ORIGINAL ARTICLE

Trends of Computed Tomography Scan Usage among Adults and Children in Yazd Province, Iran, before the Outbreak of COVID-19

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Abstract

Purpose: Excessive use of Computed Tomography (CT) has become a worrying issue due to the potential risks resulting from radiation exposure. This study was carried out to investigate trends in CT usage in Yazd Province, Iran.

Materials and Methods: In the current study, patients were categorized according to their sex and age into two general groups, pediatrics (<18 years old) and adults (≥18 years old), each group falling into multiple subcategories. The performed CT scans were classified into six categories, based on the anatomical area of interest, including head/neck, chest, spine, abdomen-pelvis, extremities, and CT angiography (CTA). The data were collected from 2015 to 2018.

Results: The mean number of CT scans increased by the Compound Annual Growth Rate (CAGR) of 11%. Across the procedures, head/neck (with an average contribution of 52% to all CT scans) was the most frequently examined region, whereas CTA had the lowest percentage (2%). More than half of the scans are performed on people over the age of 90, and among those aged<18 years old the most CT scan rates are related to 13-18-year-olds.

Conclusion: The number of CT examinations is clearly increasing in Yazd Province. Some of this increase may be warranted because of the improvements in the diagnostic power of CT. The estimated number of pediatric CT scans has risen more than past. Due to the risk of cancer, efforts should be made to reduce unnecessary CT scans.

Keywords: X-Ray Computed Tomography; Trends; Ionizing Radiation; Risk of Cancer.

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Frontiers in BIOMEDICAL TECHNOLOGIES

1. Introduction

Computed Tomography (CT), introduced in the early 1970s [1], is among the most widespread imaging modalities thanks to its excellent image quality [1,2]. Despite its relatively high delivered radiation dose to the patients, CT is showing a global increase in utilization. CT high radiation dose delivery has become a topic of increasing interest in radiation protection [3–5]. The use of CT scans is very common despite the risk of radiation [6,7], and CT imaging examinations account for over 70% of medical radiation exposures [8]. The excessive use of CT and the increased radiation-induced malignancy risk are the two very important and worrying issues for health professionals [9,10].

It has been estimated that 1.5% to 2% of future cancers in the United States will be attributable to CT scans. The more important issue here is the exposure of pediatrics since they have higher radiosensitivity and also have a longer life to live [11]; nonetheless, the radiation dose delivered to this group has been the subject of several studies, and more often than not, the conclusions have been worrying [12–14].

Based on the 1997 European Commission's directive, CT should be performed wherever the benefits far outweigh the risks [15]. However, recent studies are indicating that around a quarter of prescribed CT scans are unjustified [16]. In this regard, in the current study, we aimed to present the trend of performed CT scans in Yazd Province, Iran, with an approximate population of 1.3 million.

2. Materials and Methods

2.1. Data Collection

Due to the outbreak of the Coronavirus in late 2019 and the excessive and unusual use of CT to identify Coronavirus Disease (COVID-19), the data related to the years 2019 and 2020 have been excluded from the study. Therefore, this retrospective study was performed through processing the integrated data from the Hospital Information System (HIS) from 2015 to 2018. Five large-size educational hospitals located in diverse areas of Yazd Province were involved in this survey which are shown in Table 1. In addition, the characteristics of CT scanners installed at each hospital are summarized in this table. The data including patient administration code, type of procedure, date and time of administration, and patient characteristics (sex and age) were extracted from each institution. Note that each administration code was considered a single patient, while an individual may have been referred to the institution at various times with different administration codes.

2.2. Patients Categorization

The patients were categorized with regard to their age into two general groups, pediatrics (<18 years old) and adults (≥18 years old), with each group falling into multiple subcategories. The pediatric group was classified into five subsets, including infants or toddlers (0 to 2 years old), preschool-aged (2 to 6 years old), school-aged (6 to 13 years old), as well as adolescents (13 to 18 years old), and the adults were divided into groups by 18-year intervals.

2.3. Procedures Categorization

To be in line with analogous studies [16–18], the performed CT scans have been classified into six categories, based on the anatomical area of interest, including head/neck, chest (routine chest and chest High-Resolution Computed Tomography (HRCT)), spine, abdomen-pelvis, extremities, and CT Angiography (CTA).

Table 1. Characteristics of investigated CT scanners

Institution	Vendor	Model	Detector Rows
Zeyaei, Ardakan	Toshiba	ACTIVION	16
Imam Sadegh, Meybod	Siemens	SOMATOM SENSATION	4
Shahid Rahnemoon, Yazd	Siemens	SOMATION EMOTION	16
Shahid Sadoughi, Yazd	Toshiba	ALEXION	16
Shahid Beheshti, Taft	Siemens	SOMATOM EMOTION	16

2.4. Method of Data Analysis

By obtaining the population structure of Yazd Province from the Statistical Center of Iran, an annual age-based proportion of inhabitants who underwent a CT scan was calculated. In other words, the number of examinations for each group in any specific year was collected, and then their proportion was calculated by dividing this number by the whole population in that year. For instance, in 2015, 9,349 CT tests were performed on pediatrics with a population of 370,071, which gives a proportion of 2.52%, indicating that 2.52% of inhabitants younger than 18 years of age, regardless of the scan type, underwent a CT test. Note that since the national census is performed on a five-year basis, a linear approach was followed to estimate the population pertaining to the study period.

To assess the annual changes in the number of examinations during the 4-year period, CAGR was calculated according to the following Equation [17]:

$$CAGR(t_0, t_1) = [(\frac{N_{t_1}}{N_{t_0}})^{\frac{1}{(t_1 - t_0)}}] - 1 \qquad (1)$$

Where t_0 and t_1 are the time interval endpoints and N_t refers to the number of tests in year t.

2.5. Statistical Analysis

The variables of descriptive statistics were derived using Excel (v. 2019, Microsoft, Redmond, Wash, US). The normality of the data was initially assessed by the Kolmogorov-Smirnov (K-S) statistical test in the SPSS software (v 22, SPSS Inc., Chicago, IL) with 95% confidence interval. The correlations between different years were determined using Pearson's correlation, and R2 values were considered as an index of correlation strength.

3. Results

During 4 years, more than 320,000 CT scans were performed on patients, of whom around 200,000 (62.29%) were men, indicating a vastly different contribution across genders (Table 2). For both sexes, the CAGR of 11% was estimated.

As was shown in Table 2, CTs have been mostly performed on adult patients, who represented approximately 86 percent of Yazd population (and also 86% of all CT scans were performed on adults). It should also be noted that people over the age of 36, who account for only one-third of Yazd's population, received more than half of CT scans. Additionally, the age group over 90 has the highest CAGR (15.7%), followed by aged groups 54-72 (13.9%), 36-54 (12.3%), and 18-36 (10.4%), with the least CAGR belonging to pediatrics (7%).

The number of computed tomography scans in Yazd Province increased from approximately 67,000 tests in 2015 to more than 91,000 in 2018 with the CAGR of 11% and a very strong regression trend (R2 >0.89) (Table 3). Across the procedures, head/neck with an average contribution of 52% among all CT scans was the most common procedure followed by abdomen/pelvis (18%), chest (15%), extremities (9%), spine (4%), and CTA (2%). Contrary to others, spine examinations experienced a decrease of 32% from 2015 to 2018 (CAGR, -12%).

Table 2. Trend usage of CT by age groups from 2015 to 2018

Age group/gender	Year				Averaged over 2015-2018	CAGR
	2015	2016	2017	2018		
<18	2.5%	3.2%	2.9%	3.1%	2.9%	7.1%
18-36	5.0%	6.2%	5.8%	6.7%	5.9%	10.4%
36-54	6.4%	8.0%	7.5%	9.0%	7.7%	12.3%
54-72	12.4%	16.0%	15.3%	18.4%	15.5%	13.9%
72-90	25.9%	29.6%	32.2%	34.3%	30.5%	9.8%
>90	40.5%	58.0%	52.9%	62.8%	53.5%	15.7%
Male	41753	51087	50048	56984	62.29%	11%
Female	25062	31812	29441	34643	37.71%	11%

Note. Due to the unavailability of the population by age in previous years, the 2017 population data was used to calculate the percentages.

Table 3. Trend of CT scan usage by type of procedures and time period in Yazd Province, 2015-2018

Examination	Year[a]				Averaged over 2015-2018	CAGR[b]
	2015 (%)	2016 (%)	2017 (%)	2018 (%)		
Head/Neck	36.11 (54%)	43.49 (52%)	41.04 (52%)	46.97 (51%)	41.9 (52%)	+9%
Abdomen/pelvis	11.27 (17%)	14.16 (17%)	14.20 (18%)	16.69 (18%)	14.08 (18%)	+14%
Chest	9.02 (14%)	12.49 (15%)	12.52 (16%)	15.29 (17%)	12.33 (15%)	+19%
Extremities	5.71 (9%)	7.06 (9%)	7.21 (9%)	8.71 (10%)	7.17 (9%)	+15%
Spine	3.60 (5%)	4.13 (5%)	2.91 (4%)	2.45 (3%)	3.27 (4%)	-12%
CTA	1.09 (2%)	1.54 (2%)	1.57 (2%)	1.49 (2%)	1.42 (2%)	+11%
Total	66.81 (100%)	82.89 (100%)	79.48 (100%)	91.62 (100%)	80.17 (100%)	11%

Numbers are in thousand
CAGR is given in percentage of increase (+) and decrease (-)

As depicted in Figure 1, most CT scan rates are related to 13-18-year-old children. Additionally, head/neck procedure is most abundant for every age group (70% of all types of CTs in the four-year period).

Table 4 presents the number of CT tests performed on patients upon each administration categorized by age intervals. Of almost 169 thousand patients, 46% experienced one CT examination, 39% experienced two, and the rest underwent 3 or more CT tests. Approximately an average of 1.9 CT scans were performed on patients through 2015-2018, ranging from 1.7 to 2.3. It is notable that the number of examinations for each age was collected using PACS systems (picture archiving and communication system) through the variable of year.

Moreover, CT examination from extremities, abdomen/pelvis, chest, spine and CTA occupy the next places in terms of the abundant CT scan types, in that order.

4. Discussion

The most remarkable result to emerge from the data is that over the past 4 years, in general, a CAGR of approximately +11% in demand for CT scans has been seen in Yazd Province. This is in good agreement with other research, especially in developing countries [19–21]. Since CT is regarded as an excellent imaging modality for its accuracy, availability, presentability details, and extensive clinical use, this rate is justified [6,7,22]. Furthermore, this upward trend of CT utilization may be attributed to several factors, such as the increasing number of devices and the existence of helical and multi-slice CTs. Having helical and multi-slice CT has enabled healthcare centers to reduce acquisition time. Studies have also shown that in developing countries there may be also an increase in the demand for CT scans due to a lack of appropriate

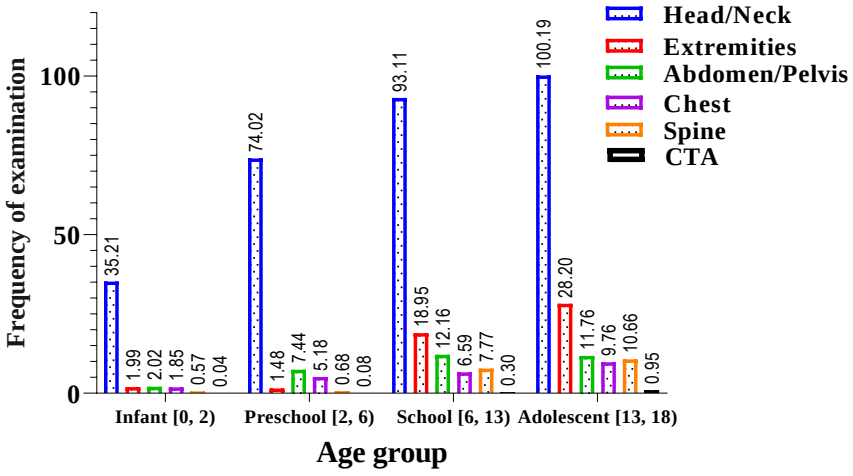

Figure 1. Sum of frequency of computed tomography use for each procedure in 4 age groups of pediatrics in four years; Infant [0,2), Preschool [2,6), School [6,13), and Adolescent [13,18)
Note: All numbers are in hundred

Table 4. Number of examinations for each person and percentages for different age groups during 2015 to 2018. (The number of CT examinations is based on the PACS information)

Age group	Number of examinations						Total
	1	2	3	4	5	6+	
<18	8372 (4.97%)	6888 (4.09%)	532 (0.32%)	885 (0.52%)	79 (0.05%)	359 (0.21%)	17115 (10.15%)
18-36	19702 (11.69%)	18786 (11.14%)	1832 (1.09%)	2454 (1.46%)	418 (0.25%)	1513 (0.9%)	44705 (26.51%)
36-54	19328 (11.46%)	15467 (9.17%)	1212 (0.72%)	1813 (1.08%)	226 (0.13%)	6842 (4.06%)	44888 (26.62%)
54-72	18106 (10.74%)	14291 (8.48%)	1102 (0.65%)	1732 (1.03%)	173 (0.1%)	664 (0.39%)	36068 (21.39%)
72-90	11633 (6.90%)	10213 (6.06%)	605 (0.36%)	1275 (0.76%)	92 (0.05%)	420 (0.25%)	24238 (14.38%)
>90	786 (0.47%)	629 (0.37%)	36 (0.02%)	108 (0.06%)	3 (<0.01%)	33 (0.02%)	1595 (0.95%)
Total	77927 (46.22%)	66274 (39.31%)	5319 (3.15%)	8267 (4.9%)	991 (0.59%)	9831 (5.83%)	168609 (100%)

Note: Percentages, compared to the total number of CTs performed over four years for each age group

criteria for CT imaging as well as lack of access to alternative high-resolution imaging modalities [17]. Also, the proficiency of the physician in prescribing the most appropriate imaging modalities can be very effective.

Similar to the findings of Larson *et al.* [23], we have not found a specific connection between gender and the rate of CT utilization. However, some studies mentioned in the literature that the growth rate of CT was higher in men than in women [16].

CT usage also increases dramatically with age. As it is shown in Table 2, more than half of the scans are performed on people over the age of 90. Some studies indicate that people in the older age group are more likely to have CT scans [24]. We can cite one of the reasons as there being less concern about radiation risks in older patients because of lower life expectancy after radiation.

At the beginning of the emergence of CT scans, this modality was used only for the brain and then began to be used for other parts of the body as technology advanced in the early 1980s [25]. As can be seen from Table 3, head/neck CT scans are the most widely used among anatomical sites in the body in adults. This is similar to what has been reported in other studies about CT utilization for both pediatrics and adults [17,26]. Additionally, according to Figure 1, this is also true for the use of head/neck CT scans in children under 18 years old, which accounts for 70.2% of all CT scans performed. Since brain CT scans are a detailed imaging modality for the diagnosis of skull injuries and an effective adjunct to the physician to detect the possible need for surgical intervention, they are very often seen as justified on top of brain CT scans. Common reasons that a patient or physician requests a brain scan may include headaches, an accidental injury to the skull, or the possibility of a stroke, and sometimes the family's insistence that the concern is addressed. In addition, brain scans expose the eye lens to radiation (24-62 mGy per procedure) which does not provide any diagnostic information but increases the risk of cataracts [27].

Also, CAGR for the abdomen/pelvis is considerable and it is one of the most effective examinations to increase the collective effective dose [28]. Since ultrasound is a safe and non-invasive procedure, the use of ultrasound instead of CT in abdominal imaging is cost-effective in addition to reducing the number of CT examinations, especially in children, which results in reduced radiation exposure [29]. As demonstrated in Table 3, spinal CT scans have a declining rate that may be due to increased access to MRI which was less common in past decades.

In CT scans, the effective dose of the head, abdomen, and chest scans is almost 7, 5.5, and 67.5 times higher, respectively, compared to conventional radiography [25]. Repetition of the CTs leads to an increase in the cumulative dose and thus increases the risk of malignancy [30]. It has been reported that repeating the scan up to three or more would increase the hazard risk by about five times [31]. The reported information from Figure 1 shows that the adolescents (age range of 13-18) had the highest likelihood of undergoing CTs. This may be because people at this age are more prone to represent risky behaviors that include those leading to skull damage. As can be seen, head/neck examinations have the highest rate of use among all children's age groups. Some studies have shown that CT scans especially in childhood increase the risk of developing Central Nervous System (CNS) tumors [31,32]. In addition, it has been reported that

an infant is ten times more likely to get malignancy per head CT scan than middle-aged adults [30]. It is also worth mentioning to know that radiation doses from head CTs for children are linearly related to their age [33]. In general, the effects of ionizing radiation are considered stochastic effects, however, the higher radiation risks in the pediatric group may be due to the higher life span and the long latent period of cancers which increase the chance of cancer occurring in them [17].

Abdominal pain is one of the most common causes of referral to medical centers which may be due to various causes, including the occurrence of appendicitis. Tsze and colleagues showed that CT utilization for abdominal pain had increased from 0% to 53% from 1996 to 2006 while the diagnosis of appendicitis in children has not seen any significant increase in this period [34]. Protocols have been developed to reduce the exposure of children to CT-induced abdominal radiation, one of which is a system of scoring for acute appendicitis called Alvarado score, although CT is the gold standard for diagnosing appendicitis [35,36]. In a study, Brenner *et al.* estimated that one in every 550 abdomen/pelvis scans can cause death from cancer [37]. If the abdominal CT scan protocols are set correctly, the effective dose will be reduced almost fourfold [13]. Generally, radiologists have the task of adjusting the protocols according to the age and size of the patient. Naturally, the diagnostic radiation needed for children is less than that of adults.

Finally, each scan must be evaluated by radiologists and emergency physicians in terms of justification and optimization before being performed. So the knowledge about ionizing radiation and its risks of exposure have to be increased.

5. Conclusion

The number of CT examinations is increasing in Yazd Province and is exceeding population growth. Some of this increase may be warranted considering the improvements in the diagnostic power of CTs. From this study, it is evident that this growth rate is significant for 0 to 30-year-olds. The estimated number of pediatric CT scans is much higher than in the past. Strategies must be adopted to achieve the goal of reducing execs exposures such as: performing CT scans only when necessary; education, which might be the most effective way to reduce the number of CT scans to a clinically acceptable minimum.

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