Environment International 120 (2018) 1–10

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Subtle excess in lifetime cancer risk related to CT scanning in Spanish young people

Magda Bosch de Basea[a,b,c,*], David Moriña[d], Jordi Figuerola[a,b,c], Ignasi Barber[e], Jordi Muchart[e], Choonsik Lee[f], Elisabeth Cardis[a,b,c]

[a] Institut de Salut Global (ISGlobal), Centre de Recerca en Epidemiologia Ambiental, Parc de Recerca Biomèdica de Barcelona (PRBB), Carrer del Dr. Aiguader 88, E-08003 Barcelona, Spain
[b] Universitat Pompeu Fabra (UPF), Barcelona, Spain
[c] CIBER Epidemiología y Salud Pública (CIBERESP), Spain
[d] Unit of Infections and Cancer (UNIC-I & I), Catalan Institute of Oncology (ICO)-IDIBELL, Av Gran Via, 199-203, 08908 L'Hospitalet de Llobregat, Barcelona, Spain
[e] Radiology department, Hospital Sant Joan de Deu, Barcelona, Spain
[f] Division of Cancer Epidemiology and Genetics, National Cancer Institute (NCI), National Institutes of Health, Rockville, MD, United States

A R T I C L E I N F O

Handling Editor: Olga-Ioanna Kalantzi

Keywords:
CT scan
Risk
Cancer
Young population
Ionising radiation

A B S T R A C T

Background: CT scan is a life-saving medical diagnostic tool, entailing higher levels of ionising radiation exposure than conventional radiography, which may result in an increase in cancer risk, particularly in children. Information about the use and potential health effects of CT scan imaging among young people in Spain is scarce.
Objective: This paper aims to estimate the number of radiation-related cancer cases which can be expected due to the use of CT scanning in Spanish children and young adults in a single year (2013).
Methods: The 2013 distribution of number and types of CT scans performed in young people was obtained for Catalonia and extrapolated to the whole Spain. Organ doses were estimated based on the technical characteristics of 17,406 CT examinations extracted from radiology records. Age and sex-specific data on cancer incidence and life tables were obtained for the Spanish population. Age and sex-specific risk models developed by the Committee on Health Risks of Exposure to Low Levels of Ionizing Radiations (BEIR VII) and Berrington de Gonzalez were used, together, with the dose estimates to derive the lifetime attributable risks of cancer in Spain due to one year of CT scanning and project the number of future cancer cases to be expected.
Results: In 2013, 105,802 CT scans were estimated to have been performed in people younger than age 21. It was estimated that a total of 168.6 cancer cases (95% CrI: 30.1–421.1) will arise over life due to the ionising radiation exposure received during these CTs. Lifetime attributable risks per 100,000 exposed patients were highest for breast and lung cancer. The largest proportion of CTs was to the head and neck and hence the highest numbers of projected cancer cases were of thyroid and oral cavity/pharynx.
Conclusions: Despite the undeniable medical effectiveness of CT scans, this risk assessment suggests a small excess in cancer cases which underlines the need for justification and optimisation in paediatric scanning. Given the intrinsic uncertainties of these risk projection exercises, care should be taken when interpreting the predicted risks.

1. Background

Nowadays, medical radiation has become the largest man-made source of ionising radiation exposure for human beings (UNSCEAR, 2010), and in particular, computed tomography (CT) scanning largely dominates the medical radiation exposures, accounting worldwide for approximately 34% of the annual collective dose (UNSCEAR, 2010). CT scanning is routinely used in patient management from diagnostic and

Abbreviations: AQuAS, Agència de Qualitat i Avaluació Sanitàries de Catalunya (Agency of Quality and Healthcare Evaluation of Catalonia); BEIR VII, Biological Effects of Ionizing Radiation; CT, Computerised Tomography; DICOM, Digital Imaging and Communications in Medicine; LAR, Lifetime attributable risk; LBR, Lifetime baseline risk; LSS, Life Span Study of the atomic bomb survivors in Hiroshima and Nagasaki; NCICT, National Cancer Institute dosimetry system for CT; PerMoS, Performance Monitoring Server for Clinical Data

* Corresponding author at: Institut de Salut Global (ISGlobal), Centre de Recerca en Epidemiologia Ambiental, Parc de Recerca Biomèdica de Barcelona (PRBB), Carrer del Dr. Aiguader 88, E-08003 Barcelona, Spain.
E-mail address: magda.boschdebasea@gmail.com (M. Bosch de Basea).

https://doi.org/10.1016/j.envint.2018.07.020
Received 23 June 2017; Received in revised form 12 July 2018; Accepted 13 July 2018

treatment planning, to disease follow-up. As in most European countries, since its introduction in 1976, Spanish hospitals have progressively adopted this diagnostic technique for its recognised clinical value. Approximately 750 CT scanners are currently in use in Spain (Ministerio de sanidad, servicios sociales e igualdad [Spanish Ministry of Health, social services and equality], 2015), which annually perform > 4.3 million CT scans (90.6% in the public healthcare system (Ministerio de sanidad, servicios sociales e igualdad [Spanish Ministry of health, social services and equality], n.d.)). According to international data, CT imaging in children and adolescents is estimated to account for 3–11% of the total CT activity (UNSCEAR, 2013). In this age group, typical CT organ doses range between tens of mGy for an organ in the scanning field to hundreds of μGy for a distal organ (Lee et al., 2012; Santa-Olalla et al., 2005).

Epidemiological studies have shown that radiation exposure in childhood is linked to a dose-related excess in the rates of tumours, in particular brain tumours, leukaemia, breast and thyroid cancer (Wakeford et al., 2010; Land, 1993; Ron et al., 1995; National Research Council (U.S.), 2006; Monty, 2001; Neglia et al., 2006; Ron et al., 1988), with higher lifetime risk of cancer per unit dose of radiation than for exposure in adulthood (UNSCEAR, 2013). Because little direct evidence is available on risks at doses below 100 mGy, a linear no-threshold (LNT) model is generally used to extrapolate the risk of cancer for doses lower than this (National Research Council (U.S.), 2006) (as in the dose range for most CT imaging). Through this, several studies have projected the risk of incident primary cancers associated with diagnostic CT scan doses in young people (Miglioretti et al., 2013; Journy et al., 2013; Egan et al., 2012; Journy et al., 2017; Li et al., 2011; Su et al., 2014), adults (Richards et al., 2008; Smith-Bindman et al., 2009) or in both (Sodickson et al., 2009; Gibson et al., 2014; Berrington de González and Darby, 2004; Berrington de González, 2009) in different countries applying risk models derived by the BEIR VII committee (National Research Council (U.S.), 2006) and other authoritative agencies (US EPA, 2015; UNSCEAR, 2008; ICRP (International Commission on Radiological Protection), 2007). These studies estimated that a small, but non-negligible, excess in cancer risk can be expected in relation to the widespread use of CT scanning.

In recent years, different studies in the UK (Pearce et al., 2012; Berrington de Gonzalez et al., 2016), Australia (Mathews et al., 2013), and Taiwan (Huang et al., 2014) have attempted to estimate directly the magnitude of radiation-induced cancer risks from paediatric CT scanning. The leukaemia and brain cancer risk estimates resulting from the UK and Australian studies were larger than the estimates obtained using the latest Life Span Study data (Hsu et al., 2013; Preston et al., 2007). At present, methodological limitations such as the inclusion of patients with cancer-prone syndromes, reverse causation, dosimetric flaws, short follow-up and potential residual confounding due to unmeasured factors prevented deriving precise risk estimates from these studies. Although the EPI-CT study, a large scale European study on CT scan risks including over one million exposed children, will produce results soon (Bosch de Basea et al., 2015), extrapolation from higher dose studies remains the most solid basis for predicting risk from CT scanning in young people.

For the first time, we estimated the use of CT imaging in Spanish young population and subsequently assessed the potential impact of the current practices of paediatric and young adult CT scanning on the cancer burden of Spain.

2. Methods

2.1. Study population and related data

The Spanish National health care system reported that the annual number of CT scans in Spain increased from 3,830,238 CT scans in 2010 to 4,307,391 in 2013 (Ministerio de Sanidad, Servicios Sociales e Igualdad [Ministry of Health, Social Services and Equality], 2013), according to the latest data at the time of this analysis. The distribution of CT scans by age, sex and body part scanned was not available at the country level. However, the Agency of Quality and Healthcare Evaluation of Catalonia (Agència de Qualitat i Avaluació Sanitàries de Catalunya; AQuAS) of the Catalan Department of Health, made it accessible for the year 2015 for Catalonia, the 2nd most populated Autonomous Community of Spain were 15.9% of its population reside. A total of 374,270 CT scans were performed in the general population aged 0 to 100 years. Approximately 3% of these were performed in the population below 21 years of age. The Catalan relative distribution was applied to the 2013 country-level figures in order to estimate the age, sex and anatomical area-specific distribution of CT scans performed in Spain, assuming stable (over the years) and similar CT distributions between Catalonia and Spain.

In order to estimate the number of cancer cases that could be induced by CT scan radiation, we used the most up-to-date age and sex-specific Spanish cancer incidence rates available in the *Cancer Incidence in Five Continents* (*CIV*) (Forman et al., 2007) series to infer the background rates of cancer among children and young adults. Due to the lack of a national population-based registry, the incidence data are based on the 2007 CIV rates provided by the 7 population-based Spanish cancer registries. In the absence of more recent data we had to assume the rates were similar to the 2013 rates and will continue to be stable in the future (Forman et al., 2007). Spanish age and sex-specific survival data (latest available data) was obtained for the year 2013 at the National Statistics Institute (Instituto Nacional de Estadística) (2013). Using data from the Spanish branch of the EPI-CT cohort study we estimated that 6.64% CTs were performed in young people who would not survive long enough (at least 5 years) to develop a potentially radiation-induced cancer. These CTs were removed (by age bands, sex and body area scanned) from the population at risk as was done in Berrington's risk projections (2009). An important indication for CT scanning is suspicion of and follow-up for cancer. These CT examinations have to be excluded from our risk prediction analyses because their related CT scan radiation would not be responsible for the onset of the cancer they were used to diagnose/monitor. Therefore, we used the data from the only Spanish EPI-CT participating hospital that provided complete reason for the scan and estimated that, in 2013, out of the 2624 CT scans performed in patients aged 0 to 20 years, 8.8% were related to a cancer code (suspicion, diagnosis or follow-up of the condition). Therefore, this proportion of CT scans with similar age-sex-anatomical area distribution was excluded.

2.2. Dosimetry at the organ level

For the estimation of absorbed doses to the organ, protocol parameters (kVp, mAs and pitch), machine specifications (model and manufacturer), anonymous patient characteristics (age and sex), and the descriptions of the anatomical areas scanned were extracted from the DICOM headers of 33,947 CT performed on patients below 21 years old between 2010 and 2013. This information was collected using the software PerMoS (Luxembourg Institute of Science and Technology, Luxembourg) in 9 EPI-CT participating Spanish hospitals. For each type of CT examination, the start and end of the exposed body region were defined on computational anthropometric phantoms by a radiologist and validated by an independent paediatric radiologist. The gender-specific phantoms used were compliant with the International Commission on Radiological Protection references (ICRP 89) and represented newborns, children at ages 1, 5, 10, and 15 and adults (ICRP, 2002). Due to the lack of registered information on the use of a bowtie filter as the x-ray beam shaping attenuator, we used expert opinion to impute the use of a head filter in newborns as by 50%:50% chance irrespective of the scanned area. In older patients, head and body filters were imputed in head/neck and thorax/abdomen + pelvis/extremities scans, respectively. After discarding 16,541 examinations due to missing parameters, absorbed organ-doses (mGy) were estimated for