Procedural radiation exposure of interventional cardiologists and radiologists
Kuipers, G.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
CHAPTER 1

Introduction of the thesis
In the Academic Medical Center ‘AMC’ in Amsterdam, interventional cardiologists and radiologists make use of ionizing radiation for fluoroscopy-guided procedures. Such interventional procedures expose both patients and interventional specialists to radiation. However, patients are mainly exposed to primary radiation beams, whereas interventional specialists are primarily exposed to scattered radiation beams.

During the years, radiation exposure of interventional specialists has steadily increased, related to the increasing demand for interventional procedures. Consequently, some interventional specialists exceed the annual limit of occupational exposure of 20 mSv (the effective dose limit)\(^1\)-\(^4\). Simultaneously, chances of developing fatal tumors (stochastic effects) increase proportionally. In addition to this, somatic effects such as cataract (deterministic effects) can occur if threshold doses are exceeded\(^5\). In order to prevent radiation effects, occupational exposure of interventional specialists is monitored\(^6\).

The exposure of the interventional specialists is monitored by means of personal dosemeters. These are placed outside and/or inside a lead apron, which interventional specialist wear during procedures. The dose measured with the personal dosemeter placed outside the lead apron, is higher than the effective dose received by the interventional specialist. On the other hand, the dose measured inside the lead apron is lower than the effective dose of the interventional specialist\(^7\). Because of these differences, it is recommended to wear a personal dosemeter outside the lead apron as well as an additional personal dosemeter inside the lead apron\(^8,9\). If two personal dosemeters are used, additional information on radiation exposure of the interventional specialist can be collected (see Figure I).

In the past, interventional specialists at the AMC wore one personal dosemeter. This personal dosemeter was placed outside the lead apron. As a result of the aforementioned arguments, the policy regarding personal dosemeters was changed in 1999. A second personal dosemeter was introduced. Initially, only three interventional cardiologists of the department of Cardiology were provided with a second personal dosemeter. Starting 2004, all interventional cardiologists and radiologists in the AMC were provided with an additional personal dosemeter.
Currently, the added value of an additional personal dose meter for routine personal dosimetry is unknown. Firstly, the measured dose is influenced by differences in placement of the personal dose meter\textsuperscript{10}. Secondly, reported dose can be inaccurate, as the measured dose is corrected for the contribution of natural background radiation\textsuperscript{11,12}. Therefore, the doses measured both outside and inside the lead apron, have to be assessed in order to evaluate the usefulness of a second personal dosemeter.

\textbf{Figure I:} Position of the personal dosemeter and the protective measurements during fluoroscopy-guided procedures.

Personal dosemeters measure the radiation dose at the position of the dosemeter. In general, the exposure to ionizing radiation is non-uniform. Thus, the dose measured with a personal dosemeter has to be converted to an ‘effective dose’. The effective dose was introduced by the ICRP in the 1990 recommendations\textsuperscript{13}. The effective dose is the weighted sum of equivalent doses to a selected group of organs that are sensitive to radiation exposure. For example, the sensitivity to radiation of gonads and bone marrow differs compared to other organs. Such differences are corrected which thus allows a comparison of the effects of radiation exposure on different parts of the body.
If interventional specialists wear a single personal dosemeter placed outside the lead apron, the effective dose can be calculated from the measured dose by means of using a correction factor. If an additional personal dosemeter is placed inside the lead apron, the effective dose can be estimated using an algorithm. In this case, doses measured inside and outside the lead apron are weighted separately. The application of a correction factor or algorithm in the process of estimating the effective dose, is described in several publications\textsuperscript{14-17}. In these publications, it is assumed that the effective dose can be calculated more accurately using an algorithm instead of a correction factor. However, if the dose inside the lead apron is close to the detection threshold of the personal dosemeter, the effective dose is mainly determined by the weight of the dose outside the lead apron. In that case, a second personal dosemeter contributes only minimally to a more accurate estimation of the effective dose.

Large and striking differences in measured doses are found among interventional cardiologists in the AMC. It appears that there are several reasons that contribute to these profound differences. Firstly, it is expected that differences in the amount of procedures performed by the interventional specialists influence the dose measured. Secondly, the complexity of interventional procedures may differ and could influence the exposure of the interventional specialist, simply because complex procedures are mostly accompanied by longer exposure times\textsuperscript{18-20}. For the interventional cardiologists at the AMC, it was therefore assumed that differences in exposure are caused by the amount of procedures performed as well as the amount of complex procedures. If these variables cannot completely explain differences in radiation exposure, other potentially influencing factors have to be examined/evaluated. This could further explain differences in exposure among interventional cardiologists at the AMC.

The site of access is also indicated as a factor that influences the exposure of the interventional cardiologists during diagnostic and therapeutic procedures (CAG and PCI). The radial approach was introduced in the 90’s as an alternative for the femoral route. The major advantage of the arteria radialis is the reduction of bleeding complications for the patient\textsuperscript{21}. However, this new technique requires a learning curve for interventional cardiologists and therefore it could result in higher radiation exposures for patients as well as interventional cardiologists. Several comparative studies were published regarding the radiation exposure of patients during both radial route procedures.
and femoral route procedures. In general, these studies were carried out with a relatively small number of patients and yielded contradictory results\textsuperscript{22-27}. Thus, additional analyses are required to determine differences in exposure between both methods. For a proper comparison of the exposure of both methods, it is important to correct the results for the complexity of the interventional procedures as well as for the experience of the interventional cardiologists with both procedures.

In this thesis several studies are described with the aim to answer the following questions:

1. which method to monitor personal doses is to be preferred to determine the occupational exposure of interventional specialists;
2. which factors influence the radiation exposure of interventional specialists.

To answer these questions the following studies were carried out. The studies are described in chapters 2-6.

**Chapter 2** describes a study that determines the effect of the position of the personal dosemeters on the body, on the dose measured. The study was performed during the period of 1999 – 2004 and describes dose measurements amongst interventional cardiologists. In the study, different positions of the personal dosemeter on the interventional cardiologists were evaluated e.g. on the arm, on the lead collar as well as on the outside and inside of the lead apron. The different positions hindered a proper evaluation of the results.

Therefore in **chapter 3** a follow up study is described. For this study the interventional specialists received special instructions concerning the positions of the dosemeters. The personal dosemeters were placed both outside and inside the lead aprons. The dosemeters were positioned with a special mounting device keeping the dosemeter (in place) on the predetermined position. The investigation focused on finding a relation between doses measured outside and inside the lead apron.

**Chapter 4** describes a study that evaluates three methods that allow calculations of the effective dose for interventional specialists. According to the first method, the dose measured outside the lead apron was corrected with a correction factor in order to estimate the effective dose. According to the two other methods, two different algorithms for double dosimetry were used to estimate the effective dose. Finally, the results of the
three estimation methods were compared.

In order to determine a relation between the complexity of interventional procedures and radiation exposure of interventional cardiologists, parameters related to the radiation exposure of patients were analyzed in combination with data of doses measured for interventional cardiologists (chapter 5).

Chapter 6 compares the radiation exposure of patients between procedures performed by the radial route to procedures performed by the femoral route.
References


