CHAPTER 8

Summary
In the Academic Medical Center ‘AMC’ in Amsterdam interventional specialists make use of ionizing radiation during fluoroscopy-guided procedures. During the procedures both, patients and interventional specialists are exposed to radiation. The patient is mainly exposed to primary radiation beams, whereas interventional specialists are primarily exposed to scattered radiation beams.

Exceeding amounts of exposure to ionizing radiation increases the chance of developing fatal tumors (stochastic effects) proportionally. Additionally, interventional cardiologists and radiologists will be predisposed to develop somatic effects like cataract (deterministic effects). As a consequence it is worthwhile to study the radiation exposure of these employees in the hospital. Chapter 1 describes the different aims of the study on radiation exposure of employees on which this thesis is based.

Chapter 2 contains data of personal dose measurements of 3 interventional cardiologists of the AMC Heartcenter during the period 1999-2004. In the study, the position of the personal dosemeters was evaluated. Moreover, the relation between the measurements obtained from dosemeters positioned outside and inside the lead apron were studied. Between 1999 and 2003, one personal dosemeter was placed on the left sleeve outside the lead apron and one personal dosemeter inside the lead apron. From 2003 until 2004, one personal dosemeter was placed outside the lead apron at the collar and one inside the lead apron. The personal dosemeter inside the lead apron was generally placed in the breast pocket. The thickness of the lead aprons and lead collars of the interventional cardiologists was 0.50 mm. The measured doses on the left sleeve were higher than the measured doses at the collar. The difference in doses between both positions was a factor 1.9. A relation could not be determined between the measured dose outside and inside the lead apron. It was concluded that it is important to predetermine the position of the personal dosemeter to enable a study concerning the relation between the measured doses outside and inside the lead apron. To evaluate the relation between both measurements, it is also important to replace the two personal dosemeters simultaneously.

In chapter 3 the relation between the measured doses outside and inside the lead apron was evaluated by means of applying a special mounting device to position the personal dosemeters. Moreover, the added value of a second personal dosemeter with
respect to additional information concerning radiation exposure of the interventional specialists was studied. For this study, a special mounting device for the personal dosimeters was developed. As a result, the positioning of the personal dosimeters was equal for all measurements. This investigation involved eight interventional radiologists wearing the personal dosimeters both outside and inside the lead aprons. The lead equivalent thickness of the aprons was 0.25 mm. The results of the study indicate that a linear relation exists between the doses measured outside and inside the lead apron. This relation can be described with the comparison: \( Hp(10)_{\text{inside}} = (0.036 \times Hp(10)_{\text{outside}}) - 0.004 \). Moreover, it was found that if the measured dose outside the lead apron is less than 0.25 mSv/4-weeks, doses inside the lead apron cannot be measured. However, it is concluded that the measured dose inside the lead apron of the interventional radiologists can be estimated from the measured dose outside the lead apron. In this study, the use of two personal dosimeters did not provide additional information compared to the use of a single personal dosemeter. Finally, it was also concluded that an estimation of the dose outside the lead apron based on the measured dose inside the lead apron resulted in an underestimation of the effective dose of the interventional radiologists.

Chapter 4 contains an evaluation concerning the accuracy of double dosimetry in determining the effective dose of interventional specialists (compared to single dosimetry). For the study, the radiation exposure of eleven interventional specialists (cardiologists and radiologists) was measured using personal dosimeters. The personal dosimeters were placed outside and inside the lead aprons of the interventional specialists. The lead apron of the interventional specialists had a lead equivalent thickness of 0.25 mm. Dose measurements were used to estimate the effective doses for the interventional specialists. Three methods were applied for this estimate. The first method calculates an estimate of the effective dose based on the dose measured outside the lead apron. For this, a correction factor was applied to convert the measured dose to the effective dose. For the other two methods, two specific algorithms for double dosimetry were applied. The study shows that the method for single dosimetry results in higher estimates of the effective dose compared to the method for double dosimetry. However, a comparison of the results obtained with the method for single dosimetry and the methods for double dosimetry revealed a linear relation between the effective doses.
In **chapter 5** the individual differences between radiation exposures of interventional cardiologists were studied. For this study, it was assumed that a relation exists between the exposure of interventional cardiologists and the exposure of their patients. Moreover, it was assumed that the exposure of interventional cardiologists is associated with the amount and the complexity of their procedures. The doses measured outside the lead apron were used to determine the exposure of the interventional cardiologists. The exposure of the patients was measured with a DAP-meter. Moreover, a separation was made between the radiation exposure of patients in the fluoroscopy mode and the cine mode. The results of the study confirm the linear relation between the exposure of patients and the interventional cardiologists. This relation can be described with the comparison $\text{Hp}(10) \text{ (mSv)} = 0.36 \cdot 10^{-3} \times \text{DAP (Gy}\cdot\text{cm}^2)$ and apply for all seven cardiologists. With this formula the radiation exposure of patients can be used as reliable predictor for the exposure of interventional cardiologists. Thus, it was concluded that the exposure of the interventional cardiologists was not related to the complexity of the procedures. The differences in radiation exposure may be explained by the choice between the fluoroscopy mode and/or the cine mode. These differences depend on the preferences of interventional cardiologists for equipment settings, among which dose mode settings, field size and the frequency in which equipment in cine mode is used.

**Chapter 6** concerned a study that compared radiation exposure of patients in procedures using radial or femoral route. The patient population consists of patients undergoing diagnostic or therapeutic coronary procedures. The radiation exposure data and clinical data of 3973 procedures performed during 2004-2008 were used. The mean radiation exposure of the patients who underwent a PCI via the artery femoralis was $112 \pm 115 \text{ Gy}\cdot\text{cm}^2$ and via the artery radialis $106 \pm 102 \text{ Gy}\cdot\text{cm}^2$. The mean radiation exposure for CAG was $59 \pm 51 \text{ Gy}\cdot\text{cm}^2$ and $52 \pm 46 \text{ Gy}\cdot\text{cm}^2$ for procedures via the femoral or radial route respectively. Multivariate analysis showed that sex, BMI, number of lesions, type c lesions and the presence of right coronary artery lesions and the presence of left circumflex coronary lesions are determinants for the radiation exposure of patients. Moreover, this analysis showed that all operators are also determents for the radiation exposure of patients. A prediction model was used based on DAP-values of the procedures performed via femoral route, to correct for selection bias and other confounding factors. The results from this model were used to
compare to the radiation exposure of patients that underwent a procedure via the radial route. The study indicates that a procedure performed via the radial route does not result in a higher radiation exposure of the patient compared to a procedure performed via the femoral route.