Trends in examination frequency and population doses in Norway, 2002 - 2008.

OLERUD H.M.[1], **FRIBERG E.G.**[1], **WIDMARK A.**[1] **& ALMÉN A.**[2]

[1] *Norwegian Radiation Protection Authority, P.O.box 55, NO-1332 Østerås, Norway*
[2] *Swedish Radiation Safety Authority, SE-171 16 Stockholm, Sweden*

Abstract. A new population dose survey in Norway anno 2008 gave the following key figures: 4,3 mill examinations (900 per 1000 inhabitants), 1.1 mSv/caput whereof 80% of the dose from CT. 23% of the examinations were done in private sector. Planar X-ray is reduced in number; ultrasound is about the same, while both CT and MR have doubled in frequency since 2002. The collective effective dose has however not changed since 2002. This is partly explained by technological advances in CT, but also the implementation of new radiation protection regulations since 2004, with increased focus on quality assurance and optimisation/diagnostic reference levels (DRL's).

KEYWORDS: collective effective dose, population dose, radiology, Xray, CT, DRL

INTRODUCTION

Norway has a centralized public founded health care system, and a population of about 4.5 million people. Imaging is performed in radiological departments in public hospitals as well as in private radiology institutes. Virtually all radiological examinations are submitted to a public reimbursement system. The Norwegian radiation protection regulation is founded on the basic recommendations of the International Commission on Radiological Protection (ICRP). The Norwegian Radiation Protection Authority (NRPA) has the authorization to ask for information about examination frequency and patient doses and has made regular assessments of the use of diagnostic radiology in order to explore trends in the use of different imaging modalities, looking for possible regional variations and the effects from the introduction of digital technology. Recent developments in medical imaging, particularly with respect to computed tomography (CT), are expected to have significant consequences for individual patient doses and for the collective dose (S_E) to the population. On the other hand, the use of non-ionizing modalities such as ultrasound (US) and magnetic resonance (MRI), as well as various scopy techniques, has provided diagnostic advantages at no costs concerning the S_E.

NRPA has long traditions in the estimation of population doses, and has performed national surveys periodically since the early eighties. The trends up to 2002 has been analysed and reviewed in international publications (Olerud and Saxebøl 1997, Børretzen et.al. 2007). The aim of this paper is to highlight the trends in examination frequency and patient doses in Norway between 2002 and 2008, these data has only been published nationally so far (Almén et.al. 2010).

MATERIALS AND METHOD

Information about examination frequency in Norway

In Norway we have used the definition suggested in the European guidance on estimating population doses from medical x-ray procedures and annexes (RP154, 2008): 'An x-ray examination or interventional procedure is defined as one or a series of x-ray exposures of one anatomical region/organ/organ system, using a single imaging modality (i.e. radiography/fluoroscopy or CT), needed to answer a specific diagnostic problem or clinical question, during one visit to the radiology department, hospital or clinic'.

Annual numbers of examinations have been obtained directly by questionnaires sent to all Norwegian hospitals, clinics and practices, both in 2002 and 2008, i.e. it has not been necessary to scale up to cover the whole country. The Norwegian College of Radiology has through more than twenty years developed a code system that has been used both for activity analysis and reimbursement. All enterprises in Norway have for a long time had radiological information systems (RIS), and the number of codes could easily be gathered from the RIS systems in the departments. The codes had, however, to be interpreted into actual numbers of examinations, i.e. some problems of double-counting, particularly with examinations of double-sided organs had to be adjusted for, and likewise examinations which consisted of several contrast series that would create more than one radiological code in the system.

Surveys on patient doses in Norway

For radiographic and fluoroscopic X-ray examinations the dosimetry in Norway has been based on the dose-area product, P_{KA}. During the eighties, the data were collected by site visits to all hospitals by the NRPA (Olerud and Saxebøl, 1997). For CT examinations the CT dose indexes for the actual scanners, C_K, were either measured or looked up in the literature, while the technique parameters for standard protocols and for certain clinical indications were collected by questionnaires to all CT rooms (Olerud 1997). The Monte Carlo based conversion coefficients published by the former NRPB in the UK (now part of the Health Protection Agency) were used to calculate the effective dose. According to the International Commission on Radiation Units and Measurements (ICRU 2005):

$$P_{KA} = \int K_a (A)\, dA \qquad (1)$$

$$C_K = \frac{1}{N_i T_i} \int_{-0\,mm}^{+0\,mm} K_a (z)\, dz \qquad (2)$$

Since 2004 we instead have collected information from the hospitals and X-ray institutes by asking for their local diagnostic reference levels (DRL's) or "representative dose values"; these are the mean values for 20 representative patients in each X-ray or CT room. The practical dose quantities used for CT are now connected to measurements in standard CT dosimetry PMMA phantoms with diameters of 16 or 32 cm (head or body FOV), given as the weighted CT doseindex, $C_{K,PMMA,w}$ corrected for the pitch, and the dose length product, $P_{KL,CT}$. The European guidance (RP154, 2008) suggest that in order to reduce the overall uncertainties in mean effective dose estimates, dose data should be collected from 20 – 100 X-ray or CT rooms (sample size). If the sample size decrease to 5 – 20 rooms the uncertainty increase from 10% to 25% (pragmatic approach).

RESULTS

Trends in the examination frequency in Norway

A total number of 4 265 533 radiological examinations were performed in Norway in 2008. That corresponds to 900 per 1000 inhabitants (dental examinations excluded), which is about the same as in 2002. Still conventional Xray examinations (RG) is the most used modality, however, computed tomography (CT) examinations now constitute 21% of all radiological examinations (Table 1). Compared to 2002 the use of X-ray is decreasing, while the use of CT and Magnetic resonance imaging (MR) are increasing, and the number of ultrasound (US) examinations is about the same (Figure 1). 23% of all examinations accounted for in the survey are done in private sector (radiological institutes). The use of RG, CT and US examinations in private sector has been some reduced since 2002, while MR investigations are being performed to the same extent in the private sector as before.

Tab.1 No of radiological examinations performed in Norway per modality and totally in 2008

Modality	Total number of examination	Exams per 1000 inhabitant
XRAY	2 253 262	476
CT	918 361	194
ULTRASOUND	498 078	105
MR	595 832	126
Total	4 265 533	900

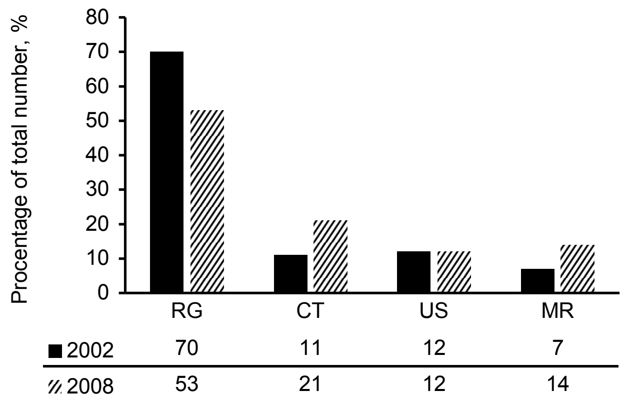


Fig.1 The trends in use of conventional X-ray (RG), computed tomography (CT), ultrasound (US) and magnetresonance tomography (MR) between 2002 and 2008.

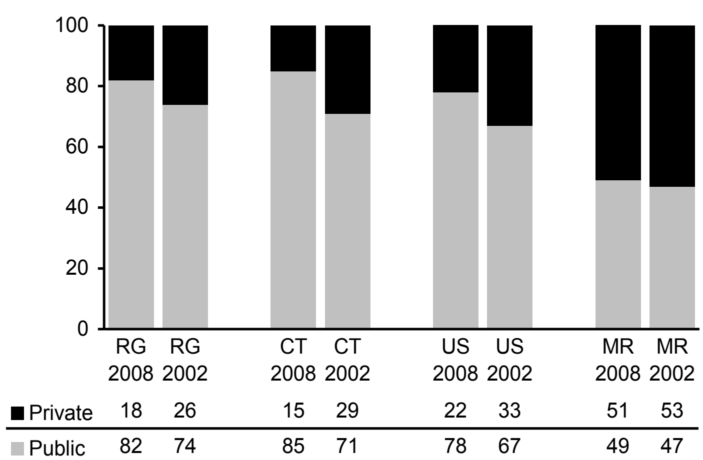
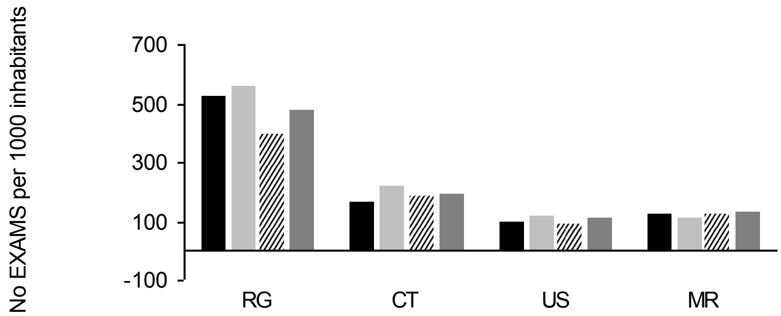


Fig.2 The market share in the use of various radiology modalitites (RG, CT, UL, MR) between public and private sector in Norway in 2002 and 2008

The Norwegian public health care system is managed in four regional areas: North, Mid, West and South-East. The examinations performed in private sector were accounted for in the corresponding geographical region. There was a certain variation in the use of radiology between the four geographical regions (Figure 3). The West region generally did less examinations compared to the country mean, while region Mid did some more. Since 2002 the biggest change was more MR done in region West and more CT done in region Mid. Such regional differences and trends are of obvious health political interest.



	RG	CT	US	MR
North	522	166	98	122
Mid	561	220	115	109
West	392	188	89	125
South-East	478	191	110	131

Fig.3 The use of the different radiological modalities (RG, CT, UL, MR) in four different regions in Norway

*Tab.2 T*he "TOP 20" list of examinations as defined in the European guidance (RP154, 2008) with country mean values of effective dose in 2002 and 2008

TOP20	Examination type	Effective dose (mSv) 2002	Effective dose (mSv) 2008	Changes in dose (mSv) 2002-2008
1	Chest/Thorax	0,1	0,07	-0,03
2	Cervical spine	0,2	0,07	-0,13
3	Thoracic spine	0,7	0,49	-0,21
4	Lumbar spine (inc. LSJ)	1,4	1,4	–
5	Mammography	0,1	0,15	0,05
6	Abdomen	3,6	1,2	-2,4
7	Pelvis&hip	0,6	0,4	-0,2
8	Barium meal	5,1	5,2	+0,1
9	Barium enema	12,5	7,3	-5,2
10	Barium follow-trhough	2,2	4,8	+2,6
11	Intravenious Urography	3,8	2,4	-1,4
12	Cardiac angiography	9,4	7,6	-1,8
13	CT Head	1,8	1,5	-0,3
14	CT neck	3,4	2,6	-0,8
15	CT Chest	11,5	4,7	-6,8
16	CT spine	4,3	5,6	+1,3
17	CT Abdomen	12,6	10	-2,6
18	CT Pelvis	9,3	7,3	-2
20	PTCA	9,9	17	+7,1

Trends in patient doses in Norway

The European guidelines defined a list of twenty examinations that contributed mostly to the collective effective dose (S_E) in 2002 (RP154, 2008). In Norway this "TOP20" list then contributed as much as 90% to S_E., therefore it was of particular concern to study what happened to the patient doses for these examinations during the last years. The dose data used in the 2002 survey were collected during the 80thies and 90this, while current dose data were collected in 2006 – 09. The results of these two time periods are compared in Table 2 (previous page).

Trends in population doses in Norway

From the 4 265 533 radiological examinations performed in Norway 2008, a number of 3 171 623 (74%) were based on X-ray technology (RG or CT) and thereby they contribute to the collective effective dose from medical use of radiation. The "TOP 20 list of examinations up to 2 225 530 examinations in 2008 (Table 3). Based on the country mean effective doses for these examinations, the collective dose in 2008 adds up to 4475 manSv. If we approximate this list of examination still constitutes 90% of the collective effective dose from all examinations, the collective effective dose in 2008 is 1.1 mSv per capita, i.e. the number is unchanged since 2002.

Tab.3 No of examinations and collective effective dose for the "TOP 20" list of examinations as defined in the European guidance (RP154, 2008)

TOP20	Examination type	Number of exams anno 2008	Collective effective dose, S_E (manSv)	Uncertainty %
1	Chest/Thorax	690 310	50	14
2	Cervical spine	47 343	3,3	35
3	Thoracic spine	27 290	14	51
4	Lumbar spine (inc. LSJ)	98 721	134	27
5	Mammography	340 701	41	11
6	Abdomen	45 126	56	27
7	Pelvis&hip	281 308	116	5
8	Barium meal	3 511	18	51
9	Barium enema	5 517	40	27
10	Barium follow-trhough	5 772	28	51
11	Intravenious Urography	5 920	14	51
12	Cardiac angiography	30 000	228	34
13	CT Head	170 793	262	34
14	CT neck	34 784	90	27
15	CT Chest	116 731	554	27
16	CT spine	22 803	128	27
17	CT Abdomen	169 158	1687	27
18	CT Pelvis	117 742	858	27
20	PTCA	12 000	202	51
	Total	2 225 530	4475	15

DISCUSSION

Explanations for the national results

It appear that simple radiographs involve lower doses to the patient today compared with the situation before the millennium, while fluoroscopic examinations shows examples of both higher and lower doses. This may probably be explained by the introduction of digital technology with more efficient detectors. It is worth noticing that CT examinations generally gives lower doses today compared with the 90thies, except for CT of the spine. CT technology has gained great advances, both with respect to better detectors, helical scan technique (pitch factor), and tube current modulation. The faster scan techniques also make it possible to cover more contrast phases during a single scan. The lower doses may also by changes in local procedures (optimisation). Since 2004 new radiation protection regulations have been implemented in Norway, addressing both the need of competence and training of all professionals (radiologists, diagnostic physicists and radiographers), QA procedures, and optimised scan protocols. As tool in the optimisation task, diagnostic reference levels were published by the NRPA in 2005, and reviewed in 2010. This may hopefully also have influenced on the dose levels in Norway.

Norwegian results in a European context

Regarding the frequency of examinations, if we compare with other European countries, the number of X-ray based examination in Norway is about on the average (670 per 1000 inhabitants). We however do a lot more of CT compared with many others (Tab. 4). This also means that CT contributes more to the total effective dose in Norway compared with many other European countries (80%) (Fig. 4).

Tab.4 Relative frequency of some radiological examinations in Norway compared with twelve other European countries (Olerud et.al. 2010)

Undersøkelse	Relative to European mean value
CT Pelvis	4,9
CT Abdomen	1,5
CT Chest	1,3
Cardiac angiography	1,3
PTCA	1,3
Mammography	1,2
CT Head	1,1
Pelvis&hip	1,1
CT neck	1
Barium meal	0,9
Chest/Thorax	0,8
Cervicalcolumna	0,6
Lumbar spine (inc. LSJ)	0,6
IVU	0,6
Barium follow-trhough	0,6
Thoracic spine	0,6
Barium enema	0,6
CT spine	0,5
Abdomen	0,4

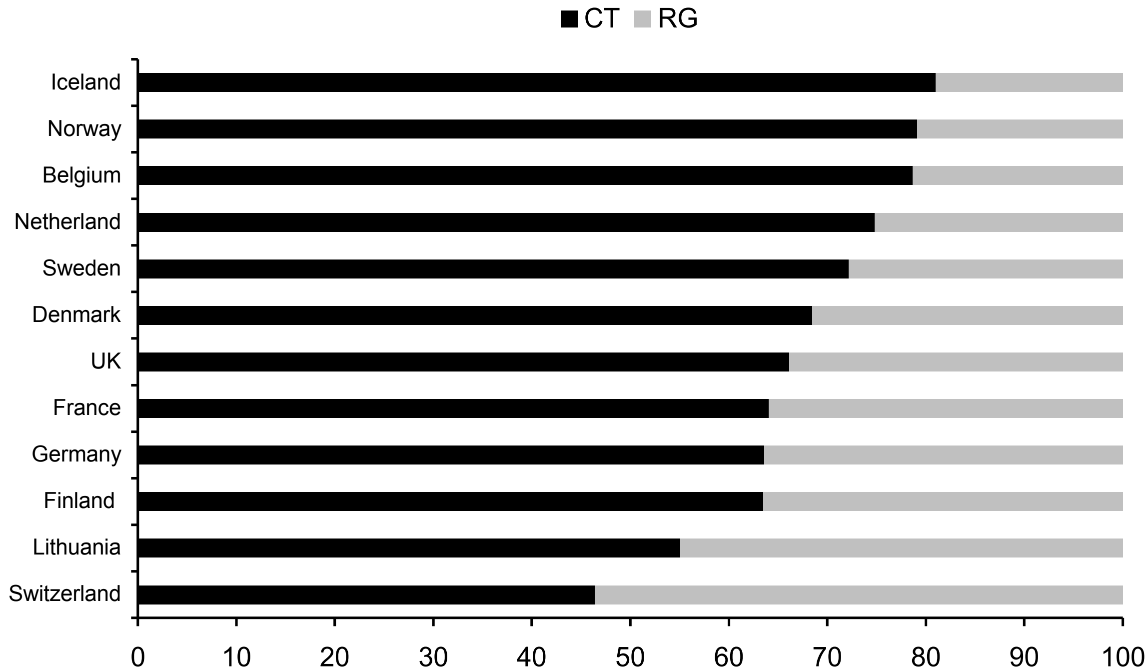


Fig. 4. The contribution to collective effective dose from Xray and CT to the total in some European counties (%)

CONCLUSION

Norway has had a public founded healthcare system and early access to digital technology included multi detector CT technology. The first may explain a moderate examination frequency on the national level, and the second the relatively high collective effective dose (S_E) compared to other western countries (1.1 mSv/ per inhabitant; almost 80% from CT). There is substantial variation in examination frequency and doses between counties, radiology institutions and X-ray rooms. This may be explained by several factors: Accessibility and referral strategy (justification), focus on quality, skills and multidisciplinary approaches (optimization), together with equipment related factors. It is also presumed that the implementation of new national regulations from 2004 have influenced the use of radiological equipment in Norway both with respect to extent and dose levels. Diagnostic reference levels have shown to be a useful tool for optimization locally, and also a source for updated national dose figures. In order to understand the development in the use of radiology it is considered important to survey both ionising (X-ray/CT) and non-ionising (US/MR) modalities. Well agreed standardised dose figures may currently be gathered automatically from the DICOM header/PACS systems, which will make future dose surveys easier. There is however a lack of harmonised radiological classification systems in Europe, something that introduces uncertainties in the comparisons between countries. The new Dosedatamed 2 project launched by the European commission in 2010 address this topic, www.ddmed.eu .

REFERENCES

Almén A, Friberg EG, Widmark A, Olerud HM (2010). Radiology in Norway anno 2008. Trends in examination frequency and collective effective dose to the population. StrålevernRapport 2010:12. Østerås: Norwegian Radiation Protection Authority (Language: Norwegian).

Borretzen I, Lysdahl KB, Olerud HM (2007) Diagnostic radiology in Norway: trends in examination frequency and collective effective dose. Radiaton Protection Dosimetry 2007; doi: 10.1093/rpd/ncm204. http://rpd.oxfordjournals.org/cgi/reprint/ncm204? ijkey=8wBFzfgwJfzmzzp&keytype=ref'.

European guidance on estimating population doses from medical x-ray procedures and annexes (2008). Radiation protection no. 154. Brussels: European Commission, Directorate General for Energy and Transport. http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/154_en.zip

Friberg EG, Widmark A, Hauge IHR (2008). National collection of local diagnostic reference levels in Norway and their role in optimization of X-ray examinations. In: IRPA 12: International Congress of the International Radiation Protection Association, Buenos Aires 2008. Strengthening radiation protection worldwide: proceedings. TS III 3.1, FP 0809.pdf. CD-Rom. Buenos Aires: IRPA, 2008

International Commission on Radiation Units and Measurements, ICRU (2005) ICRU Report 74 Patient Dosimetry for X Rays used in Medical Imaging (ICRU). Journal of the ICRU Volume 5 No 2.

Lysdahl KB, Boerretzen I (2007). Geographical variation in radiological services: a nationwide survey. BMC Health Services Research 2007, 7:21 http://www.biomedcentral.com/1472-6963/7/21 (15.2.07)
Saxebøl G, Olerud HM, Hjardemaal O, Leitz W, Servoma A, Walderhaug T (1998) Nordic guidance levels for patient doses in diagnostic radiology. Radiat Prot Dosim 80: 99-101

Olerud HM, Saxebøl G (1997) Diagnostic radiology in Norway from 1983-1993 - Examination frequency and collective effective dose to patients. Radiat Prot Dosim 74: 247-260

Olerud HM (1997) Analysis of factors influencing patient doses from CT in Norway. Radiat Prot Dosim 71: 123-133

Olerud HM, Borgen L, Friberg EG, Lysdahl KB, Silkoset RD, Widmark A, Saxeböl G (2009). Lessons learned from 25 years in exploring Norwegian radiology practices from a radiation protection point of view. Proceedings from World Congress 2009 on Medical Physics and Biomedical Engineering Munich, Sept 7 – 12 2009

Olerud H.M. et.al. (2010) Collective doses from medical exposures: an inter-comparison of the "TOP 20" radiological examinations based on the EC guidelines RP 154. Proceedings of the Third European IRPA congress, 14 – 18 June 2010, Helsinki: STUK

Regulations no. 1362 of 21 November 2003 on radiation protection and use of radiation. Oslo: Ministry of Health, 2003. http://www.nrpa.no/archive/Internett/Publikasjoner/Annet/act_eng.pdf (10.02.2002)

Silkoset RD (2009). Analysis of the variation in local reference dose levels from Computed-tomography examinations. StrålevernRapport 2009:3. Østerås: Norwegian Radiation Protection Authority, 2009. Language: Norwegian.

Widmark A, Fosmark H, Einarsson G, Gundtoft P, Hjardemaal O, Leitz O, Pukkila O (2001) Guidance levels in the Nordic countries: A preliminary report for selected interventional procedures. Radiati Prot Dosim 94: 133-135