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Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers

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ABSTRACT

Introduction: MRI is highly physics based yet no research-based inventory of physics learning outcomes specific to MRI radiographers was found in the literature. The purpose of this study was the development of such an inventory using a multi-stakeholder, multi-disciplinary approach (as advised by the WHO) and which would support a previously published competence profile.
Methods: The inventory was developed in two phases:
Phase 1: Development of an initial version of the learning outcomes inventory required to be able to deliver the competences via an analysis of textbooks and literature and validated by a small (n = 3) expert advisory group
Phase 2: Final validation carried out via a bigger (n = 15) international group of subject matter experts (SMEs). Consensus was achieved via a dichotomous web-based questionnaire.
Results: At 70% level of consensus the expert group validated an inventory of biomedical physics learning outcomes consisting of 281 knowledge and skill statements. It is subdivided into two sections: ‘fundamental’ physics learning outcomes which are generic to all competences and ‘additional’ physics learning outcomes specific to each individual competence.
Conclusion: The process used is sufficiently generic to be easily adapted to the development of physics learning outcome inventories in other specialties of radiography and for other healthcare professions whose work involves highly technological medical devices. As a result of this study, the current MRI curriculum would need to be revised as it was not based on a formal systematic research process and many learning outcomes are in fact missing.

Introduction

Radiographers have an important role in magnetic resonance imaging (MRI) service provision. Together with radiologists and medical physicists they are responsible for the planning and execution of routine and complex procedures, education of patients, informing the public and healthcare professionals about MRI procedures, carrying out quality assurance, safety and risk management, coordination of the facility and research.[1] This context requires radiographers to have sufficient biomedical physics knowledge and skills and was the major drive to develop and validate an inventory of MRI biomedical imaging physics learning outcomes.[2–5] Given the limited time for continuous professional development (CPD) activities in busy MRI centres, well considered choice of learning outcomes is of particular importance.[1] Developing CPD curricular content in a systematic and multi-disciplinary research based manner helps ensure that the curriculum design process leads to learning outcomes which would be directly relevant to clinical practice and with a high level of validity evidence.[6,7] Therefore, a validated inventory of learning outcomes can:

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1. Inform MRI managers of the biomedical physics knowledge and skills required of radiographers before planning new MRI services.
2. Help curriculum developers ensure more research based and clinically relevant learning outcomes.
3 Assist competence assessment organizations improve the assessment of knowledge and skills that shape lifelong learning

Purpose

The researcher sought to develop a comprehensive inventory of biomedical imaging physics knowledge and skill learning outcomes that would support the competences required by current and future MRI radiographers to operate MRI scanners in an effective, safe and efficient manner and participate fully in the multidisciplinary MRI environment.[1]

Methodology

A 5-step strategy based on a multistakeholder expert consensus as recommended by the World Health Organization[8] was used to develop and validate the MRI physics learning outcome inventory. Fig. 1 explains the rationale behind the sequencing of the steps leading to the development of the inventory.

The results of the first four steps have already been published and involved the developing and validating of a 2020 competence profile for MRI radiographers for Malta[1] based on a forecasted future service profile[9] and an optimized patient pathway.[10] The consensus building techniques used were Delphi and Nominal Group Technique. A survey of competence profiles from the major native English speaking countries (United Kingdom, Ireland, New Zealand, Australia, United States of America and Canada) was carried out to identify elements of good practice in existing competence profiles.[11] These countries were chosen as their educational provision and role development is relatively advanced and related documentation is often well-developed, does not require translation and easily available.[12]

Step 5 consisted of two phases:

Phase 1: Development of an initial version of the biomedical imaging physics learning outcomes inventory underpinning the competence profile via an analysis of textbooks and literature and the advice of the advisory board (AB) purposely set up for this study. The members consisted of one consultant radiologist, one medical physicist and one radiographer. All had more than 10 years of experience in MRI, education and research.

Phase 2: Final validation of the biomedical imaging learning outcomes inventory via an international group of subject matter experts (SMEs) consisting of 5 radiographers, 5 radiologists and 5 medical physicists.

A comprehensive list of MRI textbooks and peer reviewed articles that explained MRI physics was used to develop an initial blueprint of the physics knowledge and skills required for each of the MRI competences. The content was expressed in short phrases ensuring that the wording and level of detail reflected the purpose of the knowledge or skill statement and were meaningful even to an outside reviewer.

Since a substantial number of knowledge and skill statements were common to all competences the inventory was divided into two sections:

Section 1: FUNDAMENTAL physics knowledge and skills which were GENERIC TO ALL COMPETENCES and

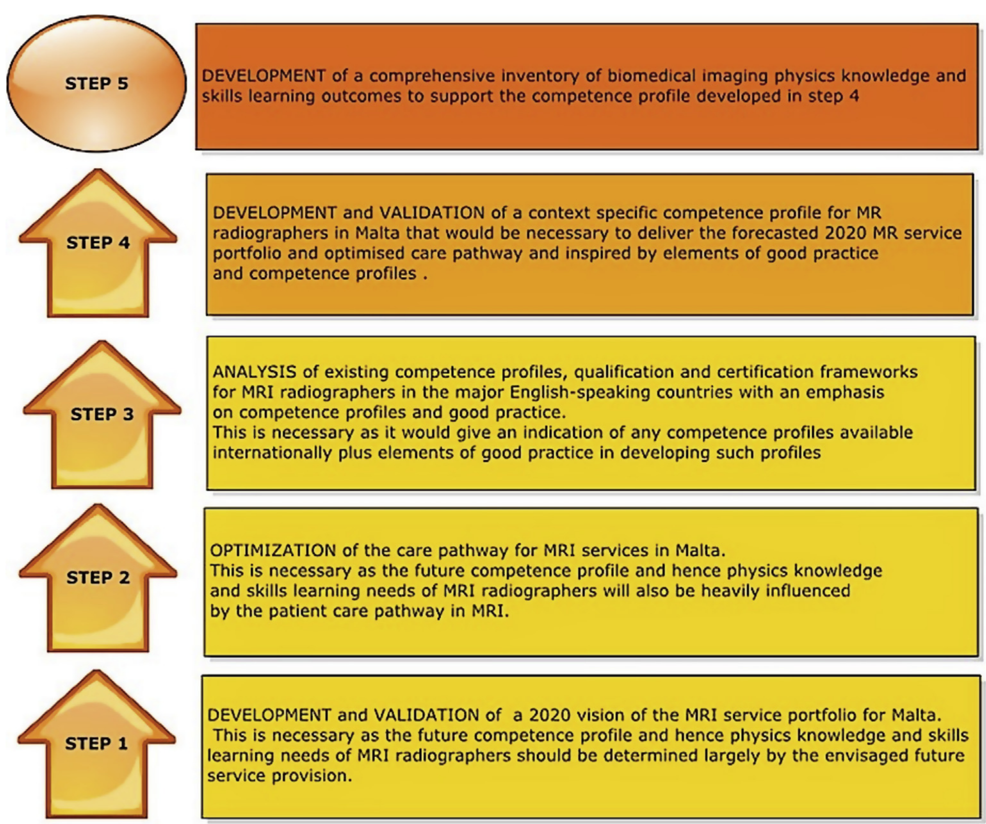

Figure 1. The five-step strategy to develop and validate an inventory of biomedical imaging physics learning outcomes.

Section 2: ADDITIONAL physics knowledge and skills SPECIFIC to each INDIVIDUAL competence.Whereas the fundamental knowledge and skills are expected to be acquired by all MRI practitioners independently of their particular competence responsibilities, the additional knowledge and skills would be those associated with the subset of competences from the competence profile which he/she is expected to deliver.

The advisory board was asked to assess each item in the initial inventory for

(i) appropriateness and accuracy of content and possible redundancy,
(ii) being essential as opposed to simply desirable, and
(iii) clarity.[13]

A dichotomous scale (1 = not essential, 2 = essential) was used in both phases. In the case of phase 1 the Content Validity Index (CVI) was used to estimate the validity of the items.[14] Owing to the large number of knowledge and skill learning outcomes only statements with a minimum CVI approval rating of 67% (i.e., at least 2 out of three experts in favour) were included in the final blueprint. The advisory board was also asked to suggest additions or deletions and provide an overall evaluation of the blueprint, with attention paid to comprehensiveness (whether the inventory adequately covers the domain content i.e., all the competences in the competence profile) and clarity hence ensuring face validity.[15] The researcher proceeded in the creation of serial drafts based on the feedback of the advisory board. In total, there were 7 revisions which resulted in an inventory containing 324 knowledge and skill statements.

Final validation of the learning outcomes inventory was carried out by a larger (n = 15) consensus group of subject matter experts (SMEs). A purposive sampling approach was used in the selection of participants, since it was desirable to source participants with sufficient experience and knowledge. Morse[16] and Hsu and Sanford[17] indicate the following criteria for recruiting experts suitable to a study: the participant must have knowledge and experience of the phenomenon under scrutiny, they must have the capacity to express themselves, and must be willing to participate in the study. Purposive sampling is believed to enhance the trustworthiness of a study.[18]

Panel members were identified based on qualification and their clinical and research expertise in MRI. A minimum of 10 SMEs are recommended to yield acceptably consistent responses and to avoid chance agreement.[19] In this study a panel of 15 international SMEs (5 radiographers, 5 radiologists and 5 medical physicists) participated in the final validation exercise which was carried out as an anonymous web-based survey. For recruitment, a “snowball” strategy was used based on the personal contacts of the advisory board members, who in turn proposed other suitable candidates in their professional settings.[20]

Once panel members were identified, a cover letter explaining the goals of the project was sent via email. The cover letter included a link to the web based survey and consent to participate.

Again owing to the large number of learning outcome statements (324) the survey did not consider various levels of agreement and consensus based on an extended Likert scale but a dichotomous scale with 2 levels of agreement only – agree/disagree. The use of a dichotomous scale when the purpose of the consensus method is to seek convergence of opinions on the final product, is common for large inventories.[21–23]

The level of consensus used by different researchers for inclusion of a particular learning outcome in the final version of an inventory is quite variable. Von der Gracht[24] recommends to base consensus on an accepted standard, such as political voting systems (e.g. simple majority, two-thirds majority). Stemler[25] states that a typical guideline for evaluating the level of consensus is that of 70% or greater. Some researchers use a ‘75% or greater’ participant consensus cut-off point.[21,23] Masud et al.[26] in developing a European curriculum for geriatric undergraduate medicine chose a 100% level of consensus. However, this is rare and only really appropriate for small inventories and when many consensus iterations are possible. For this study, the researcher chose 70% as the level of consensus for the final version of the inventory. This value was chosen to ensure that there is a right balance between avoiding an overlong inventory whilst avoiding losing knowledge and skills learning outcomes considered important by the advisory board. However, versions of the inventory at 80% and 90% levels of consensus were also considered. These can be utilised if CPD time is not sufficient to deliver the full 70% level of consensus inventory. Approval to carry out this research was obtained from the University of Malta Research Ethics Committee, Malta (proposal no 004/2016).

Results

The final version of the inventory at the 70% level of consensus is shown in Supplementary Table 1. Supplementary Table 2, provided supplementary online material shows an analysis of the knowledge and skills statements lost at the 70% version by profession including researcher's comments. A high level of consensus within a given profession (4 or 5 Yes out of a possible maximum of 5) is highlighted as green, while low level of consensus (1Y or 2Y) is highlighted as red. Medium level of consensus (3Y) is highlighted as orange. Medians were calculated to assess overall similarities and differences between professions with regard to the inventory as a whole.

Discussion

The primary objective of this study was to reach consensus on the biomedical imaging physics learning outcomes required by MRI radiographers. Starting with a published list of MRI competences developed in an earlier study (itself based on a forecasting of service needs, analysis of the patient pathway and elements of good practice in existing competence profiles), this study involved a systematic research-based process of learning outcome development and validation aimed at supporting that competence profile. This is one of the hallmarks of authentic curriculum development as outlined by Lee et al.[27] and Totte, Huyghe and Verhagen.[28] For a relatively new content domain such as physics for MRI radiographers, formulation of learning outcomes presents an important challenge. The researchers believe that this is the first time that an inventory of physics learning outcomes for MRI radiographers has been developed using such a comprehensive, systematic, multi-stakeholder, research-based collaboration and the process can be useful in other domains and in the case of other health care professions who use advanced physics based healthcare technologies.

Validation by consensus by multi-disciplinary groups was emphasized at every step of the process. The forecasted service portfolio, clinical care pathway and competence profile were also developed by consensus with multistakeholder groups. The physics inventory itself was also validated by a multi-disciplinary group of SMEs. The web based survey method can be an important source of validity evidence in medical imaging education providing an acceptable solution to the problem of geographical distances. In addition, because the survey is anonymous, there is less risk that strong personalities bias the input from other colleagues or that a group from any institution dominates the debate.

The consensus method of validation has its advantages but also its weaknesses. At very stringent levels of consensus (e.g., 90%

levels of consensus and higher) knowledge and skills that may be considered important by a large number of the participants may end up eliminated. At the other extreme, setting very low consensus thresholds would lead to inordinately large inventories which would not be deliverable in the CPD time available. With this in mind, the researcher chose 70% as the cut-off criterion for level of consensus for the final suggested version of the inventory. At 70% level of consensus, the expert group rejected 35 knowledge and 8 skill statements which in total amount to 13%, of the initial blueprint inventory.

Consensus at the 70% level was obtained for the complete set of Fundamental MRI Physics learning outcomes bar one with the experts commenting that at this level radiographers should also demonstrate basic knowledge of Diffusion Weighted Imaging (DWI) and Susceptibility Weighted Imaging (SWI), daily quality control (QC), and explain and identify the various types of artefacts. This confirmed that the knowledge and skills in this section were indeed generic to all competences and could be used as an introductory course for radiographers starting their MRI careers.

Of note is that the majority of statements that were rejected in the Image Acquisition key activity all focused on advanced applications specifically Diffusion Tensor Imaging, Time-intensity curves, Spectroscopy, Kinematic Imaging, ultrashort TE, Spin labelling imaging and MRI-PET. This could mean that knowledge and skills about procedures which currently are not yet routine practice were being side-lined in favour of focusing more on knowledge and skills required for the more common techniques. The comments from medical physicists also indicated that the underlying physics concepts are too technical, and participants commented that they are not really necessary for radiographers to know particularly given the fact that radiographers have other subject areas on top of physics. '*Some of the topics here are very advanced and/or specialised I don't think necessary for the radiographer (medical physicist, personal communication, 23rd March 2017)* ', '*These are very advanced topics. I would only expect the radiographer to be conversant with practical aspects (medical physicist, personal communication, 22nd March, 2017)*'. Other statements which referred to generation and analysis of time–intensity curves, MR spectroscopy metabolites maps, liver iron maps, fat in liver were also rejected with comments suggesting that radiographers should not be involved in analysis ' *… produce but not analyse, be aware if it does not look correct- (radiologist, personal communication 3rd April, 2017)' and 'display and be able to discriminate between good quality from bad but not to analyse the study (radiologist, personal communication, 12th April, 2017).*

There was only one competence the knowledge and skills of which were totally rejected by radiographers. This was related to facility management specifically about knowledge of MRI physics terminology to liaise with medical physicists in the development of referral guidelines and learning outcomes. The only comment was that '*radiographers should focus on the patients imaging experience as opposed to the before and after the journey (radiographer, personal communication, 30th March 2017)*'. Another comment was that '*Referral guidelines are clinically based and the liaison is more appropriate to be with radiologists rather than medical physicists (radiographer, personal communication, 10th May, 2017)*'. These comments seem to indicate that participants expected the radiographer as focusing on the image production rather than playing a key role at the interface between patient and technology, or being the pivot between referrers, patients and radiologists as identified in a workshop on the implementation of referral guidelines.[29] The comments from radiographers and radiologists also indicate that some participants do not appreciate sufficiently the clinical contribution of medical physicists. This is quite surprising because the design of guidelines should involve multidisciplinary collaboration.[29]

Interestingly, regarding the statements rejected at this level of consensus (70%), if one considers the inventory in its totality and compares the medians of the number of participants opting for a yes by professional group, less radiographers (median = 3) and Medical Physicists (median = 3) than Radiologists (median = 4) agreed with statements pointing to the possibility that radiologists expect a higher level of physics knowledge and skills from radiographers.

Conclusion

A comprehensive and validated inventory of MRI biomedical imaging physics learning outcomes has been developed using data originating from the local MRI setting and using a formal multiprofessional research process. Content validation by consensus was central and was further strengthened through the collaboration from an international panel of experts, having equal representation from the three professions directly involved in the MRI service. The inventory of learning outcomes was divided into two sections – 'Fundamental' biomedical imaging physics generic to all competences and 'Additional' biomedical imaging physics specific to each individual competence. The fundamental biomedical physics set of learning outcomes achieved a high content validation indicating that it could be used on its own as an introductory CPD to entry level radiographers in MRI. The Fundamental physics learning outcomes could ideally be included in the undergraduate radiography curriculum. Image Acquisition learning outcomes related to some less frequently used advanced applications were rejected at the 70% level of consensus. The comparative results between the three professions, in general indicate that medical physicists and radiologists are more open towards interprofessional collaboration than radiographers. It is important to note that although this study targeted physics knowledge and skill learning outcomes for MRI radiographers and in a particular context *from a methodological perspective* the process used to develop and validate the learning outcomes inventory is sufficiently generic to be easily adapted to the development of curricular content for other healthcare professions which make use of physics based complex technologies.

Conflict of interest statement

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.radi.2019.01.002.

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