of the RF was measured in order to determine muscle size. To establish the location of the CSA of the RF muscle, a mark between the superior patella border and the Anterior Superior Iliac Spine (ASIS) was made on the right upper leg. This point represents the maximum size of the RF muscle.

Three measurement methods were considered when measuring the CSA during this research; manual trackball, automatic ROI and ellipse equation. (8,10) assessing its concordance with dual energy X-ray densitometry (DEXA To assess RF CSA on the Toshiba SSA-660A, the manual trackball was used. As a manual trackball is not available on the VISIQ, an automatic ROI was used to determine RF CSA on the VISIQ. The last measurement was the CSA of the RF using an ellipse equation. Half of the depth (a; representing the minor ellipse axis) and half of the width (b; representing the major ellipse axes) were calculated using the equation, πab, to give the area of the ellipse. For all the three measurement methods, RF-CSA was expressed in cm^2.

Method of analysis

Data was analysed using IBM SPSS Statistics 20, for windows. Two outcomes were calculated; inter-rater reliability and validity. The inter-rater reliability was assessed by comparing the first VISIQ scan from sonographer 1, with the first VISIQ scan from sonographer 2. The validity was assessed by comparing the first VISIQ scan carried

out by sonographer 1, with the Toshiba SSA-660A scan carried out by sonographer 1. An Intra-class Correlation Coefficient (ICC) test was carried out to assess the level of agreement between both sonographers. A Bland Altman plot was constructed to visualize the spread of the data.

Results

Subjects

Thirty nine volunteers were used for this study, of which 26 were females and 13 males. The age of the volunteers ranged between 18 and 62 years. The mean diameter of the RF at its thickest point, measured by the Toshiba SSA-660A, was 2.07 cm for females and 2.31 cm for the males. The mean CSA of the RF measured using the trackball function on the Toshiba SSA-660A, was 9.40 cm^2 for the females and 12.96 cm^2 for the males. More participant characteristics are listed in Table 2.

Validity

Table 3 shows the results of the validity assessment of the different measurement methods. The comparison of the CSA of the manual trackball and the automatic ROI yielded an ICC score of .907. The manual trackball compared to the ellipse equation yielded an ICC of .802. Comparing the ellipse equations between both devices resulted in an ICC of .867.

Two outliers were identified (Fig 2a). These outliers were re-measured and the ICC tests were repeated (Fig 2b). The results of the CSA range improved from .802 - .907 to .826 - .968.

Table 2 Participant characteristics

	Mean	Min	Max	SD
Age (years)	29.3	18	62	11.92
Weight (kg)	72.49	58.10	103.60	13.32
Height (m)	1.74	1.60	1.99	.089
BMI (kg/m2)	23.9	17.80	31.90	3.87
Upper leg(cm)	44.4	41.0	51.0	2.77
RF- Diameter (cm)	2.15	1.63	3.29	.33
CSA(cm2)	10.43	2.13	19.29	2.93

Min= minimum, Max= maximum, SD= standard deviation
Upper leg = distance between Anterior Superior Iliac Spine (ASIS) and Patella, RF-Diameter= Rectus femoris diameter measured with Toshiba SSA-660,CSA = Cross-sectional area

	Initial measurement		Re-measurement	
	ICC	95% CI	ICC	95 % CI
CSA Manual trackball vs. Automatic ROI*	.907*	.822 - .951	.968*	.932 - .984
CSA Manual trackball vs. Ellipse equation*	.802*	.508- .909	.826*	.327- .934
Ellipse equations	.867*	.746- .930	.911*	.795- .957

Table 3 Validity measurements between the Toshiba and VISIQ devices of the different measurements methods

*ICC= intraclass correlation, 95%CI = 95% Confidence Interval, CSA = Cross-sectional area, ROI= Region of Interest, Ellipse= ellipse equation, * p-value <.001*

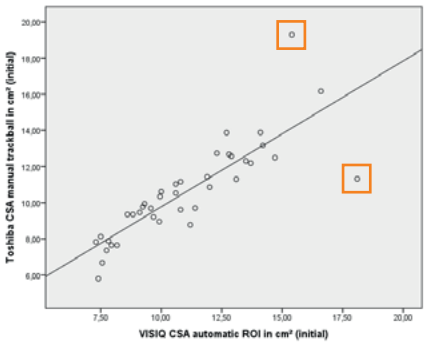


Fig 2a Scatter plot of initial measurements of the Cross-sectional area (CSA) using the trackball function on the Toshiba SSA-660A compared to the automatic Region of interest (ROI) function on the VISIQ device.

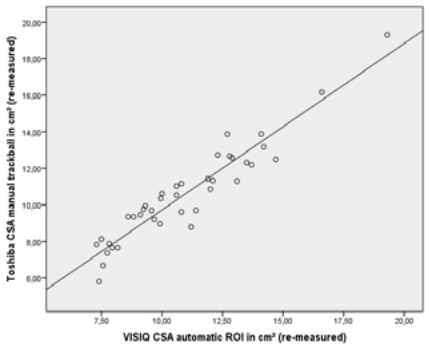


Fig 2b Scatter plot of re-measurements of the Cross-sectional area (CSA) using the trackball function on the Toshiba SSA-660A compared to the automatic Region of interest (ROI) function on the VISIQ device.

Reliability

The ICC of the CSA measured by the automatic ROI (.881) and the ellipse equations (.787) carried out by the two sonographers (Table 4), show a strong positive correlation. The correlation increased to .905 and .842 respectively after re-measurement. A Bland Altman plot illustrates the spread of the differences of the measurements between the two devices, with a systematic error of -.29 and limits of agreement between -3.10 and 2.52 (Fig 3).

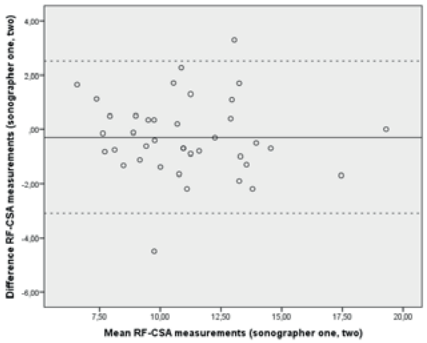


Fig3 Bland Altman plot between sonographer one and sonographer two measurements of RF-CSA with the automatic ROI after re-measurement. A positive value indicates that the measured value of the RF-CSA of sonographer one is higher than the measurement of sonographer two.

	Initial measurement		Re-measurement	
	ICC	95% CI	ICC	95 % CI
CSA-ROI	.881*	.773-.837	.905*	.820-.950
CSA- Ellipse	.787*	.593-.888	.842*	.701-.917

ICC= intraclass correlation, 95%CI = 95% Confidence Interval,
*CSA = Cross-sectional area, ROI= Region of Interest, Ellipse= ellipse equation, * p-value <.00*

Table 4 Inter- rater Reliability

Discussion

The aim of this research was to investigate the validity and reliability of the VISIQ compared to the Toshiba SSA-660A for measuring the CSA of the RF. Results show that the level of agreement between the sonographers (ICC between .787 to .881) and the validity of the VISIQ compared to the Toshiba SSA-660A (ICC between .802 to .907) are both excellent.

Three measurement methods were considered for measuring CSA during this research; manual trackball, automatic ROI and ellipse equation. In accordance with previous studies, e.g. Reeves et al.(2004), our study considered the manual trackball CSA measurement as the gold standard.(11)disuse and ageing. The considered 'gold standard' for cross-sectional area measurements of muscle size is magnetic resonance imaging (MRI Our study is the first to use an automatic ROI to determine the RF CSA. A disadvantage of this method is that it is impossible to delineate the edge of the muscle because the ROI has fixed borders. Despite this

limitation the correlation between the trackball and the automatic ROI is high (ICC .907) (table 3). An automatic ROI and an ellipse equation were also used to determine CSA. ICC values of .802 for the ellipse equation and .867 for the automatic ROI suggest there is a strong correlation between the trackball and the ellipse measurements. Awadh et al. (2006) suggested that an ellipse measurement can be used to measure the CSA of the heart as a valid and reliable measurement.(10)

On initial analysis, two outliers were identified (Fig2a). After the outliers were investigated and subsequently re-measured (Fig2b), the ICC RF CSA (Toshiba) versus the automatic ROI measurement (VISIQ) improved from .907 to .948. Prior to analysis, we recommend that the ROI and ellipse positions should be reviewed to ensure placement accuracy. Another explanation for the outliers may be due to the difficulty of measuring the CSA on the VISIQ. The VISIQ has fixed borders which restrict measurement parameters of the muscle.

Strengths

Confidence in the results are strengthened by a number of factors. In this study a curved-array transducer was used on both devices. Hammond et al(2014) showed that this transducer is valid and reliable when measuring muscle size.(13) This study population is comparable to studies such as Thomaes et al (2012) (25 participants) and Seymour et al. (26 participants).(12,14) An additional strength of our method is that a blinded phantom test has been performed to minimise measurement biases between the two sonographers. The outcome of this study was that both sonographers performed similarly and consistently accurately.

Limitations

During the research some limitations of the method came to light. First; the different methods of measurements used on both devices were a limitation of the study. The VISIQ did not have a manual trackball function meaning the CSA could not be assessed in the same way as the Toshiba SSA-660A. In order to assess the CSA on the VISIQ an ellipse equation (πab) was used. An advantage of using the equation to assess the CSA of the RF is that the calculation can be applied to the scans from both the VISIQ and the Toshiba SSA-660A. The fact that this kind of calculation can be done on both devices allows the results to be truly comparable. A previous study used this equation to measure CSA.(10) Second; the CSA was measured using the trackball on the Toshiba, and the automatic ROI on the VISIQ. The automatic ROI function (ICC .907) and the ellipse equation (ICC .802) of the VISIQ were compared to the CSA measured by the manual trackball function of the Toshiba device. Even though the correlation between the ellipse equation (VISIQ) and the manual

measurement of the CSA (Toshiba) is the lowest of all, it still indicates a strong positive correlation ($p<0.001$) (Initial ICC .802, Re-measurement ICC .826).

In further research a more precise comparison can be made if the data from both devices is exported into a suitable graphics package so that ROI can be used to accurately define the edge of RF, which could potentially improve the accuracy of RF area estimation.

This study was conducted on healthy adults and may not necessarily apply to the elderly population as both functional and structural changes in muscles are common with aging. Therefore, further research in the use of the VISIQ to measure muscle size of the elderly may give more information. Similarly, to assess the use of the VISIQ for diagnosing sarcopenia in elderly, more research is needed.

Conclusion

VISIQ is a valid and reliable device for measuring RF CSA. In clinical practice VISIQ could be used for measuring RF CSA. Consequently it could be an economical and easily portable technology for use in both clinical and residential settings.

Acknowledgements

We would like to thank the Hanze University of Applied Sciences, Groningen, The Netherlands, for allowing us to carry out the research within the university and also for the use of the VISIQ ultrasound device. We are also grateful to volunteers from the OPTIMAX summer school, who participated in this study. A special thanks to Eva Gorter for her help during the data collection.

References

1. United Nations Department of Economic and Social Affairs Population Devision. Profiles of Ageing 2013 [Internet]. December 2013. 2013. Available from: http://www.un.org/en/development/desa/population/publications/dataset/urban/profilesOfAgeing2013.shtml
2. Rosenberg I. Summary comments: epidemiological and methodological problems in determining nutritional status of older persons. Am J Clin Nutr. 1987;50:1231–2133.
3. Mijnarends DM, Meijers JMM, Halfens RJG, Ter Borg S, Luiking YC, Verlaan S, et al. Validity and Reliability of Tools to Measure Muscle Mass, Strength, and Physical Performance in Community-Dwelling Older People: A Systematic Review. J Am Med Dir Assoc. Elsevier Ltd; 2013;14(3):170–8.
4. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing [Internet]. 2010 Jul [cited 2014 Jul 9];39(4):412–23. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2886201&tool=pmcentrez&rendertype=abstract
5. Malafarina V, Uriz-Otano F, Iniesta R, Gil-Guerrero L. Sarcopenia in the elderly: diagnosis, physiopathology and treatment. Maturitas [Internet]. Elsevier Ireland Ltd; 2012 Feb [cited 2015 Aug 27];71(2):109–14. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22153348
6. English C, Fisher L, Thoirs K. Reliability of real-time ultrasound for measuring skeletal muscle size in human limbs in vivo: a systematic review. Clin Rehabil [Internet]. 2012 Oct [cited 2015 Aug 18];26(10):934–44. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22324054
7. Giles LS, Webster KE, McClelland J a, Cook J. Can ultrasound measurements of muscle thickness be used to measure the size of individual quadriceps muscles in people with patellofemoral pain? Phys Ther Sport [Internet]. Elsevier Ltd; 2015 Feb [cited 2015 Aug 18];16(1):45–52. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24894764
8. Berger J, Bunout D, Barrera G, de la Maza MP, Henriquez S, Leiva L, et al. Rectus femoris (RF) ultrasound for the assessment of muscle mass in older people. Arch Gerontol Geriatr [Internet]. 2015 [cited 2015 Aug 18];61(1):33–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25890633
9. Szczepura K. personal communication [12-08-2015]. 2015.
10. Awadh a M a, Prefumo F, Bland JM, Carvalho JS. Assessment of the intraobserver variability in the measurement of fetal cardiothoracic ratio using ellipse and diameter methods. Ultrasound Obstet Gynecol [Internet]. 2006 Jul [cited 2015 Aug 21];28(1):53–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16758439
11. Reeves ND, Maganaris CN, Narici M V. Ultrasonographic assessment of human skeletal muscle size. Eur J Appl Physiol [Internet]. 2004 Jan [cited 2015 Aug 27];91(1):116–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/14639480
12. Seymour JM, Ward K, Sidhu PS, Puthucheary Z, Steier J, Jolley CJ, et al. Ultrasound measurement of rectus femoris cross-sectional area and the relationship with quadriceps strength in COPD. Thorax [Internet]. 2009 May [cited 2015 Aug 27];64(5):418–23. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19158125
13. Hammond K, Mampilly J, Laghi F a, Goyal A, Collins EG, McBurney C, et al. Validity and reliability of rectus femoris ultrasound measurements: Comparison of curved-array and linear-array transducers. J Rehabil Res Dev [Internet]. 2014 Jan;51(7):1155–64. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25437305
14. Thomaes T, Thomis M, Onkelinx S, Coudyzer W, Cornelissen V, Vanhees L. Reliability and validity of the ultrasound technique to measure the rectus femoris muscle diameter in older CAD-patients. BMC Med Imaging [Internet]. BioMed Central Ltd; 2012 Jan [cited 2015 Jul 14];12(1):7. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3342139&tool=pmcentrez&rendertype=abstract

The reliability and validity of detecting low dose radiation when using radiation detection applications and devices for smartphones.

Hendrik G. Erenstein[a], Libby D. Chamberlain[b], Aniek Forsten[a], Anna E.D. Lamprecht[c], Tina Sohrabi[d], Emilie Thomassen[d], Suzanne C.M. van der Wal[a], Maria Werner[d], Audun Sanderud[d]

a) Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, The Netherlands
b) School of Health Sciences, University of Salford, Manchester, United Kingdom
c) Department of Clinical Science, Radiography, Central University of Technology, Bloemfontein, South Africa
d) Department of Life Sciences and Health, Radiography, Oslo and Akershus University College of Applied Sciences, Oslo, Norway

Keywords
Smartphone
Radiation
Protection
Dosimetry
CMOS

Abstract

Introduction: Recent studies have stated that the use of real time dosimeters decreases occupational dose. Since 2015, 54.9% of the European population carries a smartphone and new technology gives us the opportunity to use smartphones as real time dosimeters. The aim of the study is to investigate the reliability and validity of using the smartphone with applications or peripherals as a personal real time dosimeter.

Method: Three different makes of Android smartphones were used with RadioactivityCounter, Pocket Geiger Type6 and Smart Geiger. Tests were done with x-ray radiation, and the devices were used to measure the dose rate from sources of the isotopes; ^{57}Co, ^{99m}Tc and ^{137}Cs.

Results: The short exposure time (x-ray pulse) showed measurement equal to the background radiation, however the constant exposure time showed some reliable and valid results. The Smart Geiger showed -71.51 ±7.1% average accuracy, the RadioactivityCounter showed -55.79% ±44.7% average accuracy while the Pocket Geiger Type6 showed a -25.52% ±10.8% average accuracy.
Discussion and conclusion: During the short exposure test, no radiation was detected. This is due to the software being designed for constant dose rates. When exposed to a constant radiation source; The Smart Geiger reported low doses, but there was no proof to suggest the device was actually detecting radiation; the RadioactivityCounter had a higher reliability and validity than the Smart Geiger; the results suggest that the Pocket Geiger Type6 could be possible reliable and valid detection device.

Introduction

According to the World Health Organisation there are 3.6 billion X-ray examinations performed, 37 million nuclear medicine procedures carried out and 7.5 million radiotherapy treatments delivered worldwide annually. Several of these scenarios involve a member of staff receiving a low dose of radiation

Recent studies suggest that using real time dosimeter in certain clinical settings reduces occupation dose.[2] Different technologies are available to demonstrate occupation dose measurement, for example, bespoke technology (e.g. TLD badges) or generic technology (e.g. Smartphones). Smartphones have the potential to be converted into personal real time dosimeters by the use of radiation detection applications and peripherals (interface devices), as they contain a complimentary metal-oxide-semiconductor (CMOS) sensor in the camera.[3] As of 2015, 54.9% of all the European population carry smartphones, with predictions for 2017 reaching over 65%.[4] This indicates a great potential for the smartphone as a dose monitor.

The criteria and performance limits of the personal dosimeters for ionising radiation are set in the ISO14146:2000 standard. It states that the personal dosimeter can have an accuracy with an error of anywhere between ± 50% of the true dose, and still be valid for use.[5]

Due to shortage of research into the potential clinical use of the applications and peripherals for smartphones, this research will provide information about the reliability and validity of the application "RadioactivityCounter",[6] the USB attachable "Pocket Geiger Type6",[7] and the audio jack attachable "Smart Geiger".[8] These will be compared to standard dose rate measurement equipment, the UNFORS Xi and a Messbereich FH40F2.

Should dose readings from smartphones be proven reliable and valid as the personal dosimeters used in hospitals today,[5] they would provide a readily available way to measure dose in real time. This has the potential to reduce occupation dose.

Materials and methods

Equipment

In this study two peripherals and one stand-alone application (collectively referred to as devices) for measuring radiation are discussed. All of which are available to the public as they are easily purchased from internet suppliers (Table 1). The devices were combined with three different smartphones from HTC, Samsung and Sony (Table 2). The different types of smartphones provide inter-rater reliability in this study.

The CMOS chip in the camera of the smartphones is a semiconductor, which converts photons into electrical charges. This is measured by the RadioactivityCounter,[6] as a count, which is then converted into a dose rate. The CMOS chip is sensitive to visible light,[9] therefore; two pieces of electrical insulating tape were placed over the lens

Table 1 The price and producer for the devices

Device	Price	Producer
RadioactivityCounter	€3,5	Rolf-Dieter Klein
Pocket Geiger Type6	€40	Radiation-Watch
Smart Geiger	€30	FT Lab

Table 2 The distributor, model and FCC ID for the smartphones

Manufacturer	Model	FCC ID
Samsung	Galaxy s4	A3LGTI9506
HTC	One M7	NM8PN07100
Sony	Z3 compact	PY7PM-0810

of the camera to reduce the chance of visible light being detected.[6] The CMOS chip would then only be exposed to ionising radiation able to penetrate the insulating tape.[6] The Pocket Geiger Type6 and the Smart Geiger have external semiconductors, and these are used to detect the radiation, instead of the camera CMOS chip.[7,8]

The data was collected separately in three experiments; therefore, the method will be divided in three parts; short exposure time, constant exposure with different sources and constant exposure with different distances

Short exposure time using X-Radiation

An x-ray unit (DIGITAL DIAGNOSTIC NZR 83, PHILIPS, Netherlands), with a 0.22 mmCu and a 1.0 mmAl filter was used to perform this experiment. A stack of Plexiglas measuring 16 cm in height and a width of 30 cm was used as a phantom to create realistic scattered radiation.

The phantom was positioned at the end of the x-ray table, correctly centred to the main radiation beam, with collimation of 18cm x 18cm. Tube voltage was set on 125 kVp and the tube load was set at 25 mAs. The devices were placed 30 cm away from the edge of the phantom, as illustrated in Figure 1.

Basic measurements with an UNFORS Xi dosimeter were done to ensure the secondary radiation was the same at different angles and heights, so that the position of the devices had no effect on the results.

Constant exposure with different radiation sources

To achieve a constant exposure time with different gamma energies and dose rates, three radioactive sources with different isotopes were used. The isotopes, activity and the calculated dose rates of the sources at 30 cm are listed in Table 3. Cobalt - 57 and Technetium - 99m emit photons with energy of 122keV and 141keV respectively and are often used in nuclear

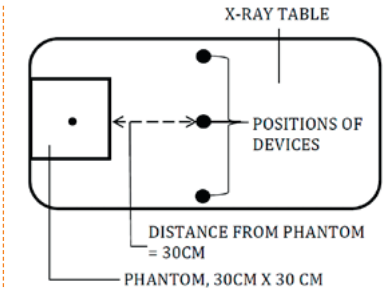


Figure 1 Setup of the short exposure time measurements

Table 3 The main energy, activity and calculated dose rate at 30 cm of the radioactive sources used.

	Main energy (keV)	Activity (μBq)	Calculated dose rate (μSv/h)
57Co	122	1.10	0.28
137Cs	662	6.74	6.96
99mTc	141	82.4	21.06

medicine.[10] Caesium - 137 (gamma energy 662keV) is used in medical therapy as a cancer treatment.[11]

The setup of the measurement is seen in Figure 2. All radioactive sources were individually placed at point O. The three devices were placed at each of the points A, B and C, all 30 cm from point O. The Messbereich FH40F2 was placed at D, also 30 cm from point O. The devices remained in the same spot for each measurement, but the placement of the smartphones were alternated to create the different combinations. The sensors were pointed towards the source, to ensure directional sensitivity did not affect the results.[13] The smartphones were set in flight mode, the Wi-Fi was turned off and the media volume was turned up to optimise the working conditions of the devices.

The level of radiation at each position was measured using a Messbereich FH40F2, to ensure the results could be compared. The FH40F2 was seen to give the true value, due to it being calibrated for hospital use. Each time the isotope was changed, points A, B, C and D were measured for 3 minutes using the FH40F2, to ensure all four points were receiving the same level of radiation.

The Pocket Geiger Type6 and the Smart Geiger showed an average dose rate after 5 minutes of continuous recording. The RadioactivityCounter logged a dose rate every minute and was left to record for 5 minutes and an average was taken. The results are shown in Table 5.

Constant exposure with different distances

To further test the abilities of the devices to measure different dose rates, another ^{137}Cs source (0.22MBq) was used and the devices were tested at three different distances; 15 cm, 30 cm and 45 cm from the source, see Figure 3.

The true dose rate was calculated for the low activity ^{137}Cs source, 0.912 μSv/h at 15 cm, 0.228μSv/h at 30 cm and 0.101μSv/h at 45 cm. Dose rate measurements of the nine combinations of devices and smartphones were recorded for 5 minutes at each of the three distances. The results are displayed as three graphs in Figure 4. The calculated

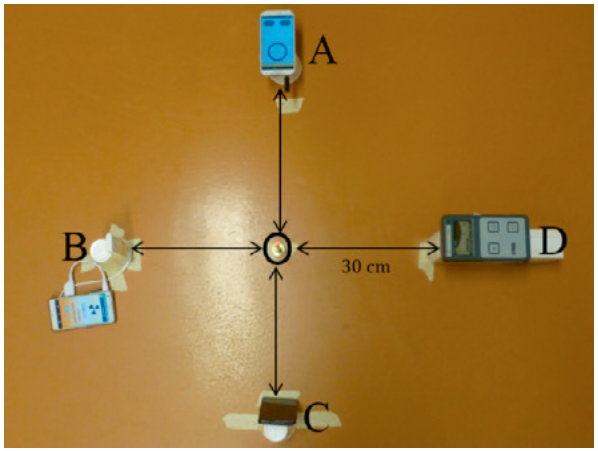


Figure 2 Setup of measurement with Constant exposure, different sources. The devices are A: Smart Geiger, B: Pocket Geiger Type6, C: RadioactivityCounter and D: Messbereich FH40F2. Aall devices were 30 cm from point O were the different radioactive sources were placed.

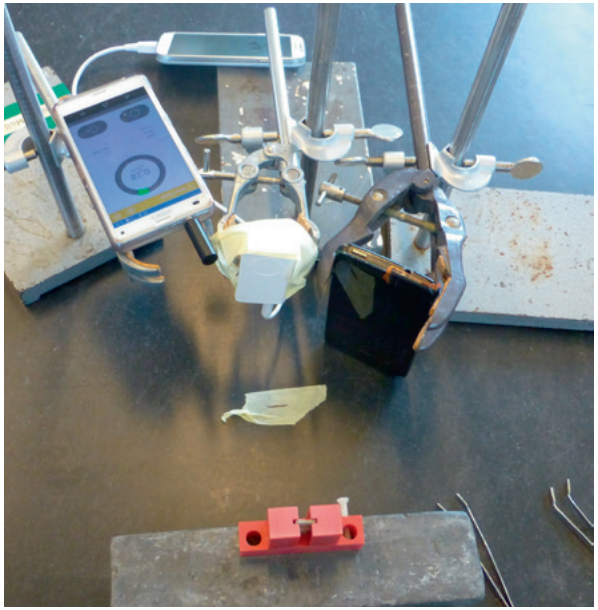


Figure 3 Setup of the measurement with constant exposure, different distances (15 cm, 30 cm and 45 cm) from the source, to get different dose rates with a ^{137}Cs source. The image shows the situation with 15 cm.

true dose rate is also shown in the graphs to provide a visual comparison.

Data analysis

The data were compiled into a table using Microsoft Excel 2010, displaying all values taken from the different combinations of the equipment. The accuracy from the different smartphone and devices was determined. And an equation was used to determine the validity of the results compared with the standard detection device or calculation, allowing the validity to be seen as % error:

$$\% \text{ error} = h - h\ h\ *100\%. \quad \text{Eq 1}$$

Where *h* is measured dose (μSv) per hour with one of the devices and *h* is the same unit from standard dose measurement equipment or calculated dose rate, seen as the true dose. If the % error is between ± 50%, the device will have the reliability needed to be used as a personal dosimeter.[5]

To assess the validity of each device the standard deviation of the % error was calculated, both for each smartphone used with one device and all measurements done with that device.

Results

Short exposure time

The measurements received when using the short exposure times all showed a peak at the point of exposure. However, these readings dropped to a background dose rate in a few seconds due to the short exposure. The background exposure measurements can be seen in Table 4. The UNFORSE Xi measured the short time exposure to give a dose between 5.3 and 9.2 μSv per exposure.

Table 4 Measurements of the background dose rate and counts per minutes(CPM) using the different brands of smartphones and all devices

Smart-phone	Radioactivity-Counter		Pocket Geiger Type6		Smart Geiger	
	Dose rate (uSv/h)	CPM	Dose rate (μSv/h)	CPM	Dose rate (μSv/h)	CPM
HTC	18.54	15.2	0.03	1.80	0.10	0.0
Samsung	0.06	1.8	0.06	3.20	0.10	0.0
Sony	0.08	9.0	0.07	3.80	0.10	0.0

Radiactivity-Counter	COBALT			CAESIUM			TECHNETIUM		
	Dose rate 0.29 µSv/h			Dose rate 6.43 µSv/h			Dose rate 13.77 µSv/h		
	Average CPM	µSv/h	% error	Average CPM	µSv/h	% error	Average CPM	µSv/h	% error
HTC	13.6	0.07± 0.00	-75.86	7.0	0.06± 0.00	-99.07	29.4	10.52±10.48	-23.60
Samsung	2.3	0.13± 0.12	-55.17	4.2	0.68± 0.55	-89.42	44.8	17.72±2.95	28.69
Sony	11.6	0.07± 0.00	-75.86	43.2	21.32± 17.05	231.57	613.0	413.88±293.14	2905.66

Pocket Geiger Type6	Average CPM	µSv/h	% error	Average CPM	µSv/h	% error	Average CPM	µSv/h	% error
HTC	14.8	0.28± 0.03	-3.45	229.4	4.33± 0.13	-32.66	565.6	10.67± 0.20	-22.51
Samsung	9.6	0.18± 0.03	-37.93	225.6	4.25± 0.13	-33.90	536.0	10.11± 0.20	-26.58
Sony	12.8	0.24± 0.03	-17.24	225.0	4.24± 0.13	-34.06	574.2	10.83± 0.20	-21.35

Smart Geiger	Average CPM	µSv/h	% error	Average CPM	µSv/h	% error	Average CPM	µSv/h	% error
HTC	0.4	0.10	-65.52	11.6	1.82	-71.70	16.4	2.57	-81.34
Samsung	0.0	0.10	-65.52	13.2	2.07	-67.07	14.0	2.20	-84.02
Sony	0.0	0.10	-65.52	12.0	1.88	-70.76	11.8	1.85	-86.57

Table 5: Measured counts per minute. dose rate (µSv/h) and calculated % error of the devices for each smartphone and radioactive source. The dose rate of each source measured with the Messbereich FH40F2 is seen as the true dose rate when Eq. 1 is used.

Table 6 The standard deviation of the % error given in Table 5 of each of the devices both for each smartphone used with one device and all measurements done with that device

Device	Smartphone			Total
	HTC	Samsung	Sony	
RadioactivityCounter	±38.7 %	±60.8 %	±1640 %	±981 %
Pocket Geiger Type 6	±14.8 %	±5.8 %	±8.8 %	±10.8 %
Smart Geiger	±8.0 %	±10.1 %	±11.0 %	±8.5 %

Constant exposure with different sources

The results gathered when using a constant exposure with different sources are listed in Table 5. The average error and variation expressed as standard deviation are listed in Table 6. This variation will give an indication on the reliability of the measurements done with a device.

All devices were able to detect the increase in dose rate with different isotopes on all smartphones. However, the results from the RadiactivityCounter vary widely between -99.07% and +2905.66%. Two measurements with the Sony smartphone are obvious anomalies, ^{137}Cs and ^{99m}Tc, and just two of the nine measurements (^{99m}Tc with HTC and Samsung) are between ± 50% of the true dose. Due to the anomalies, the standard deviations seen in Table 6 are very large for the RadiactivityCounter when using the Sony smartphone, ±1640 %. Also the measurements with HTC and Samsung have a substantial variation with standard deviations, 38.7 % and 60.8 % respectively.

As seen in Table 5, the Pocket Geiger Type6 is able to follow the increase in dose rate as stronger radioactivity sources are applied. The accuracy ranges from -3.45% to -39.93%. In Table 6 the variation of the measurement with this device have a standard deviation of total ±10.8%, in the case of the Pocket Geiger Type6 it is the HTC which has the largest variation with a standard deviation of ±14.8%.

Table 6 also shows that the Smart Geiger has the lowest variation in error between the nine measurements done with this device. It can be noted that the Smart Geiger will not give dose rate values below 0.1 μSv/h. It will give this value as an estimate of the background radiation. When measuring the lowest dose rate from the ^{57}Co all of the measurements are equal this “background” dose rate. When looking at the reliability all the nine % error calculated from Eq. 1 are negative and larger than the ± 50% error.

Constant exposure with different distances

When testing the devices’ ability to detect change in dose rate due to change in distance, the RadioactivityCounter did not follow the expected pattern (Figure 4a). The Samsung smartphone did initially show a decrease in dose rate when the distance was increased from 15 to 30 cm. But when the distance was 45 cm it was followed by an unexpected increase. The HTC smartphone maintained an almost constant dose rate regardless of distance from the source, and the Sony smartphone showed an increase in dose rate as the distance increased.

As seen in Figure 4b the Pocket Geiger Type6 did follow the expected decrease in dose rate as the distance was increased. All three brands of smartphones followed a same declining pattern.

The Smart Geiger followed the expected pattern of dose rate declining as distance increased, shown in figure 4c. All three devices stopped at 0.10µSv/h at the 45 cm distance, the lowest dose value reported on this device. The device behaved in this way when attached to all three smartphones. However, the different phones have different dose rate response and the Sony with the reached the 0.10µSv/h at 30 cm.

Discussion

The results of the experimental study show that there is the potential to use smartphones to detect radiation in a clinical setting.

Short exposure time

The short exposure results proved that the devices are unable to detect short time exposure. This is not unexpected as all are dose rate meters designed to measure a constant exposure.6-8 The equivalent dose (µSv) from one short exposure would be averaged over the 5 minutes or in the case of the RadioactivityCounter 1 minute. The UNFORSE Xi measured the short time exposure to give a dose between 5.3 and 9.2 µSv. If a 5 µSv short time exposure was detected by the device in a 5 minute period, the dose rate per hour would be 12 times this, 60 µSv/h. All the devices possibly have an algorithm that categorize the short exposure as noise, thus not taking the short exposure into account when calculating the dose rate. If the software is adapted to measure dose and not in dose rate, it could possibly be used to detect short time exposures from x-ray imaging exposure. But it could also be that the dose rate is too large to be measured with the devices. Regardless as the devices are constructed the reliability or validity are very low when used in short time exposure situations.

The Smart Geiger

The Smart Geiger does not seem to have reliability or validity to be seen as a potential personal dosimeter. The measurements performed with the device all have a low dose rate reading or a measurement equal to the background estimate of 0.1 µSv/h. Failing to measure below 0.1 µSv/h reduces the reliability and validity for this device. It can also be added that during the experiment, the Smart Geiger also showed a high sensitivity to external signals -especially cell phone signals. Due to time constraints, this could not be investigated further.

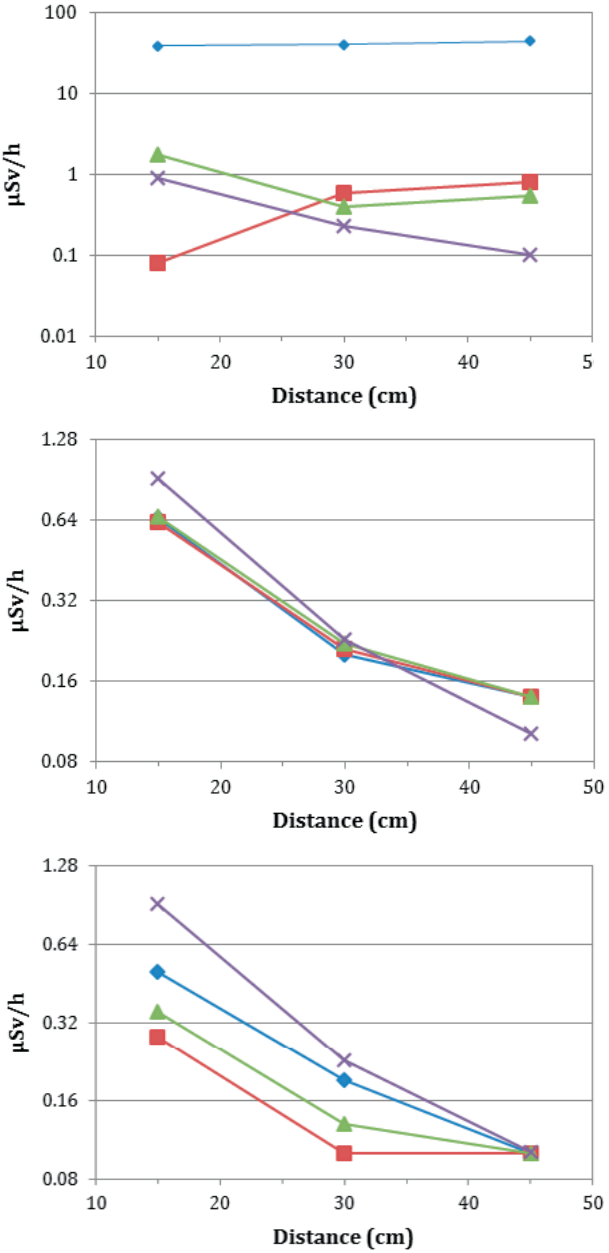


Figure 4 How the dose rate, detected by,
a) the RadioacticityCounter,
b) Pocket Geiger Type6 and
c) Smart Geiger changes with distance, all with use of the three smartphones HTC(blue), Samsung(green), Sony(red) and the calculated dose rate(purple).

The RadioactivityCounter

The RadioactivityCounter showed a higher reliability and validity to detect low dose rate radiation compared to the Smart Geiger. The counts per minute detected were dependent upon the hardware of the smartphone. To take the different smartphone hardware into account, the translation dose rate data found on the RadioactivityCounter website was used to calibrate all smartphones prior to use. Due to the lack data for the Sony Z3 Compact, an average of listed Sony smartphones was used. This potentially caused the high deviation the smartphones results. The HTC One gave the best reliability and validity of all the smartphones tested, even though it was stated on the RadioactivityCounter website that it should not be used.[6]

Tests regarding the influence of distance showed an increased in dose rate along with the distance from the radiation source. This unexpected result is not in accordance with inverse square law. A possible explanation for this is due to natural light from windows without curtains in the laboratory. When the experiment started at 15 cm, the sky was cloudy, but as the distance increased the sun broke through the clouds and the level of natural light in the laboratory increased. The RadioactivityCounter uses the built in camera of the smartphones and the camera have to be covered with black tape to prevent the light to expose the camera. The result seen in Figure 4a could be a result of the double layer of tape was too some degree transparent to light. Thus in a situation with variable light the covering of the lens should be infallible.

The Pocket Geiger Type6

The Pocket Geiger Type6 was shown to be the most reliable and valid device for measuring low dose rates. The best results were received when a Caesium isotope was used, which could be expected, as the original design was calibrated with Caesium.[7]

All measurements from combinations of radioactive sources and smartphones with this device are within ± 50% error, but all of them are too low.

Due to time constraints this experiment did not investigate possible directional sensitivity into account. As pointed out by Cogliati et al.[9] and Kaandorp and de Lange[12] this could interfere with the reliability and validity.

Conclusion

From our results it seems as the Pocket Geiger Type6 can be used as a reliable and valid detection device. A continual exposure situation with dose rates between 0.1-14μSv/h is an important margin. This device had an average error reading -25.52%, while a personal dosimeter may have an accuracy of anywhere between ± 50% of the true dose, and still be valid for use.[5]

It is interesting to see if this research could be followed up with an investigation into the use of the Pocket Geiger type6 during fluoroscopy.

Another approach is an investigation into the possibility to modify the software from the Pocket Geiger type6 to measure short exposures.

Acknowledgments

We would like to take this opportunity to acknowledge The Martini Hospital, Groningen, The Netherlands, for letting us use their facilities, equipment and time. We also want to acknowledge Ruurd Visser (MSc), *Hanze University of Applied Sciences Groningen*, for his assistance with the statistics, professor Peter Hogg, *Salford University*, for his guidance, Carst Buissink (MEd), *Hanze University of Applied Sciences Groningen,* and Esther Van Nieuwenhoven, *Hanze University of Applied Sciences Groningen,* for organizing the Optimax 2015. Dr. Robert Klein-Douwel, *University of Groningen*, for his interest in our research and supplying the facilities.

References

1. World Health Organization. Medical radiation exposure [Internet]. World Health Organization; 2015 [cited 2015 Aug 26]. Available from: *http://www.who.int/ionizing_radiation/about/med_exposure/en/index3.html*
2. Müller MC, Welle K, Strauss A, Naehle PC, Pennekamp PH, Weber O, et al. Real-time dosimetry reduces radiation exposure of orthopaedic surgeons. Orthop Traumatol Surg Res [Internet]. 2014 Dec [cited 2015 Aug 26];100(8):947–51. Available from: *http://www.ncbi.nlm.nih.gov/pubmed/25459455*
3. Van Hoey O, Salavrakos A, Marques A, Nagao A, Willems R, Vanhavere F, et al. Radiation Dosimetry Properties Of Smartphone CMOS Sensors. Radiat Prot Dosimetry [Internet]. 2015 Jun 3 [cited 2015 Aug 26];ncv352 – . Available from: *http://rpd.oxfordjournals.org/content/early/2015/06/02/rpd.ncv352*
4. statista. Smartphone user penetration Western Europe 2011-2018 [Internet]. 2015 [cited 2015 Aug 26]. Available from: *http://www.statista.com/statistics/203722/smartphone-penetration-per-capita-in-western-europe-since-2000/*
5. ISO 2000. Radiation protection: criteria and performance limits for the periodic evaluation of processors of personal dosemeters for X and gamma radiation. Int Organ Stand [Internet]. 2000; Available from: *http://www.iso.org/iso/catalogue_detail.htm?csnumber=20876*
6. Klein R-D. RadioActivity [Internet]. MultiMediaStudio. 2014. Available from: *http://www.hotray-info.de/html/radioactivity.html*
7. Radiation Watch UK. Introducing the Radiation Watch Pocket Geiger Counter [Internet]. Radiation Watch UK. 2013 [cited 2015 Aug 25]. Available from: *http://www.radiation-watch.co.uk/*
8. FTLab. Miniature Radiation Sensor of national popular type [Internet]. FTLab. 2015 [cited 2015 Aug 25]. Available from: *http://allsmartlab.com/eng/Smart_Geiger.php*
9. Cogliati JJ, Derr KW, Wharton J. Using CMOS Sensors in a Cellphone for Gamma Detection and Classification. arXiv:14010766 [physics.ins-det] [Internet]. 2014;1–26. Available from: *http://arxiv.org/pdf/1401.0766v1.pdf*
10. World Nuclear Association. Radioisotopes in Medicine [Internet]. 2015 [cited 2015 Aug 25]. Available from: *http://www.world-nuclear.org/info/Non-Power-Nuclear-Applications/Radioisotopes/Radioisotopes-in-Medicine/*
11. US EPA OORPD. Cesium [Internet]. 2000 [cited 2015 Aug 26]. Available from: *http://www.epa.gov/radiation/radionuclides/cesium.html*
12. Kaandorp J, de Lange R. Onderzoek naar de betrouwbaarheid van het meten van radioactiviteit binnen de Nucleaire Geneeskunde met behulp van smartphones. MIRT Hanze University of Applied Sciences; 2015.

The Influence of CT Reconstruction Methods on the Accuracy of Monitoring Lung Nodule Diameters at Different Dose Levels

P.Plasman[1], H.Baxter[2], L. Coleman[2], P. Hogg[2], H.Hustveit[3], A. Rizvi[2],L. van der Sluis[1], C. Telle[3], J.Zigterman[1]

1 Department of Medical Imaging and Radiation Therapy,Hanze University of Applied Sciences, Groningen, the Netherlands
2 School of Health Sciences, University of Salford, United Kingdom
3 Department of Health, Radiography, Oslo and Akershus University College of Applied Sciences, Norway

Abstract

Purpose: This study aims to investigate the effect of filtered back projection (FBP) and sinogram-affirmed iterative reconstruction (SAFIRE) on the accuracy of lung nodule diameter measurements at different dose levels.

Method: 48 CT images were acquired (at tube-current time product of 10, 20, 30 and 40 mAs) using an anthropomorphic phantom Lungman N1 ©, containing simulated spherical lung nodules of +100 Hounsfield Units of 5, 8 and 12mm diameter. Images were reconstructed with FBP and SAFIRE strengths 1, 3, and 5. Twelve participants, with radiographic experience, performed nodule diameter measurements for all images. Nodule edge sharpness was calculated for all images by measuring the angle of profile edge slope.Contrast to Noise Ratio (CNR) values were obtained from pixel values in regions of interest (ROIs) in the lung nodule and background air. Measurement accuracy was assessed by calculating the absolute error percentage (AEP) between participant's measurements and actual nodule size.

Results: There is no significant difference in nodule diameter measurement between mAs values and reconstruction algorithms (p-value 0,009 - 0,969). AEP showed no significant difference (p-value 0,041-0,969) for any of the reconstruction algorithms.
Discussion: Previous research using SAFIRE suggests a decrease of mAs while maintaining image quality. Furthermore, SAFIRE has the ability to increase CNR and decrease image artefacts. However, the findings in this study suggest that accuracy of lung nodule measurement does not improve with an increase of CNR values nor the line profiles of edge sharpness.
Conclusion: Our study suggests that image dose levels can be reduced without compromising nodule diameter measurement accuracy, regardless of reconstruction method.

Introduction

The use of computed tomography (CT) is increasing in medical imaging. UNSCEAR reported a substantial increase of more than 40% from 1997-2007 when compared to the previous decade. A consequence of this is an increased population risk of developing malignant tumours, due to possible DNA damage, caused by exposure to ionizing radiation (1)its use has increased rapidly. It is estimated that more than 62 million CT scans per year are cur- rently obtained in the United States, including at least 4 million for children.1 By its nature, CT involves larger radiation doses than the more common, conven- tional x-ray imaging procedures (Table 1. For this reason, limiting the use of radiation in medical imaging, as well as justification and optimization of image quality and dose levels is essential for every examination. Optimization of image noise and spatial resolution is paramount for accurate radiological assessment (2).

Lung nodule measurements in CT are routinely done for tumour treatment response evaluation, detection of lung nodules, or as follow-ups from previous findings (3) For nodule follow-up the development and size will be assessed with sequential scans. According to the guidelines published by the Fleischner Society, the largest diameter the nodule is measured on axial slices in order to evaluate the development with repeated scans (4). This monitoring will result in an accumulated dose over time, and to a general increased risk of developing a radiation induced cancer(1). An acknowledged dose reduction

method, for a simple and predictable result, is altering the tube current, although the consequence of this method is an increase of noise and image artefacts(5).

Iterative reconstruction (IR) techniques have been developed to reduce dose, whilst maintaining or improving objective image quality, by reducing noise and consequently improving Signal-to-Noise Ratio (SNR) (6–9)independent readers measured image noise; two readers assessed image quality of normal anatomic lung structures on a five-point scale. Radiation dose parameters were recorded. RESULTS: Image noise in datasets reconstructed with FBP (57.4 \u00b1 15.9. Sinogram-Affirmed Iterative Reconstruction (SAFIRE) is an advanced IR technique developed by Siemens© that uses both filtered back projection (FBP) and raw data-based iterations. Previous studies have shown promising results in the dose-reduction potential of SAFIRE while maintaining image quality, where image quality was assessed by objective measures (i.e. SNR and CNR values) and visual criteria such as image noise (i.e. graininess), quality of contour delineation (i.e. sharpness) and general impression (i.e. overall image quality)(2,10–13) the Definition Flash and the Definition Edge (all from Siemens, Erlangen, Germany. A potential downside of IR techniques is the requirement of high computing power which makes them time consuming, limiting its clinical application (14).

This study aims to investigate the influence of FBP and SAFIRE on the accuracy of lung nodule diameter measurements at different dose levels.

Methods

Image Acquisition

Images were acquired using a clinically based and calibrated high frequency Siemens Healthcare©, Somatom Definition AS 64 slice CT scanner and Syngo software CT VA48A.

The images were acquired using helical scanning parameters with CareDose. Slice thickness of 0.6mm, pixel spacing of 0.69mm × 0.69mm and a pitch factor of 1.2 was used. Six consecutive scans were performed with a fixed kVp of 120 and mAs levels of 40, 30, 20 and 10. All other parameters were kept constant. Each scan resulted in a total of 560 images.

An anthropomorphic Lungman© phantom (No 1, Kyoto Kagaku Co.) was scanned in supine position (head first). According to the manufacturers website, the Lungman© phantom consists of material comparable to human tissue density. To simulate tumours of different sizes, spherical nodules were placed at different locations within the lung parenchyma. The nodules all had a HU (Hounsfield Unit) of +100. The nodules selected for this study had diameters of 5, 8 and 12 mm.

Image reconstruction & dosage

Images were reconstructed using a smoothing kernel (B31f) for the FBP and SAFIRE strengths of 1, 3 and 5 with a medium smooth kernel (I31f).Three slices containing either 5, 8 or 12 mm nodules, from each scan parameter and reconstruction algorithm were selected. Each selected slice represented the nodule at its largest diameter, which was selected based on visual analysis. Three image sets were duplicated to assess intra-observer validity. In total there were 57 images included within a total of 19 image sets. All image sets were anonymised and presented in random order.

Image display and viewing conditions

Images were displayed on a diagnostic level monitor, 24,11" EizoRadiForce MX2424W, with a resolution of 1920x1200 pixels. A DICOM greyscale calibration standard was undertaken before data collection commenced. Viewing conditions of low ambient lighting remained constant for all participants.

Population & data collection

Nodule diameter measurements were performed by 12 participants, consisting of student radiographers, experienced radiographers and a medical physicist. The observers were supervised, undertaking several test measurements before actual data collection commenced. Three measurements were taken for each nodule, in vertical, horizontal and diagonal planes (Figure 1). Nodule diameter was obtained using the line measurement tool within RadiAntDicom Viewer 1.9.16. This resulted in a total of 171 measurements being performed by each observer.

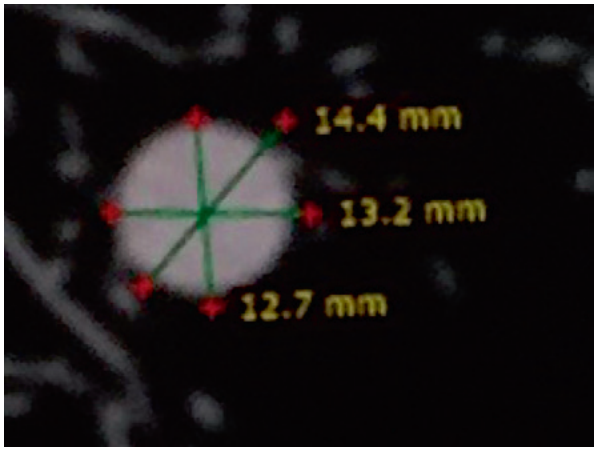


Image 1 Example of a training image

Objective measurements of Image Quality
Measurements of objective image quality were performed using ImageJ©. CNR was calculated by using two identical regions of interest (ROIs), one in the centre of the nodule and one in air surrounding the phantom, to measure the attenuation values. ROIs differed for each nodule size and were selected to fit easily within the boundaries of the nodule and as close to 50% of the nodules actual size as the software allowed (Image 1). Calculations of CNR were performed in Microsoft Excel©, using the equation

where μx is the mean signal value in ROI x, and σx the variance in ROI x, respectively.

Edge profile assessment was inspired by a method described by Manning, 2004(15). Edges were identified by visual inspection, and subsequently a line profile was drawn perpendicular to the nodule edge in ImageJ© as shown in Image 2. Edge sharpness was assessed by calculating the angle of the profile edge slope, in Microsoft Excel©.

First, a trend line was produced to assess the steepness of the line profile. R^2-values of the trend lines varied from 0,93 to 0,98 indicating good correlation. The slopes of the trend lines were then converted to angles (in degrees).

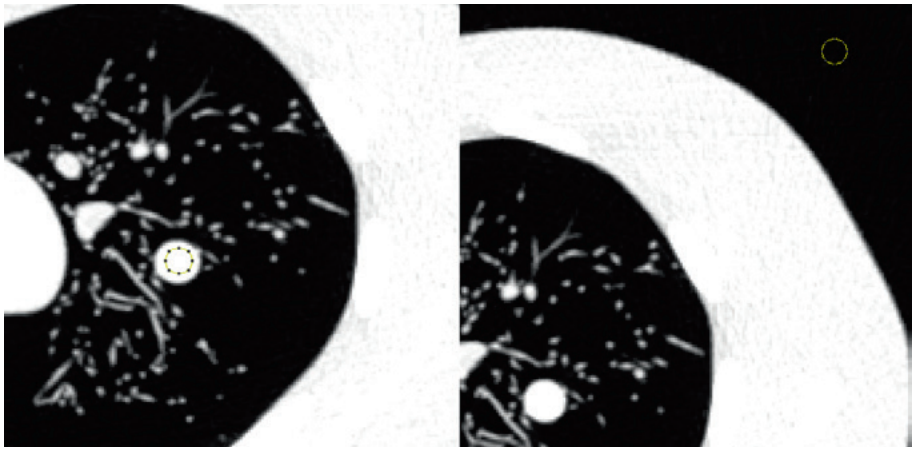


Image 1 Defined ROIs for objective image quality calculation

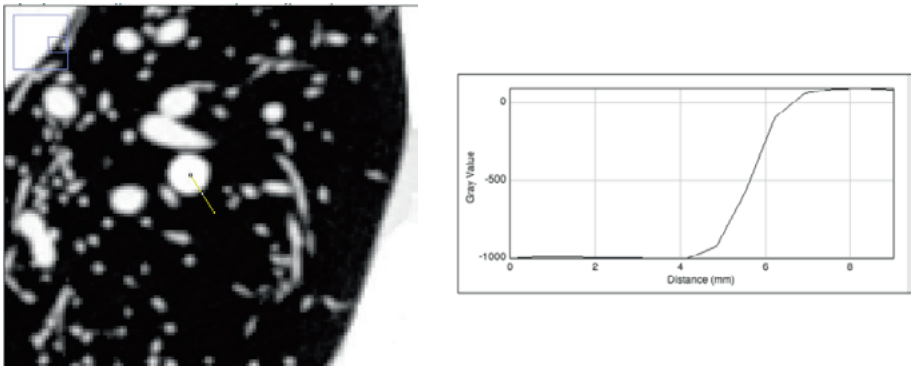


Image 2 Nodule line placement with the resulting line profile

Statistical analysis

Differences in mean nodule diameter measurement between reconstruction algorithms were analysed with a Mann-Whitney Wilcoxon test. Due to multiple testing, alpha was adjusted using a Bonferroni correction resulting in a level of significance of 0.0083.

Observer performance was assessed by calculating the absolute error percentage (AEP) for mean nodule diameter measurements with the following formula:

$$AEP =$$

where indicates the mean nodule diameter measurement and AS indicates actual nodule size. Differences in AEP were analysed with a Mann-Witney Wilcoxon test with a level of significance of 0.083.

Results

With an increase of reconstruction algorithm complexity the objective image quality, as defined by CNR, and nodule edge sharpness, increases.

Table 1 shows an improvement of CNR for increasing dose levels and reconstruction algorithm complexity.

DOSE (mAs)	FBP	SAFIRE 1	SAFIRE 3	SAFIRE 5
10	24,34	27,38	36,70	55,39
20	31,06	34,99	47,58	74,95
30	36,85	41,25	54,48	84,59
40	54,03	60,69	85,43	141,77

Table 1 CNR values vs. reconstruction algorithms and mAs (8mm nodule)

Nodule edge sharpness improves with increasing reconstruction algorithm complexity. Furthermore, edge sharpness differs for each nodule size with the largest nodule having the sharpest edge (Figure 1). For the 5mm nodule at both 30 and 40 mAs, and the 8mm nodule, at 10mAs; SAFIRE 5 produced the least sharp nodule edge and are an exception to this trend. There is, however, no defined relationship between dose and edge sharpness for the three nodule sizes.

Absolute error percentage in observer diameter measurement decreases with an increase of nodule edge sharpness. (Figure 2). However, it appears that the accuracy of nodule diameter measurements improves as nodule size increases (Figure 3).

The AEP measurement accuracy also increases as nodule diameter increases (Figure 2). For 12mm nodules, mean absolute error values are all below 3.4%. Mean AEP values for 8mm nodules range from 5.4% to 7%, 5mm nodules showing AEP values from 4.6% to 9.6% respectively.

For 8mm and 5mm nodules, accuracy is decreasing with mean AEP of around 6.2% and 8%, respectively. For 8mm and 12mm nodules, dose levels seem to have no effect on measurement accuracy (Figure 3). An effect of mAs on measurement accuracy is visible for small nodules only where mean AEP values are 6.32% at 40 mAs, increasing to 8.6% at 10 mAs. Differences in mean AEP between reconstruction algorithms are greatest in the smallest nodule, depending on mAs level. For mAs values between

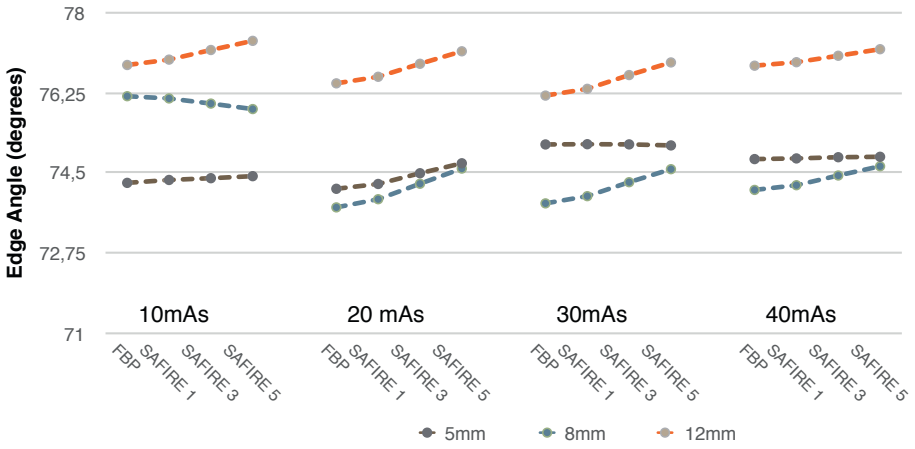


Figure 1 Edge sharpness versus mAs and reconstruction method

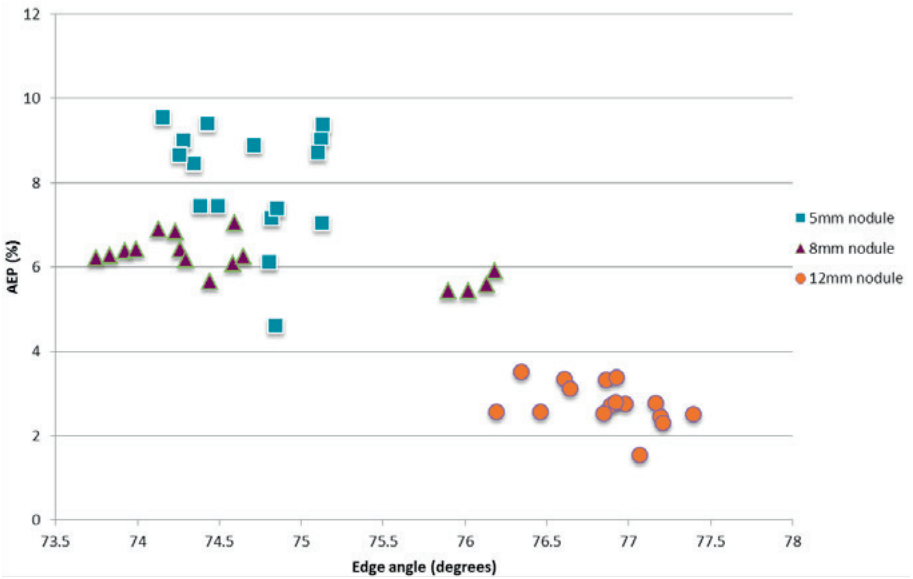


Figure 2 Mean absolute error percentage versus nodule edge angle

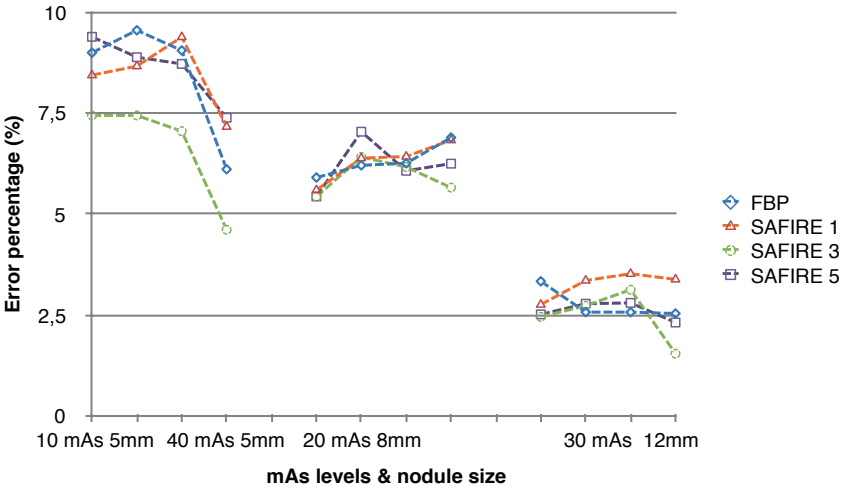


Figure 3 Absolute nodule diameter error percentage versus mAs and reconstruction method

10 and 30, standard deviation is between 0.23% and 0.47%. At 40 mAs there is a greater spread in observer performance between reconstruction algorithms, with a standard deviation of 0.9%.

For medium and large nodules, observer performance seems independent of reconstruction algorithm. For 5mm nodules, SAFIRE3 seems to have the most effect on measurement accuracy, compared to the other reconstruction methods.

Results from the Mann Whitney Wilcoxon test on mean observer measurements showed no significant difference between reconstruction algorithms.

P-values ranged from 0.009 to 0.969. An overview of p-values is given in Table 2.

P-values calculated with the Mann Whitney Wilcoxon on observer measurement accuracy showed values between 0,041 and 0,969, showing no significant difference between reconstruction algorithms.

This is illustrated in Figure 4, where absolute error percentages show similar distribution for all reconstruction methods, with a large spread in the data.

Dose level	FB vs. S1	FB vs. S3	FB vs. S5	S1 vs. S3	S1 vs. S5	S3 vs. S5
5 mm, 10 mAs	0,139	0,085	0,687	0,722	0,182	0,266
5 mm, 20 mAs	0,645	0,721	0,838	0,824	0,919	0,374
5 mm, 30 mAs	0,504	0,409	0,156	0,443	0,878	0,456
5 mm, 40 mAs	0,528	0,167	0,126	0,371	0,374	0,838
8 mm, 10 mAs	0,556	0,057	0,197	0,009	0,221	0,789
8 mm, 20 mAs	0,969	0,503	0,609	0,798	0,592	0,248
8 mm, 30 mAs	0,789	0,305	0,213	0,754	0,929	0,287
8 mm, 40 mAs	0,366	0,756	0,695	0,513	0,272	0,477
12 mm, 10 mAs	0,609	0,074	0,126	0,01	0,049	0,35
12 mm, 20 mAs	0,929	0,239	0,724	0,367	0,373	0,388
12 mm, 30 mAs	0,239	0,289	0,61	0,062	0,285	0,332
12 mm, 40 mAs	0,284	0,147	0,046	0,23	0,075	0,505

Table 2 Results of the Mann Whitney Wilcoxon analysis for mean observer measurements

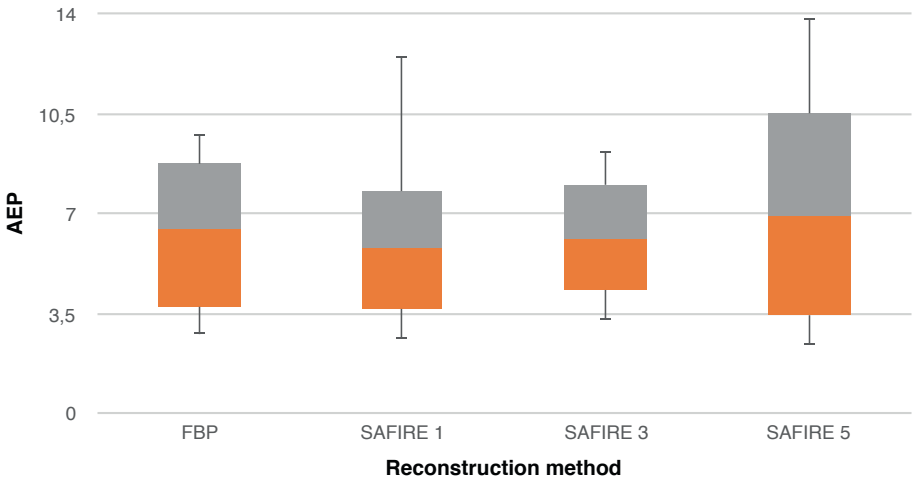


Figure 4 Box-and-whiskers of mean AEP values vs. reconstruction algorithms for the 8mm nodule scanned with 20 mAs

Intra-observer reliability was good. Observer performance difference was not significant with a mean calculated p-value of 0,452.

Discussion

Our study suggests that mAs, and therefore radiation dose, can be lowered equivalently when using FBP or SAFIRE, without compromising nodule measurement accuracy in a phantom. Previous research suggests that SAFIRE is an excellent algorithm for minimising undesirable effects of dose reduction by increasing SNR and CNR (8,10) the Definition Flash and the Definition Edge (all from Siemens, Erlangen, Germany. However, an increase of image CNR appears not to affect a correct subjective perception of the nodule edge. With an increase of CNR levels, sharpness of the nodule edges appeared to increase. Nodule measurements however did not differ statistically between reconstruction algorithms. In addition, observer performance as indicated by AEP did not show any significant difference between reconstruction methods. This suggests that the accuracy of nodule measurements does not increase with an increase of CNR values. Objective image quality is not a valid predictor of observer measurement accuracy.

Table 1 indicates that when mAs increases CNR also increases;Figure 1 indicates that when mAs increases nodule edge sharpness also increases. Mathematically speaking, the increase in CNR and nodule edge angle suggests that the nodules

should become visually clearer. However, there is no significant difference between nodule diameter measurements made by the observers across all mAs values (Table 2). This can be explained because of the very high contrast and therefore high level of conspicuity of the lesions. This is confirmed in Figure 3.

Limitations and Recommendations

Nodule diameter measurement is susceptible to error according to size. Real-life nodules are complex, their shape and distribution of attenuation will not be as well-defined as they are in a phantom. The nodules in this study possess a sharp edge separating it from surrounding tissue. In clinical practice this particular shape could represent a benign nodule, or a metastasis(16). Also, nodule size in the acquired slices might not be an accurate representation of the actual nodule size due to the slice thickness and voxel sizes, introducing an inherent error in observer measurements.

Although test-retest scores shows good intra-observer reliability, the overall observer experience was at novice level. However, since the diameter measurements can be considered a low order task, this might not pose such a limitation to the validity of the results. However, a further study should be undertaken using expert observers.

Other aspects to consider are the inherent human artefacts of respiratory and circulatory movements which are not factors in a phantom study. When eliminating these, the image might be presented in a slightly better quality. With this being a common bias when using a phantom, it raises a question regarding if this study could be considered for clinical research.

Each nodule edge angle in this study is only calculated once in one plane. For validity of measurements, multiple calculations on multiple planes are recommended by Manning's work (15). This is a limitation that needs consideration when evaluating the accuracy of the edge sharpness. Still, a trend can be seen, and highlights findings presented in Figure 1.

Conclusion

The findings in this study suggest that accuracy of lung nodule diameter measurements do not increase with an increase of CNR values, but do suggest that image dose levels can be reduced without compromising measurement accuracy, regardless of reconstruction method.

Bibliography

1. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277–84.
2. Greffier J, Macri F, Larbi a., Fernandez a., Khasanova E, Pereira F, et al. Dose reduction with iterative reconstruction: Optimization of CT protocols in clinical practice. Diagn Interv Imaging [Internet]. Elsevier Masson SAS; 2015;96(5):477–86. Available from: *http://linkinghub.elsevier.com/retrieve/pii/S2211568415000789*
3. Kim H, Park CM, Song YS, Lee SM, Goo JM. Influence of radiation dose and iterative reconstruction algorithms for measurement accuracy and reproducibility of pulmonary nodule volumetry: A phantom study. Eur J Radiol [Internet]. Elsevier Ireland Ltd; 2014;83(5):848–57. Available from: *http://dx.doi.org/10.1016/j.ejrad.2014.01.025*
4. MacMahon H, Austin JHM, Gamsu G, Herold CJ, Jett JR, Naidich DP, et al. Guidelines for management of small pulmonary nodules detected on CT scans: a statement from the Fleischner Society. Radiology. 2005;237(2):395–400.
5. Kubo T, Lin P-JP, Stiller W, Takahashi M, Kauczor H-U, Ohno Y, et al. Radiation dose reduction in chest CT: a review. AJR Am J Roentgenol. 2008;190(2):335–43.
6. Elliott a. Committee on Medical Aspects of Radiation in the Environment: Fourteenth Report. 2011.
7. Baumueller S, Winklehner A, Karlo C, Goetti R, Flohr T, Russi EW, et al. Low-dose CT of the lung: Potential value of iterative reconstructions. Eur Radiol. 2012;22(12):2597–606.
8. Willemink MJ, De Jong P a., Leiner T, De Heer LM, Nievelstein R a J, Budde RPJ, et al. Iterative reconstruction techniques for computed tomography Part 1: Technical principles. Eur Radiol. 2013;23(6):1623–31.
9. Kim JH, Kim MJ, Kim HY, Lee MJ. Radiation dose reduction and image quality in pediatric abdominal CT with kVp and mAs modulation and an iterative reconstruction technique. Clin Imaging [Internet]. Elsevier Inc.; 2014;38(5):710–4. Available from: *http://dx.doi.org/10.1016/j.clinimag.2014.05.008*
10. Christe A, Heverhagen J, Ozdoba C, Weisstanner C, Ulzheimer S, Ebner L. CT dose and image quality in the last three scanner generations. World J Radiol [Internet]. 2013;5(11):421–9. Available from: *http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3856334&tool=pmcentrez&rendertype=abstract*
11. Wang R, Schoepf UJ, Wu R, Reddy RP, Zhang C, Yu W, et al. Image quality and radiation dose of low dose coronary CT angiography in obese patients: Sinogram affirmed iterative reconstruction versus filtered back projection. Eur J Radiol [Internet]. Elsevier Ireland Ltd; 2012 Nov [cited 2014 Aug 8];81(11):3141–5. Available from: *http://www.ncbi.nlm.nih.gov/pubmed/22578834*
12. Schulz B, Beeres M, Bodelle B, Bauer R, Thalhammer A, Vogl TJ, et al. Performance of Iterative Image Reconstruction in CT of the Paranasal Sinuses : A Phantom Study. 2013;1–5.
13. Corcuera-Solano I, Doshi a H, Noor a, Tanenbaum LN. Repeated Head CT in the Neurosurgical Intensive Care Unit: Feasibility of Sinogram-Affirmed Iterative Reconstruction-Based Ultra-Low-Dose CT for Surveillance. AJNR Am J Neuroradiol [Internet]. 2014; Available from: *http://www.ncbi.nlm.nih.gov/pubmed/24557704*
14. Han BK, Grant KLR, Garberich R, Sedlmair M, Lindberg J, Lesser JR. Assessment of an iterative reconstruction algorithm (SAFIRE) on image quality in pediatric cardiac CT datasets. J Cardiovasc Comput Tomogr [Internet]. Mosby, Inc; 2012 [cited 2014 Aug 8];6(3):200–4. Available from: *http://www.ncbi.nlm.nih.gov/pubmed/22682262*
15. Manning DJ, Ethell SC, Donovan T. Detection or decision errors? Missed lung cancer from the posteroanterior chest radiograph. Br J Radiol. 2004;77(915):231–5.
16. Jeong YJ, Yi C a., Lee KS. Solitary pulmonary nodules: Detection, characterization, and guidance for further diagnostic workup and treatment. Am J Roentgenol. 2007;188(1):57–68.

Optimisation of chest Computed Tomography using a phantom: impact of mAs and reconstruction techniques on Image Quality

C.S. Reis[1]; T. Faqir[2]; V. Harsaker[3]; P. Hogg [2]; L. Kristoffersen[3]; I.L. van Rein[4]; K. Stancombe[2]; N.C. Warmerdam[4]; C. Wergeland[3]

1 Escola Superior de Tecnologia da Saúde de Lisboa/Lisbon School of Health Technology (ESTeSL), Lisbon, Portugal
2 University of Salford, Salford, United Kingdom
3 Oslo and Akershus University College of Applied Sciences, Oslo, Norway
4 Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, the Netherlands

Abstract:

Objectives: To verify if the mAs and reconstruction techniques affect the visualisation of relevant structures in lung Computed Tomography (CT) using a phantom.

Methods: Images were acquired using various mAs and reconstruction techniques. Image quality (IQ) was analysed applying two approaches: perceptual, using 5 observers and objective (edge gradient calculation) to verify the sharpness of the structures. Dose was recorded. Wilcoxon Signed Rank test was used to compare the data from the perceptual image analysis. *P*-values were calculated (Bonferroni-Correction method) to compare reconstruction techniques and mAs. A Kappa Test with linear weighting was performed to calculate the level of agreement between observers.

Results: The Wilcoxon-Signed-Rank-Test showed no significant difference between the reconstruction techniques tested ($p<0.05$). In addition, the test showed no significant difference between any of the mAs values with a Bonferroni correction ($p = 0.0167$). For 10 mAs the observers scored differently, depending on which structures they were looking at. The overall IQ was acceptable and the nodules were well defined. The agreement for visualising the range of anatomical regions (Kappa test linear-weighting) suggests that observer 2 and 3 had a poor agreement level (0-0.366) and observer 1,4 and 5 had moderate agreement (0.5714-0.751).
Conclusion: The visual measures of IQ were largely unaffected by reconstruction techniques or mAs values. However, further work is needed for a better understanding of visual and clinical value of reconstruction techniques at lower doses.
Keywords: Lungs CT, reconstruction techniques, mAs, Image Quality, Optimisation.

Introduction

According to the Eurostat Database and the UK National Health Service, Computed Tomography (CT) is the radiological examination with the highest growth showing an increase of 10.3% in the UK alone for 10 consecutive years (1,2). The requests for CT scans has increased over time due to the improvements in detection of many pathologies (3). For this reason CT is used in screening programs such as lung and colon cancer detection, where asymptomatic patients are examined and early detection can be made (4). This increase in use has made optimisation a major topic. CT scans are associated with high radiation doses with an effective dose ranging from 2 to 16 mSv (5). These examinations may be associated with an increase in the risk of developing cancer, with a chance of approximately 1 in 2000 (6). In comparison, conventional radiography has a lower effective dose, ranging from 0.001 to 8 mSv for the more extensive exams (5). The increase in number of CT scans performed with the associated increase in risk is becoming a public health issue and for that reason it is important to reduce these risks by optimising the examinations according to the principle of 'As Low As Reasonably Possible/Practicable' (ALARP). Therefore, it is necessary to reduce dose while maintaining diagnostic image quality (IQ).

Manufacturers have implemented several techniques using both hardware and software in order to reduce dose without compromising IQ (7)we investigated whether images reconstructed using filtered back projection (FBP. One of the most recent strategies is the use of reconstruction techniques to improve the quality of images acquired with lower radiation dose. Filtered back projection (FBP) is frequently used for modern CT systems. FBP assumes the data is exact, but the projection data is noisy. The filter amplifies the noise and enhances or diminishes details on the image (8). This technique is considered an adequate method for reconstruction; however low doses or morbidly obese patients affect the performance of FBP, as they can promote artefacts. An alternative to FBP is iterative reconstruction (IR). Although this technique is not new, CT technology did not have the computational power to run this software until recently. IR can reduce dose by using algebraic reconstruction and is expected to allow imaging with similar noise levels and IQ as FBP (9).

There are several IR software solutions available and SAFIRE (Sinogram-Affirmed Iterative Reconstruction; Siemens Medical Solutions) is one of the most recent. SAFIRE is a hybrid technique that combines FBP and IR. Previous studies have shown that SAFIRE is capable of a 65% dose reduction without losing diagnostic information (10). The objectives of this study were to verify if the mAs and the reconstruction techniques affect the visualisation of anatomical details in lung CT exams using a phantom.

Methods

Image Acquisition

A multipurpose chest phantom (N1 “LUNGMAN”; Kyoto Kagaku) was used to produce the images (11). The phantom was positioned supine, head-first into the CT gantry and remained untouched during all acquisitions.

A Siemens Somatom Definition AS 128 slice CT scanner was used to acquire the images (12). The scanner was located at University Medical Centre in Groningen (UMCG). The scanner was warmed up and calibrated. All equipment used was subjected to the manufacturer specification for quality controls to ensure accuracy of the results. Six sets of 560 images were acquired (table1).

For each acquisition the Dose Length Product (DLP) was recorded. From the six sets provided, IQ analysis was only carried out on the three lower mAs values (10, 20, and 30 mAs). This was to verify if the observers could visualise various anatomical structures at a low mAs, which in turn meant a lower dose to the patient.

Exposure Parameters	Values
mAs	10, 20, 30, 40, 50, 66
kVp	120
Pitch	1.2
Slice Thickness	0.6mm
Matrix	512 x 512
Reconstruction Techniques	FBP, SAFIRE level 1, 3, 5
Body Kernel(13)	B31f, I31f
Reconstruction Plans	Axial, Coronal

Table 1 Exposure parameters used for image acquisition and reconstruction

Criteria	Likert scale used for each parameter
Lung edge	1 - It is not visible
Borders of larger vessels	2 - I can see it partially
Calcification in right main bronchi	3 - I can see it
Border of nodule	4 - It is clearly defined
Overall noise	1 - very poor: excessive noise or poor vessel wall definition
	2 - poor: poor vessel wall definition and prominent image noise
	3 - adequate: some image noise, vessel walls definition is minimal
	4 - good: minimal image noise definition of vessel walls are visible
	5 - very good: excellent definition of vessel walls, limited perceptual image noise
Overall image quality	1 - very poor: poor IQ due to artefacts, no definition between anatomical structures
	2 - poor; prominent artefacts, minimal definition between anatomical structures
	3 - adequate: minor artefacts present, definition between anatomical structures
	4 - good: no perceptual artefacts present, clear definition between anatomical structures
	5 - very good: no perceptual artefacts present, total definition between anatomical structures

Table 2 Criteria analysed by the observers and Likert scales provided

Perceptual IQ Analysis

The same axial and coronal slices were selected for each data set and analysed according to anatomical criteria provided by European guidelines (14), as well as for noise and overall IQ (table 2). Both axial and coronal slices were randomised, anonymised and four repeats were present in both axial and coronal data sets to determine the intra-observer-reliability. Slice selection was performed considering the anatomical details presented in each image.

A blind analysis of all images was undertaken by 5 qualified radiographers ranging in age of 31-58 years, with 5-32 years experience. Questionnaires were provided to all the observers to check whether they have had their eyesight tested within the last 12 months, if their eyesight was compromised and whether they wore glasses or contact lenses to correct it. The observers were trained using a presentation to show which relevant structures they had to analyse (figure 1 and 2). The images were randomised and the observers had to verbalise their answers. Three researchers were present at the time of scoring; one to train the observer and select the images, a second to manually enter the data from the observers and a third to monitor the two researchers to minimise error.

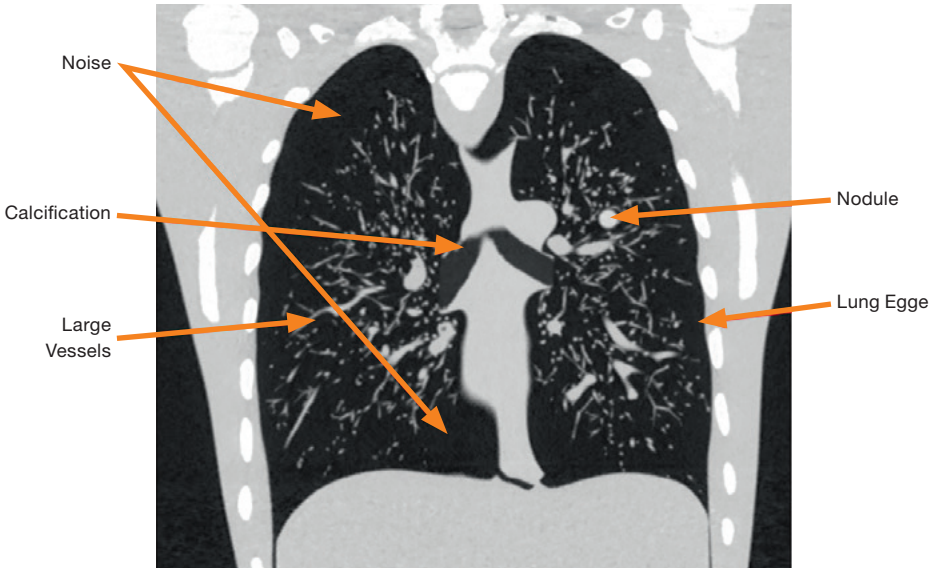


Figure1 Example of a coronal image scored by observers

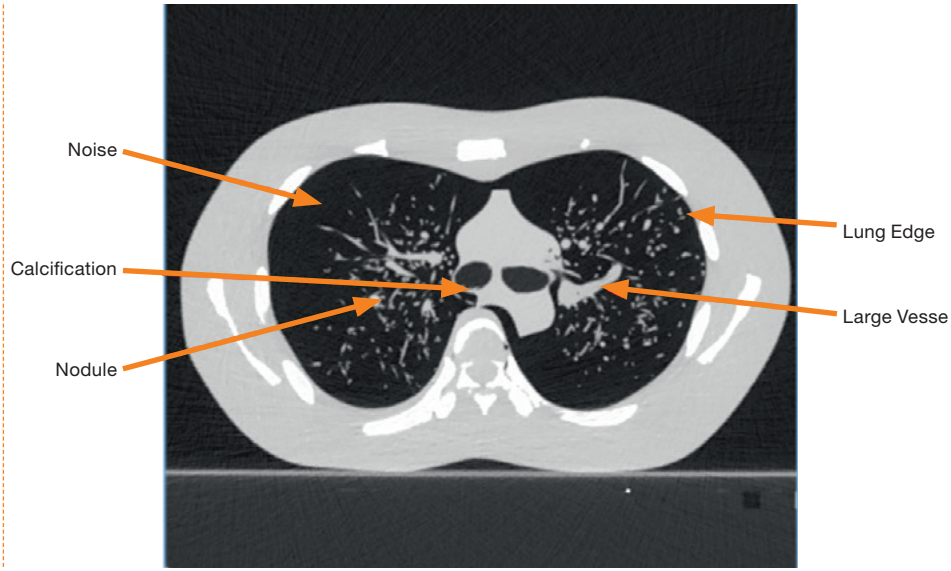


Figure 2 Example of anaxial image scored by observers

For all images, the scores were totaled in order to obtain a global score for each image. For questions 1-4 the global score was given at max=16, whereas for questions 5-6 the global score for each image was given at max=5. The scores were set in order to give an overall representation of all answers and observers combined. Since the scores did not differ significantly, the overall scoring is considered valid for comparison.

Two monitors were used, one for the axial and one for the coronal views. Images were viewed using calibrated Diagnostic 24.1" EIZO monitors with 1920 x 1200 pixels and the images were loaded using a DICOM Viewing Software. All images were set to the CT lung window at a window width of 1500 and a window level of -400 similar to clinical practice(15). The observers were not allowed to manipulate the images and had to keep their distance from the monitor constant to keep the same conditions for all observers. The room lights were turned off to prevent any light reflecting onto the monitors and there was no noise in the room to distract the observers.

Objective IQ Analysis

To mathematically calculate how reconstruction techniques affect the edge definition of each anatomical structure, measurements were made using *ImageJ* software on the nodule, larger vessel

and the lung edge (16). A line was drawn from a low contrast point across the border of the structure to a high contrast point within the structure(figure 3). The middle of the line was placed on the visible outline of the structure and remained the same in each image. To analyse the pixel value a plot profile was created (figure 4). A trend line was added to the linear points in the plot profile (figure 5) from which the edge gradient was calculated using Microsoft Excel(16). The difference between the edge gradients was converted into percentages. This procedure was replicated in all axial images.

Statistical Data Analysis

All the data was analysed using IBM SPSS Statistics Version 22 and Microsoft Excel. For the ordinal data a non-parametric test, the Wilcoxon Signed Rank test, was used to compare the data from the subjective

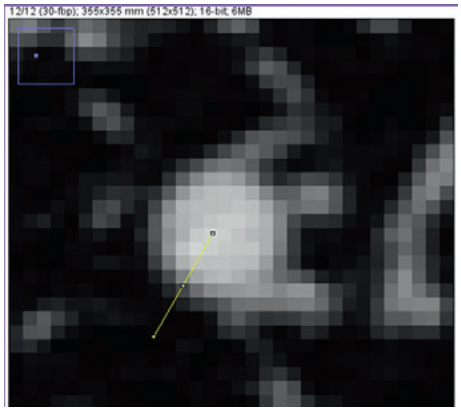


Figure 3 Line drawn from low contrast to high contrast in nodule

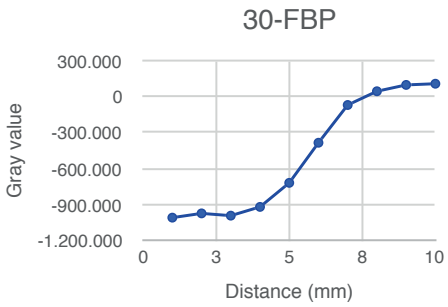


Figure 4 Graph showing the 30 mAs with FBP plot profile of the nodule

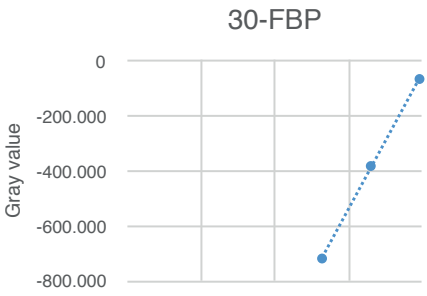


Figure 5 Graph showing the trend line from the 30 mAs with FBP nodule plot profile

Kappa value	Description
0	Same as expected by chance
< 0.40	Poor
0.40 – 0.75	Moderate
> 0.75	Excellent
1	Perfect

Table 3 Levels of Kappa values (18)

image analysis. P-values for the reconstruction techniques and mAs values were corrected with the Bonferroni Correction method. For the reconstruction techniques a p-value of <.0083 was considered significant and for the mAs values a p-value of <.0167 (17).

In order to determine the intra-observer reliability, four images were shown twice in a random order. A Kappa Test with linear weighting was performed to calculate the level of agreement, which in turn impacts the reliability of the observers (table 3).

Results

Visualisation of anatomical structures

The anatomical structures were scored using a 4-point Likert scale, with 3 being considered visible and therefore a level of acceptance for clinical practice. The values of each question were added up for all images, giving a maximum score of 16 and a level of acceptance at 12 (blue line in figures 6 and 7). However, partial identification of the anatomical structures was still possible when scored above 8 for some clinical applications.

The standard deviation shows that each reconstruction technique and mAs value causes variation in visibility, but are all still within the acceptance level. However, there was greater variation in the visualisation for the axial compared to the coronal images (figure 6 and 7).

The scores verify that some of the reconstruction techniques and mAs values compromise the partial visibility of structures, mainly at 10 mAs. For axial images reconstructed with FBP, the scores do not meet the level of acceptance in the visualisation with 10 mAs (figure 7).The results also demonstrate that the highest score was observed with 20 mAs and Safire 5 reconstruction.

The Wilcoxon Signed Rank Test showed no significant difference between the reconstruction techniques except between FBP and SAFIRE 3 (p = 0.002).

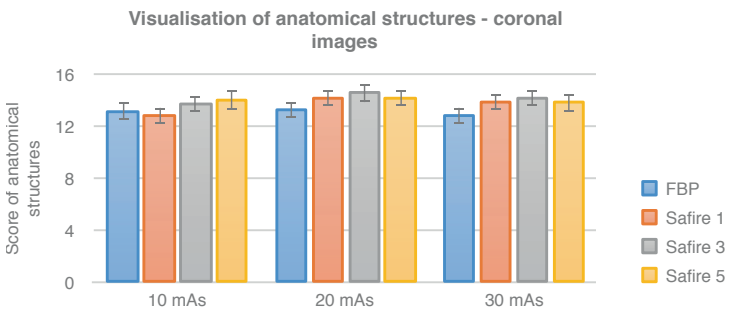


Figure 6 Visualisation of anatomical structures in coronal images comparing the mAs range (10-30) and 4 reconstruction techniques (FBP and Safire 1, 3, 5)

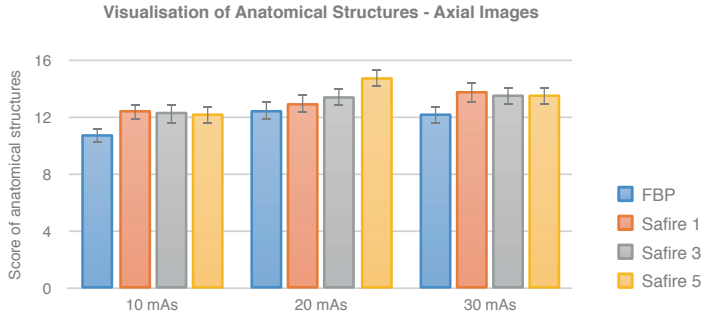


Figure 7 Visualisation of anatomical structures in axial images comparing mAs range (10-30) and 4 reconstruction techniques (FBP and Safire 1, 3, 5)

In addition, the test showed no significant difference between any of the mAs values with a Bonferroni correction ($p = 0.0167$).

Visualisation of image noise

FBP was compared with the SAFIRE levels used for this study and comparisons were made between these levels (figure 8). This suggests there is a reduction in image noise as mAs increases. Furthermore, it demonstrates that SAFIRE 5 has less overall image noise compared to the other reconstruction techniques for 10 and 20 mAs.

Looking at the raw data, the image noise was scored adequate, good and very good at 93.3% or higher for all mAs values per reconstruction technique. The Wilcoxon Signed Rank Test showed no significant difference between any of the reconstruction techniques except between FBP and SAFIRE 5 where there is a significant difference (FBP with SAFIRE 1, 3 and 5 respectively: $p = 0.033$; $p = 0.018$; $p = 0.001$; SAFIRE 1, 3 and 5: $p = 0.491$; $p = 0.124$; $p = 0.384$).

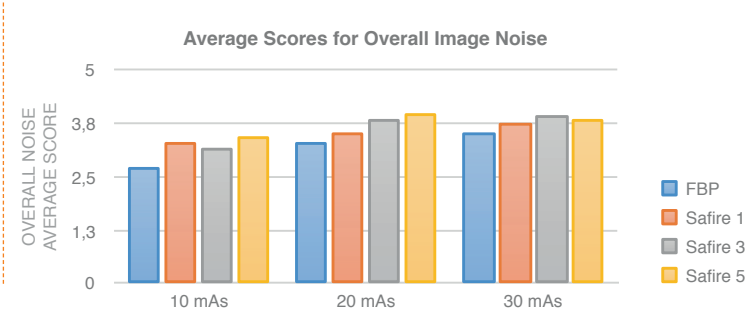


Figure 8 Bar chart demonstrating combined axial and coronal overall perceptual image noise score for each reconstruction technique at varying mAs values

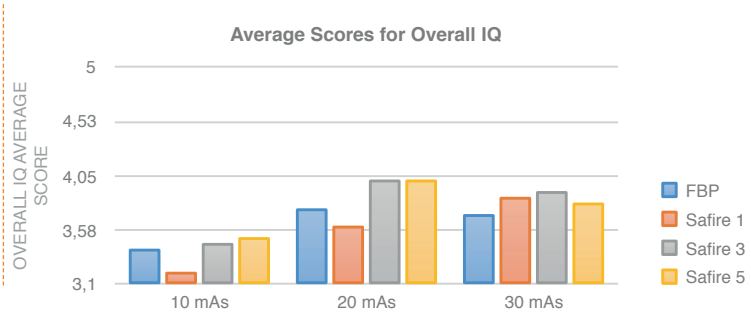


Figure 9 Bar chart demonstrating axial and coronal IQ score combined for each reconstruction technique at varying mAs values

Overall Image Quality

The overall IQ score is higher for 20 and 30 mAs compared with 10 mAs (figure 9). It also suggests that SAFIRE 3 produces images with higher quality than the other reconstruction techniques for 20 and 30 mAs. Just as with perceptual image noise, the observers scored the overall IQ at 93,3% or higher in the form of adequate, good and very good. The reconstruction techniques showed no significant difference between them as demonstrated by the Wilcoxon Signed Rank Test (FBP with SAFIRE 1, 3 and 5 respectively: $p = 0.405$; $p = 0.251$; $p = 0.083$; SAFIRE 1,3 and 5: $p = 0.046$; $p = 0.926$).

Objective Image Quality

The edge gradient increases when the reconstruction technique changes from FBP to SAFIRE 5 (figure 10). The sharpness of the structure is higher when the edge gradient is closer to 90°(16). This suggests that overall SAFIRE 5 at 20 mAs has a sharper outline in comparison to the other reconstruction techniques and mAs levels.

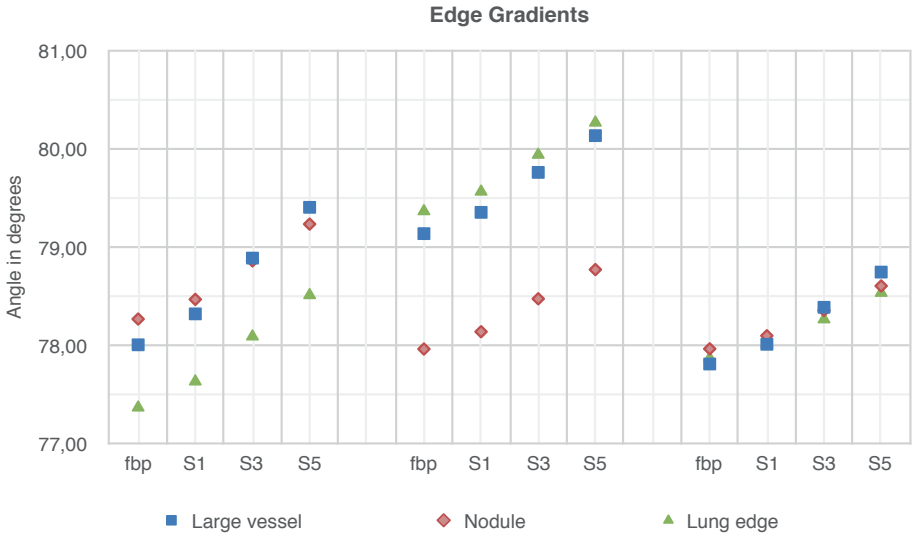


Figure 10 The calculated edge gradient against every reconstruction technique for every mAs value

The graph also shows that the biggest difference in edge gradients is between FBP and SAFIRE 5 for all mAs levels. The calculated differences between the different reconstruction techniques are minor, with a maximum increase of 1.79% (table 4).

Intra-observer reliability

The Kappa test with linear weighting suggests that observer 2 and 3 had a poor agreement level. The Kappa value for the coronal set of observer 2 could not be calculated. These observers were not excluded from the study, because of their high level of clinical experience as radiographers in CT departments. The remaining observers scored moderate for the kappa value (table 5). The kappa value of the observer 1, 4 and 5 is considered moderate.

Table 4 Difference in edge gradients between FBP and Safire 5 expressed in percentages.

mAs	Comparison of Reconstruction Techniques	Large Vessel	Nodule	Lung edge
10	FBP - SAFIRE 5	1.79%	1.23%	1.47%
20	FBP - SAFIRE 5	1.26%	1.03%	1.13%
30	FBP - SAFIRE 5	1.20%	0.82%	0.85%

	Axial	Coronal
Observer 1	0.6364	0.6924
Observer 2	0.366	N/A
Observer 3	0.1667	0.3333
Observer 4	0.5714	0.6471
Observer 5	0.7551	0.7097

Table 5 The kappa value calculated for each observer

Dose Length Product (DLP)

The DLP for the acquired images varied between 29.3, 58.6 and 87.9 mGycmfor 10, 20 and 30 mAs respectively (table 6).

Discussion

On the whole, FBP and SAFIRE 1, 3 and 5 with all mAs combinations demonstrated no significant differences in overall perceptual IQ (figure 6 and 7). For 10 mAs the observers scored different, depending on which structures they were looking at. The overall IQ was acceptable and the nodules were well defined (appendix 1). These findings are supported by other studies (19,20)bronchial polyp, solid nodule, ground glass nodule, emphysema and tree-in-bud. However, the observers could not see the calcification completely. This assumes that mAs should be considered depending on what the clinical indication is for the CT examination and also pathology protocol. Furthermore, when FBP was compared with SAFIRE, the visualisation of anatomical structures was also less defined when using FBP at 10 mAs in axial images (figure 7). This is supported by the calculated edge gradients (figure 10) and by other authors (9,21) due to the noise increase when using FBP.

This phantom based study gives an indication of potential detection of relevant structures in the clinical context for all reconstruction techniques at reduced mAs and dose. European guidelines recommend doses for CT lung below 650 mGycm. This research shows that a dose reduction of 95.5% is possible at

mAs	DLP (mGycm)	% of dose reduction against European Guidelines (650 mGycm)
10	29.3	95.5%
20	58.6	91.1%
30	87.9	86.5%

Table 6 The recorded dose for each mAs value

10 mAs (table 6). When considering the overall IQ score, a dose reduction of 91.1% can be achieved at 20mAs whilst still maintaining anatomical structure clarity. At 20 mAs, with an effective dose of 29.3 mGycm, screening for the early detection of cancer would be less harmful and spare the patient from unnecessary ionising radiation. When comparing the findings from this study with the European guidelines it is clear that it would be reasonable, as well as practicable, to lower the recommended dosage.

There were several limitations in this study, one of which was that this research was conducted on a phantom. When using a phantom the motion, breathing and heartbeat artefacts are not simulated. Also the simulated lesions are well defined and detection can be more obvious when compared to clinical exams. In addition, patients vary in size and tissue density as opposed to a phantom.

Another limitation of this study is related to the subjective IQ analysis (table 5). Observer 2 had a very low kappa value for the repeated axial images. The reliability of kappa is reduced due to few points. For observer 2 no weighted kappa could be calculated because the observed agreement was lower than the expected agreement (18,22). Subjective IQ analysis can also be influenced by the background training of the radiographers (23).

This study showed that visualisation of anatomical structures was possible even at a low mAs value of 20, and that partial visibility was made at 10 mAs. Therefore future research needs to consider values between 10 and 20mAs. Future research should include a bigger variety in clinical indications, patient size and exposure parameters (pitch, slice thickness and kVp).

Conclusion

The visual measures of IQ were largely unaffected by reconstruction techniques or mAs values. However, further work is needed for a better understanding of visual and the clinical value of reconstruction techniques at lower doses.

Acknowledgments

We would like to give acknowledgement to RuurdVisser for support in the statistical analysis, to the five observers that participated in this study, to the staff of Hanze University and UMCG that helped to collect the images for this project. Finally, we would like to thank Jesper and Paul for support using *ImageJ* and *Excel* software.

Bibliography

1. Commission E. EUROSTAT - Your key to European statistics [Internet]. Eurostat. 2015 [cited 2015 Aug 5]. p. Needs for health care. Available from: http://ec.europa.eu/eurostat/web/health/health-care/data/database
2. Steel P. NHS Imaging and Radiodiagnostic activity in England [Internet]. 2012 [cited 2015 Aug 12]. Available from: http://www.england.nhs.uk/statistics/wp-content/uploads/sites/2/2013/04/KH12-release-2012-13.pdf
3. Schmidt CW. CT scans: balancing health risks and medical benefits. Environ Health Perspect. 2012;120(3):118–21.
4. Team TNLSTR. Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening. N Engl J Med [Internet]. 2011 Aug 4;365(5):395–409. Available from: http://www.nejm.org/doi/abs/10.1056/NEJMoa1102873
5. Mettler F a, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 2008;248(1):254–63.
6. Services USD of H and H. Administration, U.S. Food and Drug [Internet]. 2015 [cited 2015 Aug 6]. Available from: http://www.fda.gov/RadiationEmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MedicalX-Rays/ucm115329.htm
7. Klink T, Obmann V, Heverhagen J, Stork A, Adam G, Begemann P. Reducing CT radiation dose with iterative reconstruction algorithms: The influence of scan and reconstruction parameters on image quality and CTDIvol. Eur J Radiol [Internet]. Elsevier Ireland Ltd; 2013;83(9):1645–54. Available from: http://dx.doi.org/10.1016/j.ejrad.2014.05.033
8. Fleischmann D, Boas FE. Computed tomography—old ideas and new technology. Eur Radiol [Internet]. 2011 Mar;21(3):510–7. Available from: http://link.springer.com/10.1007/s00330-011-2056-z
9. Willemink MJ, De Jong P a., Leiner T, De Heer LM, Nievelstein R a J, Budde RPJ, et al. Iterative reconstruction techniques for computed tomography Part 1: Technical principles. Eur Radiol. 2013;23(6):1623–31.
10. Kalra MK, Woisetschlager M, Dahlstrom N, Singh S, Digumarthy S, Do S, et al. Sinogram-Affirmed iterative reconstruction of low-dose chest CT: Effect on image quality and radiation dose. Am J Roentgenol. 2013;201(2):235–44.
11. Kyoto Kagaku Co. Patient Simulators, Imaging Phantoms for Skill Training [Internet]. 2012 [cited 2015 Aug 18]. Available from: https://www.kyotokagaku.com/products/detail03/ph-1.html
12. Siemens. SOMATOM Definition AS [Internet]. 2015 [cited 2015 Aug 17]. Available from: http://www.healthcare.siemens.nl/computed-tomography/single-source-ct/somatom-definition-as
13. Schabel C, Fenchel M, Schmidt B, Flohr TG, Wuerslin C, Thomas C, et al. Clinical Evaluation and Potential Radiation Dose Reduction of the Novel Sinogram-affirmed Iterative Reconstruction Technique (SAFIRE) in Abdominal Computed Tomography Angiography. Acad Radiol [Internet]. Elsevier Ltd; 2013;20(2):165–72. Available from: http://dx.doi.org/10.1016/j.acra.2012.08.015
14. Commission E. European Guidelines on Quality Criteria for Computed Tomography European Guidelines on Quality Criteria [Internet]. Menzel H, Jessen K, Panzer W, Shripton P, Tosi G, editors. Europe. European Commission´s Radiation Protection Actions; 1999. 1-71 p. Available from: http://www.msct.info/CT_Quality_Criteria.htm
15. Radiantviewer.com. Radiant-Viewer [Internet]. [cited 2015 Aug 21]. Available from: http://www.radiantviewer.com/dicom-viewer-manual/change_brightness_contrast.htm
16. Manning DJ, Ethell SC, Donovan T. Detection or decision errors? Missed lung cancer from the posteroanterior chest radiograph [Internet]. The British Journal of Radiology. 2004. 231-235 p. Available from: http://www.birpublications.org/doi/abs/10.1259/bjr/28883951
17. Field A. Discovering Statistics Using IBM SPSS Statistics. 4th editio. SAGE Publications Inc.; 2013. 228-235 p.
18. Fleiss JL, Levin B, Paik MC. Statistical methods for rates and proportions. 2nd ed. New York: John Wiley; 2003.

19. Botelho MPF, Agrawal R, Gonzalez-Guindalini FD, Hart EM, Patel SK, Töre HG, et al. Effect of radiation dose and iterative reconstruction on lung lesion conspicuity at MDCT: Does one size fit all? Eur J Radiol [Internet]. Elsevier Ireland Ltd; 2013;82(11):e726–33. Available from: http://dx.doi.org/10.1016/j.ejrad.2013.07.011
20. Christe A, Torrente JC, Lin M, Yen A, Hallett R, Roychoudhury K, et al. CT screening and follow-up of lung nodules: Effects of tube current-time setting and nodule size and density on detectability and of tube current-time setting on apparent size. Am J Roentgenol. 2011;197(3):623–30.
21. Baumueller S, Winklehner A, Karlo C, Goetti R, Flohr T, Russi EW, et al. Low-dose CT of the lung: potential value of iterative reconstructions. Eur Radiol [Internet]. 2012 Dec;22(12):2597–606. Available from: http://link.springer.com/10.1007/s00330-012-2524-0
22. Altman D. Practical Statistics for Medical Research. London: Chapman and Hall; 1991.
23. Kakinuma R, Ashizawa K, Kobayashi T, Fukushima A, Hayashi H, Kondo T, et al. Comparison of sensitivity of lung nodule detection between radiologists and technologists on low-dose CT lung cancer screening images. Br J Radiol [Internet]. 2012 Sep;85(1017):e603–8. Available from: http://www.birpublications.org/doi/abs/10.1259/bjr/75768386

Appendix 1

Table 5 The kappa value calculated for each observer

		Lung edgeVessel		Calcif	Nodule
		q1_axial	q2_axial	q3_axial	q4_axial
mAs	Score	Frequency			
10	Not visible	0	0	0	0
	See partially	2	3	8	1
	Visible	14	16	10	16
	Clearly defined	4	1	2	3
20	Not visible	0	0	0	0
	See partially	0	4	1	0
	Visible	8	12	13	8
	Clearly defined	12	4	6	12
30	Not visible	0	0	0	0
	See partially	0	7	1	0
	Visible	10	6	16	6
	Clearly defined	10	7	3	14

Are physical measures good indicators of image quality at low dose levels? A pilot study

Lanca L[1], Andersen EN[2], Carvalho G[1], Gerwen v. M[3], Jorge J[4], Kleiker M[5], Markali B[2], Nightingale P[6], Hogg P[7]

1 Lisbon School of Health Technology (ESTeSL) Polytechnic Institute of Lisbon, Portugal
2 Department of Life Sciences and Health, Radiography, Oslo and Akerhus University College of Applied Science, Oslo, Norway
3 Fontys University of Applied Sciences, Eindhoven, The Netherlands
4 Haute Ecole de Sante Vaud-Filiere TRM, University of Applied Sciences and Arts Western Switzerland, Switzerland
5 Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, The Netherlands
6 The Nuffield Foundation and The Blue Coat School, Oldham, United Kingdom
7 School of Health Sciences, University of Salford, Manchester, United Kingdom

Abstract

Purpose: To evaluate if physical measures of noise predict image quality at high and low noise levels.

Method: Twenty-four images were acquired on a DR system using a Pehamed DIGRAD phantom at three kVp settings (60, 70 and 81) across a range of mAs values. The image acquisition setup consisted of 14 cm of PMMA slabs with the phantom placed in the middle at 120 cm SID. Signal-to-noise ratio (SNR) and Contrast-to-noise ratio (CNR) were calculated for each of the images using ImageJ software and 14 observers performed image scoring. Images were scored according to the observer`s evaluation of objects visualized within the phantom.

Results: The R^2 values of the non-linear relationship between objective visibility score and CNR (60kVp $R^2 = 0.902$; 70Kvp $R^2 = 0.913$; 80kVp $R^2 = 0.757$) demonstrate a better fit for all 3 kVp settings than the linear R^2 values. As CNR increases for all kVp settings the Object Visibility also increases. The largest increase for SNR at low exposure values (up to 2 mGy) is observed at 60kVp, when compared with 70 or 81kVp.CNR response to exposure is similar. Pearson *r* was calculated to assess the correlation between Score, OV, SNR and CNR. None of the correlations reached a level of statistical significance ($p>0.01$).

Conclusion: For object visibility and SNR, tube potential variations may play a role in object visibility. Higher energy X-ray beam settings give lower SNR but higher object visibility. Object visibility and CNR at all three tube potentials are similar, resulting in a strong positive relationship between CNR and object visibility score. At low doses the impact of radiographic noise does not have a strong influence on object visibility scores because in noisy images objects could still be identified.

Introduction

Medical radiation exposure is increasing worldwide. From 1993 to 2008 the annual effective dose per capita more than doubled from 3.0mSv to 6.2mSv respectively for diagnostic medical radiological examinations(1). Low radiation exposure can cause stochastic effects which occur by chance and are primarily related to cancer and genetic mutations(2). It is important to minimise unnecessary patient exposure and to ensure radiation doses delivered are as low as reasonably achievable (ALARA) whilst maintaining an image quality suitable for diagnostic purposes(3).

Quantum noise has an impact on physical and quality measures of X-ray image. This type of noise is a variation in the image signal due to the random Poisson distribution of photons(4). This means that quantum noise is inversely proportional to the exposure dose(3) and can be measured by using the standard deviation of the signal variations in a radiograph(5). Quantum noise influences contrast, resolution and consequently, the representation of an object in the image (e.g. an anatomical body part). For visual perception however, the observer may still be able to the see the image detail despite the noise presented in the radiographic image.

Visual evaluation and measures of radiographic noise can appear to be different from the physical measures(3). For dose reduction, it is important to know if the physical measures and visual image quality relate. If there is no noticeable effect on the visual image quality with a low dose but there is a mathematical impact, then the overall dose may be reduced without compromising the diagnosticimage quality.

In a clinical setting, the observer evaluates the image quality and determines whether it is suitable for diagnosis. According to some literature(3,6) low dose and low image quality can be used for a certain type of examinations: for example to determine the shape and size of the heart, measuring the angles of thoracic scoliosis, locating the presence of metallic foreign body in oesophagus, internal fixation of clavicle fracture, monitoring metal implantation for osteosynthesis, pacemaker implantation and metal valve replacement, and to some extent for reviewing pneumonia and tuberculosis, and follow-up atelectasis. A research question arises from this background literature – 'what impact does radiographic noise have on physical measures and observermeasures of 2D x-ray image quality'?

This pilot study aims to establish whether physical measures of noise predict image quality at high and low noise levels. The specific objectives are to measure image noise using physical indicators such as Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) and to compare with visual perception measures. In addition, dose reduction was investigated and the impact it has on physical measures of image quality without compromising image quality.

The operational hypothesis for this pilot study was that physical measures of image quality do not inversely correlate with measures of image quality at high noise levels for radiological decisions that are not noise limited (such as those cited in refs 3 & 6)

Methods

Study design

An experimental pilot study was undertaken to determine whether physical measures such as SNR and CNR can predict visual measures of image quality. Visual measures are represented by the image scoring of a test set of images with 14 observers using a mixture of subjective and objective questions.

Twenty-four digital radiographic images were acquired in Martini Hospital, Groningen (NL). SNR and CNR were calculated in ImageJ software (National Institute of Health, Bethesda, MD). The image-scoring test was runon a clinical quality controlled monitor.

Materials, equipment and image acquisition

All the images were acquired using standard Digital Radiography (DR) equipment (Phillips, Digital Diagnostic NZR 83).

A Pehamed DIGRAD phantom was used as the imaged object for both physical measurements (SNR and CNR) and image quality evaluation. This phantom consists of a 7 copper step wedge, 6 low contrast circles (15 mm diameter) for low contrast resolution and resolution line pattern angled at 45° to determine spatial resolution up to 5 LP/mm.

The set up for image acquisition consisted of adding 14cm of PMMA and placing the phantom in the middle of the PMMA slabs (figure 1). The source to image detector distance (SID) was 120 cm and all images were acquired using the same CsI+TFT detector (43cm × 43cm; 3.5lp/mm, 143 µm pixel size) and an anti-scatter grid with 36 lines/cm.The X-ray beam was collimated 32 cm × 33 cm.

The 24 digital X-ray images were obtained with kVp values (60, 70 and 81) and a range of mAs in each kVp setting. The corresponding exposure (mGy) delivered

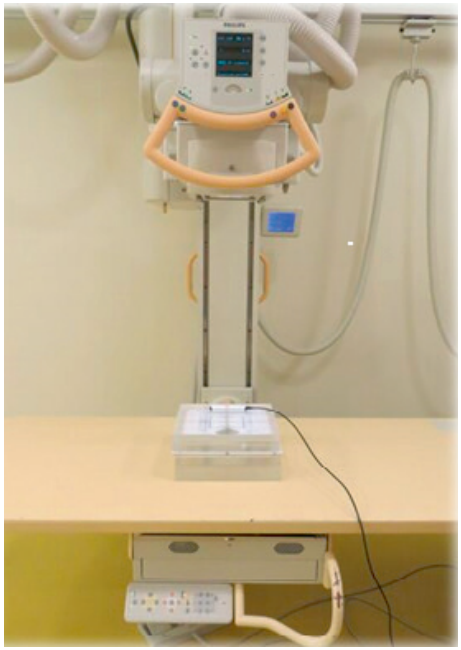


Figure 1 The setup for the X-ray equipment, phantom and the PMMA build up

60 kVp		70 kVp		81 kVp	
mAs	Exposure (mGy)	mAs	Exposure (mGy)	mAs	Exposure (mGy)
159.9	5.0	124.9	6.9	124.8	9.3
99.9	3.2	79.9	4.4	79.9	5.9
62.9	2.0	49.9	2.8	49.8	3.7
31.4	1.3	31.4	1.7	31.3	2.3
19.9	0.8	24.9	1.4	19.8	1.5
12.4	0.5	15.9	0.9	12.3	0.9
7.9	0.3	12.4	0.7	6.1	0.5
6.2	0.2	6.2	0.3	2.9	0.2

Table 1 Overview of the kVp, mAssettings and correspondent exposure (mGy) delivered to the detector

to the detector was measured using a calibrated Unfors™ Xi Prestige Platinum dosimeter. As expected the dose delivered to the detector decreased as the mAs decreased at each kVp setting (table 1).

Physical measures

The acquired images were first analysed by measuring the mean and the standard deviation (sd) pixel values of twofixed regions of interest (ROI's) to calculate SNR usingImageJ (figure 2 and equation 1a).CNR was also calculated usingtwo ROIs (Figure 3and equation1b).

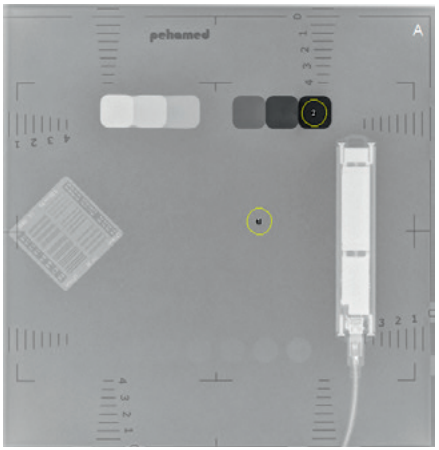
Similar studies have been done with these analytic tools (7,8).The equations *1a* and *1b*for calculating SNR and CNR are based on work by Bourne (4).

Observers and image scoring

Fourteen observers (10 female; 4 male) volunteered for the image-scoring test (mean age = 32; range, 20 – 57). All participants had normal or corrected-to-normal vision (9 corrected, 5 uncorrected) and were asked whether or not they had been to an optician in the last 12 months (11 had been to the optician, 3 had not). Observers were final year radiography students with clinical experience and qualified radiographers all of whom were participating in a European Dose Optimisation Summer School.

Figure 2 SNR region of interest

Figure 3 CNR region of interest



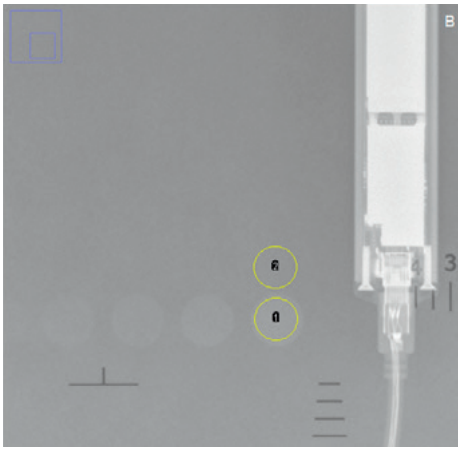


Figure 2 The homogenous area (1) of the phantom was used for the mean intensity and the air filled square (2) was used for the standard deviation of the background.
Figure 3 The area inside (1) the low contrast circle provided the mean intensity aand the homogenous background (2) provided the mean intensity b and the standard deviation b.

Equation 1a) μ_a is the mean intensity of the area of interest,$\sigma_b$is the standard deviation of the air filled area of the phantom. One standard deviation for 'correction factor' has been added. *Equation 1b)* μ_a is the mean intensity of one low contrast circle, μ_b is the mean intensity of the homogenous background and $\mu_b$is the standard deviation of the homogenous background.

$$= 0.66x = \mu \quad (eq.1a)$$

$$= |\mu - \mu| \quad (eq.1a)$$

Prior to the image scoring the observers were given full instructions and subjected to a short training session, which included examples of noise levels and images of objects to be evaluated. The observers were provided with definitions for each image quality criterion. The images were displayed in a semi-randomized order and evaluated by using an absolute scale (1 Low – 6 High). All of the images were scored according to the observer's evaluation concerning the objects visualized within the phantom. The observers were asked six questions, of which two were 'counting objects' – Objective Visibility (OV) scores - and the other 4 pertained the perception of image quality (table 2).

Question to observer	Possible answers
How sharp are the edges of the third square from the right?	On a scale from 1 – 6 (Low – High)
How many Line Pairs per millimeter do you see?	1: (0.8-0.9) lp/mm 2: (1.0-1.2) lp/mm 3: (1.4-1.6) lp/mm 4: (1.8-2.5) lp/mm 5: (2.8-3.7) lp/mm
How is the resolution of Line Pairs per millimetre?	On a scale from 1 – 6 (Low – High)
How many circles do you see?	0 – 8 circles visible
How great is the contrast between the third circle from the top and the background?	On a scale from 1 – 6 (Low – High)
Rate the quality of the image (globally)?	On a scale from 1 – 6 (Low – High)

Table 2 Complete questionnaire for image quality scoring.
For the second question the observers counted complete groups of Line Pairs (lp/mm).

The image analysis and the scoring of the images were undertaken on an EIZO Radiforce MX242W 2.3 Megapixel 24.1“LCD.

Statistical analysis

SPSS software (IBM Corp., 2011) was used to obtain descriptive and linear regression statistics.The assumptions for linear regression were not fulfilled so curve fitting was utilized to explore the trend (SNR – OV, CNR – OV) at the different kVp levels. R^2 was calculated with a linear and non-linear equation.

After the initial exploration of the relationship between SNR/CNR and exposure, correlation (Pearson *r*) analysis was done to explore the relationship between the physical and image qualitymeasures (individual scores for perception of image noise) for exposure doses ≤2 mGy (SNR – OV, CNR – OV, SNR – Score, CNR – Score).

Results

SNR

Figure 4and 5show the relationship between OV score and SNR.

Figure 4 demonstrates that at 60 kVp curve fitting for the SNR and objective visibility score has a linear R^2 value of 0.772, however the quadratic R^2 value is 0.878 (Fig 5). Both Figure 4 and 5 purposefully force the curve through the origin as zero (0) represents the absence of any visible object. At 70 kVp curve fitting for the SNR and objective visibility score has a linear R^2 value of 0.848, the quadratic R^2 value is 0.901. Finally, for the 81 kVp setting curve fitting for the SNR and objective visibility score has a linear R^2 value of 0.890, the quadratic R^2 value is 0.891.

The difference between the linear and quadratic R^2 values for 60kVp is +0.106, 70kVp is +0.053 and 81kvp is +0.001. This shows that at higher SNR values, the non-linear relationship with visual detection appears to be most fitting curve for the SNR values.

CNR

Figure 6 and 7 show the relationship between objective visibility score and CNR.

In the non-linear graph (Fig.6) the R^2 values (60kVp R^2 = 0.902; 70Kvp R^2 = 0.913; 80kVp R^2 = 0.757) demonstrate a better fit for all 3 kVp settings than the linear R^2 values (Fig.7).

As CNR increases for all kVp settings the Object Visibility also increases. However, there seems to be a point of saturation (CNR=2.8) for 81kVp.

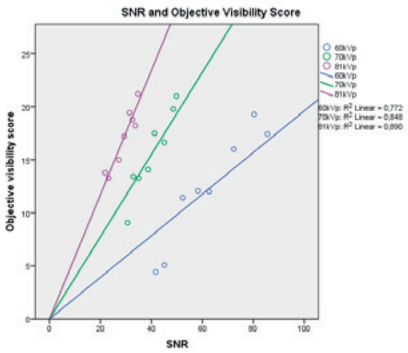


Figure 4 SNR and Objective Visibility Score (linear)

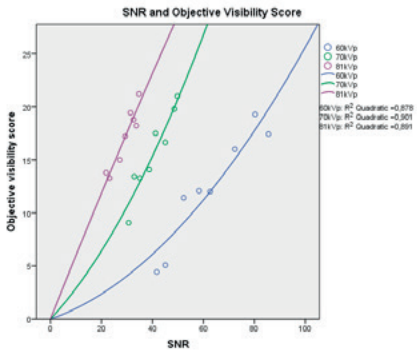


Figure 5 SNR and Objective Visibility Score (non-linear)

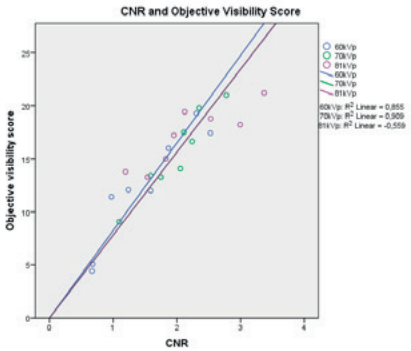


Figure 6 CNR and Objective Visibility Score (linear)

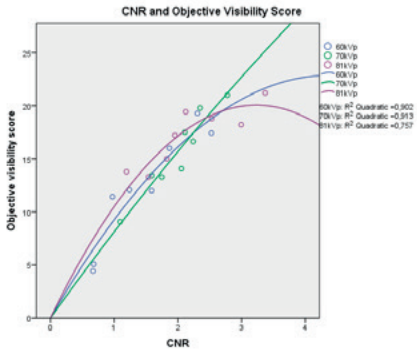


Figure 7 CNR and Objective Visibility Score (non-linear)

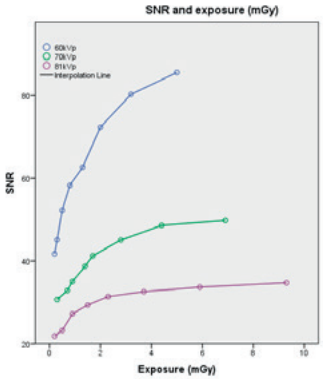


Figure 8 SNR and exposure (mGy)

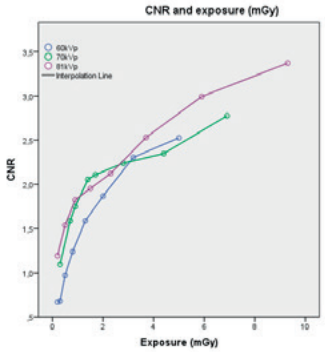


Figure 9 CNR and exposure (mGy)

Exposure

It is shown in figures 8 and 9 that as the exposure increases the SNR and CNR increase, as expected.

SNR measures the potential information content of the image data related to the detector exposure. The largest increase for SNR at lower exposure values (up to 2 mGy) is observed at 60kVp when compared with 70 or 81kVp (Fig. 8). At 81kVp the SNR is relatively stable from 2mGy up to 9.3mGy (Fig. 8), showing no benefit when increasing the dose to the detector.

For all 3 kVp settings, CNR response to exposure is similar, with CNR variation is 1.87-2.11, for low exposures ranging between 1.5 - 2mGy (Fig.9). Although the CNR increases with dose, the contrast provided by

the detector is very similar in terms of CNR among the three kVp settings. This may indicate thehuman visual perception of an object in the radiograph could not depend only on the CNR but on other factors (e.g. the size and shape of a structure). At low exposure (<2mGy) the detector is providing a CNR at the three kVp settings where the observers can see the objects. A correlation analysis between object visibility (OV), the image quality score given by the observers, SNR and CNR is given below.

Correlation analysis for low dose exposure (<2mGy)

Table 3 presents the descriptive statistics at low dose exposure (<2mGy): minimum and maximum values, mean and standard deviation for all 4 variables.

Analysis for Pearson *r* was calculated to assess the relationship between Score, SNR and CNR (table 4). For 60 kVp the correlation between Score, SNR and CNR suggest a nonlinear relationship (r = .009, r = .069). At the 70 kVp level the correlation between the 3 variables suggest a strong linear relationship (r = .782 r = .718). However, the *p*-values for the 70 kVp level did not reach the set level of significance (p>0.01). At the 81 kVp level the Score and SNR have a strong relationship

Table 3 Descriptive statistics with Object Visibility, image qualityscore, SNR and CNR at low dose exposure (<2mGy)

kVp	Measure	Minimum	Maximum	Mean	sd
60	OV	0	20	10.17	5.015
	Image quality score	1	5	2.61	1.059
	SNR	41.69	72.33	55.38	11.41
	CNR	0.69	1.86	1.17	0.49
70	OV	4	24	13.47	4.442
	Image quality score	1	6	3.25	0.881
	SNR	30.67	41.23	35.71	4.3
	CNR	1.09	2.10	1.71	0.41
81	OV	4	24	14.82	4.099
	Image quality score	1	6	3.83	0.974
	SNR	21.84	29.32	25.39	3.47
	CNR	1.19	1.95	1.62	0.33

Table 4 Correlation for image quality score, SNR and CNR. Pearson r and p-value reportedat low dose exposure (<2mGy)

		60 kVp		70 kVp		81 kVp	
		SNR	CNR	SNR	CNR	SNR	CNR
Image quality score	Pearson *r*	.009	.069	.782	.718	.720	.503
	p-value	.987	.896	.118	.172	.280	.497

Table 5 Correlation for Object Visibility, SNR and CNR. Pearson r and p-value reportedat low dose exposure (<2mGy)

		60 kVp		70 kVp		81 kVp	
		SNR	CNR	SNR	CNR	SNR	CNR
Object Visibility	Pearson *r*	.559	.538	.372	.179	-.046	.151
	p-value	.249	.271	.538	.774	.954	.849

(r = .720), but score and CNR have moderate correlation (r = .503). The p-values for the 81 kVp level did not reach the set level of significance (p>0.01).

Analysis for Pearson r was calculated to assess the relationship between OV, SNR and CNR (table 5). For 60 kVp the correlation between OV, SNR and CNR shows a moderate relationship (r = .559, r = .538). At the 70 kVp level the correlation between the 3 variables suggest a weak linear relationship between the variables (r = .372,r = .179). At the 81 kVp level the Score and SNR suggest a nonlinear relationship (r = .720), but score and CNR show a weak correlation (r = .503).

Discussion

In this study an attempt was made to produce test object images under different exposure conditions and measure SNR and CNR of those images and compare the results with observer scores from the same test object images. SNR and CNR were measured from all the 24 images and special attention was given to low dose exposure images (<2mGy).

A common way to quantify the level of noise in an image is to estimate the SNR(4). At low SNR values an increase in SNR will not affect detection as much as at higher SNR values. The results from our study suggest a non-linear relationship exists between SNR and Objective Visibility Score. It is possible that at low SNR values, SNR may not accurately predict visual

image quality, because visibility depends on contrast (the difference between signals) (4).

In this study, as the CNR value increases the object visibility also increases for all 3 kVp settings. However, figure 6 shows that object visibility does not differ between all three tube potentials. The non-linear relationship for 81 kVp between object visibility and CNR reaches a point of saturation; this may indicate that beyond a certain point an increase in CNR does not improve object visibility further. Contrast constancy, is found when observers adjust the physical contrast of different frequency ratings in order to achieve the perception of an equal apparent contrast(9). Threshold sensitivity is assumed to be a function of the signal to noise ratio, whereas perceived contrast is assumed to be a function of the signal alone and to be independent of the noise (10). In observer studies, the fall-off in threshold sensitivity to spatial contrast at high frequencies has been attributed both to optical and neural factors of contrast attenuation.

It appears that at 81 kVp the CNR continues to increase with no further increase in objective visibility score (Fig. 7), so it may be true that its unnecessary to increase the contrast in an image to see a the object more clearly. Radiologic assessment of spine scoliosis in paediatric patients is an example of a procedure which does not require high contrast to be clinically valid (3). However, further work is required to explore this finding.

As expected, increasing exposure increases both SNR and CNR (Fig. 8 and 9) in a broad range of exposures up to approximately 10mGy. However, analysing the data at low exposures up to 2mGy special attention should be given to evaluate objective visibility and image quality score.

For low dose exposures ($\leq$ 2 mGy) there is a decrease in SNR from 60 kVp (55.38) to 81 kVp (25.39), confirming the findings from other authors (11), and giving a normal response from the detector to the absorbed dose: at lower kVp and the same dose, SNR is higher, although it could not affect image visibility as the ability to see objects in an image depends on contrast. The mean values for image quality score and Object visibility increase from 60 kVp to 81 kVp (table 3). This implies that the observers are able to see more objects and evaluate the image quality on higher kVp levels. Even though the exposure doses at 70 and 81 kVp are comparable with 60 kVp. This might be because a higher tube potential results in higher energy photons that are more able to penetrate the phantom and reach the detector than lower energetic photons.

The correlation for all three kVp settings at low dose exposure (table 5 and 6) varied between nonlinear to strong linear relationship. However none of the correlations reached the set level of statistical significance (p>0.01). Because the values were not significant, these findings should be interpreted with

caution. However, practical implication could be important on the choice of the tube potential regarding the anatomical region of a radiological study, suggesting that at low exposure levels, objects are detected by the observers with no significant differences.

The correlations and the descriptive statistics suggest that object visibility and subjective evaluation measures may not be related to SNR and CNR at low dose levels. Although the higher correlation values at 70 kVp between Score, SNR and CNR (r = .782 r = .718) cannot be ignored.

The results for 60 kVp (Score – SNR, Score - CNR) presented in table 5 show a non-linear correlation between physical and visual image quality measures. This might be explained by a low agreement among the observers when evaluating low dose noisy images. Tube potential setting for 60 kVp produces a low energy X-ray beam when compared with 70 and 80 kVp. This would cause different pixel intensity values at the DR detector providing lower intensity values thus more noisy images.

For object visibility the observers might not be affected by variation in image noise level. This means that the observers are still able to differentiate between objects and the noisy image background. However when observers score the image quality at 70 and 81 kVp, SNR and CNR have strong correlation although a non-statistical significant relationship. The score for low dose images at 60 kVp do not correlate with SNR and CNR. One explanation could be related to the lower tube potential at 60 kVp, which results in a lower energetic X-ray beam reaching the digital detector and thus producing noisy images.

For the objective visibility score against SNR (Fig. 4 and 5) and CNR (Fig. 6 and 7) it was also found that the R^2 value for the fitted curve which was forced through the origin. This was decided as when the SNR is 0 the objective visibility score cannot theoretically be different than zero. However, it would be better to have more data of the lower SNR and CNR values for a more reliable extrapolation. A larger amount of data would open more possibilities in terms of statistical tests. This pilot study utilized analyses which should be considered exploratory.

A questionnaire was used to collect information about the eyesight of the observers but further research might involve an eyesight test performed before the start of the data collection to increase the reliability/ validity of the research.

The observers were able to score 24 images in this research. By conducting further research more data can be collected by increasing the number of observers and the number of images displayed. As

well as using observers with for example more than 5 years of experience in image interpretation.

The relationship between physical measures and visual image quality at low exposure levels may be determined. To get more reliable correlations between SNR, CNR and objective visibility scores, more images should be analysed for each kVp setting, with the possibility of using other kVp settings in addition.

Conclusion

For object visibility and SNR, tube potential variations may play a role in object visibility. Higher energetic X-ray beam settings give lower SNR but higher object visibility. Object visibility and CNR at all three tube potentials are similar, resulting in a strong positive relationship between CNR and object visibility score.

At low doses the impact of radiographic noise does not have a strong influence on object visibility scores because in noisy images objects could still be visible and suitable for image interpretation.

Acknowledgements

The authors would like to thank the Martini Hospital (Groningen) radiology department and staff for their cooperation in this research project. We would also like to thank all the observers and Summer school staff.

References

1. UNSCEAR. Annex A: Medical Radiation Exposures. Sources and Effects of Ionizing Radiation Volume I. 2010. 1-220 p.
2. ICRP. Annals of the ICRP Annals of the ICRP. Ann ICRP. 2007;2007.
3. Uffmann M, Schaefer-Prokop C. Digital radiography: The balance between image quality and required radiation dose. Eur J Radiol. 2009;72(2):202–8.
4. Bourne R. Fundamentals of Digital Imaging in Medicine. Springer; 2010. 200 p.
5. Lanca L, Silva A. Image quality in Diagnostic Radiology. In: Digital Imaging Systems for Plain Radiography. New York: Springer; 2013. p. 63–77.
6. Zhang M, Zhao B, Wang Y, Chen W, Hou L. Dose Optimization for Different Medical Imaging Tasks From Exposure Index, Exposure Control Factor, and mAs in Digital Radiography. Health Phys. 2012;103(3):235–40.
7. Mraity H, England a., Akhtar I, Aslam a., De Lange R, Momoniat H, et al. Development and validation of a psychometric scale for assessing PA chest image quality: A pilot study. Radiography [Internet]. Elsevier Ltd; 2014;20(4):312–7. Available from: *http://dx.doi.org/10.1016/j.radi.2014.03.007*
8. Yuan L, Hui L, III JTD, McAdams HP, Wang X, Sehnert WJ, et al. An image-based technique to assess the perceptual quality of clinical chest radiographs. Med Phys. 2012;39:7019–31.
9. Committee on Vision; Commission on Behavioral and Social Sciences and Education; Division of Behavioral and Social Sciences and Education; National Research Council. Emergent Techniques for Assessment of Visual Performance. Washington, D.C.: National Academies Press; 1985. doi:10.17226/916
10. Brady N, Field DJ. What's constant in contrast constancy? The effects of scaling on the perceived contrast of bandpass patterns. Vision Research.1995;35(6), 739–756. doi:10.1016/0042-6989(94)00172-I
11. Schaefer-Prokop C. Digital chest radiography : an update on modern technology, dose containment and control of image quality. Eur J Radiol. 2008;18:1818–30.

HANZE-16_0671