

Scientific Paper

Analysis of the frequency and type of CT examinations performed in Poland in 2022

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Abstract

Introduction: Computed tomography (CT) is one of the most widely used diagnostic procedures in modern medicine. Despite many technical improvements, CT still exposes patients to significantly higher doses of radiation than other methods of diagnostic imaging. The presented analysis of the number of CT scans performed in Poland in 2022 aims to designate priorities in the process of optimising radiation protection and makes it possible to identify those examinations and patient groups for which action is particularly justified.

Material and methods: The data presented is based on an analysis of the National Health Fund (NHF) database of medical services reimbursed in 2022. According to the NHF data, approximately 5.1 million CT examinations were performed. The coding of reimbursed medical procedures used by the NHF in 2022 included 45 different CT procedures.

Results: The highest ratio of the number of examinations performed to the number of patients was found in the age group 59-75 years (average 1.35). This ratio varied according to examination type and was closest to 1 for spine and extremities examinations (between 1.1 and 1.2 on average). Irrespective of patients' age and type of examination, the proportion of female and male patients fluctuates around 50%. Approximately 82% of head and neck examinations are single-phase CTs. Examinations with two or more phases account for about 17% and less than 1%, respectively.

Conclusions: Over the past 10 years, both the number of CT scanners and the number of annually performed scans have doubled. Relative to the population size, this is a rate of about 22 scanners per one million people, an average level for European countries, ranging from a maximum of around 37 for Italy and Germany to around 20 for France, Spain, and Romania, according to Eurostat data.

Keywords: radiation protection; computed tomography; medical exposure; population exposure.

Introduction

Computed tomography (CT) is one of the most important diagnostic tools in modern medicine. The new spatial imaging capabilities of CT, compared to the planar radiography previously used, have led to a leap forward in many medical therapies. The versatility of CT applications means that its statistical contribution to the medical exposure of the population in developed countries is significant, with the number of procedures performed annually reaching tens of millions.¹⁻³ However, despite many technical improvements, CT still exposes patients to significantly higher radiation doses than conventional X-ray or even many nuclear medicine examinations.⁴⁻⁷

Radiation risk models used in the BEIR indicate a significant dependence of the probability of adverse health effects on the sex and age of individuals exposed to ionising radiation.⁸ The

large number of CT scans performed and the associated exposure to ionising radiation have raised concerns about the potential delayed adverse effects on public health.^{9,10} Attempts to apply known radiation risk models to statistically prove the effect of large numbers of CT scans on the increase in cancer incidence have so far failed to provide satisfactory answers. Recent analyses of the incidence of malignant tumors in populations of Hiroshima and Nagasaki bombing survivors show a significant statistical increase in the excess relative risk (ERR) of cancer after exposure to doses above 100 mGy.¹¹⁻¹⁴ Exposures above this level have been demonstrated for CT. Of particular concern are patients who have been exposed to an effective dose of 100 mSv or more during a single or repeated CT procedure.¹⁵⁻¹⁹ The published data indicate that even in cases where the cumulative effective dose (CED) resulting from more than one radiological procedure does not reach 100 mSv, the

doses to internal organs can still be significant and amount to several tens of mGy.²⁰

However, there is no doubt that the introduction of CT scans into general clinical practice has direct benefits for patients that outweigh the risks of exposure to ionising radiation, which should be considered as low.²¹⁻²³ The obligation to assess the medical exposure of the population is an essential element of the system of radiation protection that has been legislated in many countries. Statistical analysis of the number of CT scans performed aims to identify priorities in the process of optimisation of radiation protection and makes it possible to identify those examinations and patient groups for which action is particularly justified. The present study analyses the number and type of CT examinations performed in Poland in 2022. The results presented are based on the number of diagnostic examinations reimbursed by the National Health Fund (NHF), which finances the vast majority of diagnostic and therapeutic procedures in Poland.

Materials and Methods

The healthcare system in Poland is based on the reimbursement of medical (diagnostic and therapeutic) services within the framework of universal health insurance. According to the law, the National Health Fund (NHF) is the institution responsible for reimbursing healthcare services and managing the financial resources accumulated under the insurance.²⁴ In 2022, the number of people insured by the NHF was more than 34 million, which is about 90 per cent of the Polish population. The NHF's extensive financial database can be a valuable source of information for the statistical analysis of medical exposure based on a very large statistical sample. The present study attempts to analyse the CT procedures performed in terms of type, number, and age distribution of patients for the Polish population based on NHF data for 2022.

Patient data (identification number, age, sex, etc.) and the parameters of the reimbursed service are recorded as part of the documentation of healthcare services, for which the reimbursement is claimed. Reimbursed medical procedures are classified according to the standard for diagnostic and inpatient hospital coding based on the Ninth Revision of the International Classification of Diseases developed by the World Health Organization, commonly referred to as ICD-9. The version of ICD-9-CM adopted by the NHF is published annually on the NHF website. A detailed list of all processed information and the way it is reported by healthcare units for reimbursement purposes is published periodically in detailed announcements by the President of the NHF.

Based on a special request supported the National Health Fund has provided aggregated statements based on the billing procedures currently in use. The data did not contain any personal data on patients or information on where the medical procedures were conducted. The summaries provided included

data on the number of CT scans by age and sex of patients and the number of patients on whom these procedures were performed for each service reported. To avoid the possibility of identifying individuals for whom the number of CT scans was low, i.e., between 1 and 4, the data were grouped together and labelled as "<5". In such cases, a value of 2 was taken as close to the median for further analysis. The error resulting from this rounding is small, less than 0.1% of the total number of examinations performed. Where possible, studies with one, two and three or more CT phases were extracted.

The total number of patients was calculated by summing the number of patients reported for each ICD-9 classified CT scan category. Due to the aggregation of data and the resulting lack of patient identifiability, this approach does not allow for situations where CT examinations defined by different ICD-9 codes (e.g., head and neck CT and thorax CT) were performed on the same patient. However, the solution used makes it possible to distinguish with a high degree of accuracy the most frequently performed CT examinations, to determine their distribution according to patient age, and to distinguish the CT categories associated with the potentially highest patient exposure to ionising radiation.

According to the 2022 data, a total of about 5.1 million CT examinations were performed on about 4 million patients in Poland. The coding of reimbursed medical procedures adopted by the NHF used in 2022 included 45 different CT procedures, which were grouped for analysis according to the following key: (1) head and neck examinations, (2) thoracic examinations, (3) abdominal and pelvic examinations, (4) spinal examinations, (5) vascular imaging in all locations, (6) imaging of the extremities, and (7) other CT examinations not classified elsewhere.

Results

Number of examinations

The analysis shows that groups (1), (2) and (3) are clearly dominant in terms of the number of examinations, accounting for a total of 81% of all CT examinations performed in 2022. Group (1) - head and neck examinations - account for about 33% of all CT examinations, which statistically corresponds to about 45 examinations per 1,000 people in Poland. Group (2) - thorax examinations - about 22% or 30 examinations per 1,000 persons and group (3) - abdomen and pelvis examinations - about 26% or around 35 examinations per 1,000 persons. The remaining 19% of fell into the other groups, with the following proportions: (4) vascular imaging in all sites - about 7% of the number of scans (about 9 scans per 1,000 persons), (5) spinal examinations about 6% (about 9 scans per 1,000 persons), (6) extremity examinations about 2% (about 2 scans per 1,000 persons), and (7) other CT examinations about 4% (about 6 scans per 1,000 persons).

Taking into account the detailed overview of CT procedures included in groups 1-7, the most frequently performed procedures were identified. The most frequently performed procedures according to ICD-9 in group (1) are "Head CT without contrast enhancement" (ICD-9 code 87.030, approx. 71% of head and neck examinations), in group (2) "Thorax CT without contrast enhancement" and "Thorax CT without and with contrast enhancement" (ICD-9 codes 87.410 and 87.411 respectively about 40% and 54% of thorax examinations), in group (3) "CT of the abdomen and small pelvis with and without contrast enhancement" (ICD-9 code 88.011 about 50% of abdominal examinations), in group (4) "Cervical spine CT without contrast enhancement" and "Lumbosacral spine CT without contrast enhancement" (ICD-9 codes 88.383 and 88.387 about 34% and 50% of spinal examinations), in group (5) "CT of head and neck arteries" and "CT of the thoracic arteries (including the aorta)" (ICD-9 codes 87.033 and 87.415 in about 33% and 26% of vascular examinations, respectively), in group (6) "CT of the upper extremities without contrast enhancement" and "CT of the lower extremities without contrast enhancement" (ICD-9 codes 88.031 and 88.030, about 35% and 53% of extremity examinations, respectively), and in group (7) "Other CT" (ICD-9 code 88.38, about 58% of the examinations in this category). **Figure 1** shows the aggregate proportion of the number of CT examinations for each of the groups 1-7. Adjusted to the population size of Poland in 2022, the average number of CT examinations performed was about 136 examinations per 1,000 inhabitants.

Number of patients

The total number of patients with a CT scan in 2022 was approximately 4 million, which is significantly lower than the number of scans performed. This result is not unexpected and confirms clinical practice, where some patients have more than one CT scan as part of their treatment. **Figure 2** shows the total number of CT examinations and the total number of patients as a function of age. Both curves have been adjusted to the size of the Polish population in 2022. In the age group 0-20 years, the number of CT examinations performed is relatively low and the number of patients is close to the number of examinations. From around the age of 20, the number of CT examinations increases faster than the number of patients. The highest ratio of the number of examinations performed to the number of patients was found in the age group 59-75 years (average 1.35).

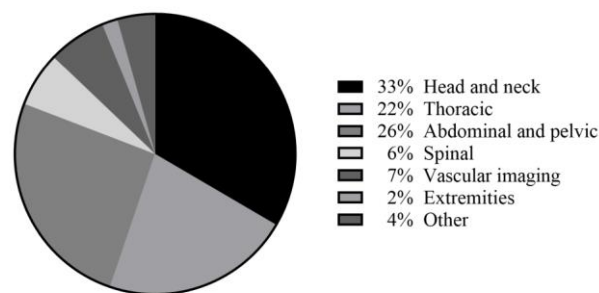


Figure 1. Share of different categories of CT examinations performed in Poland, NHF 2022.

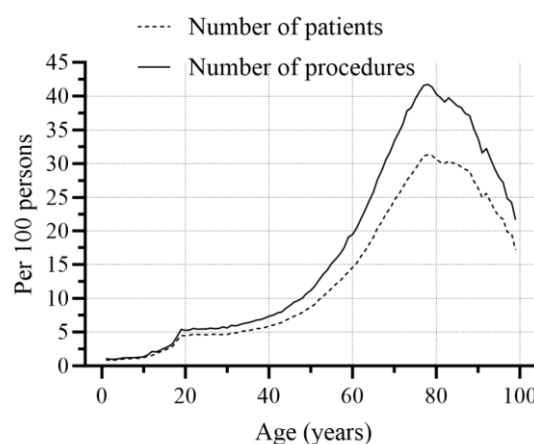


Figure 2. Number of CT examinations and the corresponding number of patients as a function of age, NHF 2022.

A closer analysis shows that the ratio of the number of CT scans performed to the number of patients on whom they were performed is not constant and varies according to the type of scan. The ratio is closest to 1 for spine and extremities examinations (on average between 1.1 and 1.2). It was around 1.3 for vascular, head and neck and thorax examinations, and reached a maximum of around 1.6 for abdomen and pelvis. The percentage of repeated examinations is clearly the highest in the abdomen and pelvis group, which means that 60% of the examinations in this group are repeated examinations. However, at this stage it is not possible to say exactly how large the group of patients with repeated CT scans was. A more detailed analysis will be presented later in this paper.

Table 1. Number of CT examinations and number of patients who underwent these examinations, by gender and percentage of paediatric patients aged <16 years, NHF 2022.

CT category	Number of examinations		Number of patients		
	All	Women	All	Women	< 16 years
Head and neck	1 724 027	51.6%	1 373 059	52.8%	4.8%
Thoracic	1 123 471	50.2%	859 461	50.5%	0.7%
Abdominal and pelvic	1 320 559	51.9%	851 409	52.2%	0.5%
Spinal	325 125	56.6%	291 360	56.1%	1.8%
Vascular imaging	346 870	48.6%	297 703	49.3%	0.6%
Extremities	91 272	50.2%	82 378	50.4%	4.9%
Other	225 279	49.7%	189 366	50.3%	1.4%
All	5 156 603	51.4%	3 944 736	52.0%	2.3%

CT examinations performed in children

The analysis showed that the total number of paediatric patients aged 0-16 years with CT examinations was approximately 90,000 in 2022 (approximately 2% of all CT examinations). For groups 1-7, the percentage of examinations performed in children varies, the most common being head and neck - 74,057 examinations (about 72% of all CT scans among children), accounting for approximately 5 per cent of all patients. **Table 1** summarises the number of examinations for all CT scans and shows the proportion of patients aged 0-16 years.

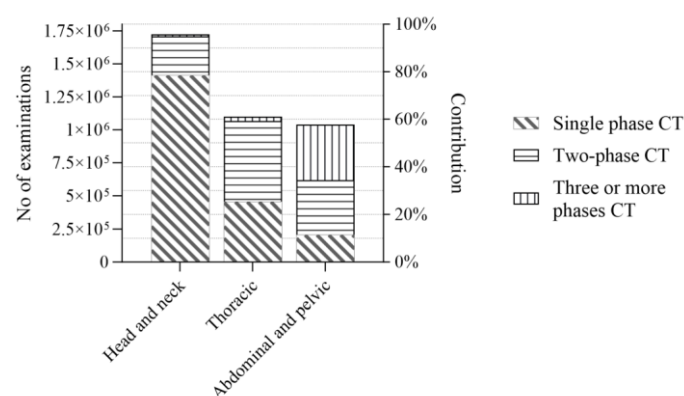
There were no significant differences in the number of examinations performed or the number of patients regarding patients' gender. The proportion of female and male patients fluctuates around 50%, regardless of patient age and type of examination.

Multi-phase CT examinations

The radiation dose to a patient resulting from X-ray exposure during a diagnostic examination depends on the area of the body covered by the radiation field and on the number of exposures that are performed. In the case of CT, the number of exposures can be determined by the number of tomographic phases performed sequentially during the examination. The introduction of multi-phase CT allows for the optimal use of intravenously administered contrast agents to obtain comprehensive diagnostic information. These examinations are tailored to specific clinical uses and are not usually among the most common procedures. However, multi-phase examinations are associated with significantly higher radiation doses to patients. In many cases, the total effective dose from one or more multi-phase examinations can easily exceed 100 mSv.^{20,25}

The ICD-9 classification used by the NHF allows a distinction between examinations consisting of one, two and three or more tomographic phases. The vast majority, approximately 82%, of head and neck examinations are single-phase CTs. Examinations with two or more phases account for about 17% and less than 1% respectively. In the other two groups, the proportions of single-phase and multi-phase examinations vary considerably.

For thorax examinations, the proportion of single-phase CT decreases significantly in favor of two-phase CT, which accounts for about 55% of all examinations in this group. For abdominal and pelvic examinations, the proportion of three-phase CTs is comparable to that of two-phase ones (about 40% each). In this case, one-phase examinations account for only about 20%. The relationships described are shown in **Figure 3**.

**Figure 3. Proportion of one-phase, two-phase and more than three-phase CT examinations for head and neck CT, thoracic CT and abdominal and pelvic CT.**

Discussion

The use of the NHF database for the statistical analysis of medical exposures requires overcoming the limitations resulting from the fact, that the database is designed strictly for financial purposes. The NHF does not collect data on the dose rate or exposure parameters used during the examination, which are relevant for the assessment of the patient's exposure. In this respect, hospital databases such as RIS (Radiological Information System), HIS (Hospital Information System) or PACS (Picture Archiving and Communication System) are much more useful. In addition, under the universal healthcare reimbursement system used in Poland, many medical services are billed in an aggregated manner that does not require detailed information on the procedures performed (this is the case, for example, for conventional X-ray examinations). However, a

different solution has been applied regarding computed tomography, which requires each provider to report each billed examination according to the ICD-9 classification. Although the NHF data do not include CT scans funded by other sources, they do cover about 90 per cent of all scans and the NHF database provides a large statistical sample and the ability to analyse data from many healthcare units across the country.²⁶

The annual number of diagnostic CT scans in Poland is steadily increasing.²⁷ Over the past 10 years, the increase has been well over 100 per cent, reaching more than 5 million examinations in 2022. At the same time, the number of CT scanners has doubled, reaching 844 scanners in 2022.^{28,29} Relative to the population size, this is a rate of about 22 scanners per one million people. This is the average level in European countries, which, according to Eurostat data, ranges from a maximum of around 37 for Italy and Germany to around 20 for France, Spain, and Romania. This demonstrates the widespread use of this imaging method and the high demand for CT examinations. The variety of applications makes CT the most relevant component of medical exposure for the population of developed countries. According to the National Atomic Energy Agency, in 2021, CT examinations already accounted for more than 70% of the statistical per capita medical exposure in Poland. In the above study, queries to the NHF database were performed by summing up patients for individual ICD-9 codes only. This means that the number of patients and the number of procedures performed is precise at the level of a single code and it is not possible to identify patients who underwent CT examinations described by other ICD-9 codes at the same time. Such patients are therefore counted more than once, leading to an overestimation of the total number of patients. This error is due to the methodology used by the NHF, which is based on the obligation to protect patients' personal data. The average ratio of the number of examinations to the number of patients obtained from the analysis of the data provided by the NHF was 1.31. Data published in 2020 from four large medical centres in the USA and Europe reported that this ratio ranged from 1.89 to 2.23, with an average value of 1.92.²⁵ In the case of NHF data for Poland, this would mean 30 to 40 per cent fewer patients. However, these are averaged data, requiring a more detailed analysis. It is known that the number of examinations performed more than once varies according to the age of the patient and the type of examination. For example, NHF data clearly shows that for bone examinations (e.g., spine or extremities) the number of repeated CT scans does not exceed ten per cent. The number of repeated scans for the same patient is a second important

parameter influencing the total radiation dose and the likelihood of exceeding the 100 mSv level. Rehani et al. report that in the group of patients whose cumulative dose exceeded the 100 mSv of the value, the median number of repeated scans ranged from 6 to 19, with a mean of 6.3 to 21 and a maximum of 57 to 109.²⁵ The percentage of patients with a cumulative dose greater than 100 mSv was 1.33%. Brambilla et al, based on a similar analysis of 28,870 patients over a period of 2.5 years, reported a value a few times higher, up to 6.1%.²⁰ Applying these values to the NHF data for Poland would suggest that this situation could affect between 30,000 and 240,000 patients.

Conclusions

The National Health Fund database is a valuable source for the statistical analysis of medical exposures. The reimbursement of CT procedures requires each provider to report each billed examination according to the ICD-9 classification, which provides a large statistical sample from many healthcare units across the country.

The annual number of diagnostic CT examinations in Poland is steadily increasing and, in relative terms is close to the number of CT scans in most European countries. With an annual number of CT examinations of more than 5 million, the estimated number of patients receiving an effective dose of more than 100 mSv is significant. In such cases, particular attention should be paid to optimising imaging procedures in the abdominal and pelvic cavities, where the percentage of multi-phase examinations is highest.

It is currently believed that the risk of adverse health effects from exposure to ionising radiation is several times higher for children and higher for women than for men. Work has been undertaken to continue to analyse the distribution of the number of patients, the number of examinations and the number of repetitions according to age and sex, also taking into account periods longer than 1 year. Further analysis will require also much less aggregation of data and a focus on the most commonly performed examinations with the highest radiation exposure. Such analyses will continue.

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