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INVITED PAPER

THE SENTINEL PROJECT

K. Faulkner[1,*], J. Malone[2], E. Vano[3], R. Padovani[4], H. P. Busch[5], J. (Hans) Zoetelief[6] and H. Bosmans[7]
[1]Unit 9 Kingfisher Way, Silverlink Business Park, Wallsend, NE28 9ND, UK
[2]Garden Hill House, St James's Hospital, Dublin 8, Ireland
[3]Complutense University, 28040 Madrid, Spain
[4]Ospedale S. Maria Della Misericordia, 33100 Udine, Italy
[5]Institute of Radiology, Nordallee 1, D-54292 Trier, Germany
[6]Radiation and Isotopes for Health, Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands
[7]UZ Gasthuisberg, Herestraat 49, B 3000 Leuven, Belgium

Health-care expenditure on radiological equipment in Europe is a growing fraction of the gross domestic product for all member states. This increase in expenditure has been driven by technical developments in equipment design, matched by the introduction of novel clinical practices, examinations and procedures. The radiation protection implications of these developments have to be assessed. The SENTINEL co-ordination action covered radiation protection, safety and related issues that arise from these technical and clinical developments. SENTINEL covered 90% of patient examinations in European Radiology, 60% of the collective dose from medical sources and ~50% of the collective dose to European citizens from man-made sources. The SENTINEL co-ordination actions 'main' objective was to address the safety and efficacy issues which are common to all digital diagnostic imaging systems, including nuclear medicine. High-dose procedures and sensitive groups (such as children) were covered by the project. Specifically, the co-ordination action aimed: (1) to establish both physical and clinical image quality criteria and link the two, (2) to undertake a series of dosimetry studies to establish the reference levels for new procedures and (3) to develop good practice guidelines for radiation protection in digital imaging and produce training material.

INTRODUCTION

Health services within the European Union are a growing fraction of national health expenditure, typically 8.5% of gross domestic product[(1)]. Within this expenditure, radiological imaging is gaining increasing prominence and now accounts for up to 10% of hospital revenue and up to 15% of capital equipment budgets in a typical district hospital. This increase in expenditure on radiological equipment has been driven, in the main, by new equipment developments in digital imaging, medical devices and information technology. These developments have been matched by an increase in clinical practices, examinations and treatment procedures.

Of particular importance in radiology has been the introduction of digital technologies to replace film/screen combinations and the range of sophisticated angiographic/interventional radiology techniques, which have become a commonplace in recent years. The introduction of new technology brings with it a number of research challenges.

The SENTINEL co-ordination action covered radiation protection, safety and related issues that arise from those technical developments. SENTINEL covered 90% of patient examinations, 60% of the collective dose from medical sources and ~50% of the collective dose to European citizens from man-made sources. SENTINEL covers all of digital imaging in radiology, with the exception of computed tomography scanning.

The past two decades have witnessed a technology-driven revolution in Radiology. At the centre of these developments has been the use of computing in diagnostic imaging. These developments have also been driven by the introduction of new detectors and imaging devices in radiology and nuclear medicine, as well as the widespread application of computing techniques to enhance and extract information from within the images acquired. However, these technological developments have not been matched by justification and optimisation studies to ensure that these imaging devices and clinical techniques are as effective as they might be, or performed at the lowest possible dose. The SENTINEL co-ordination action related to a series of studies into digital imaging, interventional radiology, cardiology, digital mammography health screening, paediatrics and nuclear medicine. These studies focused on the justification and optimisation of new and emerging imaging techniques. These examinations, mainly, were associated with high individual doses or applied to more sensitive groups (Figures 1 and 2). The main

*Corresponding author: keith.faulkner@nhs.net

Figure 1. Interventional radiology suite (photograph courtesy of Prof E. Vano, Madrid).

Figure 2. Screening mammography (photograph courtesy of Agfa-Gevaert, Belgium).

objectives of the SENTINEL co-ordination action were to:

(1) establish both physical and clinical image quality criteria and link the two,

Table 1. SENTINEL participants and consortium.

Number	Organisation name	Country
1	QARC, Newcastle	UK
2	Haughton Institute, Dublin	IR
3	Krankenhaus der Barmherzigen Bruder, Trier	D
4	Azienda Ospedaliera S Maria Della Misericordia	I
5	Complutense University, Madrid	ES
6	Katholieke Universiteit, Leuven	BE
7	Department of Radiology, Innsbruk Medical University	AU
8	Radiation Protection Department, Ministry of Health, Luxembourg	LU
9	STUK—Radiation and Nuclear Safety Authority	FIN
10	Delft University of Technology, The Netherlands	NL
11	Athens General Hospital	GR
12	Radiation Protection Department, Nofer Institute of Occupational Medicine, Lodz	PO
13	Biomedical Research Foundation, Nicosia	CY
14	MEDICONTROL, Vrbove	SK
15	Tartu Uelikool	EE
16	Institute of Occupational Safety, Slovenia	SI
17	Faculty of Engineering, Ankara University	TR
18	Physics Department, University of Pisa	I
19	National Centre of Radiobiology and Radiation Protection, Sofia	BG
20	National Research Institute for Radiobiology and Radiohygiene, Budapest	HU
21	NHS Lanarkshire Health Board, Scotland	UK
22	Institute of Public Health, Bucharest	RO

(2) perform a series of dosimetry studies to deduce the reference levels,
(3) develop good practice guidelines for radiation protection and to publish training material.

The SENTINEL consortium comprised 22 members from 19 member states. These were complemented by partners from candidate member states and international organisations (Table 1).

SENTINEL CO-ORDINATION ACTION ACTIVITIES

Justification and optimisation form the basic elements for the radiological protection of individuals in the case of medical exposures[2]. Justification includes the development of referral criteria. Medical exposure for diagnostic applications is only justified in the case of a sufficient net benefit. This

has its origins in the Hippocratic Oath[3], which most doctors swear, and may be summarised as doing more good than harm. In the case of medical exposures, this implies that patient doses should be relatively low to restrict the detriment caused by ionising radiation, whereas image quality should be sufficient to allow potential diagnostic benefits.

According to the Medical Exposures Directive[2], diagnostic reference levels should be established and used as an aid to optimisation. This process is ongoing within the European Union member states. Optimisation should result in improved image quality at equal or lower dose to the patient or in a dose reduction at an image quality sufficient for obtaining diagnostic information.

The Medical Exposures Directive[2] places special attention on the medical exposure of children, exposures received as part of a health screening programme, such as mammography and examinations involving high individual doses to the patient. Radiation protection of children is considered to be especially important, in view of the higher radiation risk factors for children. Health screening programmes, for example, for the early detection of breast cancer, involve a healthy population in which a small percentage of women have a malignant lesion, which may be detected using mammography. Interventional radiology, cardiology and some nuclear medicine procedures result in high radiation doses to the patient.

Clinical image quality criteria, referral guidelines and reference doses were established for the latest digital detectors by building on previous work and a series of consensus meetings. In nuclear medicine, there was a debate on the administered activity for various nuclide procedures. This debate was addressed via consensus meetings and surveys of national practice.

The relationship between physical and clinical image quality indices was addressed. This assisted in international standardisation activities.

Patient dose surveys and quality assurance tests were undertaken on various high-dose procedures. Similar work was undertaken in mammography, bone mineral densitometry and paediatric radiology. Ethical issues in radiation protection were assessed.

SUMMARY

In summary, the intended benefits of the SENTINEL co-ordination action were:

(1) safer, more effective procedures and examinations using new technology in radiology,
(2) greater public acceptance of the use of radiation in medicine,
(3) safer, more cost-effective, health care,
(4) supporting the legislative agenda of the European Union,
(5) contribution to the training of researchers.

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2. Council Directive 97/43/Euratom of 30 June 1997 on Health Protection of individuals against radiation in relation to medical exposure (CEC, 1997).
3. http://www.bma.org.uk/ap.nsf/content/Azusefulsites?open Document&Highlight=2,hippocratic,oath#hippocraticoath