Journal of Human Environment and Health Promotion
Print ISSN: 2476-5481 Online ISSN: 2476-549X

The Impact of the COVID-19 Pandemic on the Radiation-Induced Cancer Risk in Zanjan, Iran

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ARTICLE INFO

Article type:
Original article

Article history:
Received: 10 March 2024
Revised: 4 April 2024
Accepted: 17 April 2024

© The Author(s)

https://doi.org/10.61186/jhehp.10.2.74

Keywords:
Chest CT scans
Absorbed dose
Neoplasm
Coronavirus
Pandemic

ABSTRACT

Background: The coronavirus resulted in a global pandemic and infected millions of people worldwide in 2019. The number of chest CT scans significantly increased due to the virus's effect on the upper respiratory tract. This retrospective cross-sectional analytic study aimed to investigate the COVID-19 effect on the number of chest CT scans and to estimate the probability of radiation-induced cancers as a result of the incremental number of scans in hospitals in Zanjan, Iran.
Methods: This study included all chest CT scans performed during a three-month period before the pandemic (2019) and the pandemic (2020). In 2020, the scans were meticulously examined for COVID-19 signs, and relevant epidemiological and dosimetric factors were recorded to calculate the risk of radiation-induced cancer using the IRCP103.
Results: The results reveal a four-fold increase in the number of scans in 2020, with 9095 scans compared to 2235 in 2019. Patients referred for a chest CT scan during the COVID-19 outbreak were significantly younger. Although the Dose-length Product (DLP) decreased in 2020, the anticipated number of new cases of radiation-induced cancers exhibited an approximately four-fold increase for different organs in the thorax region. Also, 55.6 % of CT scans were considered normal in 2020.
Conclusion: The current study shows that the high probability of radiation-induced cancers should be considered the long-term effects of the COVID-19 pandemic.

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which was first observed in Wuhan, China as COVID-19, has resulted in over 6 million deaths worldwide and rapidly infected more than 600 million people in under three years (Fu et al., 2022; Kalra et al., 2020; Kooraki et al., 2020; Lee, 2021; Tofighi et al., 2020). This virus also infects the upper respiratory tract and mainly causes pneumonia, dry cough, shortness of breath, fever, fatigue, myalgia, and pharyngitis. Further, this disease is diagnosed through the detection of the Ribonucleic Acid (RNA) of the virus from the upper respiratory tract of patients using the real-time Reverse Transcriptase-polymerase Chain Reactions (RT-PCR) method, which was not fast enough. Consequently, healthcare professionals searched for a more accurate and efficient COVID-19 detection method, considering that the accuracy and efficacy of RT-PCR kits were not adequately

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How to cite: Chehre H, Moradi H, Moghimi P, Yazdi N, Sattari S, Rezaeejam H. The Impact of the COVID-19 Pandemic on the Radiation-Induced Cancer Risk in Zanjan, Iran. *J Hum Environ Health Promot.* 2024; 10(2): 74-8.

tested. According to some studies, the accuracy of the early kits available was lower than 60 % (Ai et al., 2020; Tofighi et al., 2020). The low accuracy and time-consuming nature of RT-PCR kits led to alternative techniques such as chest radiography, chest Computed Tomography (CT) scans, and ultrasonography as helpful diagnostic and monitoring tools for individuals with COVID-19 or those with mild to severe respiratory syndromes (Dangis et al., 2020; Kalra et al., 2020; Lomoro et al., 2020). Chest CT scan is a fast, accessible, and accurate imaging modality using Ionizing radiations (X-ray) with greater sensitivity than the RT-PCR method for COVID-19 diagnosis. A substantial proportion of patients showed ground-glass opacity and consolidation, the two main signs of COVID-19 infection (Ai et al., 2020; Dangis et al., 2020), even in cases with negative RT-PCR results (Chen et al., 2020; Schalekamp et al., 2021). Therefore, the global use of CT scans for COVID-19 diagnostic purposes increased (Ai et al., 2020; Homayounieh et al., 2021; Kalra et al., 2020; Lee, 2021). However, while chest CT scans are highly sensitive, their limited specificity is considered a significant drawback. CT findings in COVID-19 patients can overlap with those of other viral infections such as H_1N_1 influenza, SARS, and Middle East Respiratory Syndrome (MERS) (Kalra et al., 2020; Wen et al., 2020). Furthermore, the use of CT scans should be limited as much as possible to reduce radiation exposure to patients and healthcare workers, based on the As Low As Reasonably Achievable (ALARA) principle (Axiaq et al., 2021; Davies et al., 2020; Lee, 2021). Exposure to ionizing radiation increases the risk of cancer, especially in younger individuals. Due to the COVID-19 pandemic and its control, the amount of radiation exposure increased worldwide (Homayounieh et al., 2021). This study aimed to assess the effect of the COVID-19 pandemic on the utilization of chest CT scans and to estimate their potential risk of radiation-induced cancer.

2. Materials and Methods

2.1 Data Extraction

This retrospective cross-sectional analytical study included all chest CT and High-resolution CT (HRCT) scans during the autumn of 2019 (pre-pandemic) and 2020 (during one of the peaks of the pandemic in Iran) at the two main hospitals located in Zanjan, Iran. The data in this analysis were extracted from the hospitals' Picture Archiving and Communication System (PACS) and consisted of lung CT and HRCT images, patients′ age and gender, and the Dose-length Product (DLP) in milligrays (mGy). All scans were reviewed by an experienced radiologist to identify any indications of COVID-19, and the patients were categorized into positive and negative COVID-19 groups.

2.2 Dosimetric Calculations

The Effective Dose (ED) in millisieverts (mSv) was calculated using equation 1 to assess the Risk of Radiation-induced Cancer (RRIC), as follows:

$$\text{Effective dose (mSv)} = k \times \text{DLP} \qquad \text{Eq.1}$$

where the k-factor represents the conversion factor from DLP to effective dose (ED) for different body regions, was determined for the chest region across different age groups using data from Table 1 in the AAPM report No. 96 (AAPM, 2008).

Table 1. K-factors for chest region based on AAPM report No.96

Age Group (years)	K Factor
0	0.039
1	0.026
2-5	0.018
6-10	0.013
Above 11	0.014

The RRIC was evaluated for the esophagus, lung, thyroid, and breasts in the chest region, which typically receive a substantial amount of primary beam radiation during chest CT scans (based on the International Commission on Radiological Protection (ICRP) report No. 103 for Asian populations) (Protection, 2007). For the mentioned organs, the Normal Cancer Risk Coefficient (NCRC) in males and females exposed to X-rays was obtained from ICRP 103 and is summarized in Table 2.

Table 2. Normal Cancer Risk Coefficient (NCRC) (cases per 10,000 people per mSv)

		Organ			
Sex		Esophagus	Lung	Breast	Thyroid
NCRC	male	0.0015	0.0076	0	0.012
	Female	0.0016	0.0153	0.0224	0.053

* NCRC: normal cancer risk coefficient

The RRIC was then calculated using equation 2, as follows (Protection, 2007):

$$\text{RRIC (new cancer cases per 10000 people per mSv)} = \text{NCRC} \times \frac{\text{ED(mSv)}}{\text{DLP(mGy)}} \qquad \text{Eq.2}$$

2.3 Ethical Consideration

The present study was approved by the Vice-Chancellor for Education and Research of Zanjan University of Medical Sciences (ZUMS) under the ethics code IR.ZUMS.REC.1400.090. The identity of all patients in this study was anonymous, and privacy was emphasized.

2.4 Statistical Analysis

The calculations and statistical analysis were performed using SPSS software version 22 (SPSS Inc., Chicago, IL, USA). The independent t-test was utilized to compare means, with a significance level of *P-Value* < 0.05.

3. Results and Discussion

In this study, 11305 chest CT and HRCT scans were investigated. Table 3 shows the demographic characteristics of the study population, including age and gender. According to Table 3, there was a four-fold increase in the number of chest scans conducted in 2020 compared to 2019. No significant relationship was observed between age and gender (*P-value* > 0.05); however, the population was significantly younger in 2020 than those in 2019 (*P-value* < 0.05). The DLP was 184.23 (SD = 93.25) and 172.54 (SD = 107.86) in 2019 and 2020, respectively. Similarly, the mean ED was 2.58 (SD = 1.3) in 2019 and 2.41 (SD = 1.4) in 2020 (*P-value* < 0.05). Among the 9,095 scans conducted in autumn 2020, 4,248 cases (44.4 %) showed signs of COVID-19 infection.

Table 3. Population age (mean ± SD) and gender

Population	Number (%)	Age Range	Mean	SD
Total	11305 (100)	0 - 103	52.00	19.56
Females	5146 (45.5)	2 – 103	52.90	19.02
Males	6159 (54.5)	0 – 99	51.24	19.99
2020 Total	9095 (80.3)	0 – 99	49.98	19.11
2020 Females	4366 (45.7)	2 – 99	50.83	18.61
2020 Males	5179 (54.3)	0 – 99	49.27	19.52
2019 Total	2235 (19.7)	2-103	60.22	19.26
2019 Females	1005 (44)	3 – 103	61.75	18.23
2019 Males	1277 (56)	2 – 98	59.00	19.98

Table 4 displays the frequency of COVID-positive and COVID-negative scans across different genders in 2020.

Table 4. Normal and infected Chest scans (COVID positive and COVID negative)

COVID status	Number (%)
COVID Positive	4248 (44.4 %)
COVID Negative	5317 (55.6 %)
Male (COVID Positive)	2318 (54.7 %)
Female (COVID Positive)	1923 (45.3 %)
Male (COVID Negative)	2816 (53.9 %)
Female (COVID Negative)	2443 (46.1 %)

The RRIC was calculated for the esophagus, lung, breast, and thyroid as new cancer cases per 10,000 persons per Gray (Gy), and the values were multiplied by 1,000 to facilitate the readability and interpretation of the data. Table 5 shows the RRIC results as new cancer cases per 1 million persons per Gy.

Table 5. The RRIC for different organs in the chest region (new cases per 1 million persons per Gy)

Year	Sex	RRIC for organs (new cases per 1 million persons per Gy)			
		Esophagus	Lung	Breast	Thyroid
2019	Male	21	108	0	16
	Female	22	214	314	74
2020	Male	20	106	0	16
	Female	24	214	314	74

Table 6 illustrates the new cancer cases computed for 2019 and 2020 by multiplying the exposed population in each year by the corresponding RRIC value presented in Table 5.

Table 6. The expected new cancer cases in the chest region in the studied population (new cases per Gy)

Year	Sex	Expected New Cancer Cases (new cases per Gy)			
		Esophagus	Lung	Breast	Thyroid
2019	Male	0.026817	0.137916	0	0.020432
	Female	0.02211	0.21507	0.31557	0.07437
2020	Male	0.10358	0.548974	0	0.082864
	Female	0.104784	0.934324	1.370924	0.323084

Table 7 displays the sexand organ-specific differences in the cancer incidence rate amplification between 2020 and 2019.

Table 7. The amplification of the expected number of new cancer cases (2020 compared to 2019 in males and females for each organ)

Sex	Amplification of Expected New Cancer Cases			
	Esophagus	Lung	Breast	Thyroid
Male	3.86	3.98	1	4.05
Female	4.73	4.34	4.34	4.34

The COVID-19 pandemic has led to a significant increase in the use of lung CT scans (Tofighi et al., 2020). This study aimed to investigate the potential impacts of CT scans on individuals' radiation exposure during the pandemic. The results of this study revealed that the average age of individuals undergoing chest CT scans during the pandemic was 11 years younger than those in the pre-pandemic period. The adverse effects resulting from ionizing radiation exposure are inversely related to age, i.e., younger individuals are more vulnerable to the long-term detrimental effects of radiation. Therefore, the decrease in the age of individuals undergoing chest CT scans significantly led to concern about the potential for increased radiation-induced cancers in the future (Homayounieh et al., 2021). The current study revealed that the number of chest CT scans during the pandemic was four times higher than that in the pre-pandemic period. Exposing more individuals to X-rays from CT scans resulted in increasing the probability of radiation-induced cancer over time. In 2020, the DLP for chest CT scans was observed to be 11.69 mGy lower than the corresponding value in 2019, indicating that Iranian diagnostic-therapeutic centers adopted low-dose CT protocols during the pandemic (Agostini et al., 2020; Beregi & Greffier, 2019; Dangis et al., 2020; Kang et al., 2020; Tofighi et al., 2020). However, some studies have suggested that low-dose and ultra-low-dose CT protocols may be less sensitive than routine protocols (Christe et al., 2013; Kubo et al., 2016). However, the chest CT images were standard and acceptable by radiologists in our study. It is worth noting that most countries have not implemented low-dose CT protocols worldwide (Homayounieh et al., 2021). The study revealed that only 44.4 % of the chest CT scans showed signs of COVID-19 infection, and lung CT scans were unnecessarily performed for the remaining 55 %. Additionally, many patients insisted on a CT scan due to their COVID-19 symptoms or contact with infected or potentially infected

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individuals due to a mistaken belief that CT scans are a reliable first-line diagnostic tool for COVID-19. To our knowledge, no other studies have reported the rate of normal chest CT scans during the pandemic era in Iran. In China, the rate of normal scans was 42 % (Ohno et al., 2012). Table 5 shows that the ICRP 103 considers only the age, gender, and radio sensitivity of organs in assessing the potential increase of radiation-induced cancers in the future while disregarding the number of exposed individuals. In the present study, the radiation-induced cancers in 1 million exposed individuals either remained stable or decreased in almost all cases, except for breast cancer in women, possibly due to a significant decrease in the age of the women studied in 2020. It is worth noting that these results are based on calculations in a hypothetical framework on 1 million individuals exposed to low-dose ionizing radiation. To obtain a more accurate estimate, the present study computed the expected number of new cancer cases (Table 6). A comparison between the expected new cancer cases in 2020 and those in 2019 shows the severe effect of the indiscriminate use of chest CT scans during the COVID period (Table 7). Based on factors such as the age and gender of the population and the radio sensitivity of organs, the number of expected new radiation-induced cancer cases in Zanjan city could be four times or even higher due to the significant use of chest CT scans. The probability of radiation-induced cancer is subject to uncertainty. Moreover, this study only examined a small group of the Iranian population during a limited timeline of the COVID outbreak, and patients may have undergone multiple imaging procedures involving ionizing radiation, not just during the pandemic. According to the significant number of patients with multiple chest CT scans during the pandemic, it is vital not to overlook the cumulative effects of ionizing radiation (Bell DJ; Tofighi et al., 2020). Homayoinieh *et al.* (2021) reported that a total of 30 % of COVID patients underwent different CT procedures between 2 to 8 times within a month (Homayounieh et al., 2021). Conversely, the COVID-19 pandemic resulted in the suspension of several cancer screening programs for months (Fu et al., 2022). A study conducted in Ontario, Canada revealed that over 12,000 new cancer cases were not diagnosed during the first six months of the pandemic (Eskander et al., 2022), likely due to people's fear of going to hospitals and the need to prioritize hospitalization for COVID-19 patients. Except for China (Committee, 2020) and Italy (Nicastri et al., 2020), most national and international health organizations, including the Centers for Disease Control and Prevention (CDC), World Health Organization (WHO), American College of Radiology (ACR), and Royal College of Radiologists (RCR), do not recommend using a CT scan alone or as the primary diagnostic tool for COVID-19 patients (Kalra et al., 2020; Lee, 2021). However, CT scans are frequently used as the only method to detect COVID-19 in many cases in Iran and several other countries. Homayounieh *et al.* (2021) found that this method is being used in 40 % of the studied countries as the first or only line of COVID-19 diagnosis (Homayounieh et al., 2021). The evidence-based guidelines and recommendations must be followed for accurate COVID-19 diagnosis and prevention of unnecessary radiation exposure. Some countries, including Iran, have repeatedly requested the lung HRCT for diagnosing COVID-19, raising concerns about potential long-term health consequences due to the risk of radiation-induced cancers. However, no study has suggested the necessity or efficacy of HRCT in diagnosing COVID-19 (Kalra et al., 2020). It seems that there is a high probability of a rise in the number of radiation-induced and COVID-induced cancers in the future, as described by Rui Fu *et al.* (2022) as: "the tsunami after the earthquake." (Fu et al., 2022).

4. Conclusion

Despite the optimization of protocols in Zanjan hospitals, the radiation exposure received by society during the COVID-19 pandemic was not justified. Consequently, there has been a growing concern about the potential long-term health consequences, particularly the risk of radiation-induced cancers. Hence, medical physicists play a vital role in protecting society against radiation-related risks. Collaborating closely with healthcare providers, medical physicists can contribute significantly to minimizing radiation exposure while ensuring accurate diagnoses and effective treatments. Additionally, medical physicists can help public health and minimize the potential risks associated with radiation exposure.

Authors' Contributions

Hossein Chehre: Conceptualization; Formal analysis; Methodology; Investigation; Writing original draft. Hadi Moradi: Investigation; Data curation; Writing original draft. Parastoo Moghimi: Investigation; Data curation; Writing original draft. Negar Yazdi: Investigation; Data curation; Writing original draft. Sara Sattari: Investigation; Writing original draft. Hamed Rezaeejam: Conceptualization; Formal analysis; Methodology; Investigation; Writing original draft; Project administration; Supervision.

Funding

This study has been approved and supported by the student research committee of Zanjan University of Medical Sciences (grant number: A-11-1307-7).

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgements

The authors would like to express their gratitude to the imaging department personnel of Zanjan Hospitals for their invaluable assistance.

Ethical considerations

The present study was approved by the Vice-Chancellor for

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