
NORDISK RAPPORTSERIE OM STRÅLSKYDDSFÅGOR

Report on Nordic Radiation Protection Co-operation.

No. 5

**Nordic guidance levels for patient doses
in diagnostic radiology.**

The radiation protection and nuclear safety authorities in
Denmark, Finland, Iceland, Norway and Sweden

Norwegian Radiation Protection Authority,
Grini Næringspark 13, P.O. Box 55, N-1345 Østerås
Norway

Serie : Nordisk rapportserie i strålskyddsfrågor
ISSN : 0804-5038
Tittel : Nordiske veiledende verdier for pasientdoser i røntgendiagnostikk
No : 5
Arbeidsgruppe : Røntgendiagnostikk, leder Gunnar Saxebøl
Redaksjon : Gunnar Saxebøl og Hilde M. Olerud, Statens strålevern, Norge
Medforfattere : Ole Hjardemaal (Danmark), Wolfram Leitz (Sverige),
Antti Servomaa (Finland), Tord Walderhaug (Island)

Sammendrag : Rapporten inneholder anbefalinger fra Nordiske strålevernmyndigheter angående pasientdoser ved 6 ulike røntgenundersøkelser. Doseverdiene skal forstås som veiledende (dose constraints) i henhold til anbefalinger fra den internasjonale strålevernkommissjon, ICRP. Det gis råd om måling og fortolkning av måleresultater, samt mulige tiltak. Bakgrunnsmateriale for fastsetting av doseverdiene er gitt i appendiks, sammen med relevant informasjon om dosebestemmende faktorer i røntgendiagnostikk.

Nøkkelord : Pasientdoser, røntgendiagnostikk, optimalisering, strålevern, veiledende doser

Omslag : Graf, Oslo

Series : Report on Nordic radiation protection co-operation
ISSN : 0804-5038
Title : Nordic guidance levels for patient doses in diagnostic radiology
No : 5
Task group : X-ray diagnostic, chairman Gunnar Saxeböl
Editors : Gunnar Saxeböl and Hilde M. Olerud, NRPA, Norway.
Co-authors : Ole Hjardemaal (Denmark), Wolfram Leitz (Sweden),
Antti Servomaa (Finland), Tord Walderhaug (Iceland)

Summary : The Nordic radiation protection authorities recommend guidance levels for patient doses for six radiological examinations. The guidance levels should be understood as dose constraints as recommended by the International Radiological Protection Committee, ICRP. Advice concerning measurements and interpretation of results are given, as well as possible measures. Background material for the guidance levels are given in the appendixes together with relevant information on factors influencing patient doses in diagnostic radiology.

Key words : Patient doses, diagnostic radiology, optimisation, radiation protection, guidance level

Cover design : Graf, Oslo.

Nordic guidance levels for patient doses in diagnostic radiology.

Summary

The Nordic radiation protection authorities recommend guidance levels for patient doses to be used in medical radiology. The guidance level is related to the concept dose constraints, or investigation level as stated in ICRP 60. When used in a constructive manner, guidance levels can be an efficient tool in improving the radiation protection in medical exposure. Guidance levels are given for six specific examinations. These are common conventional examinations performed in radiological departments involving both radiography and fluoroscopy. Compliance with the guidance levels for the specified examinations should normally be an indication of good medical practise for other examinations as well. The Nordic radiation protection authorities recommend that measurements or assessments of patient doses are performed regularly and that the relevant information is recorded and filed in order to check compliance with the recommended levels and follow the trends with respect to patient doses. Adequate measures should be taken if substantial deviations are demonstrated compared to the guidance levels. More detailed information with respect to measurements, background data for the selected examinations and discussion of technical parameters influencing the patient doses is given in the appendixes.

INTRODUCTION

1. The medical diagnostic progress made in this century can to a great extent be linked to the use of radiation sources. Particularly, the application of x-rays for diagnostic purposes has been fundamental in the development of modern medicine, but also the use of radioactive substances play an important role in the diagnostic field.
2. The need for radiation protection measures was first realised by the radiologists themselves and British radiological pioneers already in 1915 made recommendation concerning radiation protection¹. The motives were first of all to protect the physicians and their assistants, but radiation damages were observed in patients as well. More systematic radiation protection efforts were initiated in 1928 with the establishment of an international committee, now known as International Commission on Radiological Protection, ICRP.

3. ICRP has through several decades developed a radiation protection philosophy based on a broad scientific basis, and formulated some fundamental principles given by the key words *justification*, *optimisation* and *dose limitation*². The dose limits, which have changed several times, apply to radiation workers and members of the public. For medical exposures of patients as part of their own investigation or treatment, dose limits have not been specified by the ICRP, since such exposures are usually intended to provide a direct benefit to the exposed individual. However, the principles of justification and optimisation apply, and are important for the radiation protection in this case. Optimisation will in practice be a task of making the best possible balance between necessary doses and adequate image quality, as well as economical, practical and social factors.

4. For diagnostic medical exposures the optimisation principle has two major aspects. First, the optimisation of protection for the medical staff and member of the public. Secondly, the optimisation of the medical examinations, taking into account the clinical requirements of the examination and the patient doses involved. Done properly, optimisation can contribute to the achievement of «good medical practice». ICRP has given supplementary recommendations and information with respect to radiation protection in medical exposure^{3, 4}.

PATIENT DOSES IN MEDICAL DIAGNOSTIC RADIOLOGY

5. The collective population doses from artificial radiation sources have, since their introduction in different practices, been dominated by medical radiology due to the high frequency of examinations and the patient doses involved. Certainly, this situation will continue also for the decades to come. New diagnostic imaging technologies not involving ionising radiation, such as ultrasound and magnetic resonance, are to day applied in addition to X-rays, and are not expected to replace the use of X-rays for diagnostic purposes in the near future.

6. Medical diagnostic radiology has since its introduction a century ago, developed towards lower patient doses and more medical information for the benefit of the patients. This medical discipline has been fundamental in the development of modern health care in our societies. Every day, approximately 50 000 radiological examinations are performed in the Nordic countries, excluding dental examinations.

7. New radiological modalities and procedures have resulted in higher medical quality with respect to diagnosis and treatment. The detriment associated with these medical advances, has in some cases been increased patient doses. Especially the computed tomography examinations, which now are quite frequent, contribute significantly to the collective population dose. For the individual patient, interventional radiological procedures might also involve doses causing deterministic effects such as radiation erythema.

8. Through the last two decades, several surveys have been performed studying the patient doses in a number of countries^{5, 6, 7, 8}. The lessons learned are first of all the recognition of the significant variations in patient doses between different radiological departments for the same type of examinations. An important object of this document is to introduce methods for demonstrating these variations and to promote actions which decrease unreasonably high patient doses.

9. There are several causes for these variations and the factors involved contribute in a complex manner. Differences in equipment performance, competence, skills, working habits and examination procedures are important factors which influence the patient dose. In order to optimise and improve the radiological protection, knowledge and information about the patient doses at the local level is necessary.

10. The Nordic radiation protection authorities stress the importance of being aware of patient doses in medical X-ray diagnostics. Having the dose variations in mind, the potential for dose reduction is significant compared to many other applications of radiation. The reduction of unnecessary high patient doses is considered to be cost-effective and can be done without impairing the diagnostic quality of the medical examinations. Generally, the reduction of patient doses will also be beneficial to the radiation protection of the staff.

GUIDANCE LEVELS FOR PATIENT DOSES

11. In its revision of the basic recommendations 1990, ICRP introduced the source related «dose constraint» as a conceptual tool with regard to the optimisation of the radiation protection. As recommended by the ICRP, dose constraints or investigation levels should be specified for some common diagnostic procedures. The constraints must be applied with flexibility to allow higher doses in special situations or if indicated by sound clinical judgement.

12. The Nordic radiation protection authorities consider the concept of dose constraint or investigation level useful and will use the term guidance level for it in the field of medical radiology, as also used by the IAEA⁹. In some countries, the term reference level have been used in the same conceptual meaning. It is assumed that specified guidance levels for some typical X-ray examinations will be helpful for radiological departments in the evaluation of their own patient dose situation. Compliance with the levels should not discourage efforts towards even lower patient doses in radiological departments.

13. The guidance levels have the following meaning and interpretation :

- They represent specified «dose» values for certain complete X-ray examinations, or single projections.
- They are not intended to be used as investigation levels for individual patients, but are to be compared with representative measured or assessed mean values for a sample of patients.

- They should be used by the responsible medical practitioner in order to improve the radiation protection in medical radiology such that:
 - a) If doses are systematically higher than the guidance levels, reviews shall be performed and corrective measures shall be considered in order to ensure optimised protection of the patient and good medical practice.
 - b) If doses are much lower than the guidance levels, reviews related to the obtained diagnostic information may reveal that the expected medical benefit to the patients is not adequate.

14. The chosen examinations are procedures with either high frequency, or of significance with respect to individual or collective dose aspects. It is assumed that if the guidance levels are met for the specified examinations, other examinations will probably also be performed reasonably optimised with respect to patient doses.

15. Ideally, the guidance levels should be given as radiation risk or effective dose. However, in practice this cannot be obtained by direct measurements. For operative reasons it is considered more appropriate to use other quantities for assessing patient doses. The Nordic radiation protection authorities have evaluated this question and concluded that guidance levels are to be specified as kerma-area product, KAP, or entrance surface dose, ESD. Measuring methodology, dosimetric approaches and a description of the relevant information are discussed in Appendix A.

RECOMMENDED EXAMINATIONS AND GUIDANCE LEVELS

16. The guidance levels are to be interpreted as mean values for adult patients. The KAP values apply for complete examinations, while the ESD values are for single projections. The examinations selected for monitoring patient doses are :

Chest
Pelvis
Lumbar spine
Urography
Barium meal
Barium enema

Preferably all these examinations should be monitored, as far as they are regularly performed at the hospital.

17. The guidance levels recommended for the patient doses in diagnostic radiology are presented in Table 1. Basic information concerning the selected examinations are presented in Appendix B.

Table 1 Nordic guidance levels for six diagnostic procedures
 i) KAP is the kerma-area product, ESD is the entrance surface dose in terms of air kerma including backscatter from the patient (or phantom)

Examination type	Guidance levels ⁱ⁾	
	KAP (Gy·cm ²)	ESD (mGy)
Chest, PA and Lat	1	0,2 PA 0,5 Lat
Pelvis	4	5 AP
Lumbar spine	10	6 AP
Urography	20	
Barium meal	25	
Barium enema	50	

18. In order to investigate and compare local patient doses with the guidance levels it will be necessary to make measurements on a regular basis. It is suggested that a set of measurements are carried out every 3-5 years, or at other intervals if circumstances so indicate. Whenever major changes in equipment or radiological procedures are done which might influence the patient doses, measurements should be carried out.

19. For each examination a sufficient number of patient measurements should be made and all relevant exposure parameters should be recorded in order to detect trends. Other methods may be used, substituting direct patient dose measurements, provided such methods give results that can be compared with the guidance levels for the examination in question. It is recommended that the kerma-area product is measured in such a way that data concerning radiography and fluoroscopy can be separated.

MEASURES

20. If the average patient doses substantially exceed the guidance levels without obvious clinical reasons, the reasons for this should be analysed, and appropriate measures should be considered. The measures might be to alter the examination procedures or to update the equipment performance. It might also include education, training or other aspects related to competence, in order to improve the working techniques. If the patient doses are considerably lower than the guidance levels, the diagnostic quality might be questioned, and it should be confirmed that the clinical demands are met. Some important technical factors affecting the patient doses are discussed in Appendix C, and typical radiological procedures for the six types of examinations are suggested.

REFERENCES

1. *Recommendations for the protection of X-ray operators..* England: Roentgen Society (November 1915)
2. International Commission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection.* ICRP Publication 60. Oxford: Pergamon Press (1991).
3. International Commission on Radiological Protection. *Protection against Ionising Radiation from External Sources Used in Medicine.* ICRP Publication 33. Oxford: Pergamon Press (1982)
4. International Commission on Radiological Protection. *Protection of the Patient in Diagnostic Radiology.* ICRP Publication 34. Oxford: Pergamon Press (1982).
5. Saxebøl, G., Olerud, H.M. and Lundgren, L.E. *Radiation hygiene analysis of radiological activities in Norway.* In: Brustad, T., Langmark, F. and Reitan, J., eds. Radiation and cancer risk. New York: Hemisphere Publishing Corporation, 139 -147 (1990).
6. Shrimpton P.C. et. al. *A national survey of doses to patients undergoing a selection of routine X-ray examinations in English hospitals.* NRPB-R200. Chilton: National Radiological Protection Board (1986).
7. Hart, D., et.al. *Doses to patients from medical x-ray examinations in the UK-1995 review.* NRPB-R289. Chilton: National Radiological Protection Board (1996).
8. United Nations Scientific Committee on the effects of atomic radiation. *Sources and effects of ionising radiation.* UNSCEAR 1993 Report to the General Assembly, with scientific annexes. New York : United Nations (1993).
9. International Atomic Energy Agency. *International basic safety standards for the protection against ionising radiation and for the safety of radiation sources.* Vienna : IAEA (1994) (interim edition)

Appendix A

Measurement methodology

The kerma-area product

The kerma-area product (KAP) is defined as the air kerma, K_{air} , integrated over the x-ray beam cross-sectional area, A :

$$KAP = \int_A K_{air} dA$$

The KAP can be measured with a large plane-parallel ionisation chamber intercepting the entire x-ray beam. The response of the ionisation chamber is approximately independent of the distance from the x-ray tube focus and the chamber can conveniently be mounted on the tube diaphragm housing, not interfering with the examination procedure or patient. The kerma-area product can be expressed in units of $Gy \cdot m^2$, but usually $Gy \cdot cm^2$, $mGy \cdot cm^2$ or $cGy \cdot cm^2$ are used.

A favourable characteristic of the kerma-area product is the possibility of a simple estimation of the energy imparted to the patient²⁻⁶, the latter being connected to the mean patient dose and risk. By providing a single measurement even for complex x-ray examinations, different examination procedures can easily be compared with respect to dose saving techniques.

The performance of the measuring equipment in indicating the kerma-area product as defined above, is first of all dependent on a careful calibration of the equipment. The standard calibration procedure is to compare the kerma-area product meter response with the response from an air kerma reference standard at a point in the x-ray field multiplied with the corresponding exposed area as measured on an x-ray film⁷. This procedure is both sensitive to the lateral positioning of the reference dosimeter, since the x-ray field is usually highly inhomogeneous, and to the accuracy in the measurement of the beam area. If not carried out correctly, calibration according to the above method may therefore introduce large errors into the measurements, and is not recommended on a routine basis in a x-ray department. Another method is to have one chamber fully calibrated under laboratory conditions, and use it as a standard for intercomparison with other chambers.

Commercially available kerma-area product meters are calibrated at the factory. When the intended use of the kerma-area product meter is to check compliance with the guidance levels, the factory calibration is regarded sufficient. The traceability of the calibration to a primary standard should be documented, and the calibration must be checked when receiving the equipment. A laboratory calibration is recommended at regular intervals, i.e. every fifth year.

In addition to the error associated with the calibration of the equipment, the following sources of errors can be identified:

- 1) The position of the ionisation chamber with respect to the patient couch. The basic calibration at the factory is normally performed with an absorber simulating a mean value between undercouch and overcouch x-ray tube installation, which without correction will lead to an under-reading when used on an overcouch tube and an over-reading on an undercouch tube.
- 2) Scattered radiation from x-ray tube diaphragm, patient or patient couch reaching the ionisation chamber.
- 3) The equipment is used with an x-ray quality, exposure rate or field size dissimilar to the one used with the calibration.
- 4) Other deviations related to performance of the equipment, such as temperature and humidity, changes in main voltage or leakage current.

Taking all these errors into account, the overall measurement uncertainty should be within 20%.

The entrance surface dose

The entrance surface dose (ESD) is defined as the air kerma at the patient entrance in the centre of the beam, including backscattered radiation. If the air kerma is measured free in air at a distance l from the tube focus, the entrance surface dose can be expressed as :

$$ESD = K_{air} \cdot (l/FSD)^2 \cdot BSF$$

where FSD is the focus skin distance and BSF is the back scatter factor. The latter is a slowly varying function of x-ray energy, beam area and patient thickness, with values between 1.2 and 1.4 in the diagnostic x-ray energy range and field sizes normally encountered in examinations of the trunk. The entrance surface dose can be expressed in Gy, but usually mGy is used. It can be converted to patient effective dose by applying published conversion factors,⁶

The following two methods for assessing the entrance surface dose are especially convenient and do only to a little extent interfere with the diagnostic procedure:

- 1) Measurements with thermoluminescence dosimeters, TLD, attached to the patient or phantom. If correctly calibrated to measure air kerma free in air, the TLDs should give a direct reading of the entrance dose, and no correction is needed for back scattered radiation or distance from the tube focus.
- 2) The relationship between x-ray unit current time product (mAs) and the air kerma free in air is established at a reference point in the x-ray field for the range of tube potentials encountered. Subsequent estimate of the entrance dose can be done by recording the relevant parameters (tube potential, filtration, mAs and FSD) and correcting for distances and back scattered radiation as implied in the formula above.

The measurements must be done with care, and corrected for sources of error such as energy dependence, atmospheric pressure and temperature. For accurate dosimetry the dosimeters require careful calibration, and a regular calibration against a national standard is recommended.

Significance of average values

An evaluation of an x-ray department's compliance with the guidance levels can be based on the average value from several patients. The sample of patients must however be selected with some care. The guidance levels represent a standard for specific examinations of adult patients, and the patient sample must reflect this, especially with respect to patient thickness and weight. The overall uncertainties in the values must be estimated and accounted for when analysing the results.

The fractional uncertainty of the average values can be estimated at the 95% significance level with the following expression:

$$1.96 \cdot (cv/\sqrt{n}) + \Delta k$$

where cv is the coefficient of variance of the measurements (standard deviation divided by average value) and n is the number of measurements constituting the average value. The factor k is the instrument reading uncertainty, see above, which is here treated as an independent, systematic error.

Record keeping

Monitoring the patient radiation doses and comparing them with reference values, also means that together with the actual measurements, some kind of record keeping, to keep track of examinations and other relevant quantities is needed. Information which needs to be recorded is on the one hand the diagnostic examination type, which is essential, but other variables may also be of interest such as tube voltage, filtration, film-screen combination, manual or automatic exposure control and patient weight, age and sex. The radiation dose information may be complemented by the number of radiographs and fluoroscopy time. This information will both enable the radiographic procedure to be analysed further with emphasis on radiation dose, and may be used to explain deviations from previous surveys and detect trends in the radiological procedure.

References

1. International Commission on Radiation Units and Measurements. *Quantities and Units in Radiation Protection Dosimetry*. ICRU Report 51. ICRU: Bethesda Md, USA (1993).

2. Carlsson, C. *Determination of Integral Absorbed Dose from Exposure Measurements*. Acta Radiologica **1** (6) 433-457 (1963).
3. Alm Carlsson, G., Carlsson, C.A. and Persliden, J. *Energy imparted to the patient in diagnostic radiology: calculation of conversion factors for determining the energy imparted from measurements of the air collision kerma integrated over beam area*. Phys. Med. Biol. **29** (11) 1329-1341 (1984).
4. Persliden, J. and Alm Carlsson, G. *Energy imparted to water slabs by photons in the energy range 5-300 keV. Calculations using Monte Carlo photon transport model*. Phys. Med. Biol. **29** (9) 1075-1088 (1984).
5. Alm Carlsson, G. and Carlsson, C.A. *Relations between effective dose equivalent and mean absorbed dose (energy imparted) to patients in diagnostic radiology*. Phys. Med. Biol. **31** (8) 911-921 (1986).
6. Hart, D., Jones, D.G. and Wall, B.F. *Estimation of Effective Dose in Diagnostic Radiology from Entrance Surface Dose and Dose-Area Product Measurements*. NRPB-R262. Chilton, Didcot: National Radiological Protection Board (1994).
7. Shrimpton, P.C. and Wall, B.F. *An evaluation of the Diamentor transmission ionisation chamber in indicating exposure-area product ($R \text{ cm}^2$) during diagnostic radiological examinations*. Phys. Med. Biol. **27** (6) 871-878 (1982).

Appendix B Information concerning the guidance levels and the selected x-ray examination types

Introduction

In a radiological department, normally a large number of different and specialised x-ray examinations are performed. Often, certain examinations are performed in dedicated laboratories or with specialised equipment. In order to monitor the patient doses, ideally all types of examinations should be regularly evaluated, but this will be time-consuming and probably not cost-effective. Experience has shown that patient dose information, from a few and well chosen examinations, can serve as indicators for the general situation in a radiological department with respect to patient doses.

The examinations pinpointed in this document are typical examinations in a radiological department, representing simple radiographic examinations and more complex examinations which might include radiography as well as fluoroscopy, and examinations with small and relatively large patient doses. Relevant data are described in the following.

Chest

The conventional chest examination is the most frequent in medical x-ray diagnostics. The frequency of chest examinations in the Nordic countries is presented in Table 2. Chest examinations can be performed with procedures involving radiography or photofluoroscopy (massminiature). In this document the guideline for the chest examination is the radiographic procedure including both PA and LAT projections.

Table 2 Frequency of chest examinations per 1000 inhabitants in the Nordic countries.

Country	No. of chest exam. per 1000 inhab.per year
Denmark	120
Finland	180
Iceland	150
Norway	120
Sweden	120

Since the total frequency of x-ray examinations in the Nordic countries is in the range 500-800 per 1000 inhabitants, it can be concluded that the chest accounts for about 20% of all examinations. However, the dose contribution for the chest is quite small. Based on Monte Carlo calculations it is estimated that chest contributes approximately 2% of the collective effective dose due to x-ray diagnostics.

The patient dose for the chest examinations is normally low. However, as for all other examinations it varies due to the equipment available, the chosen exposure parameters, the patient size etc. Patient dose measurements on adult patients (i.e. weight > 40 kg) performed in Norway, expressed as the kerma-area product (KAP) are presented in Figure 1. Based on this material, obtained through a 10-year period with more than 1100 measurements of the chest examinations from approximately 50 hospitals, the chosen guidance level of 1 Gy cm² is close to the calculated mean value. The patient doses for chest have declined the last years. The dose from the lateral projection is approximately twice the dose from the PA projection. It is an observation made during the measurements, that several hospitals had considerably lower local mean doses than the mean values obtained in the national survey. This indicates that it should not be very difficult to meet the guidance level.

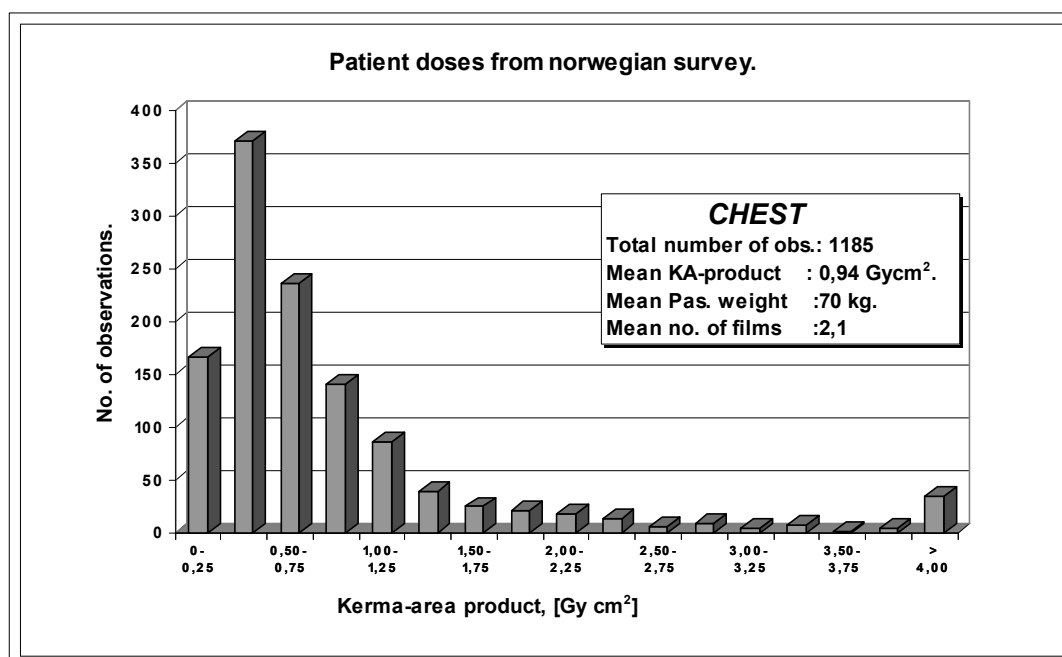


Figure 1 Distribution of the patient dose for the chest x-ray examination obtained from the Norwegian national survey

Urography

Intravenous urography is an old and classic radiographic examination with roots to the early 1930' ies. The examination will normally be performed with several successive radiographs in the abdominal and pelvic region. The procedures used, vary somewhat from one department to the other, but nevertheless it is a standard examination suitable for monitoring. The frequency of this examination has decreased during the last decade, mainly due to ultrasound diagnostics as an alternative examination method. Data, based on complete registrations in Norway 1983, 1988 and 1993 shows a reduction in frequency from 19 to 9 per 1000 inhabitants in this 10-years period. At present the frequency in some of the Nordic countries is in the range 7-14 per 1000 inhabitants, or roughly 1 % of all examinations.

The doses involved in urography is typically in the medium patient dose range. Based on more than 500 observations in the Norwegian patient dose survey for adult patients, the observed average KA-product was 20.7 Gy cm^2 . The distribution of the measured KAP-values for urographies are given in Figure 2. The most frequent patient dose is in the range $7.5\text{-}15 \text{ Gy cm}^2$. Thus the guidance level of 20 Gy cm^2 should not be difficult to meet in normal radiological circumstances. With respect to other relevant mean values it can be mentioned that the number of films used were 8.7 and the average patient weight was 70 kg. The diagnostic collective effective dose, due to urographic examinations, contribute in the range 5-7 %.

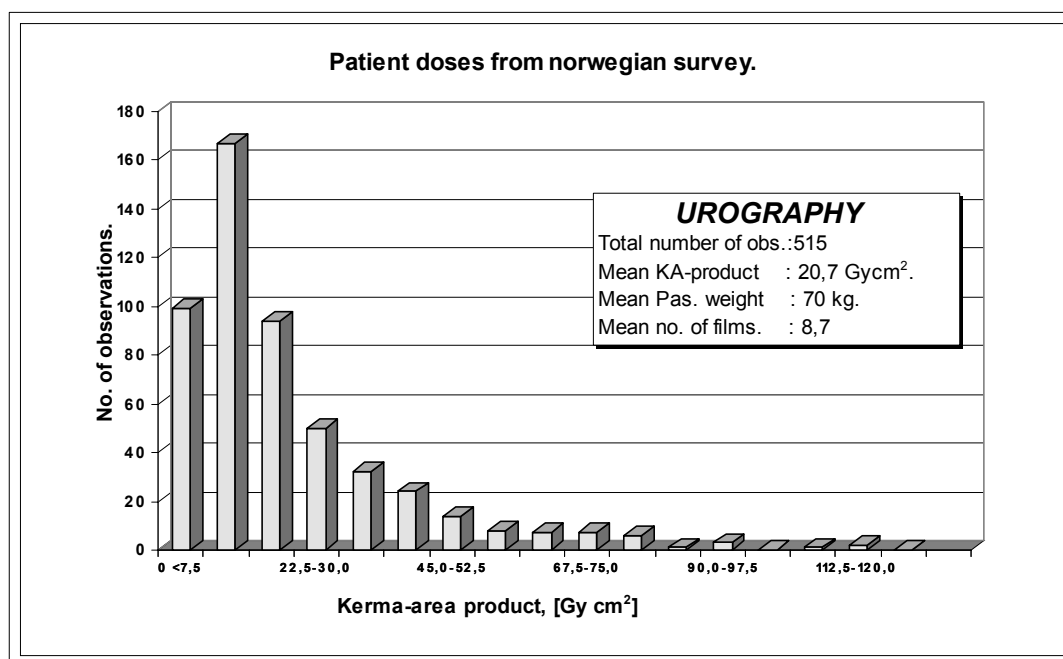


Figure 2 Distribution of the patient dose for the urography x-ray examination obtained from the Norwegian national survey.

Pelvis

Pelvis is a typical examination in the lower abdominal region. The frequency surveys have shown a stable occurrence through a ten year period. Pelvis is often combined with special projections of the hip joints (Lauenstein projections), however in this context with the pelvis as a monitoring examination these special projections is not to be included. Thus, pelvis examinations to be compared with the guidance level should only be procedures with the AP-projection. This examination is similar to other examinations in the abdominal region and for this reason suitable for monitoring purposes.

The mean values from the Norwegian survey (101 observations) were 4.0 Gy cm², 1.1 films and the patient average weight was 68 kg. It was observed that fluoroscopy was used in a number of hospitals for this examination. For observations including fluoroscopy, the mean fluoroscopy time was 0.1 minute and the dose from fluoroscopy was 12 % of the total patient dose. The KAP distribution for pelvis is principally similar to the other patient dose distributions. The chosen guidance level of 4 Gy cm² is as the observed mean value, and in similarity with the other distributions, practical experience from measurements shows that the most probable KA-product value for pelvis is far below the guidance level, that is in the range 1.5-2.25 Gy cm². The collective effective dose from the pelvis examination is in the same range as chest, that is 2-3 %.

Lumbar spine

The guidance level recommended for the examination of the lumbar spine (LS) is 10 Gy cm². The frequency of LS-examinations have not changed dramatically and is in the range 25-35 per 1000 inhabitants in some of the Nordic countries. The contribution from LS-examinations is estimated to be in the order 10 % of the collective effective dose. Average parameters and other relevant information from the Norwegian survey is presented in Figure 3. Compared with the chosen guidance level and the fact that it is quite common to have KAP results lower than the level of 10 Gy cm², the recommended guidance level should be reasonably achievable.

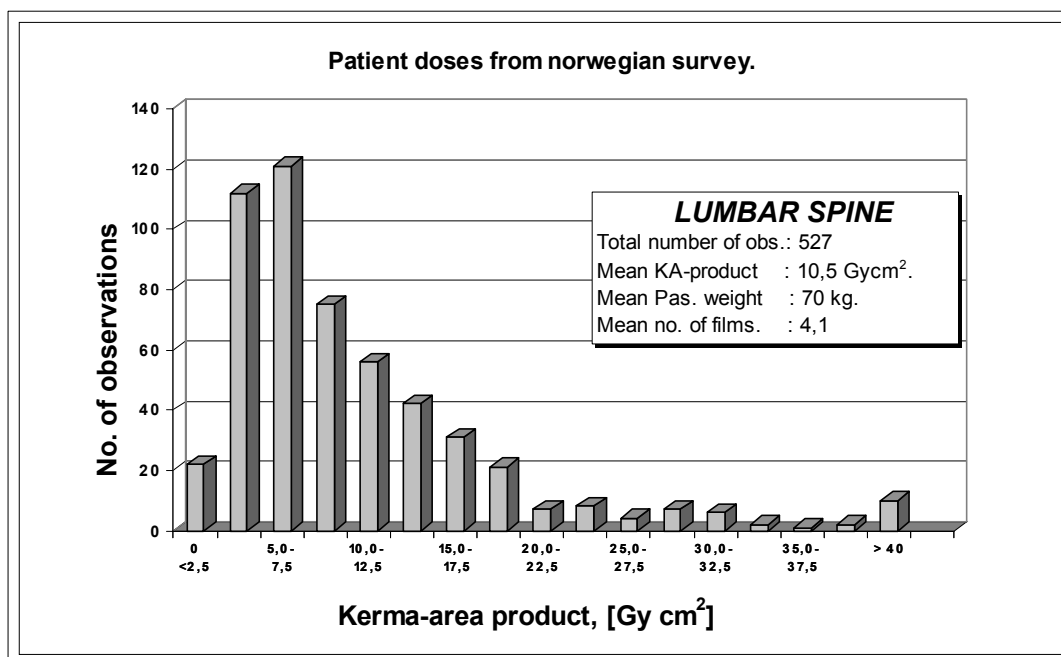


Figure 3 Distribution of the patient dose for the lumbar spine x-ray examination obtained from the Norwegian national survey.

Barium meal and Barium enema

Barium meal, another classical examination introduced in the early radiological practice, seems now to have lost much of its diagnostic status. From the frequency surveys it can be deduced that barium meal, including both single and doublecontrast technique, have decreased approximately from 30 to 5 examinations per 1000 inhabitants during the last decade. The main reason for this development is that alternative endoscopic techniques have been favoured as diagnostic methods. Nevertheless, barium meal is still performed in several hospitals and is a typical examination involving both radiography and fluoroscopy. As such this examination is suitable for monitoring. If barium meal is not regularly performed, the barium enema can serve as monitor for this kind of examination. The enema examination has had a rather stable occurrence of 10 per 1000 inhabitants in the last decade. The majority of examinations are performed with doublecontrast technique for both the barium enema and the barium meal. The selected guidance levels for these two gastrointestinal examinations are based on measurements and observations with doublecontrast technique.

Mean values for parameters relevant for the barium meal and barium enema observations from the Norwegian patient dose project are shown in Table 3. Based on observed frequencies and patient doses, these gastrointestinal examinations accounts for approximately 20-30 % of the collective diagnostic doses. This might change significantly if alternative endoscopic methods (rectoscopy) will replace barium enema even more in the future.

Table 3 Mean values and parameters of interest for the barium meal and barium enema examinations from the Norwegian patient dose survey obtained in the period 1983-1994.

- i) kerma-area product (KAP) in units of Gy·cm²
- ii) kV is the x-ray tube potential in kilovolts used for radiographs

Examination/Parameter	Barium meal	Barium enema
No. of observations	379	277
KAP, mean valueⁱ⁾	28.3 Gy·cm ²	56.0 Gy·cm ²
% of KAP due to radiographs	46 %	46 %
% of KAP due to fluoroscopy	54 %	54 %
No. of radiographs	10.9	12.8
Fluoroscopy time	3.4 min	4.1 min
Fluoroscopy KAP- rate	4.6 Gy·cm ² /min	7.4 Gy·cm ² /min
Mean patient weight	67 kg	68 kg
Mean kV-settingⁱⁱ⁾	105 kV	106 kV
Guidance level	25 Gy·cm²	50 Gy·cm²

The Kerma-area product and effective doses

Kerma-area products or entrance surface doses are convenient for patient dose monitoring purposes. However, for further risk assessments, it is also of interest to obtain information concerning the patient effective dose associated with the different examinations. Conversion

coefficients for the deviation of effective dose from measurements of entrance surface dose or kerma-area product have been published from the National Radiological Protection Board in England based on Monte Carlo methods ¹. The effective dose values corresponding to the Nordic KAP guidance level values are shown in Table 4.

Table 4 The Nordic guidance levels, conversion factors between effective dose and kerma-area products ¹, and the corresponding effective dose (mSv)
 i) In the Nordic countries Chest examinations are normally performed with the tube voltages above 120 kV, and the conversion factor was adjusted accordingly

Examination	Guidance level Gy·cm²	Conversion factor mSv/Gy·cm²	Effective dose [mSv]
Chest	1	0.18 ⁱ⁾	0.2
Pelvis	4	0.29	1.2
Lumbar spine	10	0.21	2.1
Urography	20	0.18	3.6
Barium meal	25	0.20	5.0
Barium Enema	50	0.28	14

1. Hart, D., Jones, D.G. and Wall, B.F. *Estimation of Effective Dose in Diagnostic radiology from Entrance Surface dose and Dose-Area product Measurements*. NRPB-R262. Chilton: National Radiological Protection Board (1995)

Appendix C Factors affecting the patient dose

The kerma-area product to a patient undergoing a radiological examination depends on several technical and physical factors, how the examination is carried out, on special diagnostic requests, and on the patient's anatomy. Some of these factors are discussed in the following, and guidance is given on how to deal with them in the context of this document.

Technical and physical factors in radiography

The patient's anatomy has a large influence on the dose, especially when expressed as kerma area product. An increase from 20 to 25 cm thickness will lead to an increase in dose by a factor of approximately 3 due to the higher attenuation, and provided the size of anatomical region of interest is proportional to the thickness, a 50 percent larger field size. An indication on various technical factors and their influence on the patient dose, expressed as kerma-area product, is given in the Table 5. The figures are valid for 20 cm tissue and are calculated for equal air kerma at the image receptor plane.

Table 5 Example of the influence of technical parameters on the kerma-area product

Parameter	Standard settings	Changed setting	Change in kerma-area product (%)
Tube voltage	75 kV	66 kV	+50
Filtration	3 mm Al	2 mm Al	+25
Waveform	DC	AC (single phase)	+10
Field size in the image plane	24 x 30 cm ²	26 x 32 cm ²	+15
Table top absorption	1 mm Al	2 mm Al	+20
Grid type	ratio 8	ratio 12	+30
AEC setting (film density)	1.2	1.7	+40
Film-screen speed class	320	160	+100
Developer temperature	35 °C	33 °C	+20
Focal spot to film distance	140 cm	100 cm	0
For fluoroscopy :			
Image intensifier field of view (zoom)	23 cm Ø	17 cm Ø	0
Automatic brightness control (air kerma in the receptor plane)	0.4 µGy/s	0.8 µGy/s	+100

Typical radiological procedures

Typical radiological procedures for the six examination types are presented in Table 6. These figures may be largely influenced by the particular diagnostic demands for the patient in question, leading to deviations from the standard protocol. This fact must be taken into consideration when judging measured patient doses. However, the procedures in Table 6 should normally give dose values in compliance with the guidance levels.

Table 6 Typical radiological procedures for six conventional x-ray examinations
i) Stated as the mean number of views in the Nordic countries

Chest	Tube voltage :	120 - 150 kV
	Film-screen speed class :	200-400
	Number of views :	1 PA and 1 Lat
	Miscellaneous :	Total filtration ≥ 2.5 mm Al + 0.1 - 0.2 mm Cu
Pelvis	Tube voltage :	70 - 90 kV
	Film-screen speed class :	400
	Number of views :	1 AP
Lumbar spine	Tube voltage :	70 - 110 kV
	Film-screen speed class :	400-800
	Number of views :	3-4
	Miscellaneous :	lower kV for AP views, higher kV for lat views
Urography	Tube voltage :	70 - 90 kV
	Film-screen speed class :	400
	Number of views ⁱ⁾ :	9
Barium meal	Tube voltage :	100 - 140 kV
	Film-screen speed class :	400
	Number of views ⁱ⁾ :	9
	Miscellaneous :	fluoroscopy time < 5 min
Barium enema	Tube voltage :	100 - 140 kV
	Film-screen speed class :	400
	Number of views ⁱ⁾ :	12
	Miscellaneous :	fluoroscopy time < 5 min