AN e-LEARNING PACKAGE FOR PERSONAL DOSIMETRY TRAINING PURPOSES

M. Koutalonis[1], A.J. Porter[1], A.C. Moreton[1], E. Hogbin[1]

[1] Colchester Hospital University NHS Foundation Trust/Medical Physics Department, Colchester, UK

Abstract— **Personal dose monitoring is a legislative requirement under the Ionising Radiations Regulations 1999 (IRR99) in the UK. Regulation 18(3) says that "An employer who has designated an area as a controlled area shall not permit a person to enter or remain in such area in accordance with the written arrangements under paragraph 2(c), unless he can demonstrate, by personal dose monitoring or other suitable measurements, that the doses are restricted in accordance with that sub-paragraph". Members of staff who work in controlled areas with ionising radiation are therefore issued with personal dosimeters to monitor the doses they receive and satisfy the regulations. However, there is evidence that awareness of personal dosimetry among staff who work with ionising radiation is low. In particular, in our hospital it was noticed that, despite given relevant written instructions, some members of staff did not know how to distinguish among different types of dosimeters, which body position to wear each one at, what to do if they lose them, when to return them for replacement etc. As a result of this, an e-learning package was developed aiming to increase the awareness of matters relating to personal dosimetry among staff. The e-learning package consisted of training slides followed by a mandatory assessment. The training slides covered topics relevant to legislation on personal dosimetry, types of dosimeters and how to distinguish among each type, correct wearing of dosimeters, local investigation levels, when to return each dosimeter for replacement, what to do if it is lost etc. Awareness of our staff appears to have improved since the introduction of this e-learning package which is now mandatory for all new staff in order for them to be issued with a personal dosimeter.**

Keywords — **e-Learning, education, training, personal dosimetry.**

I. INTRODUCTION

Personal dose monitoring for members of staff working with ionising radiations is very important not only in order to comply with national and international regulations, but also to monitor the radiation doses that staff receive and to minimize the risk of any health effects. In the UK, the Ionising Radiation Regulations 1999 (IRR99) [1] have been implemented to comply with the European Council Directive 96/29 Euratom "Protection of health of workers and general public against the dangers arising from ionising radiation" [2]. Regulation 18(3) of IRR99 refers to personal dose monitoring of staff working in controlled areas.

Personal dose monitoring has been in use in hospitals for many years. Members of staff working with ionising radiations are issued with personal dosimeters that monitor the doses they receive over a period of time. Based on the type of work they perform, staff can be issued with various types of dosimeters: whole body dosimeters (most common), collar dosimeters, rings, wrist bands or eye dosimeters. Different types of dosimeters are used for different types of work, e.g. whole body dosimeters are used for most types of work (general radiography etc.); collar badges are mainly used in fluoroscopy; rings are used in Nuclear Medicine and Radiopharmacy and wrist bands can be used in interventional radiology and cardiology together with rings. Eye dosimeters are becoming more common following the latest recommendation for the reduction of the eye lens dose limit from the Basic Safety Standard of the European Union [3].

It is easily understood that members of staff, who perform complicated procedures and therefore who are issued with two or three different types of dosimeters, can get confused over various matters, such as which body part they should wear each one at, what is the correct orientation, when to return them for replacement etc. In our hospital, despite providing written instructions and information to our staff regarding their dosimeters, we have noticed in the past that their awareness is still low. In addition, several members of staff do not return their dosimeters for replacement at the specified times, something that has financial implications and also leads to inaccurate dose records.

Following these findings, it was decided to develop a mandatory e-learning package for all existing and new members of staff who work with ionising radiations in our hospital. E-Learning is becoming popular nowadays as it provides an easy and quick way of providing training to members of staff. Various e-learning packages are being published and one source of these in the UK for the health sector is the e-learning for Health website (e-LfH) [4]. The aim of this e-learning package was to increase the awareness of our members of staff on matters relating to personal dosimetry.

II. MATERIALS AND METHODS

The e-Learning package: The e-Learning package was developed using Microsoft Office PowerPoint2010®. It

consists of 21 slides (including a title slide and a final slide with instructions regarding the assessment). The main topics covered by the package are the following: legislation relevant to personal dosimetry; where can members of staff find information about personal monitoring; various types of dosimeters, what they are made of and which body part they should be worn at; when and where to return the personal dosimeters; consequences of late and non-returned dosimeters (financial, legislative enforcement and dose records); information on the storage of dosimeters; results from personal dosimetry; local investigation levels for staff doses; current dose limits and typical staff doses for various working environments. The slides include a combination of text as well as pictures showing for example the correct way of wearing the various types of dosimeters. Some example slides are presented in Figures 1, 2 and 3 that follow.

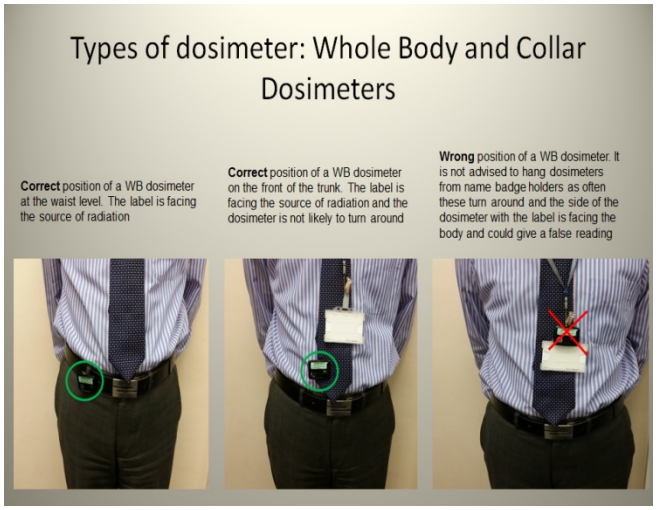

Fig. 1 Correct and wrong positioning of a whole body dosimeter

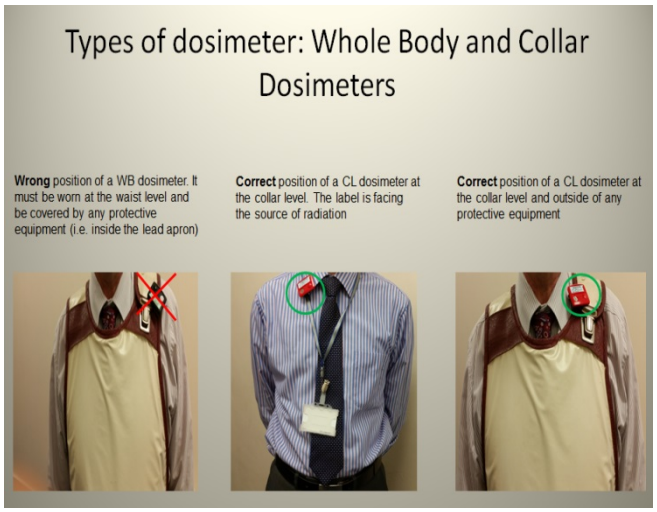

Fig. 2 Correct and wrong positioning of a whole body and collar dosimeter

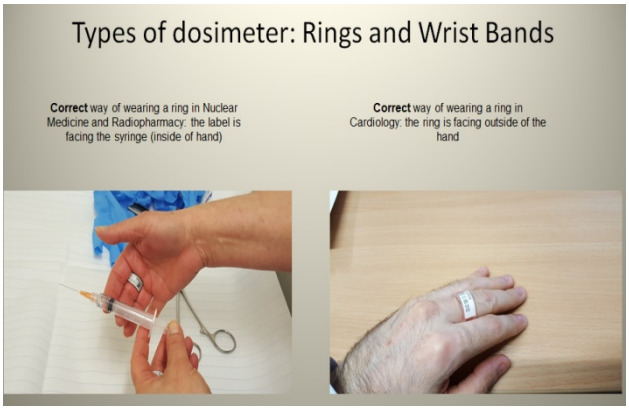

Fig. 3 Correct way of wearing ring dosimeters in Nuclear Medicine, Radiopharmacy and Cardiology departments

The assessment: The training slides are followed by a mandatory assessment that consists of 10 multiple choice questions. Most of the questions have a choice of four possible answers while some others have two. Also, some questions have two correct answers that both need to be selected in order for the answer to be considered fully correct. Each question has a score of 10. The pass mark for the assessment was initially set to 80/100, although this is currently under review and likely to increase to 90/100. Upon successful completion of the training and the assessment, each member of staff is issued with a certificate which they submit to the Radiation Protection Section in order to be issued with their personal dosimeter(s). A copy of the assessment questions and answers is presented in the Appendix.

The e-learning package was submitted to the e-learning team of the Hospital and was entered on to the Hospital's e-learning system. This is now part of the mandatory training that all new members of staff requiring personal monitoring have to undergo before they can be issued with their personal dosimeter. Also, all existing members of staff that are monitored were asked to complete this training and provide Radiation Protection with their certificate. The training slides of the e-learning package are also available on our Department's website [5].

Statistical analysis of the results: Six months after the introduction of this e-learning package, the results were collected and analysed in order to evaluate the effectiveness of the package and review its content. Various statistical parameters were calculated to this end. These are summarized below:

Facility Index F: this is the mean score of all staff on each question and it is a measure of how easy or difficult a question is. It is calculated as $FI=X_{average}/X_{max}$, where $X_{average}$ is the mean credit obtained by all staff attempting the question and X_{max} is the maximum credit achievable for that question. In our case where most of the answers can be distributed dichotomically into correct/wrong categories, this index coincides with the percentage of staff that answered each question correctly. Table 1

shows a range of values for the facility index FI and their interpretation.

Standard Deviation (SD): this is a measure of the spread of scores around the mean score and therefore the extent to which the question can discriminate. If the FI index is very high or very low it is impossible for the spread to be large. However, a good SD does not automatically ensure good discrimination. A value of SD of less than about a third of the question maximum (i.e. 33%) in the table is considered not satisfactory in general.

Table 1 Facility Index (FI) and interpretation

FI range	Interpretation
5 or less	Extremely difficult or something wrong with the question
6-10	Very difficult
11-20	Difficult
21-34	Moderately difficult
35-64	About right for the average staff
65-80	Fairly easy
81-89	Easy
90-94	Very easy
95-100	Extremely easy

Random Guess Score (RGS): this the mean score that the members of staff would be expected to get for a random guess at each question. RGS is only available for questions that use a form of multiple choice, as in the case of this package's assessment. All random guess scores are for deferred feedback only and assume the simplest situation, e.g. for multiple response questions staff are told how many answers are correct. Values above 40% are unsatisfactory in general and show that True/False questions must be used sparsely in summative tests.

Intended and Effective weights: The intended weight is the question weight expressed as the overall test score while the effective weight is an estimate of the weight the question actually has in contributing to the overall spread of the scores. The effective weights should add to 100%.

The intended and effective weights are intended to be compared. If the effective weight is greater than the intended, it shows that the question has a greater share in the spread of scores than may have been intended. If it is less than the intended weight, it shows that it is not having as much effect in spreading out the scores as was intended.

The calculation of the effective weight relies on taking the square root of the covariance of the question scores with the overall performance. If a question's scores vary in the opposite way to the overall score, this would indicate that this is a very odd question which is testing something different from the rest. The effective weight of such questions cannot be calculated.

Discrimination Index: this is the correlation between the weighted scores on the question and those on the rest of the assessment. It indicates how effective the question is at sorting out able members of staff from those who are less able. The results of this index can be interpreted as shown in Table 2.

Table 2 Discrimination Index and interpretation

Index	Interpretation
51 and above	Very good discrimination
30-50	Adequate discrimination
20-29	Weak discrimination
0-19	Very weak discrimination
negative	Question probably invalid

Discrimination efficiency: this statistic attempts to estimate how good the discrimination index is relative to the difficulty of each question. A question which is very easy or very difficult cannot discriminate between members of staff of different ability because most of them get the same score on that question. Maximum discrimination requires a facility index in the range 30%-70% (although such a value is no guarantee of a high discrimination index). The discrimination efficiency will very rarely approach 100% but values in excess of 50% should be achievable. Lower values indicate that the question is not as effective at discriminating between staff of different ability as it might be and therefore is not a particularly good question.

III. Results

At the time this study was performed, there were a total of 367 attempts to read the training slides and pass the assessment. These 367 attempts include several repeats from members of staff who either failed on their first attempt or they passed but wished to improve their pass mark (although the pass mark did not matter). The total number of first attempts (no repeats) was 272. This corresponds to the total number of staff that did the training. Of these 272, 25.7% (70 members of staff) failed while 74.3% (202 members of staff) passed (first attempts only).

An interesting fact is the time taken by each member of staff to complete the training slides and the assessment and its correlation with the pass/fail results. It is assumed that an average member of staff (regardless of experience) would need a minimum of 20 seconds in order to read each of the 20 slides and a minimum of 30 seconds to answer each of the 10 multiple choice questions of the assessment. This corresponds to a minimum time of approximately 12 minutes. Table 3 that follows shows the

distribution of times taken by staff to complete the training and the assessment, and their correlation to pass/fail rates.

Table 3 Time spent for the training slides and assessment

Time range (min)	No of attempts (1st only)	No of fails	% of total fails
< 7	215	64	91.4%
7 – 11	21	0	0.0%
> 11	36	6	8.6%

It is easily noticed from Table 3 that the majority of the staff (79% or 215 staff) completed the training faster than expected, taking less than 7 minutes. As a result of this, 64 of them (91.4% of the total number of fails on the first attempt) failed the assessment and had to repeat it. The majority of these however spent over 11 minutes in total, including the time they took to repeat the assessment (and perhaps read through the slides again).

The members of staff from the Radiology Department (radiographers and radiologists) form the largest group of staff that had to complete this training (75 staff – first attempts only). Of those, 22 (29%) initially failed the assessment and had to repeat it. Interestingly, out of these 22 staff that failed the assessment, 19 completed the training in less than 7 minutes and 15 in less than 4 minutes. The radiology department staff were also divided into more experienced (more than 10 years) and less experienced (less than 10 years) staff in order to investigate whether there is any correlation between experience and pass/fail rate. It was noticed that the time taken to complete the training was the dominant affecting factor for the pass/fail rate rather than the experience of each member of staff, as 33% of the more experienced staff and 37% of the less experienced staff failed the assessment.

The highest fail rate (25.9%) was noticed for Question 1, asking which regulations are related to the personal dosimetry. This was followed by a 25.2% fail rate for Question 4, which was asking the staff to select two correct answers out of four possible. The question was asking for how long the members of staff are expected to wear their whole body and collar dosimeters. 24.5% of our staff answered incorrectly Question 8, asking where the local investigation levels for staff doses can be found. Finally, 20.6% of the staff answered incorrectly Question 9, related to the correct orientation in which whole body and collar dosimeters, rings and wrist bands should be worn. This question was also asking for two correct answers out of four possible. The fail rates for the remaining six questions of the assessment were less than 10%. The lowest fail rate was noticed for Question 5 asking what the members of staff should do if their dosimeter is lost.

Table 4 that follows shows the Facility Index (FI), Standard Deviation (SD) and Random Guess Score (RGS) for each of the assessment questions. All questions had 367 attempts in total.

Table 4 Facility Index (FI), Standard Deviation (SD) and Random Guess Score (RGS) for each of the assessment questions

Q	FI	SD	RGS
1	74.1%	43.9%	25.0%
2	92.9%	25.7%	25.0%
3	94.6%	22.7%	50.0%
4	74.8%	40.0%	---
5	99.7%	5.2%	25.0%
6	90.5%	29.4%	25.0%
7	91.0%	28.7%	50.0%
8	75.5%	43.1%	25.0%
9	79.4%	38.7%	---
10	98.4%	12.7%	50.0%

Looking at the FI values from Table 3 and their interpretation from Table 1, it can be seen that most questions can be characterized as being fairly easy to extremely easy. This was the initial aim of the e-learning package assessment, to be simple and consist of questions that would test basic knowledge, rather than including difficult questions.

Questions 5 and 10 which are classified as extremely easy have led to a very low fail rate (very high FI) and also a very low SD (spread of scores around the mean). These questions may need to be modified or replaced when the e-learning package is next reviewed. The remaining 8 questions have an average SD value of about 34%.

Table 5 Intended Weight (IW), Effective Weight (EW), Discrimination Index (DI) and Discriminative Efficiency (DE) for each of the assessment questions

Q	IW	EW	DI	DE
1	10.0%	14.6%	28.2%	33.6%
2	10.0%	9.2%	20.7%	31.4%
3	10.0%	8.0%	16.5%	27.0%
4	10.0%	13.2%	23.3%	27.2%
5	10.0%	1.5%	0.8%	3.7%
6	10.0%	11.3%	31.1%	45.6%
7	10.0%	10.4%	23.9%	35.7%
8	10.0%	13.4%	18.4%	22.6%
9	10.0%	13.6%	30.9%	37.7%
10	10.0%	4.9%	12.7%	31.0%

Questions 4 and 9 were asking for two correct answers out of four possible and therefore do not have a calculated RGS value. The majority of the questions have a satisfactory RGS value of 25% as they provided four

possible answers. Questions 3, 7 and 10 have an RGS value of 50% because they provided two possible answers. These questions may be replaced in future versions of the e-learning package.

Table 5 above presents the Intended and Effective Weight (IW), (EW) for each assessment question, as well as their Discrimination Index (DI) and Discriminative Efficiency (DE). All questions had 367 attempts.

The Intended Weight for each question was the same and equal to 10%. As mentioned in the materials and methods section, the intended and effective weight scores should be compared. Ideally, they should be the same or as close as possible. Looking at Table 5, one can see that most questions have an EW of around 10% with the exception of Questions 5 and 10 where the EW is much lower than the IW. This means that these questions are not having as much effect in spreading out the scores as was intended. Questions 5 and 10 have already been identified as being extremely easy from the facility index analysis above.

Finally, the discrimination index and the discriminative efficiency were also calculated in Table 5. Looking at the DI results and their interpretation from Table 2, one can see that the majority of the questions fall into the categories of very weak discrimination, weak discrimination or adequate discrimination. Question 5 again, is considered probably invalid based on its DI value and Question 10 is just above the "question probably invalid" category. Similarly, most of the questions have a discriminative efficiency value of about 30% (with the exception of Question 5) which indicates that the questions are probably easier than expected and as a result they are not very effective at discriminating between staff of different ability. This result was also noticed above when analysing the Radiology Department results.

IV. Discussion and conclusions

This e-learning package was developed aiming to increase the awareness of our staff working with ionising radiations on matters related to personal dosimetry. It was made mandatory to ensure that all staff will complete it. An assessment, consisting of questions testing basic knowledge rather than more difficult questions, was included in the package.

The analysis of the results showed that approximately one out of four members of staff failed the assessment on their first attempt. The majority of those who failed seem to have rushed while reading the e-learning package slides either due to limited time (e-learning can only be completed while at work) or because they felt confident with the content. This is an issue that needs to be looked at in the future. Also, it should be noted that the majority of the staff that attempted the training so far are already being monitored and therefore have some experience with personal monitoring.

In addition, the analysis has showed that some of the questions of the assessment are probably too easy as they cannot discriminate between more and less experienced members of staff. These questions will be reviewed and modified in future versions of the package. The pass mark of 80% is also likely to increase to 90%, in accordance with most mandatory e-learning training packages in our hospital.

The process of unannounced audits on personal dosimetry is being introduced currently in various departments where members of staff work with ionising radiations. The audits look at topics covered by the e-learning package and aim to assess its efficiency in improving the awareness of our staff. Initial findings have showed that most staff wore the correct dosimeters and these were worn correctly (correct body part and orientation). Also, our staff seemed to have a better understanding of when the dosimeters need to be returned and what is the process for this. Some staff were also asked if they know/have seen their doses recently and most of them knew what doses they receive on average.

The developed e-learning package seems to be achieving its purpose to increase the awareness of our staff on matters related to personal dosimetry. Further assessment is necessary in the future as well as a review of the package to improve the training slides as well as the assessment questions.

References

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Contacts of the corresponding author:

Author: Manthos Koutalonis
Institute: Colchester Hospital University NHS Foundation Trust
Street: Turner Road
City: Colchester
Country: UK
Email: Manthos.Koutalonis@nhs.net

APPENDIX

The e-learning package assessment (correct answers underlined)

Please note some questions refer to local practice only.

Question 1

Personal dosimeters are issued to members of staff who enter controlled areas to satisfy:

a) The Ionising Radiations (Medical Exposures) Regulations 2000
b) The Medical and Dental Guidance Notes
c) The Ionising Radiations Regulations 1999
d) The Environmental Permitting Regulations 2000

Question 2

What color is a whole body dosimeter and where should you wear it?

a) It is red and you should wear it at the waist level
b) It is black and you should wear it at the waist level
c) It is blue and you should wear it anywhere on your body
d) It is red and you should wear it on your collar/sleeve

Question 3

Which of the following statements is correct?

a) "A collar dosimeter should be worn on your collar or sleeve nearest to the source of radiation and outside any protective clothing"
b) "A whole body dosimeter should be worn on your collar or sleeve nearest to the source of radiation and outside any protective clothing"

Question 4

Which two of the following are correct?

a) WB and CL dosimeters are worn for three months
b) Rings and wrist bands are worn for three months
c) WB and CL dosimeters are worn for one month
d) Rings and wrist bands are worn for one month

Question 5

What should you do if your dosimeter is lost?

a) Inform the Trust's Chief Executive in writing
b) Inform your Radiation Protection Supervisor or Radiation Protection Section so that a replacement can be issued to you
c) Ring 999 and report it
d) None of the above. Wait until you receive another one at the end of the wear period

Question 6

How much is Radiation Protection Section charged for each non-returned whole body or collar dosimeter?

a) £5
b) £9
c) £14
d) £21

Question 7

Which of the following statements is correct?

a) "Personal dosimeters using LiF material to record the dose are sensitive to heat and direct sunlight"
b) "Personal dosimeters using LiF material to record the dose are not affected by heat and direct sunlight"

Question 8

Where can you find the current investigation levels for staff doses?

a) On the Hospital's Intranet, where all policies are stored
b) In the Head of Department's office
c) In the Local Rules for each controlled area
d) They are written at the back of each dosimeter

Question 9

Which two of the following statements are correct?

a) The Whole Body and Collar dosimeters must be worn with the label facing your body
b) The Whole Body and Collar dosimeters must be worn with the label facing away from your body
c) Rings and wrist bands must be worn with the label visible on the outside of the hand /wrist by all members of staff regardless of their type of work
d) Rings and wrist bands must be worn so that the chip is always exposed to the maximum amount of radiation

Question 10

Are you entitled to see your dose record?

a) Yes, my RPS/nominated person receives the results and I can ask Radiation Protection to show me my record by giving them notice
b) No due to data protection reasons