Knowledge of doses from external radiotherapy for a cancer in childhood

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Abstract

Radiation doses outside the radiotherapy treatment field are of radiation protection interest. Available studies investigating such doses, focused on specific sites, standard target volumes, and a few radiation beams or treatment conditions. We present a software package designed to perform individual dosimetry in retrospective studies. It was developed for a European cohort study of over 4400 patients who were younger than 17 years when treated for a primary solid cancer in childhood at 8 French and UK cancer centres. The methodology adopted by this software enabled the anatomical data for all patients in the cohort who were between a few days to 16 years of age, to be taken into account. It includes the characteristics of all machines used to treat the patients from 1942 to 1992. The absorbed doses are estimated directly in volum% and the lung heterogeneity is considered. Based on actual measurements, all principal sources of scattered radiation, sources of doses to out-of-beam sites, are modelled and introduced. For each patient, absorbed doses to 151 anatomical sites were calculated, according to radiation beam energy with a range of energy from 50 kV to 31 MV for photons and 4 to 32 MeV for electrons. Such a tool can provide dose estimation sufficiently accurate for radiation protection purposes.

Introduction

A cohort study of 3-year survivors of a first cancer in childhood was initiated by our group to evaluate the long-term risk of a second malignant neoplasm [1]. It included 4400 patients treated for various solid cancers in 8 French and British centres, of whom 2827 underwent radiotherapy. This study required precise individual dose calculation, for which we have developed a software package, Dosimetry Electron_Gamma (Dos_EG), able to simulate all patients and treatments in the cohort. It enabled us to estimate the radiation doses delivered to a wide range of sites, permitting the construction of a useful database for radiation protection purposes and enhancing understanding of low dose-effects. In the present paper we describe briefly, the software Dos_EG, and a few examples of absorbed doses to a few sites estimated by this software.

Materials and Methods

Population

Patients included in this study were treated for various primary solid cancer (Ewing's sarcomas, osteosarcoma, soft tissue sarcoma, Wilm's tumour of the central nervous system, retinoblastoma, Hodgkin's disease, non Hodgkin's lymphoma, etc...) from 1946 to 1992, at 8 different centres, as described in [2,3]. Therefore the population includes a wide range of different anatomical data for both male and female patients aged between a few days to 16 years at the beginning of their radiotherapy.

Patient and treatment simulations

The individual dose calculation, required for this study was performed with a software package, Dos_EG, which was developed for retrospective studies at the IGR [4]. It includes two major algorithms. The first is devoted to generating an anatomy mathematically equivalent to each patient and computes the organ positions using auxological methods as described in [5]. The parameters required to construct this anatomy, are the sex and height or age of the patient at the time of treatment. The anatomy so generated is adapted to the patient using recorded anatomical information about the patient, i.e.; lateral diameter of different sections of the body, ant-post thickness, and organ heights. This anatomy is a considerable improvement on the previous model described in [5], in that: (1) the individual phantom is articulated allowing thus for trunk inclination and back extension of the head as for mantle treatments, (2) the parameters used to adapt the generated phantom to the patient, increase to 12, allowing for better adaptation (3) it localises 151 anatomical sites using a Cartesian co-ordinate system against 64 in the previous method. Once the individual anatomy is constructed the treatment conditions are simulated using the recorded information, i.e; total dose delivered to the target volume, the number of fractions, the time from first to last fraction, the type of the treatment machine, type of radiation (photon, electron) and energy, source-skin distance, field size and shape, beam direction and wedges if any, and weighted dose from each beam. Dos_EG allows the input of the complex form of each field when shielding blocks are present.

The second algorithm is devoted to dose calculation inside and outside the beam up to 180 cm from the field edge. It takes into account all principal sources of radiation doses outside the treated volume, i.e; the actual leakage radiation from the collimator and the head of the treatment machines, and radiation scatter from the collimators, beam modifiers, walls and other obstacles. Radiation scattered inside the patient from the irradiated volumes, is also considered [6]. The penetrant bremsstrahlung radiation produced by high energy electron beams is taken into consideration both inside and outside of the useful beam. This algorithm represents a considerable improvement on the previous one developed at the IGR and described in [7]. Not only does it take into account a wide range of photon energies (50 kV to 31 MV), electron beams from 4 to 32 MeV and treatment machines (38 machines used in 8 treatment centres), but also lung heterogeneity, shielding block and wedge modifications, and all possible field shapes and sizes. The distance at which the dose could be estimated was extended from 50 cm to 180 cm from the central axis, permitting the calculation of doses to all sites of all patients from all treatments. In addition, Dos_EG, uses the measured spectrum emitted by the treatment machine in the estimation of the energy flux, for all beam energies from conventional orthovoltage tubes, Cobalt, Van der Graff, linear accelerators, and betatron equipment.

Results and discussion

The absorbed doses to 151 anatomical sites were estimated for every patient in the cohort using their appropriate treatment conditions, machine and energy. In Table I, we present an example of absorbed doses at selected sites, for a female patient who underwent 5 courses of radiotherapy for lymphoma between the ages of 5.5 and 12 years. According to our methodology, her actual anatomy at the time of each course of radiotherapy and the actual treatment conditions were all considered when doses were calculated. For the treatments with electron beams (16 and 8 MeV) from two different machines, all these sites received doses lower than 0.1mGy which are here, considered negligeable (N), but received very variable doses from the Cobalt and kV beams, reflecting the influence of the patients size, beam energy, and all treatment parameters.

For the whole population in this study, we represent the distribution of absorbed doses to the brain (figure 1) and to eye lenses (figure 2). These distributions showed that most of them have received very low doses (about 0.1 Gy) at both sites. The absorbed doses to the brain showed another peak around 20 Gy, but at 5 Gy to eye lenses.

In several examples, the estimated doses by our model showed good agreement with those measured at the IGR at several sites in an Alderson-Rando phantom.

To our knowledge, no study has supplied estimated organ dose distribution with a model fulfilling the requirements of epidemiological studies to such an extent as do Dos_EG, and may help to improve knowledge of low dose-effects for the radiation protection purposes. However several studies investigated doses to out-of beam sites, but they were either based on measurements in adult phantom, standard treatment conditions (e.g. uterine cervix), and specifique radiation beams (e.g. photon beams below 10 MV) and accessories (e.g.wedge and blocks), or focused on particular sites [8-12].

Table I. Absorbed doses (cGy) from 5 courses of radiotherapy received by a female patient between 5.5 and 12 years of age.

Treatment conditions	beam & energy	TV Dose* (cGy)	oesophagus (cGy)	stomach: upper-lower (cGy)	pancreas (cGy)	colon (cGu)	rectum (cGy)
chest AP/PA (28x23 & 28x18 cm) lung & humerus shields	Cobalt	2500	2446	1163-4056	934	28	22
upper chest-neck 2 opposed lat. (11.5x11.5 cm)	16 MeV Betatron	2500	N	N	N	N	N
lower neck, left lat. (10x10 cm)	250 kV	1050	6	2	2	1	1
neck left lat. (10x10 cm)	8 MeV linac "	2500	N	N	N	N	N
head 2 opposed lat. (10x13 & 9x13 cm) facial shields	Cobalt"	5200	15	24-16	7	3	3

* dose delivered to the target volume, N is negligible dose (below 0.1 mGy).

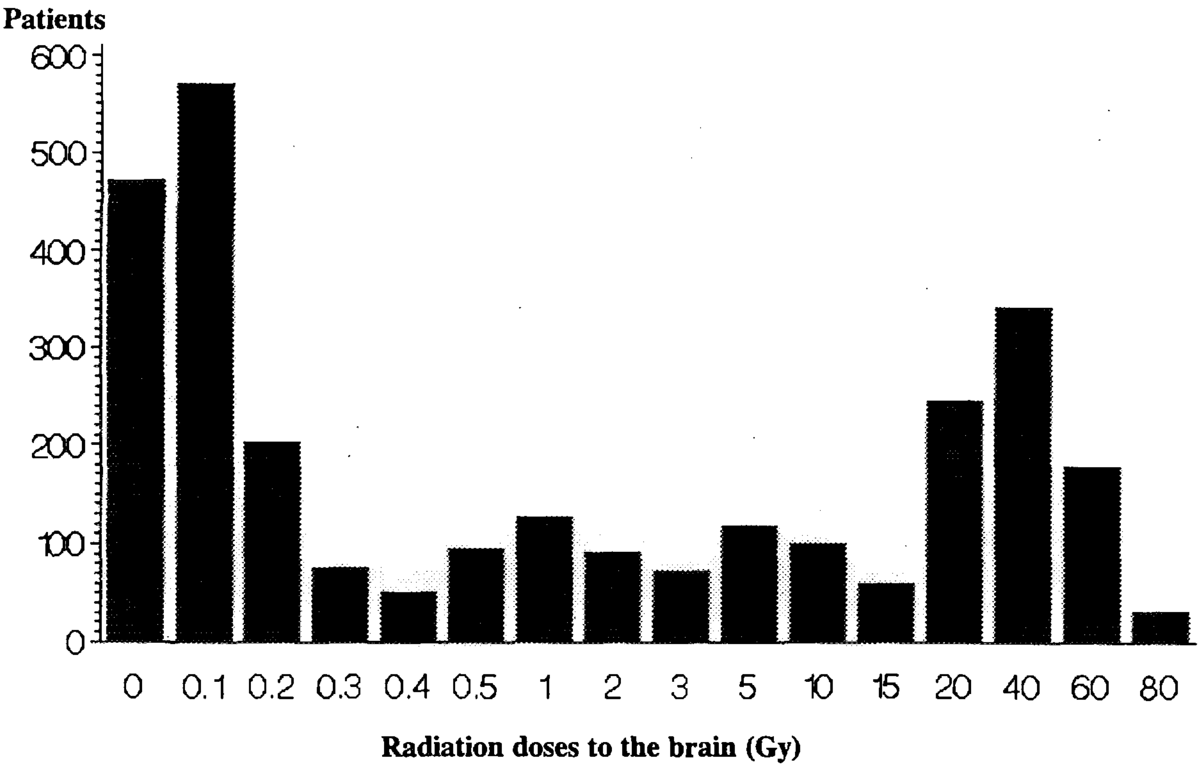

Figure 1. Distribution of absorbed doses to the brain from external radiotherapy.

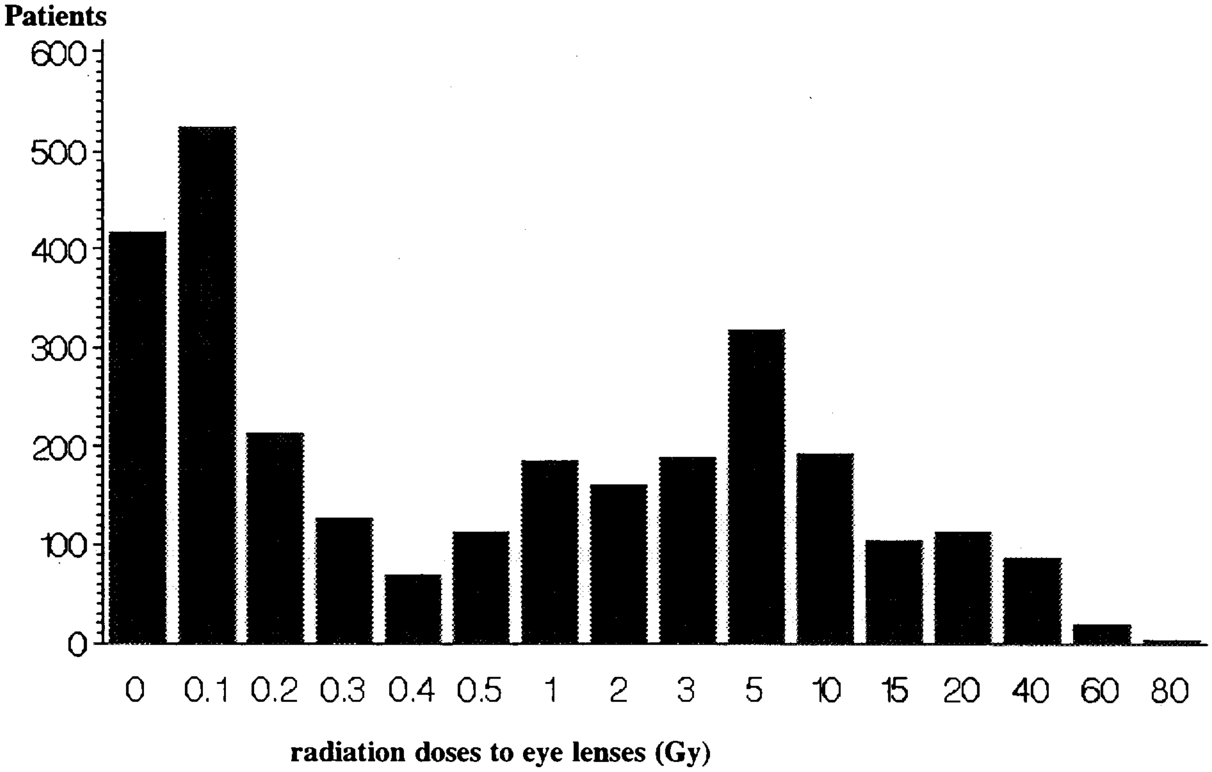

Figure 2. Distribution of absorbed doses to eye lenses from external radiotherapy.

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