Radiation Protection Standards for Medical Investigations

Lidia Dobrescu
" POLITEHNICA" University of Bucharest
ETTI Faculty,Bucharest, Romania
lidia.dobrescu@electronica.pub.ro

Diana Dobrescu
Bucharest University of Economic Studies
FABBV Faculty,Bucharest, Romania
olimpicdi@yahoo.com

Armand Ropot
S.C.CERTSIGN S.A. Bucharest, Romania
armand.ropot@certsign.ro

Silviu Stanciu
Central Military Emergency Universitary Hospital "Dr. Carol Davila" of Bucharest
silviu.stanciu@yahoo.com

Abstract— ***Large-scale using of ionizing radiation for medical investigations has benefits and risks.***

Every country has national standards for radiation protection, defining responsibilities of individuals and organizations for radiation control. In spite of the rich legislation, the total cumulated dose absorbed by a patient during medical investigations is not cumulated or established in a unified manner. A national Romanian project is surveying radiation doses involved in medical investigations. The effective doses received by patients are unified and cumulated in a pilot study. The International System of Units uses the Sievert (Sv) as a derived unit in order to estimate the effective dose. The new system is based on smart cards and Public Key Infrastructure.

Keywords- radiation effective dose; radiation protection; medical investigations; smart cards; Public Key Infrastructure.

I. INTRODUCTION

Radiation is usually perceived as a natural phenomenon in our environment or we can also talk about increased doses of radiation produced by all kind of man activities.

Every country has national policies and strategies for general radiation protection, national, regional, local or specific organizations and national radiation standards.

The number of medical investigations using radiation has increased and the effects are not highlighted among the radiation sources.

International commissions on radiology protection are also active for radiological protection standards, legislation, guidelines, programmers, and practice.

Besides monitoring the human natural environment with natural sources of radiations in soil, water or air, the exposure to medical investigations is also monitored.

The work of the International Commission on Radiological Protection (ICRP) helps to prevent diseases, cancer and effects of patients exposed to ionizing radiation, protecting the environment. ICRP has published a lot of reports on multiple aspects of human protection. The reports subjects are generally radiological protection, but all of them describe the whole system of radiological protection [1].

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established by the General Assembly of the United Nations in 1955. Its role in the United Nations system is to highlights the levels and effects of exposure to ionizing radiation. " Governments and organizations throughout the world rely on the Committee's estimates as the scientific basis for evaluating radiation risk and for establishing protective measures" [2].

In Romania, CNCAN is the national competent authority in nuclear field "having responsibilities of regulation, authorization and control stipulated in this Law is the National Commission for Nuclear Activities Control, public institution of national interest, legal entity, with the head office in Bucharest, being headed by a President having the rank of State Secretary, coordinated by the Prime Minister"[3].

National Institute of Public Health, Bucharest, Romania is another organization that publishes reports on a nation-wide evaluation of ionizing radiation exposure of the Romanian population due to the radiological examinations is performed in accordance with European Directive 97/43 EURATOM implemented in national regulations.

In order to investigate radiological doses absorbed by patients during different medical investigations, a Romanian project must cumulate and express in the same manner the absorbed radiation doses. The project is implemented using smart cards and Public Key Infrastructure software base.

Generally the radiation measurement units, biological effects and safety threshold values are often unclear in spite the dangerous spread perception.

One can be usually tempted to consider the harmful effect of every radiation exposure. Low-level exposure risk and high-level exposures related to medical investigations are not quite different perceived.

Patients and doctors usually excess in demanding, using and prescribing medical investigations in spite of harmful effects associated with radiation delivery.

Computed tomographies(CTs), scintigraphies and classical radiographies are medical radiological investigations that expose the patients to no negligible doses of radiation.

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online)

Injuries are often associated with prolonged procedures, although short procedures have caused severe effects in a small number of cases.

The actual volume of medical prescription for investigations using radiological methods strongly increases the cumulative radiation dose absorbed by patients.

A serious lack in monitoring and tracking of the cumulative radiation doses, absorbed by patients that have been treated and evaluated in many health services, can be noticed all over the world.

The relationship between the radiation doses and radiation protection, the impact of nuclear radiation is not well quantified, so a computed tomography or a chest radiography risks are quite equally perceived.

A good balance between the desired image quality and the applied medical radiation and must be considered, towards a proper radiological risk versus the diagnostic gain. In the practice of medicine, there must be a judgment made concerning the benefit/risk ratio. This requires a good knowledge of radiation risks and medicine practice also.

The aim of managing radiation exposure is to minimize the irradiative risk without sacrificing, or unduly limiting, the obvious benefits in the prevention, diagnosis and also in effective cure of diseases (optimization).

Usually a medium dose for a specific type of investigation is established and this is used for further reports on total radiation doses in medical investigations.

II. Radiation Exposure Risk

In our environment, radiation is a natural phenomenon even it is commonlz perceived as a human activity result.

The natural sources of radiations are in soil, water or air.

Alpha, beta, gamma cosmic rays, and X-rays are well known ionizing radiation. Because of their use in medicine, X-rays are commonly recognised and classified for their radiative effects.

Any human activity that produces or uses radioactive material becomes a source of radiation such as nuclear power generation, defense weapons, nuclear medicine, mining, oil and gas production and scientific research.

The process of exposing a person to ionizing radiation can be either externally or internally.

CTs are externally absorbed, while in angiography, fluoroscopy or scintigraphy investigations a radioactive substance is ingested.

Overall, it is known that exposure to ionizing radiation increases the future incidence of cancer, but quantitative models predicting the level of risk are still not worldwide accepted.

Induced cancer can be analyzed as a stochastic effect because its probability of occurrence increases with the dose, while the severity is independent of dose.

A threshold dose can be established in deterministic effects. For example, usually over the threshold of 10 Sv, death and severe health effects are always present.

The problem of the difference between the stochastic and deterministic effects becomes important.

The risk of radiation exposure has a huge importance in the case of a nuclear accident with high absorbed doses of radiation leading to deterministic effects.

Other types of biological effects inducing cancer or other diseases have the probability related to the exposure. In this case it cannot be predicted who exactly will be affected. Generally we can only say that a specified number of people from 1 billion will be affected. These effects are called stochastic effects even at low exposure doses.

Commonly is hard to distinguish between them.

Different methods for radiation risk calculus were developed.

One of them is the linear no-threshold (LNT) model. The LNT model assumes proportionality between dose and cancer risk. The relationship between dose and DNA damage is considered linear. The LNT model represents a strong concept to facilitate radiation protection and the International Commission on Radiological Protection (ICRP) recommends the use of the LNT model [4].

The threshold model assumes that very small exposures are harmless while the Hormesis model claims that radiation at very small doses can be beneficial. The adaptive responses of the human cells were observed at low doses and disappear with higher doses [5].

Generally people believe that any radiation exposure is dangerous. The risk factor must be also regarding as strongly dependent on age [6].

III. Radiation Units and Different Types of Doses

„The International Commission on Radiological Protection (ICRP) recommends that the public limit of artificial irradiation should not exceed an average of 1 mSv effective dose per year, not including medical and occupational exposures. ICRP limits for occupational workers are 20 mSv per year, averaged over defined periods of five years, with the further provision that the dose should not exceed 50 mSv in any single year "[7].

The Sievert (Sv) is a derived unit in the International System of Units (SI) used for equivalent absorbed radiation dose measurement. This is the central unit of the implemented project.

There are many different units for absorbed radiation used on a large scale. Becquerel (Bq) and Curie (Ci) as SI units are used for released radioactivity, while Coulomb/Kilogram (C/kg) and Roentgen (R) are used for the dose travelling through the air, Gray (Gy) and Rad, used with quantities of absorbed dose. A lot of Internet sites provide convertors between them.

The biological effects of the absorbed amount of radiation can be described with Roentgen equivalent man (rem) and Sievert (Sv). They are specific measurement units.

The Sievert can better describe the effective equivalent dose absorbed by biological tissues while the Gray can describe the absorbed dose of any material.

Modern radiological apparatus for computerized tomographies or scintigraphies can provide the radiation doses during a particular investigation, but the recorded doses' types

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online)

TABLE I. ROMANIAN RADIATION DOSES IN 2010

CT examinations	*Effective dose (mSv)*
Chest /Thorax	*0,1*
Cervical spine	*0.09*
Thoracic spine	*0,14*
Lumbar spine	*1,27*
Mammography	*0,12*
Abdomen	*0,22*
Pelvis and hip	*0,29*
Ba meal	*12,61*
Ba enema	*9,95*
Ba follow-through	*2,43*
IVU	*3,67*
Cardiac angiography	*4,83*
CT head	*3,92*
CT neck	*2,51*
CT chest	*2,03*
CT spine	*2,38*
CT abdomen	*2,61*
CT pelvis	*2,15*
PTCA	*8,71*

and the radiation measurement units in different types of investigations are not the same.

In the classic radiological investigation an important topic for data management is the measurement and the calculation of radiation dose expressed in Dose area product (DAP), expressed in (Gy*cm^{2})

The dose length product (DLP) was chosen as input data for the system in CTs investigations and it is expressed in mGy*cm. The DLP must be converted to mSv in order to unify the results.

IV. SOFTWARE APPLICATION DESIGN

The proposed system includes the following components:

- Smart cards dedicated to patients: Citizen Radiation Safety Card – CRSC

- Professional Radiation Safety Card – PRSC – intended to medical and investigation laboratories personnel. Among them an Administrator Radiation Card is also design for system changing like new casettes dimensions in radiology.

- Smart card readers and writers in order to record and retrieve the information about the type of investigations and the specific emitted doses

- A data base that will record all the necessary information in order to replicate a lost or destroyed card but also this database will provide the possibility of collecting data about the patients on several criteria.

- The security solutions such as public key infrastructure PKI in order to achieve a high level of security of recording and retrieving data. A public-key infrastructure (PKI) is a set of hardware, software, people, policies, and procedures needed to create, manage, distribute, use, store, and revoke digital certificates.

TABLE II. EUROPEAN MEDIUM RADIATION DOSES

Investigation type	***Effective Dose (mSv)***
Chest/Thorax	*0.1*
Cervical Spine	*0.2*
Thoracic Spine	*0.6*
Lumbar Spine	*1.2*
Mammography	*0.3*
Abdomen	*0.9*
Pelvis and Hip	*0.7*
Ba meal	*6.2*
Ba enema	*8.5*
Ba follow-through	*7.2*
IVU	*2.9*
Cardiac angio-graphy	*7.7*
CT head	*1.9*
CT neck	*2.5*
CT chest	*6.6*
CT spine	*7.7*
CT abdomen	*11.3*
CT pelvis	*7.3*
CT trunk	*14.8*
PTCA	*15.2*

A PKI establishes and maintains a trustworthy networking environment by providing key and certificate management services that enable encryption and digital signature capabilities across applications — all in a manner that is transparent and easy to use.

V. EXPERIMENTAL RESULTS

In the classic radiological investigation the calculus for radiation dose expressed in DAP. Dose area product (DAP) is expressed in (Gy*cm^{2}). It is an indicator of the overall risk of inducing cancer. It also has the advantages of being easily measured, with a DAP meter on the X-ray set.

In order to obtain the effective dose measured in Sv, the DAP is divided by the film area and then it is multiplied by the tissue factor [8].

A sensible situation was determined by CT-s registered dose. More related CT radiation doses are available on CT consoles. Dose length Product DLP was chosen as input data for the system in CTs investigations but the required reported data is the effective dose. Conversion factors were used. The conversion factors can slightly vary from different manufacturers.

The top 20 of X-ray examination performed at national level in 2010 are shown in Table I [9].

The values were extracted from a new study for 36 European countries, including Romania [10] are shown in Table II.

There are more important differences between the two reports. Focusing on high doses, one can easily notice that CT investigations imply high radiation doses.

Using a medium dose for a specific type of investigation for periodically reports generally implies great errors.

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online)

Anew system, designed on smart cards technology covers one major need of the health-care system.

The system was implemented in Central Military University Emergency Hospital, Dr. Carol Davila, and Bucharest, Romania.

The new designed radiation safety system can provide a couple of secure services like electronic record of patient's radiological investigations, assistance in prescription of future radiological investigations based on patient's history and different reports and statistics. The smart cards allow authentication, digital signature and secure data storage.

A. Objective:

An 8 months study surveyed in a single general medical department has collected data for computerized tomography, scintigraphy and classical radiology .The collected data shows that in CTs the implied radiation doses are higher.

B. Materials and Methods:

From 347 patients from one single unit that has been investigated using radiological procedures, 52 of them were sent for CTs investigations. 19 of them were women and 33 men. For 20 of them the received CT DLP doses remain unavailable due to different causes including storing data faults or delays in introducing data. The maximum effective dose was obtained in a combined thoracic+abdomen+pelvis

The typical medium dose for common head CTs without contrast substance is 2.3403 mSv, lower than the medium dose from table I or II, but a single head CT with contrast substance overpass 16mSv.

The limit dose of 20 mSv was overpassed in 15 cases. The types of performed CT scans are shown in Figure 1.

Many patients have received more than a single investigation.

The study will continue for one year. The final results will be analyzed from the central data base.

The software application will provide different kinds of reports. The reports will be organized around the types of medical procedures.

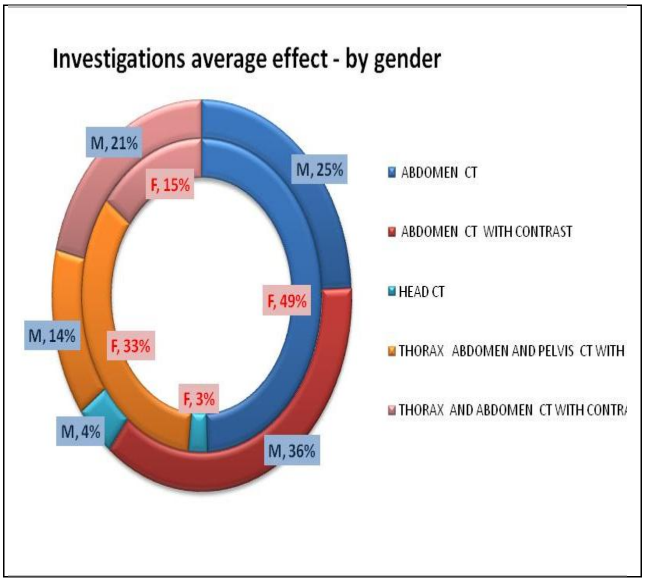

Fig. 1 Types of performed CT scans

VI. CONCLUSIONS

Human medical radiation exposure and protection is a general policy for every nation and international organizations have a lot of internet sites and publications for using simple, easily and understandable information regarding common acceptable risks in the case of medical investigations using radiological methods. Radiation effects can be deterministic or stochastic.

DLP and the effective dose received by a patient during a CT scan are a main concern taking into accounts the risk for radiation-induced malignancy with repeated exposure.

Compared to classical radiography, CT is a high-dose imaging method, although doses are still below the threshold doses for deterministic effects.

The Sievert as measurement unit for radiation biological effect is not known and understood by general public or media. The radiation doses thresholds in radioprotection are also not familiar.

ACKNOWLEDGMENT

The article results were obtained from the 187/2012 SRSPIRIM project in Romanian National Partnerships Program, Collaborative Applied Research Projects - PCCA 2. Many thanks to all the persons involved in this project for their support, work and ideas.

REFERENCES

[1] International Commission on Radiological Protection, http://www.icrp.org/index.asp

[2] United Nations Scientific Committee on the Effects of Atomic Radiation http://www.unscear.org/unscear/en/about_us.html

[3] Romanian National Commission for Nuclear Activities Control, http://www.cncan.ro/

[4] Kenneth L. Mossman, "The Linear-No-Threshold Debate in Radiation Protection", RSO Magazine, vol.8, no.6, 1997. Available: http://www. radpro.com /mohttp //www. radpro.com /mossman.pdfssman .pdf.

[5] Kaiser J. Hormesis, "A a healthful dab of radiation?", Science vol. 302, pp. 378, Oct. 2003

[6] EUROPEAN COMMISSION, European guidelines on radiation protection in dental radiology, Radiation Protection 136, page 17, Available: https://ec.europa.eu/energy/sites/ener/files/documents/136.pdf.

[7] Corbet Mc. Donald, "Epidemiology of Work Related Diseases", MPG Books, Bodmin,Cornwall, 2000, Available: http:// onlinelibrary.wiley.com/doi./10.1002/9780470695005.fmatter/pdf.

[8] Available at http:// www.euronuclear.org /info/ encyclopedia /t / tissue-weight-factor.htm.

[9] O. Girjoaba, A. Cucu, "Patient exposure evaluation in Romanian Radiological Departments", Available: http://www.iaea.org/ inis/collection/NCLCollectionStore/_Public/43/130/43130506.pdf.

[10] Medical Radiation Exposure of the European Population, POart1/2, Radiation protection No 180, Directorate-General for Energy Directorate D — Nuclear Safety & Fuel Cycle Unit D3 — Radiation Protection, 2014, pp.55, Available: https://ec.europa.eu/energy/ sites/ener/files/ documents/RP180.pdf.

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online)