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Brief communication (Original)

Organ doses, effective dose, and radiation risk assessment in radiography of pediatric paranasal sinuses (Waters view)

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Background: For diagnosis of acute sinusitis, conventional radiography is the investigative method of choice. While radiological examinations undoubtedly help in the proper diagnosis of various diseases, their excessive use can lead to unnecessary exposure to radiation, the biggest long-term risk of which is cancer. Awareness of effective dose and radiation risk from the radiological procedure is necessary for taking decisions about executing an X- ray examination.

Objective: We evaluated organ doses, effective doses (E), and the corresponding risk of exposure-induced cancer death resulting from paranasal sinus radiography for male and female patients in all age groups.

Materials ad Method: The radiographic technique variables used for this examination of 'standard patients' of six different ages (newborn, 1, 5, 10, 15-year-old, and adult) were obtained from the departments of radiology of seven public hospitals in Yazd city. PCXMC software was used to simulate projections and calculate the resulting organ and effective doses from these projections. The program also calculated the risk of death for radiation-induced cancers.

Result: For the six age groups, mean effective doses (E) were found to be 20.34, 22.52, 24.52, 25.96, 31.82 and 39.81 μSv, respectively. For male and female patients, the corresponding risk ranges were 1.14–2.59 and 1.31–3.22 per million, respectively.

Conclusion: Results of this study can be used as a guide by physicians to conduct a risk-benefit analysis to justify radiographic assessment of paranasal sinuses before it is requested; especially for children.

Keywords: Paranasal sinuses, pediatric, radiation-induced cancer, radiography

Diagnostic radiological examinations carry a higher risk per unit of radiation dose for the development of cancer in infants and children compared with adults. The higher risk is explained by the longer life expectancy in children for any harmful effects of radiation to manifest and that developing organs and tissues are more sensitive to the effects of radiation [1]. The European Commission (EC) [2] states that 'radiation exposure in the first 10 years of life is estimated to have a risk about 4 times greater than exposures incurred at 30–40 years of age for some detrimental effects'.

Sinusitis is one of the most frequent diseases in children and computed tomography is the criterion standard for its diagnosis [3, 4]. However, if acute sinusitis is suspected, conventional radiography is the investigative method of choice [5]. Some clinical studies have demonstrated that a single Waters (occipitomental) view has adequate accuracy in the diagnosis of acute sinusitis in children [6, 7]. Although radiation doses during other diagnostic X-ray examinations of pediatric patients have been extensively studied [8, 9], only one study [10] has evaluated the frequency of radiographic assessment of paranasal sinuses in pediatric patients.

The present study aimed to evaluate organ doses, effective doses (E), and the corresponding risk of exposure-induced cancer death resulting from paranasal sinus radiography (Waters view) for male and female patients in all age groups.

Materials and methods

The radiographic technique variables used for the Waters view examination of 'standard patients' at six different ages (newborn, 1, 5, 10, 15-year-old, and adult) were obtained from the departments of radiology

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of seven public hospitals in Yazd city by asking expert technologists. The radiographic technique variables included the X-ray tube voltage (kVp), tube-current time product (mAs), Source–Skin Distance (SSD), filtration, and the approximate collimator settings (field size).

The Entrance Skin Exposure (ESE) was measured using a solid state dosimeter (UNFORS model 6001) at the Source–Skin Distance (SSD) for each technique used in the Waters view for each age group in the mentioned departments.

PCXMC software [11], developed by STUK (Radiation and Nuclear Safety Authority in Finland), was used to simulate projections and calculate the resulting effective doses from these projections. The software calculated both organ doses for a large number of organs/tissues and the resulting effective dose to the patient by using anatomical data from mathematical phantom models. The latest version of PCXMC (PCXMC version 2.0) was released in 2008 and uses organ weighting factors of both ICRP Publication 103 [12] and ICRP Publication 60 [13].

Input data for calculation were as follows: SSD, field size, kVp, ESE, coordinates of the point inside the phantom through which point the central axis of the X-ray beam is directed, total filtration, and anode angle. The PCXMC was constructed with six different phantom sizes, representing patients of different ages, from newborn to standard adult. The program also calculated the risk of death for radiation-induced cancers. The risk estimates were based on the combined absolute and relative risk models of the BEIR VII committee [14]. These models are sex- and age-dependent. A more thorough explanation of the calculation details of the program can be found in a technical program document [11].

Results

Table 1 shows the range of tube voltage (kVp) and tube current (mAs) values used for the Waters view of patients in the six age groups that were obtained from the departments of radiology of the hospitals included in the present study. The mean, minimum and maximum related values of ESE (Gy) measurements are also presented.

The highest organ doses in radiography of the paranasal sinuses as calculated by PCXMC software are shown in **Table 2**. Effective doses were calculated from these organ doses. **Table 3** summarizes mean values of effective doses (E) and the corresponding risk (per million) of exposure-induced cancer death for male and female patients in the six age ranges. For the six age groups, mean values of effective doses (E) were found to be 20.34, 22.52, 24.52, 25.96, 31.82 and 39.81 μSv, respectively. Increasing patient age caused a reduction of fatal cancer based on the risk models of BEIR VII committee [13]

Discussion

Our preparatory study showed that the projection most frequently used for paranasal sinus assessment at all age groups was the Waters or occipitomental view. For this reason, the Waters view was used in the present study. The present study provides information regarding the risk of fatal cancer whenever patient undergoes paranasal sinus radiography. Furthermore, it should be emphasized that low doses of ionizing radiation to the brain in infancy influence not only the risk for cancer development, but also for reduced cognitive abilities in adulthood [15].

Table 1. The range of tube voltage (kVp) and tube current (mAs) values used for the Waters view and the mean, minimum and maximum related values of ESE (μGy) measurements

Age (years)	Tube voltage (kVp)	Tube current (mAs)	ESE (μGy)		
			Minimum	Maximum	Mean
newborn	50–60	12.5–40	200.50	653.85	388.56
1	50–66	12.5–60	412.14	1249.38	638.20
5	52–70	20–60	547.76	2017.96	961.79
10	54–73	25–64	764.84	2598.37	1393.88
15	58–76	32–80	1295.40	3431.52	1943.48
Adult	62–80	40–100	1676.55	3739.77	2640.62

Table 2. Mean organ doses resulting from radiography of the paranasal sinuses as calculated by PCXMC software (μGy)

Organ	Age group (years)					
	Newborn	1	5	10	15	Adult
Salivary glands	233	288	408	573	787	1063
Skeleton	141	197	249	254	263	321
Brain	133	157	179	249	346	475
Oral mucosa	108	127	160	196	239	323
Thyroid	74	68	111	101	117	122
Active bone marrow	62	67	51	50	56	67
Extrathoracic airways	50	50	67	99	140	202
Lymph nodes	33	38	52	68	91	122
Muscle	31	35	31	27	31	34
Oesophagus	16	15	16	5	6	4
Thymus	15	11	9	3	2	2
Lungs	9	8	8	4	3	4

Table 3. Mean values of effective doses (E) and the corresponding risk (per million) of exposure-induced cancer death for male and female patients

Age (years)	Mean effective dose (μSv)	Risk of exposure-induced cancer death ($\times 10^{-6}$)	
		Male	Female
newborn	20.34	2.59	3.22
1	22.52	2.52	3.10
5	24.52	2.05	2.47
10	25.96	1.60	1.86
15	31.82	1.55	1.82
Adult	39.81	1.14	1.31

Many mathematical models have been developed to estimate the cancer risk resulting from exposure to ionizing radiation; PCXMC software uses a model developed by the BEIR VII committee [14]. Many factors, e.g. limitations in the epidemiologic data, contribute to the uncertainty of risk estimation. To assess the risk of radiation-induced cancer death for a given patient, the user is required to enter correct patient data for the 'Age', 'Sex', and mortality 'Statistics' (Euro-American, Asian) of the patient. The Asian and Euro-American mortality data were obtained from ICRP Publication 103 [12].

To our knowledge, no previous information exists for the risk of exposure-induced cancer death to children during paranasal sinus X-ray examinations. The results of our study reveal that for male and female patients, the corresponding risk ranges were found to be 1.14–2.59 and 1.31–3.22 per million, respectively, depending upon the age of the patients. As shown Table 3, paranasal sinus radiography has the highest risk in newborn and 1-year-old patients. This is according to a recent report of the ICRP [1]. Sinus radiography in an infant or child under 6 years suspected of having sinusitis must be carefully planned and justified.

According to Perlmutter et al. [2] a risk of death of more than of 1 in a million may not be generally ignored. Therefore, the lifetime cancer mortality risk to children from paranasal sinus radiography may not be considered negligible. Furthermore, repeat the radiographs as a result of either improper selection of exposure parameters or patient motion will increase the cancer risk.

Conclusion

The current study provides a detailed data set regarding ESE, effective dose, and risk of death to patients undergoing paranasal sinus radiography. The dependence of these risks upon the age and sex at exposure was also investigated. Results of this study could be used as a guide by physicians to conduct a risk-benefit analysis to justify radiographic assessment of paranasal sinuses before it is requested, especially for children.

The authors have no conflicts of interest to declare.

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