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INTRODUCTION TO CONSTANCY CHECK PROTOCOLS IN FLUOROSCOPIC SYSTEMS

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Abstract — Reference dose or guidance levels are a well established approach to the reduction of patient doses in diagnostic radiology. There are two main methods of determining reference doses, one involves patient dose measurements and the other phantom dosimetry. The latter approach lends itself to the development of constancy test protocols, which may be used as part of an acceptance testing programme or to compare the performance of different imaging systems. Various constancy test protocols and procedures have been proposed and these are reviewed. The constancy test protocols developed within the DIMOND concerted action will be described in detail. The advantages and disadvantages of the various methods and approaches are compared and contrasted. The complementary nature of constancy check protocols with patient dosimetry studies is discussed.

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INTRODUCTION

The concept of diagnostic reference levels was introduced by the International Commission on Radiological Protection in Publication 73[1]. Diagnostic reference levels are intended to be a radiation protection tool to assist with the process of optimisation. It is intended that radiation dose surveys are performed on X ray equipment. The results of these surveys are then compared with the relevant diagnostic reference level. Optimisation studies are then concentrated on those departments or rooms where doses are higher than the norm. The purpose of these optimisation studies is to reduce patient doses to a level as low as reasonable achievable, economic and social factors being taken into account[2]. In the context of medical exposures in diagnostic radiology this may be considered to be reducing the dose to a level without compromising on the image quality required for the clinical diagnosis to be made.

Dose limits, such as these for occupational exposures, do not apply to medical exposures. Thus, diagnostic reference levels have been developed as a radiation protection measure to avoid unnecessarily high patient doses. The role of diagnostic reference levels has been recognised in the Medical Exposures Directive[3] as part of the optimisation process. It is expected that dose reduction measures[4] are implemented in high dose departments as a means of reducing the population dose to the citizens of Europe from medical exposures.

In interventional radiology, deterministic effects, such as skin necrosis, have been seen in patients from procedures performed on unoptimised radiological equipment. Thus there is a need to develop reference levels to identify intrinsically high dose radiological equipment which has not been optimised. This process is fundamentally different to that of assessing patient doses from examinations and comparing the findings with the norm. The process of identifying unoptimised radiological equipment demands the development of constancy check protocols for interventional radiology. Constancy tests would be performed in addition to a patient dose survey. Constancy tests would also form part of an acceptance testing programme for the commissioning of new radiological equipment.

The objectives of this paper are to:

(1) Review the concept of constancy check protocols.
(2) Describe the constancy test protocols developed within the DIMOND concerted action, and to a limited extent, compare and contrast the various methods and approaches to constancy testing.

CONSTANCY CHECK PROTOCOLS IN DIGITAL AND INTERVENTIONAL RADIOLOGY

In developing reference levels for digital and interventional radiology, there is one fundamental choice, which is to perform the measurements with scatter radiation or with scattered radiation minimised[5]. If the objective of the constancy check were to simulate the examination of a patient, it would be appropriate to use a patient equivalent phantom. This phantom could be constructed from a series of Perspex blocks or tissue-equivalent material. Alternatively, a water phantom could be used. Perspex has the advantage of being relatively inexpensive and easy to machine, but is not tissue-equivalent. The disadvantage of tissue-equivalent material is the cost, although by definition they are tissue-equivalent. Water is, to a reasonable approximation, tissue equivalent, but it is difficult to obtain a suitable range of container sizes. Typically, the area of the phantom should be at least 20 cm × 20 cm. Up to 25 1 cm thick sheets are needed to simulate a large

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patient. Both the entrance dose/image in digital mode and entrance dose rate can be measured with a patient phantom, as well as the dose/image and dose rate at the image intensifier input surface. Alternatively, measurements can be performed in terms of air kerma.

If measurements with the effects of scattered radiation reduced are to be undertaken, it is suggested that a thin metal sheet can be used in a constancy test programme. Copper sheets either 1 mm or 1.5 mm thick may be used.

Various international organisations have proposed the equivalent of reference levels for fluoroscopy. These have usually been expressed in terms of patient entrance surface dose rates during fluoroscopy (see Table 1).

If the constancy test is to be performed to include the effect of scattered radiation, then the phantom is placed on the table top, with the image intensifier placed approximately 5 cm from the exit surface. Patient entrance dose rate and dose/image may be determined by placing an ionisation chamber on the input surface of the phantom. The accepted practice is to perform the measurements both with the antiscatter grid present and removed under automatic exposure control. Constancy tests should be performed for a representative selection of automatic settings.

Dose rates and dose/image of the image intensifier input surface could also be assessed. For these measurements the ionisation chamber is placed on the surface of the image intensifier housing nearest to the patient. It may be necessary to apply an inverse square law correction to the readings, to correct the position of the image intensifier input surface. Measurements are performed both with and without the grid for a range of automatic settings.

The approach agreed within the DIMOND concerted action is to use a copper filter placed on top of the patient couch (see Figure 1). An ionisation chamber is placed on the side of the copper sheet nearest to the X ray table. Measurements are performed of dose rate and dose/image, with and without the grid for a range of automatic settings. Once again it may be necessary to apply an inverse square law correction.

Air kerma rate and air kerma/image at the image intensifier input may also be assessed using either a 1 mm or 1.5 mm copper filter. The copper filter should be at least 10 cm × 10 cm in size and is attached to the X ray tube diaphragm. An ionisation chamber is placed on the surface of the image intensifier housing (see Figure 2). Measurements are performed both with and without the grid for a range of automatic settings. Once again an inverse square law correction may be necessary.

Table 1. International recommendations on patient entrance surface dose rates during fluoroscopy.

Organisation	Fluoroscopy	Dose rate (mGy.min^{-1})
IAEA[6]	Normal	25
IAEA[6]	High level	100
UK[7]	Any	100*
FDA USA[8]	Normal	50
AAPM[9]	Normal	65

*Should not exceed 50 mGy.min^{-1}.

DISCUSSION

At present there is no internationally accepted constancy check protocol for routine use in assessing the performance of digital and fluoroscopy units. There is no international consensus on reference levels for fluoroscopy either. There is clearly a need to develop internationally agreed protocols for the constancy checking of fluoroscopy and digital imaging units. With this objective, a constancy check protocol has been proposed

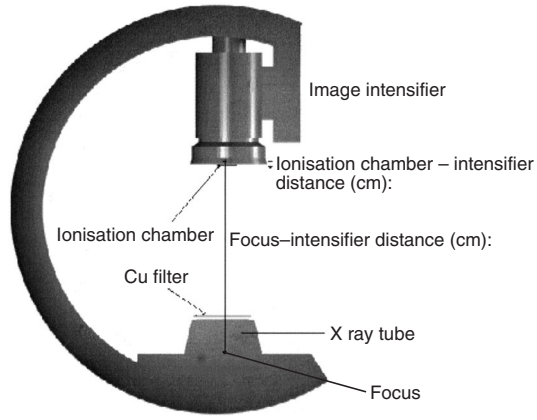

Figure 1. Schematic diagram of measurement methodology: patient entrance surface dose rate.

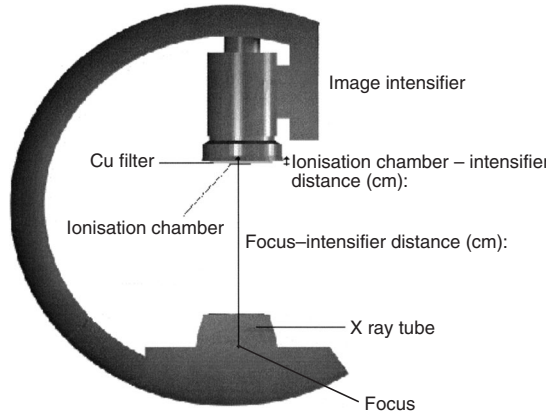

Figure 2. Schematic diagram of measurement methodology: dose rate at the image intensifier input.

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by the DIMOND concerted action. This protocol uses 1 mm and 1.5 mm copper sheets, which incidentally form part of the test equipment for fluoroscopy and digital fluoroscopy equipment. Measurements should be performed with the antiscatter grid in position, and also with it removed if this is possible without dismantling the X ray equipment. Once the constancy test protocol has been agreed, reference levels can be developed using large scale international equipment performance surveys. The DIMOND concerted action wishes to support this overall approach by agreeing and adopting a common protocol.

Patient dose measurements in fluoroscopy, rely in part on the assessment of entrance skin dose rate measurements. The later quantity can be deduced from a measurement performed as part of a constancy check. Thus the constancy check protocol described here complements patient dosimetry measurements.

When deciding upon a constancy check protocol for fluoroscopy equipment there is a choice between whether to simulate the effects of scattered radiation accurately or not. The use of a patient equivalent phantom would simulate closely an actual examination, but it would be impractical to use an anthropomorphic phantom in routine use. The alternative of using a perspex alternator stack or a water phantom, would produce a scattered radiation spectrum close to that in clinical practice. However, the use of both these types of phantom has its drawback. Consequently, the simple approach of using a copper filter was adopted by the DIMOND consortium.

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APPENDIX 1
CONSTANCY CHECK PROTOCOLS

Constancy test for quality control in fluoroscopy equipment

Objective: To obtain information about the relevant parameters for patient dosimetry and image quality in fluoroscopy procedures.

Material: Ionisation chamber or TL dosemeters. Copper filters (1 mm + 1.5 mm, 25 × 25 cm^2).

Method

(1) *Image Quality*. Place the test object on the intensifier entrance window and the copper filter on the output of the X ray tube housing, intercepting the whole beam. Spatial resolution, distortion and low contrast threshold sensitivity values will be recorded under optimum viewing conditions.

(2) *Patient Entrance Surface Dose Rate Simulation*. Place the copper filter on the entrance surface of the image intensifier. The ionisation chamber is placed on top of the copper filter (see Figure 1). If automatic brightness control is available, note the technical parameters employed.

Otherwise, select the manual technique as for the image quality test, taking care that the whole volume of the chamber is irradiated and that the copper filter covers up all the radiation fields. Make exposures and record dose rate values for all the operating modes and intensifier sizes available in the equipment (at least with normal mode (23 cm) and the most unfavourable conditions). Note the focus to chamber and chamber to image intensifier entrance distances. Normalise dose rates at 50 cm from the X ray tube focus.

(3) *Dose Rate at the Input of the Image Intensifier*. Place the ionisation chamber on the intensifier entrance window and the copper filter on the output of the X ray tube housing, intercepting the whole beam (see Figure 2). If automatic brightness control is available, note the technical parameters employed.

Otherwise, select the same manual parameter set as for the image quality test, taking care that the whole volume of the chamber is irradiated and that the copper filter covers up all the radiation fields. Make exposures and record dose rates values for all the operating modes and intensifier sizes available for the equipment (at least with normal mode and 23 cm size). If the antiscatter grid can be removed, do so, and repeat the control without the grid.

NOTE: All the tests must be performed without the couch if it is possible.

FREQUENCY: Annually or after changes or modifications.

RESULTS: A written report, making a summary of measure values and technical parameters shall be delivered after the test control.

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