Defining the Key Competencies in Radiation Protection for Endovascular Procedures

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Defining the Key Competencies in Radiation Protection for Endovascular Procedures: A Multispecialty Delphi Consensus Study

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WHAT THIS PAPER ADDS

This paper defines the key competencies in radiation protection. These are the knowledge skills, technical skills, and attitudes that all healthcare workers involved in endovascular procedures should know, to ensure the safety of both patients and themselves. The paper explores the discrepancies in ratings between vascular surgeons, interventional radiologists, and interventional cardiologists, and addresses problems with the current system of radiation protection education and the need for up to date and relevant, concise training programs.

Objectives: Radiation protection training courses currently focus on broad knowledge topics which may not always be relevant in daily practice. The goal of this study was to determine the key competencies in radiation protection that every endovascular team member should possess and apply routinely, through multispecialty clinical content expert consensus.

Methods: Consensus was obtained through a two round modified Delphi methodology. The expert panel consisted of European vascular surgeons, interventional radiologists, and interventional cardiologists/angiologists experienced in endovascular procedures. An initial list of statements, covering knowledge skills, technical skills and attitudes was created, based on a literature search. Additional statements could be suggested by the experts in the first Delphi round. Each of the statements had to be rated on a 5- point Likert scale. A statement was considered to be a key competency when the internal consistency was greater than alpha = 0.80 and at least 80% of the experts agreed (rating 4/5) or strongly agreed (rating 5/5) with the statement. Questionnaires were emailed to panel members using the Surveymonkey service.

Results: Forty-one of 65 (63.1%) invited experts agreed to participate in the study. The response rates were 36 out of 41 (87.8%): overall 38 out of 41(92.6%) in the first round and 36 out of 38 (94.7%) in the second round. The 71 primary statements were supplemented with nine items suggested by the panel. The results showed excellent consensus among responders (Cronbach's alpha = 0.937 first round; 0.958 s round). Experts achieved a consensus that 30 of 33 knowledge skills (90.9%), 23 of 27 technical skills (82.1%), and 15 of 20 attitudes (75.0%) should be considered as key competencies.

Conclusions: A multispecialty European endovascular expert panel reached consensus about the key competencies in radiation protection. These results may serve to create practical and relevant radiation protection training courses in the future, enhancing radiation safety for both patients and the entire endovascular team.

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INTRODUCTION

Background/rationale

Endovascular procedures have become the treatment choice for most cardiovascular pathologies. Often, these minimally invasive procedures result in shorter recovery times than conventional approaches. However, X-rays used during these procedures can cause important biological effects: deterministic effects occur if a threshold dose is exceeded, causing skin damage, hair loss, etc.; and

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stochastic effects, responsible for various solid organ cancers and leukemia, which can occur at any dose, but the risk increases at higher doses.[1,2] Both patients and healthcare workers are at risk, as increased incidences of conditions such as posterior subcapsular cataract have been reported in healthcare workers chronically exposed to ionizing radiation.[3,4] Therefore, to protect patients and healthcare workers, it is crucial that radiation doses are minimized, without jeopardising quality or safety during endovascular procedures. This is the basis of radiation protection, also called the ALARA principle (As Low As Reasonably Achievable).[1,5]

To ensure that healthcare workers apply these principles in daily practice, appropriate education, followed by refresher courses is essential.[6,7] The Euratom Basic Safety Standards Directive 2013/59, issued by the European Commission states: "...practitioners and individuals involved in the practical aspects of medical radiological procedures have adequate education, information and theoretical and practical training for the purpose of medical radiological practices, as well as relevant competence in radiation protection."[8]

Unfortunately, "adequate" training has not been clearly defined and specific training curricula are lacking, causing variations in content, format and requirements across Europe. International guidelines[8–10] were developed to design more uniform radiation protection training; however, these documents often cover a multitude of topics (e.g. elemental physics, practical radiation protection aspects, various imaging modalities), which may not always be relevant or feasible to implement in daily practice. Additionally, these guidelines are often not up to date with new technologies, which are increasingly being used to reduce radiation.[11,12]

To create relevant and uniform European training and refresher courses, it is necessary to first define which competencies in radiation protection (knowledge skills, technical skills and attitudes) are the most important and relevant for all healthcare workers active in (hybrid) angiography suites. This study was initiated to identify these key competencies.

MATERIALS AND METHODS

The Delphi technique

This study was conducted using an email based modified Delphi technique. The Delphi methodology has already been used in various areas of healthcare research to obtain expert consensus.[13] It is an iterative and structured consensus forming process, conducted through multiple successive rating rounds. Participants evaluate Delphi statements and further re-evaluate these statements in subsequent rounds, based upon anonymous controlled feedback about group responses. This process is repeated until consensus is achieved or a predetermined number of rounds is completed.[13–16]

This technique has important benefits. Firstly, emailed questionnaires allow panel members from various geographical locations to participate without logistic problems. Secondly, the modified Delphi technique is conducted anonymously, ensuring that participants have equal possibilities to give or change their opinion during the process, eliminating the risk of having dominant panel members, which may occur with face to face consensus formation strategies.

Expert panel

A heterogeneous expert panel of European vascular surgeons, interventional radiologists, and interventional cardiologists/angiologists was identified through purposive sampling and invited. An expert was defined as someone with experience in endovascular procedures, a high volume clinical practice, and sufficient knowledge about clinical content (indicated by their publication track record and/or appearance as congress faculty). Considering expert dropout, the study aimed to have at least 5—10 experts per discipline, which has been suggested as a minimum when working with different professional groups.[16,17] All participants gave written consent prior to the start of the study and their identity remained hidden during the study's course.

Survey and Delphi statements

The first round Delphi statements were defined prior the start of the study, based on radiation protection literature and international recommendations and adapted to the knowledge/skills/attitudes framework.[1,5,8–10,18] All statements were reviewed by the research team, comprising three vascular surgeons and one physicist. In total, the first Delphi round contained 71 statements (29 knowledge, 25 technical skill and 17 attitude statements) which had to be rated on a 5 point Likert scale ranging from '1, Strongly disagree' to '3, Neutral' to '5, Strongly agree'. Additionally, experts could provide comments and suggest new statements. Information about participants' demographics, endovascular experience and radiation protection habits were collected through a questionnaire included in the first round survey.

Consensus

There are no formal criteria to define consensus in an expert panel,[13] therefore this study used two frequently used measures: firstly, the Cronbach's Alpha score,[7,19] for which an alpha value of 0.80 was chosen as an indicator of consensus; secondly, the percentage of experts (dis) agreeing with a statement.[13,17] If at least 80% of the experts scored an item as "(Dis)agree" or "Strongly (dis)agree", it was considered as panel (dis)agreement.

Delphi rounds: Data collection

Responses were collected through SurveyMonkey (SurveyMonkey Inc., San Mateo, CA, USA). Participants had 5 weeks to complete each round, with reminders being sent to nonresponders in the third and fifth week. After the first round, participants' comments about the Delphi statements and suggestions for new statements were processed and distribution parameters (mean and standard deviation) were calculated. The second volume round survey was sent to the experts who had completed the first round and contained the adjusted Delphi statements, with the distribution parameters and the newly added statements.

Statistical analysis

Statistical analysis was performed using SPSS 24.0 (Statistical Package for the Social Sciences, IBM Company, Armonk, NY, USA). Final ranking of the statements was established using mean values of the first round ratings. Statistical analysis was only performed for the participants who completed all rounds. The Kruskal—Wallis H test was used to determine if there were differences in ratings between two or multiple groups and the Wilcoxon signed rank test was used to compare ratings between different rounds. A p value $< .05$ was considered to be statistically significant.

RESULTS

Participants: Demographics and radiation protection habits

Forty-one of 65 high volume, clinical content experts participated in this study. Thirty-eight experts (22 vascular surgeons; 10 interventional radiologists; 6 interventional cardiologists), representing 16 European countries (Table 1), completed the demographics and radiation protection habits questionnaires (Table 2). In three of 16 countries (Greece, Serbia, and Portugal), a radiation protection course was not mandatory and in the remaining countries a theory based course was required.

Delphi results

The overall response rate was 87.8%: 38 of 41 experts completed the first Delphi round and 36 completed the second round. Table 3 provides the detailed response rates per round and specialty.

Consensus was achieved for 68 of 80 statements (85.0%) in the second round. Overall internal consistency was excellent in both rounds (first, 0.937; second, 0.958). Between rounds, nine statements were added (4 knowledge skills, 3 technical skills, and 2 attitudes). One technical skill was transferred to the category attitudes. Twenty-four statements were adjusted after the first round; mainly minor additions such as “whenever possible” (15/24) and clarifications of the context (9/24). A detailed overview of the ratings for both rounds can be found in Supplementary Appendix 1. The following section summarises the results of the second Delphi round.

For the knowledge skills, Cronbach’s alpha was 0.948 and 0.949 in the first and second rounds. Three of 33 (9.10%) statements were not considered key competencies and removed: “The mechanism of X-ray production”, “the electromagnetic spectrum & the position of x-rays” and “The difference between flat panel detectors and old school image intensifiers”. The top three knowledge statements were “Specific risks for healthcare workers”, “Management of pregnant staff, threshold doses & period of highest risk” and “Cause and importance of scatter radiation” (Table 4).

Cronbach’s alpha for the technical skills was 0.832 in the first and 0.897 in the second round. Twenty-three of 27 technical skill statements (85.18%) were considered key competencies. The top three technical skill

Table 2. Participant demographics and radiation protection habits.

Mean (range) age, years	49.5 (38—65)
Mean (range) experience as specialist, years	14.5 (2—27)[a]
Gender M/F, n	36/2
Active in a (hybrid) angiography suite, n (%)	27 (71.1)
Active in academic hospital, n (%)	34 (89.5)
Number of total endovascular procedures, n (%)	
51—100	1 (2.6)
101—500	6 (15.8)
Over 500	31 (81.6)
Number of endovascular procedures past year, n (%)	
None	1 (2.6)
1—50	4 (10.5)
51—100	8 (21.1)
101—500	16 (42.1)
Over 500	9 (23.7)
Use of personal protective equipment, n (%)	
Lead apron	38 (100)
Thyroid collar	36 (94.7)
Lead glasses	19 (50)
Lead gloves	1 (2.6)
Use of shielding equipment, n (%)	
Table mounted lead flaps	30 (78.9)
Ceiling mounted systems	18 (47.4)
Mobile shielding	11 (28.9)
Number of dosimeters used, median (IQR)	2 (1—2)
Use of passive dosimeters, n (%)	35 (92.1)
Use of active dosimeters, n (%)	8 (21.1)

[a] $n = 37$ due to erroneous input.

Table 1. Represented countries.

Countries	Participants	Countries	Participants
Austria	3	Italy	5
Belgium	2	The Netherlands	5
Denmark	1	Portugal	1
France	2	Serbia	1
Germany	3	Spain	1
Greece	1	Sweden	2
Hungary	1	Switzerland	3
Ireland	1	United Kingdom	6

Table 3. Participant response rates per specialty.

	Vascular surgeons	Interventional radiologists	Interventional cardiologists
Invited	31	18	16
Agreed to participate, N (% of invited)	24/31, 77.42	10/18, 44.44	7/16, 43.75
Responses round 1, N (% of participating)	22/24, 91.67	10/10, 100	6/7, 85.71
Responses round 2, N (% of participating)	22/24, 91.67	10/10, 100	4/7, 57.14

Table 4. Top rated statements for each of the three categories.

Top 3 statements per category	Round 1 (n = 38) Mean	SD	Median	Consensus (%)	Round 2 (n = 36) Mean	SD	Median	Consensus (%)
Knowledge skills								
Specific risks for the healthcare workers	4.71	0.46	5	100	4.92	0.28	5	100
The management of pregnant staff, threshold doses and period of highest risk	4.68	0.74	5	97.4	4.81	0.40	5	100
The cause and importance of scatter radiation	4.84	0.37	5	100	4.78	0.59	5	97.2
Technical skills								
Increase distance from radiation source when performing DSA runs	4.95	0.23	5	100	4.94	0.23	5	100
Avoid putting hand within the fluoroscopy field	4.82	0.39	5	100	4.94	0.23	5	100
Maximize their distance from radiation source whenever possible	4.82	0.39	5	100	4.89	0.32	5	100
Attitudes								
Use a lead apron and thyroid collar	4.92	0.27	5	100	4.97	0.17	5	100
Only use X-rays when all team members are adequately protected	4.84	0.55	5	97.4	4.92	0.37	5	97.2
Confirm adequate protection of other team members before using X-rays	4.84	0.55	5	97.4	4.86	0.54	5	97.2

statements were “Increase distance from radiation source when performing DSA runs”, “Avoid putting hands within the fluoroscopy field”, “Maximize distance from radiation source, whenever possible” (Table 4). There was no consensus for the statements “Use a live feedback personal dosimeter“, “Vary fluoroscopy angles to limit patient peak skin dose” and statements regarding control of the C-arm.

For attitudes, Cronbach’s alpha in the first and second round was 0.750 and 0.820 respectively. Expert consensus was achieved in 15 out of 20 statements (75%). The statements “Use a lead apron and thyroid collar”, “Only use X-rays when all team members are adequately protected”, “Confirm adequate protection of other team members before using X-rays” were rated the highest (Table 4). No consensus was achieved for the statements: “Register the administered radiation doses in the patients file”, “Consider the risk/benefits for each procedure (justification principle)”, “Inform patients of the radiation related risks”, “Use leaded leg protection” and “Use radioprotective gloves”.

Seven statements were rated significantly different between rounds (Table 5), of which two (“The difference between flat panel detectors and old school image intensifiers” and ”Consider the risks/benefits for each procedure (justification principle)”) were removed after the second round. Alternatively, “Use 3D overlay imaging to reduce the number of DSA runs”, “adjust table and gantry positions without X-rays” and “Avoid the use of steep angulations whenever possible” only achieved consensus after statement re-evaluation.

There were no differences in ratings among different specialties for knowledge skills and attitudes. However, for technical skills three statements were rated significantly lower by vascular surgeons than other specialties (Table 6).

When comparing expert ratings based on their radioprotective behavior, users of active dosimeters ($n = 8$) did not rate statements regarding dosimeter use different from other experts: “Use passive dosimeters in a correct way” (mean 4.57 vs. 4.75; $p = 0.61$) and “Use a live feedback (active) personal dosimeter (e.g. dose aware)” (mean 3.82 vs. 4.38; $p = 0.26$).

Ratings for the statement “The C-arm movements & settings should only be controlled by people who are scrubbed in” were significantly different between participants who always ($n = 20$), sometimes ($n = 10$) or never ($n = 6$) controlled the C-arm themselves (mean 4.80 vs. 3.50 vs. 2.83; P<0.01). Ratings for “A radiographer should be in control of the C-Arm” did not differ between these groups (mean 2.95 vs. 3.20 vs. 3.83; $p = 0.54$).

Table 5. Significant changes in ratings between the two rounds.

Statement	Rating round 1 Mean (SD)	Rating round 2 Mean (SD)	p
The electromagnetic spectrum and the position of x-rays			
	4 **(**1.10)	3.56 **(**1.16)	0.04
Specific risks for the healthcare workers			
	4.72 (0.45)	4.92 (0.28)	0.04
The difference between flat panel detectors and old school image intensifiers			
	4.14 (0.80)	3.83 (0.85)	0.03
Use and position radioprotective drapes correctly, if available			
	4.31 **(**0.82)	4.56 (0.65)	0.02
Avoid the use of steep angulations whenever possible			
	3.86 (1.10)	4.36 (0.76)	0.003
Use 3D overlay imaging to reduce the number of DSA runs and adjust table and gantry positions without X-rays			
	4.08 (1.00)	4.42 **(**0.73)	0.02
Use radioprotective gloves			
	3.08 (1.18)	2.69 **(**1.12)	0.005

DISCUSSION

Radiation protection is essential in specialties where ionising X-rays are used for diagnostic and/or therapeutic purposes to warrant the safety of team members and patients.

Table 6. Significant differences in ratings between the three participating specialties.

Round	Vascular surgeons ($n = 22$) Mean (*SD*)	Interventional radiologists ($n = 10$) Mean (*SD*)	Interventional cardiologists ($n = 4$) Mean (*SD*)	*p*
Use and position radioprotective drapes correctly				
Round 1	4.23 (0.869)	4.3 (0.823)	4.75 (0.5)	0.50
Round 2	4.32 (0.716)	4.9 (0.316)	5 (0)	0.02
Adapt table height to the primary operator				
Round 1	3.95 (0.95)	4.7 (0.483)	4.75 (0.5)	0.04
Round 2	4 (0.976)	4.7 (0.483)	4.75 (0.5)	0.06
Use 3D overlay imaging to reduce the number of DSA runs, and adjust table and gantry positions without X-rays				
Round 1	3.91 (1.065)	4.7 (0.483)	3.5 (1)	0.03
Round 2	4.27 (0.767)	4.7 (0.483)	4.5 (1)	0.26

This study aimed to define the key competencies in radiation protection as viewed from the perspective of high volume, clinical content experts. Using a two round modified Delphi methodology, a European multispecialty panel identified which competencies should be mastered by every healthcare worker involved in endovascular procedures.

Knowledge skills

Traditional radiation protection trainings often cover topics such as theoretical aspects and basic physics. However, in this study, these topics were among the lowest rated, with some not considered key knowledge. This may indicate clinical content experts believe these theoretical topics may be touched upon during radiation protection training, but possibly not extensively nor during refresher courses, since it may not be relevant during actual clinical practice. In contrast, experts perceived scattered radiation and practical knowledge about radiation reducing measures as very important topics, suggesting these should be extensively covered during training courses.

Other statements scored highly by the panel included knowledge about risks associated with ionising radiation, especially the risks and management of radiation during pregnancy. The latter is logical, considering the increasing number of women among staff and because foetal X-ray exposure may have important effects on foetal development, depending on the exposure doses and timing.[20,21] This is indeed relevant for patients, who may be exposed to high X-ray doses, but far less for pregnant healthcare workers, as the doses they receive are spread out over time and not high enough (given adequate protection) to cause meaningful effects on foetal development or childhood malignancy rates.[21] Therefore, radiation protection training should handle the risks for patients and personnel in a realistic and pragmatic way.

Technical skills

The main principles of radiation protection are considered to be “reducing exposure time”, “increasing distance from the radiation source”, and “adequate shielding”.[1,5] In this study, these skills were among the highest rated and scored as ‘relevant’ by nearly all experts, emphasising that these basic but effective principles should be mastered by everyone in the angiography suite.

Although operator controlled imaging during EVAR procedures has been shown to lower radiation doses,[12,22] experts did not reach consensus on who should control the C-arm. Differences in local practices may play a role in this, since the role of radiographers is strongly dependent on local rules/habits. In this study, experts who controlled the table themselves scored the statement about “on table control” significantly higher than other experts. However, such differences were not observed for the statement about radiographers controlling the C-arm.

While live feedback dosimeters provide operators with useful information and reduce radiation doses,[23–25] they were used less than passive dosimeters and were not considered important in routine practice. Although ratings may have been influenced by who had access to this technology, experts’ scores did not differ significantly between those who used this technology and those who did not. Panel members commented that this technology could be very useful under specific circumstances; for example, people at risk of surpassing their dose limits or for training and alerting new team members.

Attitudes

This study also gained insight into the radio-protective attitudes that should be present during occupational radiation exposure, such as personal protection, ensuring safety of team members, and the importance of communication.

“Wear a lead apron and thyroid collar” was rated the highest, reflecting current practices reported by the experts. Lead gloves and leg protectors were the only types of personal protective equipment not considered standard use, possibly because use of lead gloves during interventional procedures is being questioned, as they are only beneficial when hands are kept out of the primary X-ray beam.[26] Additionally, use of leaded leg protection was not considered a key attitude, possibly because research in this area is rather new and the topic requires further study.

This study also touched upon topics of justification and patient consent, concepts regarded as cornerstones of radiation protection and medical practice and legally required in multiple European countries, following the European Council Medical Exposures Directive 97/43/Euratom.[10] Malone[27,28] previously raised concerns about informing patients of the risks associated with diagnostic radiology, possibly due to a lack of knowledge about the administered X-ray dose and its possible effects and overestimation of an examination's benefits.

Malone's concerns may also apply to endovascular treatments since statements about justification and patient consent were not seen as key competencies. Endovascular clinicians may overestimate treatment benefits and thereby over-prioritise treatment of the acute illness (e.g., limb salvage, aneurysm repair), especially since direct damage to patients rarely occurs[29] and knowledge about longer term consequences of radiation exposure may be lacking.[30] Additionally, experts commented that patients may easily overestimate the risks of radiation exposure during a procedure and thus may refuse treatment. As clinicians, this has been interpreted as a concern that long-term effects may cloud patients' judgment of the acute issue, which possibly explains why informing patients was not regarded as a key competency. This also suggests that endovascular clinicians may require more education about the methods for informed consent and the true risks of long-term harm of radiation doses and their effects.

Limitations

Since this study used the Delphi methodology, it may be subject to some limitations characteristic for this type of research. The observed dropout rates between rounds resulted in a small number of interventional cardiologists in the second round, which may make it difficult to generalise the findings within this field. However, an increase in Cronbach's alpha scores was observed between rounds for all competency categories. Since alpha normally decreases with fewer participants, the effect of consensus formation in this study was more important than the attrition.

Delphi studies have been criticised because the included items are chosen by the researcher, potentially inducing bias.[19] To counteract this, a literature search was performed before creating the statements and experts had the opportunity to comment on statements, or suggest additional ones. This strategy resulted in a complete, yet very long list of statements, which may have caused some of the attrition.

Thirdly, possible selection bias cannot be ruled out, since selection of experts at random or free participation are not feasible, because experts need to match quality requirements. Therefore, a rather large group of experts from across Europe was invited. Additionally, even though all experts were respected specialists in their respective fields, they were drawn from a pool of interventionalists. It was assumed that expertise in clinical content where use of radiation is necessary would also confer expertise in radiation dose awareness. In fact, this may not always be the case, which is a key finding in this article. It should be acknowledged that experts in radiation, such as physicists, would probably have come to a different overall conclusion. However, the deliberate design of the study to include content experts was to understand the impact and scope of radiation education at the coalface of clinical care.

Finally, all experts worked in different hospitals and countries, thus it is possible that participants' answers were influenced by local traditions and hospital policies. Additionally, participants' specialty may also have affected their ratings; however, only few statements were scored differently between the three groups, meaning this effect was rather small.

Future perspectives

Since radiation protection is constantly evolving, it may be necessary to regularly update the consensus achieved in this study, possibly with addition of other expert groups.

The competencies identified in this study may be used to construct future curricula. Further research should be conducted to identify and/or develop modern training methods to acquire, practice and improve radio-protective skills. Not only traditional lectures but modern and interactive media such as e-learning, simulation, and game based learning may allow users to learn about and/or practice these principles in safe environments, without using actual X-rays. This could improve user participation and possibly stimulate continued learning, outside of the classroom or angiography suite.

CONCLUSION

To achieve optimal radiation protection practice, appropriate education of healthcare workers is essential. Unfortunately, current training courses are often too theoretical and cover topics that may not always be relevant or applicable in daily practice. In this study, an international and multispecialty expert panel reached consensus about the radio-protective knowledge skills, technical skills and attitudes that should be considered as key competencies, creating the basis for future relevant and practical training and refresher courses.

CONFLICT OF INTEREST

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejvs.2017.11.020

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