Radiation Protection Dosimetry (2007), Vol. 124, No. 4, pp. 339–347
Advance Access publication 25 May 2007
doi:10.1093/rpd/ncm204

DIAGNOSTIC RADIOLOGY IN NORWAY—TRENDS IN EXAMINATION FREQUENCY AND COLLECTIVE EFFECTIVE DOSE

Ingelin Børretzen[1,*], Kristin Bakke Lysdahl[2], and Hilde Merete Olerud[1]
[1]Norwegian Radiation Protection Authority, Oslo, Norway
[2]Radiography Programme, Faculty of Health Sciences, Oslo University College, Oslo, Norway

Received December 13 2006, amended February 27 2007, accepted February 27 2007

The objective of the present work was to determine current levels and recent nationwide trends in radiological examination frequency, as well as to update corresponding collective effective dose estimates. Examination frequencies were obtained from radiology management systems at all hospitals and private radiology enterprises across Norway in terms of number of examination codes. During the last decade, the overall examination frequency increased by 16% to 910 per 1000 inhabitants, excluding nuclear imaging and dental radiology. The largest increase in examination frequency occurred in MRI (10-fold increase), followed by CT (more than doubling) and mammography (nearly 70% increase). The contribution to collective effective dose from radiological examinations was estimated to 4960 man Sv or 1.09 mSv per inhabitant; representing a 40% increase from 1993 to 2002. CT contribution to collective effective dose was estimated to account for 59% of the total as opposed to 30% in the previous survey.

INTRODUCTION

Radiological examination frequencies in Norway have earlier been investigated based on statistics from the years 1983, 1988 and 1993. Between 1983 and 1993, overall examination frequency increased by 10%, while CT doubled every fifth year. Updated knowledge about the trends has been highly anticipated nationally since these results were published in 1997[1].

For the latest survey, it was desirable to make use of frequency data available from radiological (information) management systems (RiS). Establishment of these systems and a new version of the underlying radiological code system (NORAKO) were therefore awaited.

By 2002, all radiology services in Norway used some kind of RiS so that information was available in digital form. Current reporting routines meant that data collection could start by the second half of 2003. The number of examinations is generally reported from each service as the number of examination codes. The code system, NORAKO[2], was designed by the Norwegian College of Radiology and is adopted by close to 100% of radiology services. This system forms the basis for the reimbursement scheme in Norway. The health care system is predominantly public and the national insurance scheme covers the vast majority of radiology services. All patients who hold a referral from a physician (GP or specialist) are covered, regardless of whether the examination is carried out in a public or private radiology service.

Between 1993 and the latest survey, digitalisation of nearly all radiology departments, nationwide distribution of MRI and CT scanners, establishment of a national mammography screening programme and introduction of new procedures and techniques are all factors that are expected to have affected the use of pattern of radiological examinations and population dose estimates. Several European countries have experienced increasing collective effective doses from radiology services during the nineties and as reported from Great Britain[3], Switzerland[4] and by UNSCEAR[5] as a general pattern from several countries, has CT become an increasingly important contributor to collective effective dose.

The objectives of the present work were to study alterations in radiological examination frequencies from 1993 to 2002 and accordingly changes in collective effective dose estimates. The key questions were the following:

(1) How has overall examination frequency changed in the period?
(2) Have CT and/or MRI replaced conventional radiography for certain anatomical sections or indications?
(3) Which changes can be observed with respect to main contributors to patient collective effective dose estimates in the period?

*Corresponding author: Ingelin.Borretzen@rikshospitalet.no

METHODS AND MATERIALS

Examination frequencies from national surveys

The Norwegian Radiation Protection Authority (NRPA) has surveyed radiological examination frequencies for 1993 and 2002, excluding dental and chiropractic use, nuclear medicine and bone densitometry; 2002 data also excluded the assumingly very low use of radiology in primary health care services. Activity data were received from all radiology services (72 public and 9 private hospitals, 25 mammography screening laboratories and 25 private radiology enterprises in 2002). Hence, the results are based on a complete count. Data regarding the activity at the mammography screening laboratories were obtained from the Cancer Registry of Norway.

The requested reporting format was not fulfilled by 14 of the 131 reporting services. For six of these, examinations were coded manually on the basis of received descriptive texts. The remaining eight small services reported on examination group level (e.g. number of skeleton X-rays), and average distributions for similar services were used to estimate the number of examination codes within each group. The total number of codes studied in 1993 and 2002 varied owing to the introduction of new codes and the discontinuation of outdated codes, thereby resulting in an analysis that included 325 codes in 1993 and 401 in 2002.

The concept of examination is here delimited to include only a single organ, organ system or anatomical section, corresponding to how NORAKO defined examination codes and how available dose surveys provide effective dose values for complete examinations. The following examinations are examples of analysed examination frequencies with designated dose values: CT abdomen, CT thorax, colon double contrast, colon single contrast, lumbar spine and knee.

The 2002 data included some descriptive codes in addition to the actual examination codes. If not corrected for, these descriptors would impose too high frequencies in 2002 and the data would be incomparable with the 1993 data. Furthermore, correct dose values would be hard to attribute. To overcome these potential errors, adjustments were carried out in two ways. First, codes which clearly did not represent an examination, e.g. reinterpretation of radiographs, were excluded. Secondly, procedure codes for additional series were not included. Both adjustments were in accordance with the NORAKO user manual, which defines some codes as descriptors of the examination procedure rather than examinations and also states how additional series should be coded. The details are further described in a national project report[6] and will also to some extent emerge from the discussion of data limitations.

Assessment of collective effective dose

Total patient collective effective dose from diagnostic radiological examinations, CED, in units of man Sv, was calculated according to the formula, $\mathrm{CED} = \Sigma_i E_i N_i$, where E_i is the mean effective dose to patients from a particular examination type and E_i is the corresponding number of examinations of that type performed each year.

Estimates of the mean effective dose for each examination type were predominantly obtained from national dose surveys carried out by NRPA and published by Olerud and colleagues[1,7]. Organ-weighting factors according to ICRP Publication 60[8] were used in these dose surveys. The Norwegian CT survey[7] is based on a registration of scan parameters and how the complete examination is performed. The national mean effective dose value for CT abdomen will therefore, e.g. reflect various numbers of contrast series, scan lengths, scan parameters and all types of scanner models represented on the Norwegian market at that time (1995). For some examinations, dose values had to be taken from internationally published surveys. Countries with presumably similar X-ray equipment and population to Norway were preferred, and a Swiss study as published by Aroua and colleagues in 2000[9] and UK/NRPB data as published by Hart and colleagues in 2002[10] were the main sources for information. All cardiovascular interventional procedures (13 800 procedures, 61 procedure types) were assigned to dose values as published by Aroua. For examinations and procedures where no value was published, the dose from a similar examination/procedure was used. All in all, dose values for 84% of the examinations were taken from Norwegian national surveys, 14% from similar procedures and 2% from international publications.

Mammography

The effective dose from mammography was calculated according to the ICRP formula, $E = \sum w_T H_T$, where w_T is the organ weight factor which equals 0.05 for breast and H_T is the organ absorbed dose. For mammography, all radiosensitive ICRP organs other than the breast were assumed to receive zero dose. The mean value of average glandular doses from mammography screening examinations in Norway was assessed to equal 2.55 mGy per examination and one examination consisted of 2.05 exposures[11]. It was assumed that the dose per exposure in clinical mammography was equal to the dose in screening mammography, but that the mean number of exposures per breast was 3.0.

RESULTS

Results are presented as levels and trends in national examination frequencies between 1993 and 2002, followed by corresponding levels and trends in patient collective effective dose estimates.

Examination frequency

Table 1 shows nationwide examination frequencies (number of examinations per 1000 inhabitants), as well as the percentage change in examination frequencies between 1993 and 2002. A 16% increase in total examination frequency occurred during the 9-y period, despite the decrease in all conventional radiography frequencies except from extremities. Use of US, MRI and CT increased for all anatomic sections. The largest percentage increases in examination frequency from 1993 to 2002 occurred in MRI examinations of the spine, followed by head/brain and CT thorax. MRI of extremities was practically

Table 1. Nationwide trends in examination frequency between 1993 and 2002.

Modality	Anatomic region	Examination frequency[a] 1993	Examination frequency[a] 2002	Percentage change between 1993 and 2002
X-rays	Head/face	19.1 (2.4)	7.3 (0.8)	−61.8
	Spine	77.9 (9.9)	64.8 (7.1)	−16.8
	Gastro intestinal tract	30.7 (3.9)	25.1 (2.8)	−18.2
	Head/neck/chest[b]	203.2 (25.8)	160.7 (17.7)	−20.9
	Extremities[c]	256.1 (32.5)	274.2 (30.1)	7.1
	Neuroradiology	1.8 (0.2)	0.1 (0.0)	−94.4
	Other	16.4 (2.1)	15.5 (1.7)	−5.5
Total		605.2 (76.9)	547.7 (60.2)	−9.5
	Mammae	45.8 (5.8)	76.7 (8.4)	67.5
	Angiography and interventions	11.7 (1.5)	13.1 (1.4)	12.0
CT	Head/brain	20.0 (2.5)	40.4 (4.4)	102.0
	Thorax	2.7 (0.3)	10.9 (1.2)	303.7
	Abdomen/trunk	6.0 (0.8)	17.9 (2.0)	198.3
	Spine	8.8 (1.1)	16.9 (1.9)	92.0
	Other	10.2 (1.3)	18.4 (2.0)	80.0
Total CT		47.7 (6.1)	104.5 (11.5)	119.0
Total X-rays		710.4 (90.2)	742.0 (81.6)	4.4
US	Abdomen/trunk[d]	45.2 (5.7)	60.5 (6.7)	33.8
	Pelvis/genitals[e]	6.2 (0.8)	14.9 (1.6)	140.3
	Extremities	3.1 (0.4)	11.6 (1.3)	274.2
	Other	17.2 (2.2)	19.9 (2.2)	15.7
Total US		71.7 (9.1)	106.9 (11.8)	49.1
MRI	Head/brain	2.3 (0.3)	15.9 (1.7)	591.3
	Spine	1.3 (0.2)	18.1 (2.0)	1292.3
	Extremities	0.3 (0.0)	19.3 (2.1)	6333.3
	Other	1.5 (0.2)	7.6 (0.8)	405.0
Total MRI		5.4 (0.7)	60.9 (6.7)	1027.3
Total		787.5 (100.0)	909.7 (100.0)	15.5

[a]The 1993 data are mostly taken from a NRPA survey published by Olerud and colleagues [(1)], but some of NRPAs original data were also used where the publication did not cover the examination in question. For example is CT lumbar spine included in the publication, while the other CT spine examination frequencies were taken from NRPA data. The 1993 data included some unspecified examinations for each modality. These were distributed on the categories like the distribution of the specified examinations.
[b]Soft tissue, mostly lung examinations.
[c]Including hips and pelvis.
[d]Including urinary tract.
[e]Including urinary bladder.
Total number of examinations in 2002 and 1993 was 4.14×10^6 and 3.39×10^6, respectively, while total populations were $4.55 \times 10^6$and 4.31×10^6. Numbers in parentheses are percentages. Percentages may not add up to subtotals or totals due to rounding.

non-existent in 1993, which is reflected in the large increase (a factor 64). Radiography of the extremities, followed by radiography of the head/neck/chest (soft tissue), was the most frequent examinations both in 1993 and 2002.

In 1993, the use of X-ray examinations amounted to 710 per 1000 inhabitants (90% of total frequency). In 2002, the frequency was increased by 4% to 742 (82% of total). The overall decreased proportion of use of X-rays, despite the increased frequency, is explained by the increase in non-ionising examination frequency from 77.1 to 167.8 during this time period.

A shift towards less use of radiography, quantified by radiography covering 60% of the total activity in 2002 as opposed to 77% in 1993, is observed. This shift is demonstrated in imaging of head/neck/chest (nearly all are X-ray of thorax). Interestingly, this reduced frequency is only partly compensated by a growth in CT thorax. Imaging of head/brain and spine, as illustrated in Figure 1, on the other hand, show reduced radiography frequencies that are more than outweighed by other modalities. In total, the overall head examination frequency was increased by 54% and CT and MRI dominated the frequency with contributions of 64 and 25% each in 2002. Regarding spine examinations, radiography frequency was reduced by 17% since 1993, while MRI spine frequency increased by a factor 14 and CT spine frequency nearly doubled, resulting in a combined growth of 13% since 1993. In 2002, CT and MRI were practically equally frequently used for spine imaging.

For breast and extremities it is observed that increase in other modalities is added to the already increased frequency of X-ray examinations.

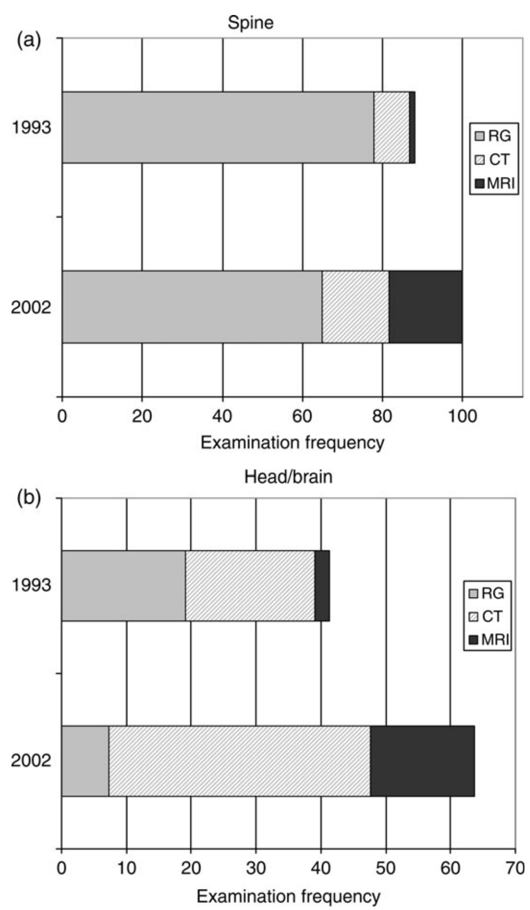

Figure 1. (**a** and **b**) Spine and head/brain examination frequencies shown for the modalities conventional radiography (RG), CT and MRI for the years 1993 and 2002.

Collective effective dose

Figure 2 depicts trends in mean effective dose per inhabitant (total CED in man Sv divided by total number of inhabitants) between 1993 and 2002. Mean effective dose increased from 0.78 to 1.09 mSv per inhabitant, representing a 40% increase over 9 y. Mean effective dose per inhabitant imposed by CT increased from 0.23 to 0.64 mSv, whereas that from other use of X-rays declined from 0.55 to 0.45 mSv per inhabitant (18% decrease). The combined effect is that CT contribution to CED is significantly larger in 2002, accounting for 59% of the total as opposed to 30% in 1993.

Trends in contributions to collective effective dose are further explored in Table 2, showing mean effective doses per examination, per 1000 inhabitants and

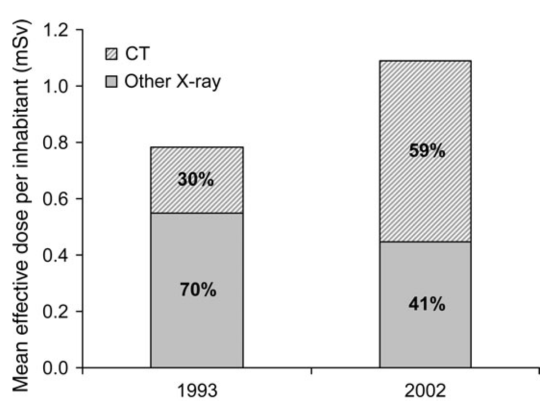

Figure 2. Contributions to the mean effective dose per inhabitant from CT and other X-ray examinations (conventional radiography, mammography and angiographies and interventions) for the years 1993 and 2002. Total CED in 1993 and 2002 were 3400 and 4960 man Sv, respectively.

Table 2. Nationwide trends in mean effective dose per 1000 inhabitants between 1993 and 2002.

Examination	Mean effective dose per examination	Mean effective dose per 1000 inhabitants		
		1993 (mSv)	2002 (mSv)	Change 1993–2002 (%)
CT Abdomen	12.8	79 (10.1)	185 (17.0)	135
CT Thorax	11.5	32 (4.1)	125 (11.5)	292
CT pelvis	9.8	22 (2.8)	101 (9.3)	364
CT lumbar spine	4.5	37 (4.8)	64 (5.8)	70
Barium enema (colon) DC[a]	13.7	108 (13.8)	63 (5.8)	−41
CT head/brain	2.0	41 (5.3)	62 (5.7)	50
Pelvis and or hips[b]	0.6	40 (5.1)	45 (4.1)	12
Lumbar spine[c]	1.9	53 (6.8)	39 (3.6)	−27
Abdomen	5.4	32 (4.1)	30 (2.8)	−5
Urography	3.8	35 (4.5)	21 (1.9)	−41
Coronary arteries[d]	8.9	18 (2.3)	20 (1.8)	12
Thorax (PA + LAT)	0.15	18 (2.3)	18 (1.6)	−1
CT liver[e]	11.9	—	15 (1.4)	—
Barium enema (colon) SC[f]	9.0	25 (3.2)	14 (1.3)	−44
Left ventricle[d]	11.4	14 (1.8)	13 (1.2)	−4
Other	—	226 (29.0)	274 (25.1)	—
Total	—	780 (100.0)	1090 (100.0)	40

[a]DC is abbreviation for double contrast.
[b]2002 data: sum of pelvis and hips. Dose value: weighted average of pelvis and hips.
[c]2002 data: lumbar spine with sacrum.
[d]1993 data: angiographies and interventions are not separated.
[e]CT liver was not specified in 1993.
[f]SC is abbreviation for single constrast.
Table is sorted by top 15 contributors to CED in 2002, the remaining examinations are summed up in 'other'. Mean effective dose per examination is given for reference. Numbers in parentheses are percentages.

trends in top 15 contributors to collective effective dose. Notably, the exact same examinations figured in the table in 2002 as in 1993, except from X-ray small intestine which was the least important of the 15 examinations in 1993 and has been replaced by CT liver in 2002 (this examination was not specified in 1993).

From Tables 1 and 2, it is clear that a large proportion of the observed increase in total CED is explained by increased frequencies of single CT examinations. Contributions to CED from CT pelvis more than tripled, from CT thorax nearly tripled, while contribution from CT abdomen more than doubled from 1993 to 2002.

The relation between examination frequency and CED is illustrated in Figure 3, showing examination frequency and CED for the top 15 contributors in 2002 (representing 75% of the total CED and 43% of the total X-ray examination frequency). It is evident that some single examinations give high contributions to CED, in spite of low frequency; CT abdomen, thorax and pelvis accounts for 38% of total CED but only for 5% of total frequency, whereas thorax radiography is contributing to only 2% of total CED but 16% of total frequency.

DISCUSSION

Trends in examination frequency and collective effective dose

Conventional radiography is still dominating the examination frequency in Norway in 2002, but the dominance has decreased compared to 1993 due to the proliferation in other modalities. CT is performed nearly twice as often as MRI examinations in 2002 despite the rapid increase in MRI examinations since 1993. Tendency of increased use of MRI, for instance, as shown for head/brain and spine examination (Figure 1) is positive seen from a radiation protection perspective, while the observed increase in use of CT and the corresponding increased population dose calls for attention. The future collective effective dose is largely determined by the development in use of CT scans, as a minor change in CT examination frequency has a large impact on the collective effective dose, as demonstrated in Table 2 and Figure 3. The doubled CT frequency is certainly the main explanation for the 40% increase in collective effective dose. The biggest contributors to collective effective dose in 1993 were the following: barium enema (colon double contrast), CT abdomen, X-ray lumbar spine and CT head/

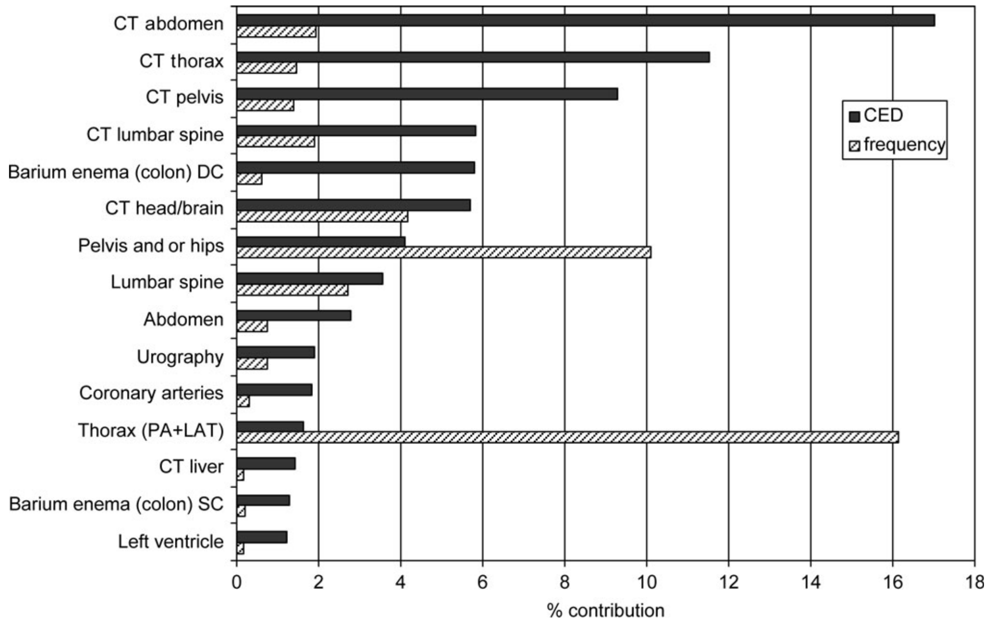

Figure 3. Largest contributors to collective effective dose, CED, in 2002. The percentage contributions of the frequencies are related to the total frequency of ionising radiation only, i.e. percentage of 742 examinations per 1000 inhabitants and percentage of 1090 mSv per 1000 inhabitants. Examinations are sorted by contribution to CED.

brain, in sum accounting for 36% of total dose. In 2002, these were replaced by the following CT examinations: abdomen, thorax, pelvis and lumbar spine, four examinations alone accounting for 44% of total dose. Reduced collective effective dose contribution from conventional radiography is due to reduced numbers of colon examinations and urographies, which were probably replaced by CT examinations, and reduction in lumbar spine examinations, which is probably explained by better access to MRI and CT.

An example of a changed examination pattern between 1993 and 2002 is MRI of the extremities which hardly existed in 1993, but was the eight most frequent category in 2002. CT abdomen/trunk and MRI spine also achieved a place among the 10 most frequent examined organ groups per modality in place of radiography of head/face and X-ray angiography/interventions. The observed development in examinations of extremities (growth in all modalities) indicates a tendency for new imaging techniques to act as supplements to existing techniques.

Comparisons with other countries

The frequency of radiological examinations applying X-rays for Norway (742 per 1000) is similar to recent estimates for other European countries, e.g. Netherlands (630 per 1000)[12] in 1998, Switzerland (756 per 1000)[4] in 1998 or Finland (786 per 1000)[13] in 2000. These numbers are directly comparable since neither dental radiography nor bone densitometry is included. Corresponding collective effective doses were reported to be 0.52 mSv per inhabitant in Netherlands[12], 0.99 mSv in Switzerland[4], while the Finns did not update their collective effective dose estimates. From Great Britain, 0.38 mSv per inhabitant[3] (including dental radiography) for 2001/2002 is reported. Proportion of collective effective dose accounted for by CT was 59% in Norway, while most other countries so far have reported a lower proportion, e.g. 47% in Netherlands[12], 28% in Switzerland[4] and 47% in Great Britain (GB percentage is based on the total which includes dental radiography). The variation in proportion suggests that a plausible explanation for some of the observed difference in CED could be found in accessibility to CT examinations. In Norway, the accessibility is rather high with 2.9 installed CTs per 100 000 inhabitants (according to NRPA's latest report to UNSCEAR) compared to, for instance, 0.7 in Great Britain[14].

ASSESSMENT AND LIMITATIONS OF THE DATA

The collected examination frequency data from 1993 and 2002 represent complete nationwide data on both in-patients and out-patients and are consequently free from the potential bias resulting from small sample sizes and limited geographic scope. Nevertheless, there are some limitations in this study.

Completeness of the material

Two potentially important categories of radiological services were left out for both 1993 and 2002: chiropractic and dental radiology. In a separate project on chiropractic activity in Norway in 2005[15], it was found that chiropractors performed 40% of the examinations themselves, while 60% was referred to hospitals or private radiology enterprises. Total frequency carried out at chiropractors was estimated to 3 examinations per 1000 inhabitants and the corresponding collective effective dose contribution was 8 man Sv (<0.2% of total population dose reported here). Recent reports[3,4] from countries where dental radiology has been included show that this amounts to 1% or less of total patient collective effective dose, while bone densitometry contributes even less[4]. Given that the situation in Norway is similar, exclusion of chiropractic and dental radiology services and bone densitometry is not regarded essential for the population dose results, but comparison with examination frequencies from other countries must be carried out with caution.

Another category of excluded use of radiology in this study is examinations not registered in the RiS. Examples of this are some ultrasound examinations performed by gynaecologists and fluoroscopy in orthopaedic procedures. The scope of these activities is not known since these are not registered anywhere. Trend analyses are not affected since these data were not available for neither of the years studied.

Use of examination codes (NORAKO)

The use of examination codes (NORAKO) in analysis of examination frequencies was generally successful. Nevertheless, the increased specificity in the 2002 version generated more codes than in 1993. In order to obtain a comparable material, certain codes were left out of the 2002 material in accordance with descriptions in the manual. This implied exclusion of 'additional series' which reduced the number of CT and angiography codes by 7.7 and 8.7% while the MRI codes were reduced by 40%. Furthermore, CT examination codes were reduced by another 7.8% due to surplus codes generated for the administration of intravenous contrast media. This latter adjustment was based on knowledge from a survey on CT techniques in Norway published by Olerud and Engen[16] which described the mean proportion of examinations with, without and both with and without intravenous contrast media in CT for the most common examinations in 1995.

Due to the NORAKO code structure angiographies and interventions had to be counted per organ and not per total examination. This means that total frequency for these procedures was overestimated in 2002. However, the possible effect on the total numbers is rather small since angiography/interventional procedures accounted for only 2% of all X-ray examinations.

Examinations of duplicate organs were not consistently reported in either of the years studied. Consequently, results are presented as number of times a given organ was examined, and whether one or both sides of the body were examined is not certain. Fortunately, this is reflected in the dose values which represent 'average examinations'. Mammography was an exception from this problem partly since more detailed analyses were carried out in order to sort out the examination frequency more accurately and examinations carried out in the national screening programme was reported from the Cancer Registry of Norway in the form of number of examined women.

Dose data

National mean effective dose values per examination were available for the most important examinations in the categories 'most frequent' or 'high dose'. In total, national data were used for 63 examination types, all together accounting for 87% of total collective effective dose. National data in the field of cardiovascular interventional procedures were not available and dose values are taken from other countries entirely. Fortunately, these procedures are calculated to cover only 4% of the total collective effective dose. Single dose values for the remaining examination types taken from abroad or derived from similar examination types were less critical for total collective effective dose.

National dose data were published in 1997[1,7] while the actual measurements took place during the eighties and nineties. The spread of multi-detector CT technology since then certainly have affected the CT procedures and possibly also the mean effective doses per examination. Corresponding changes in radiography is introduction of digital detectors and digital workflow. CT with its large contribution to collective effective dose is supposed to be the main source to uncertainty, whereas any changes in mean effective dose from radiography would cause a minor effect.

Draft recommendations of the International Commission on Radiological Protection dated 12th January 2007[17] indicate that there will be some modifications in the tissue-weighting factors to account for new information on health effects from radiation. The suggested reduction in gonad-weighting factor from 0.2 to 0.08 and increase from 0.05 to 0.12 for breasts would probably cause the largest changes to CED contributions if applied to the data at hand. CT chest and CT pelvis contribute 12 and 9% of total CED today. Introduction of new weighting factors would certainly change the percentage contributions from each of these two examinations, but quantification of how total CED would be affected from changed effective doses from these and all other examinations would require exhaustive calculations.

CONCLUSIONS

In 2002, conventional X-rays were still the modality predominantly used in Norway. This modality accounted for ~60% of all imaging procedures, with ultrasound and CT each responsible for 12%, mammography 8% and MRI 7%.

Total examination frequency increased by 16% from 1993 to 2002. The types of radiological examinations showing large increases in frequency since 1993 are MRI and CT examinations, with a 10-fold and doubled frequency, respectively. Increased numbers of some of the examination types within these modalities relay directly upon development in technology and techniques which were either not available or were in the early stages of development in 1993. Conventional radiography examinations showing large reductions in frequency are mainly those which are being superseded by other imaging modalities such as MRI or CT.

This survey has demonstrated a further growth of 40% in total patient collective effective dose estimates to the population from radiological examinations. The relative contributions of some types of examinations have changed considerably since 1993. CT has doubled its contribution and is now responsible for 59% of the total, while conventional radiography is now making a smaller contribution.

The establishment of national updated dose data in the fields of radiology which contribute significantly to collective effective dose, first and foremost CT, will be an important task in the near future as new regulations(18) focusing on optimisation and dose registration are implemented across Norway.

REFERENCES

1. Olerud, H. M. and Saxebøl, G. *Diagnostic radiology in Norway from 1983-1993- Examination frequency and collective effective dose to patients.* Radiat. Prot. Dosim. **74**, 247–260 (1997).
2. Norwegian College of Radiology. NORAKO Norwegian Radiological Code ver.1.1.2002. KITH, Trondheim. Language: Norwegian.
3. Hart, D. and Wall, B. F. *UK population dose from medical X-ray examinations.* EJR **50**, 285–291 (2004).
4. Aroua, A., Burnand, B., Decka, I., Vader, J.-P. and Valley, J.-F. *Nation-wide survey on radiation doses in diagnostic and interventional radiology in Switzerland in 1998*. Health Phys. **83**, 46–55 (2002).
5. Medical radiation exposures. In: *Sources and effects of ionizing radiation*. United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2000 report to the general assembly with scientific annexes. Volume I: Sources. New York, United Nations, 293–495 (2000).
6. Børretzen, I., Lysdahl, K. B. and Olerud, H. M. *Radiology in Norway – examination frequency per 2002, trends in time, geographical variation and population dose.* StrålevernRapport 2006:6. Østerås: Norwegian Radiation Protection Authority, 2006. Language: Norwegian. http://www.nrpa.no/archive/Internett/Publikasjoner/Stralevernrapport/2006/StralevernRapport_6_2006.pdf (12.02.2007).
7. Olerud, H. M. *Analysis of factors influencing patient doses from CT in Norway.* Radiat. Prot. Dosim. **71**, 123–133 (1997).
8. International Commission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection.* ICRP Publication 60 (Oxford: Pergamon Press) (1991).
9. Aroua, A., Vader, J.-P. and Valley, J.-F. *Survey on exposure by radiodiagnostics in Switzerland in 1998.* Lausanne: Institut Universitaire de Radiophysique Appliquée, (2000).
10. Hart, D. and Wall, B. F. *Radiation exposure of the UK population from medical and dental x-ray examinations.* NRPB-W4. Chilton: National Radiological Protection Board (2002).
11. Hauge, I. H. R. and Pedersen, K. *Radiation doses to screened women in the Norwegian Breast Cancer Screening Program.* StrålevernRapport 2005:12. Østerås: Statens strålevern (2005). Language: Norwegian. http://www.nrpa.no/archive/Internett/Publikasjoner/Stralevernrapport/2005/StralevernRapport_12_2005.pdf (12.02.2007).
12. Brugmans, M. J. P., Buijs, W. C. A. M. and Geleijns, J. *Population exposure to diagnostic use of ionizing radiation in the Netherlands.* Health Phys. **82**, 500–509 (2002).
13. Hakanen, A., Järvinen, H. and Soimakallio, S. *Trends in radiology in Finland between 1995 and 2000*. Eur. Radiol. **13**, 2705–2709 (2003).
14. European Coordination Committee of the Radiological and Electromedical Industries. Age profile medical devices third edition: *The need for sustained investment*. Frankfurt (2003). http://www.cocir.org/uploads/documents/17-17-ageprofile2003.pdf (12.02.2007).
15. Raaum, A. and Widmark, A. *Use of diagnostic x-ray in Norwegian chiropractic enterprises. Inspection according to new radiation protection regulations.* StrålevernRapport 2005: 21. Østerås: Norwegian Radiation Protection Authority (2005). Language: Norwegian. http://www.nrpa.no/archive/Internett/Publikasjoner/Stralevernrapport/2005/StralevernRapport_21_2005.pdf (12.02.2007).

16. Olerud, H. M. and Engen, I. *Survey of CT practice in Norway. Examination technique and patient doses.* StrålevernRapport 1995: 11. Østerås: Norwegian Radiation Protection Authority (1995). Language: Norwegian.
17. Draft recommendations of the international commission on radiological protection dated 12th January 2007 http://www.icrp.org/docs/ICRP_Draft_Recommendations_12_January_2007.pdf (12.02.2007).
18. Ministry of Health. Regulations No. 1362 of 21 November on radiation protection and use of radiation (radiation protection regulations). Royal Decree of 21 November 2003. Oslo (2003). http://www.nrpa.no/archive/Internett/Publikasjoner/Annet/act_eng.pdf (12.02.2007).