Estimated organ absorbed doses from almost 1 million CT scans in young Australians

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Introduction

Epidemiology studies are necessary to elucidate the dose-response relationship for exposure to ionising radiation. This is challenging in the low dose range of diagnostic medical imaging due to the cohort size required to observe small effects and, for retrospective studies, the need to reconstruct dosimetry. In our previously established cohort[1] of young Australians (0-19 years) who received government-funded (Medicare) CT scans between 1985 and 2005, we have now used retrospective dosimetry to determine organ absorbed doses. These dose estimates will be used with cancer incidence data to examine the dose-response. The retrospective dosimetry will be discussed here.

Methods

Medicare records identified over 200 different funding codes for CT scans, which were collapsed to eight anatomical regions (Table 1). We used a multi-tiered approach to retrospective dosimetry as we did not have access to technical scan information. We started with the detailed billing descriptions and reconstructed the volumetric CT dose index ($CTDI_{vol}$) using: (1) scanner-specific protocols from review of scientific literature relevant to past Australian CT usage; (2) Australian regulator databases of CT scanners registered for the relevant years; and (3) manufacturer manuals to obtain protocol parameters. Additionally, data were retrieved from national, state and local surveys and through expert interviews. Unweighted regression modelling was used to predict a $CTDI_{vol}$ matrix for 2,520 strata covering the main anatomical regions, each year of age of exposure and each year in the study period. This $CTDI_{vol}$ matrix was input to the National Cancer Institute dosimetry system for CT (NCICT) program[2], which utilises paediatric hybrid computational phantoms to calculate absorbed doses for 34 organs and effective dose in accordance with ICRP 103[3]. The Australian CT codes also identified CT procedures that involved a second (contrast) scan, doubling the final dose recorded. Where the contrast phase was optional according to the CT code, the probability that it was actually applied was estimated from historical data.

Results and Discussion

The Medicare cohort includes 11.6 million young Australians, of whom 692,879 had at least one Medicare-funded CT scan between 1985 and 2005. The vast majority of scans were of the head (Table 1). We estimated average doses for 34 different organs from 902,031 scans. The $CTDI_{vol}$ values for different age groups using the regression model are shown in Figure 1. Based on work undertaken for the UK CT cohort, we decided to keep $CTDI_{vol}$ values constant prior to the year 1990 as there was little evidence of adjustment of parameters in these early years.[4] We similarly found that the regression model was more stable if exposures prior to 1990 were coded together with exposures in 1990. A fixed value of 120 peak kilovoltage (kV_p) was used for input into NCICT based on uncertainty analyses performed for the UK cohort.[5]

Average organ doses decreased from 1985 to 2005, which is attributable to improved technology and optimised technique. The mean brain dose from a CT head scan was 47 milligray (mGy) per scan, the mean breast dose from a CT chest scan was 17 mGy and the mean liver dose from a CT abdomen/pelvis scan was 24 mGy (for dose ranges see Figure 2). The mean dose to the red bone marrow (RBM) was 9 mGy, 7 mGy and 6 mGy for CT abdomen/pelvis, head and spine scans, respectively. Using the ICRP 103 definition, the mean effective dose per scan was 4 millisieverts (mSv) and per person was 5 mSv. There was approximately 30,000 Gy total brain dose in the cohort and 6,000 Gy RBM dose.

Comparison with recent analyses of the UK cohort[5] show that for brain scans, which also dominate their dataset, the Australian $CTDI_{vol}$ values have a similar maximum value, but have a wider range in 1985 across the age groups. Furthermore, the regression fit for the Australian study demonstrates a less steep dose reduction with time.

Table 1: Number of scans for different categories for the Australian cohort

Anatomical Region	Inclusions	Number	Percentage (%)
Head	Brain, facial bones, orbits, middle ear, temporal bone, pituitary fossa and petrous bones	628,093	70%
Extremities	One or more regions	86,284	10%
Spine	Cervical, thoracic, lumbar	73,482	8%
Abdomen and/or Pelvis	Upper abdomen, pelvis, pelvimetry and colon	49,564	5%
Other	Interventional, spiral angiography, dynamic, body scans on a body scanner (years 1985-1987)	26,782	3%
Chest	Chest with or without upper abdomen	21,964	2%
Neck	Soft tissue neck	8,654	1%
Combined	Multi-region scans (e.g. chest and abdomen and pelvis)	7,208	1%
Total		**902,031**	**100%**

Figure 1: Temporal changes in $CTDI_{vol}$ for a) brain scans and b) abdomen/pelvis scans for different age groups
Values for all age groups are in terms of the 16 cm dosimetry phantom

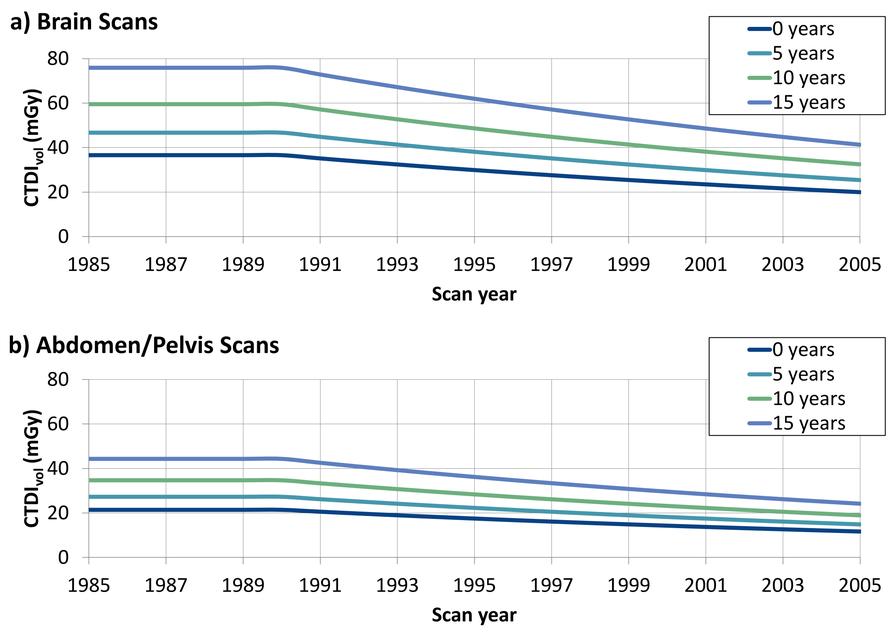
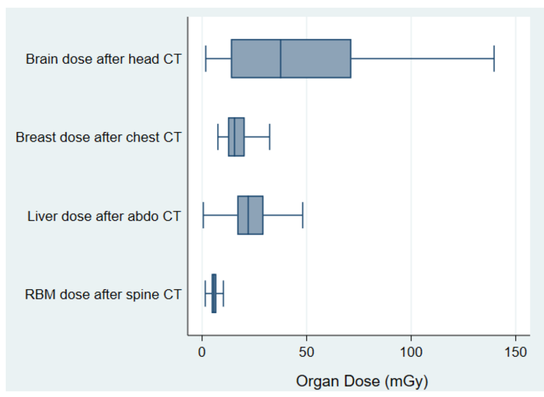


Figure 2: Distribution for specific organ doses after certain CT scan types in the entire Australian cohort
Organ absorbed dose averaged over type of CT scan in all age groups for all years
Excludes outliers > 1.5 x interquartile range above the 75th percentile



Conclusions

Overall, more than 25 million organ doses were calculated. Although limited by uncertainties, this dosimetry allows more detailed assessment of the radiation induced cancer risk in this important cohort.

Acknowledgements

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