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Patterns and trends of pediatric and young adult computed tomography use in Brazil: 2008-2014

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ABSTRACT

Computed tomography (CT) is an indispensable imaging technique, but radiation exposure from CT scans is of concern mainly due to the potential risk of developing cancer, mainly in children. Our group recently showed that CT use has greatly increased among outpatients using the Brazilian public health system (SUS) between 2001 and 2011. Further, CT examinations among patients younger than 20 years of age represented around 13.4% of all CT examinations in SUS between 2008 and 2011. In comparison, these examinations represented around 8% of the overall number of CT scans in a private hospital in Rio de Janeiro between 2005 and 2015. In this paper we extended the evaluation of pediatric and young adult CT use in Brazil to 25 private CT services in 8 Brazilian cities for the period 2008-2014. Data from SUS was updated to this period. Information about CT use in SUS was obtained from an online database. Data on the privately funded setting was retrieved from the Radiological Information Systems (RIS) of each CT service. Patients younger than 20 years of age underwent around 8.9% of the CT procedures in the private setting, while in SUS this proportion was around 12.7% in the same period. Pediatric and young adult CT greatly increased in both healthcare systems, but annual growth rates were less pronounced in the private than in the public healthcare system. One third of the patients in the private setting had more than one CT examination over the period investigated.

Keywords: **Computed tomography, pediatric, Brazil, ionizing radiation, SUS**

1. INTRODUCTION

The benefits of computed tomography (CT) imaging to diagnosis and management of a number of diseases are well known [1]. However, there are concerns about the potential risk of developing cancer following radiation exposure from CT scans [2-5]. Actually, epidemiological studies using empirical data have reported increased cancer risk following CT scans in childhood or adolescence [6-10].

Cancer risk following radiation exposure depends on the patient age, gender, and organ/tissue radiation absorbed doses [11, 12]. A number of studies have assessed pediatric CT patterns, trends and doses in many parts of the world [5, 13-22], but information is very limited in less resourced countries [23-26].

We have previously shown [27] that pediatric and young adult examinations (<20 years) represented around 13% of the more than 8 million CT procedures underwent by outpatients of SUS

- the public healthcare system of Brazil [28] - between 2008 and 2011, when CT usage increased by 13% per year. Another study [29], focused on CT procedures in a single private general hospital in the city of Rio de Janeiro, reported that patients below 20 years of age underwent around 8% of all CT examinations performed between 2005 and 2015, with an annual increasing rate of 10%.

Although about 75% of the Brazilian population depends on the public healthcare system, most of CT machines in Brazil were in the private setting (around 54% of 2,049 existing CT machines) [27]. Therefore, differences in CT usage between the public and private healthcare system in Brazil might occur and should be evaluated.

The observed high proportion and the rapid increase of pediatric CT usage in the public healthcare system deserve attention and reinforce the need to evaluate in detail the CT use among children and young adults in the private setting in Brazil. The aim of this study was to extend our previous evaluation of pediatric CT usage in the public healthcare system to include 25 private CT services in 8 Brazilian cities from 2008 to 2014. For comparison, we also updated data on CT usage from SUS to the same study period.

2. MATERIALS AND METHODS

As previously described [27], data on CT use among outpatients using SUS were retrieved from an online database of the Information Technology Department of SUS (DATASUS) [30]. For evaluation of CT examinations on the Brazilian privately funded healthcare system, data were obtained from a sample of private CT services. Several radiology services around the country were contacted to determine the availability of electronic data on CT examinations and their willingness to participate in the study. A total of 25 private CT services meeting these requirements were included in the study (hereafter referred to “private sample”), which includes: 15 general hospitals, 1 pediatric hospital and 9 outpatient diagnostic services. These CT services were located in 8 Brazilian cities: Rio de Janeiro (n=14), São Paulo (n=4), Duque de Caxias (n=2), Niterói (n=1), Volta Redonda (n=1), Brasília (n=1), Florianópolis (n=1), and Recife (n=1). Electronic information archived on the Radiological Information Systems (RIS), including patient numeric identification, dates of birth and of CT examination (or age at examination), gender, and type of CT procedure

were extracted for all CTs underwent between 2008 and 2014 in each CT service included in the study.

The patient's age at examination was categorized into groups <1, 1-4, 5-9, 10-14, 15-19, 20-39, 40-59 and >60. Body imaged region was sorted into five categories, as suggested in reference [19]: head/neck, abdomen/pelvis, chest, spine, and extremities. Examinations that did not fit in any of these categories were classified as "other" which included examinations of more than one part of the body and CT angiography. To ensure the confidentiality of the information, the patient identification number was used to identify multiple CT procedures for the same patient in a given CT service of the private sample over the study period.

This study evaluated temporal trend of CT use in the public and private healthcare systems. For the latter, we used a restricted sample which included only CT services with regular number of CT examinations for all years of the study period. This "restricted" private sample included 8 CT services (4 general hospitals and 4 outpatient diagnostic units) from 3 Brazilian cities for the period 2008-2014. Compound annual growth rate (CAGR) was then calculated by using the equation (1), where N_{t_0} and N_{t_1} were respectively the number of procedures in the first and in the last year of each time period, and t_0 and t_1 were respectively the first and the last year of the corresponding time period.

$$\mathrm{CAGR}\,(t_0, t_1) = \left[\left(N_{t_1}/N_{t_0}\right)^{1/(t_1 - t_0)}\right] - 1 \qquad (1)$$

3. RESULTS

Table 1 shows the age distribution of CT examinations on outpatients of the SUS and the private sample, between 2008 and 2014. About 17.8 and 1.5 million CT examinations were retrieved from SUS and the private setting, respectively. The proportion of CT examinations in children and young adults (less than 20 years of age) was 12.7% in SUS and 8.9% the private sample, with the youngest group of patients (infants aged less than 1 year) having 1.0% of the CT examinations in SUS, while patients of this age group underwent only 0.5% of the examinations in the private sample.

Table 1: Age distribution of CT examinations among SUS outpatients or patients using a sample of private CT services in Brazil (2008-2014).

Age	Number of CT examinations (%)	
	SUS	Private sample
<1	178,828 (1.0)	6,775 (0.5)
1-4	348,833 (2.0)	27,414 (1.8)
5-9	439,526 (2.5)	25,014 (1.7)
10-14	548,054 (3.1)	26,091 (1.7)
15-19	724,579 (4.1)	47,944 (3.2)
20-39	4,093,871 (22.9)	392,524 (26.1)
40-59	6,127,319 (34.3)	438,644 (29.1)
>60	5,390,453 (30.2)	540,228 (35.9)
All ages[a]	17,852,434 (100.0)	1,504,792 (100.0)

[a] There were 971 and 158 CT scans with missing age in SUS and the private sample, respectively

Table 2 shows the distribution of CT examinations among patients younger than 20 years of age by scanned body part and age at examination, for SUS and the private sample between 2008 and 2014. Head/neck CT was the main type of examination for all pediatric and young adult age groups, with higher proportion of head/neck CT in SUS (72.6%) than in the private sample (63.1%). In general, the proportion of head/neck CT procedures tended to decline with increasing age in both SUS and private sample, while proportions of abdomen/pelvis CT examinations tended to increase with increasing age at examination for both settings.

Temporal trends on pediatric and young adult CT examinations for SUS and the restricted private sample settings for 2008-2014 are shown in Table 3. The overall annual number of CT examinations increased in both SUS and the private funded healthcare system between 2008 and 2014, but the annual growth rate was greater in the public than in the private setting (10.8% and 6.8% per year, respectively). CT use increased for all age groups in SUS and privately funded CT services, with a greater growth rate in the public than in the private setting for most age groups, except for younger age groups (<1 and 1-4 years old) for which growth rates were greater in the private (13.1% and 10.3%, respectively) than in the public setting (7.6% and 8.9%, respectively).

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Table 2: Number (N) and proportion (%) of CT examinations among patients younger than 20 years of age in the Brazilian public healthcare system (SUS) or in a sample of privately funded CT services, by imaged body part and age at examination (2008-2014).

Imaged body part		Age at examination											
		<1		1-4		5-9		10-14		15-19		All	
Head/neck	SUS	136,975	(76.6)	284,585	(81.6)	342,606	(77.9)	396,343	(72.3)	465,499	(64.2)	1,626,008	(72.6)
	Private sample	5,850	(86.3)	22,228	(81.1)	17,996	(71.9)	15,667	(60.0)	22,397	(46.7)	84,138	(63.1)
Abdomen/pelvis	SUS	17,955	(10.0)	28,849	(8.3)	47,432	(10.8)	69,138	(12.6)	129,457	(17.9)	292,831	(13.1)
	Private sample	293	(4.3)	2,196	(8.0)	4,054	(16.2)	5,906	(22.6)	17,991	(37.5)	30,440	(22.8)
Spine	SUS	10,230	(5.7)	10,018	(2.9)	15,287	(3.5)	25,346	(4.6)	53,722	(7.4)	114,603	(5.1)
	Private sample	149	(2.2)	961	(3.5)	1,203	(4.8)	1,637	(6.3)	2,473	(5.2)	6,423	(4.8)
Chest	SUS	11,560	(6.5)	20,628	(5.9)	23,300	(5.3)	32,638	(6.0)	50,721	(7.0)	138,847	(6.2)
	Private sample	382	(5.6)	1,717	(6.3)	1,013	(4.0)	1,118	(4.3)	3,013	(6.3)	7,243	(5.4)
Extremities	SUS	2,108	(1.2)	4,753	(1.4)	10,901	(2.5)	24,589	(4.5)	25,180	(3.5)	67,531	(3.0)
	Private sample	16	(0.2)	203	(0.7)	646	(2.6)	1,588	(6.1)	1,543	(3.2)	3,996	(3.0)
Other	SUS	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	Private sample	85	(1.3)	109	(0.4)	100	(0.4)	173	(0.7)	524	(1.1)	991	(0.7)
All[a]	SUS	178,828	(100.0)	348,833	(100.0)	439,526	(100.0)	548,054	(100.0)	724,579	(100.0)	2,239,820	(100.0)

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Private sample	6,775	(100.0)	27,414	(100.0)	25,014	(100.0)	26,091	(100.0)	47,944	(100.0)	133,238	(100.0)

[a] There were 7 pediatric and young adult CT scans with missing imaged body part in the private sample

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Table 3: Annual growth rates (CAGR, %) of CT examinations among patients younger than 20 years of age in the Brazilian public healthcare system (SUS) or in a sample of privately funded CT services, by age at examination (2008-2014).

Age	Population	CAGR (%)
<1	SUS	7.6
	Private sample (restricted)	13.1
1-4	SUS	8.9
	Private sample (restricted)	10.3
5-9	SUS	7.3
	Private sample (restricted)	5.3
10-14	SUS	8.8
	Private sample (restricted)	3.8
15-19	SUS	16.4
	Private sample (restricted)	7.1
Total	SUS	10.8
	Private sample (restricted)	6.8

Figure 1 shows the proportion of multiple CT examinations among pediatric and young adult patients in the private sample of CT services. About 30% of the patients had more than one CT scan between 2008 and 2014 (20.2% having two examinations, 4.6% having 3 examinations, and 4.3% having 4 or more CT scans.) The number of CT examinations per patient increased with increasing age, from 16.2% of infants to 35.9% of the patients in the age group 15-19 years old receiving more than one CT examination in the period.

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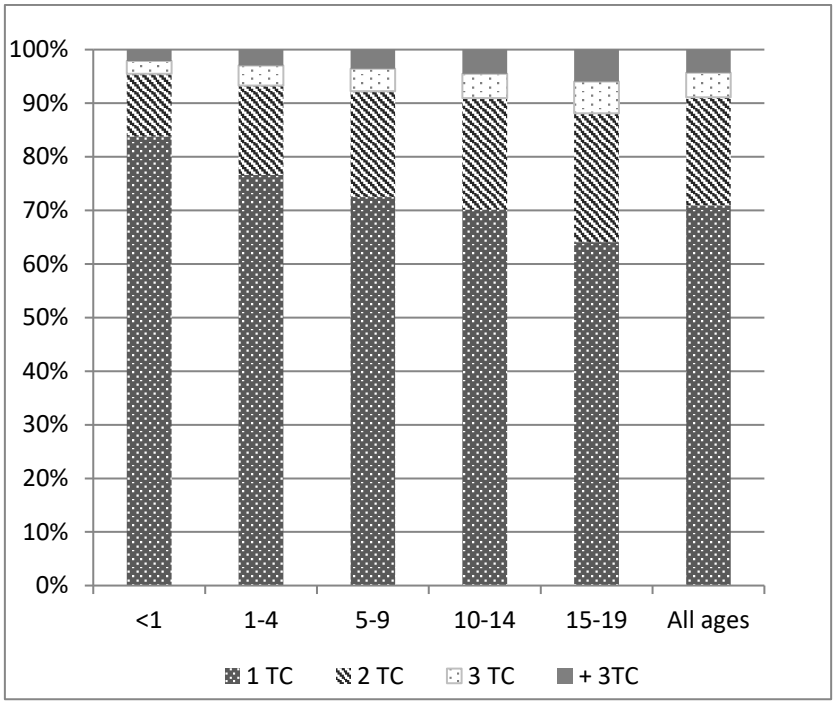
Figure 1: *Proportion of multiple CT examinations per patient among patients younger than 20 years of age using a sample of private CT services in Brazil, by age group (2008-2014).*



4. DISCUSSION

In the present study we evaluated CT patterns and trends of use among children and young adults in Brazil for the period 2008-2014. We showed that this group represented around 13% of the 17.8 million CT procedures underwent by outpatients in SUS between 2008 and 2014, and about 9% of the procedures in a sample of around 1.5 million CT examinations in privately funded CT services. Pediatric and young adult CT greatly increased in both healthcare systems over the study period, but annual growth rates were less pronounced in privately than in public funded healthcare system. Head/neck was the most frequently examined body part for all pediatric and young adult age groups in both healthcare systems, but the relative proportion of head/neck CT was greater in SUS than in the private setting, while the relative proportion of abdomen/pelvis scans was much higher in the private setting than in SUS. About one third of the patients younger than 20 years of age had more than one CT scan in the private setting over the study period.

The higher proportion of CT scans among young patients in Brazil than in many developed countries may be explained by differences in the age structures between developing and developed countries – with a higher proportion of older people in the latter [31]. Nevertheless, pediatric CT among SUS outpatients was still high even when age-standardized CT proportion was considered [27]. Differences in age structures between populations depending on SUS for healthcare or using the private setting may also explain the higher proportion of CT scans among patients younger than 20 years of age in SUS than in the private healthcare system. A higher proportion of older people is expected in the private setting, which is accessed mainly through health insurance coverage, that increases with age [32].

CT use in children and young people in Brazil increased both in public and privately funded healthcare systems between 2008 and 2014. Growth rates for all pediatric and young adult CT were higher in SUS (10.8% per year) than in the private setting (6.8% per year), but increase rate in the public healthcare system was higher than the average increase of 6.8% reported for less resourced countries between 2007 and 2009 [33]. However, a deceleration of the increasing rates of pediatric and young adult CT scans in SUS may be suggested since the annual growth rate of 10.8% reported for the study period of 2008-2014 were lower than growth rates reported by Dovales and colleagues for the period 2008-2011 (17.5%) for the same population [27]. Increasing CT trends in young people have also been reported in Great Britain [19], Australia [17], and the United States [5], but a more recent levelling or even reduction in CT use has been reported in some developing countries [5, 17, 18, 34]. It has been suggested that at least part of this decreasing trend may be a result of initiatives aiming to increase awareness about potential CT doses and risks, leading to efforts to reduce or avoid unnecessary CT exposure, mainly in children [35-37]. To our knowledge, no such attempts have been made in Brazil during the studied period. Indeed, the Image Gently campaign was introduced in Brazil only in 2018 [38]. Lack of data from previous periods impairs any conclusion about future trends of privately funded pediatric and young adult CT in Brazil.

As reported in other countries [13, 15, 19, 26], examinations of the head/neck both in SUS and the private sample represented the main type of CT procedure among children and young adults, with the proportion of head examinations tending to decrease with increasing age. The proportion of head/neck CT was higher in SUS than among patients using the private setting, while the opposite was observed for examinations of the abdomen/pelvis. It can be hypothesized that lower availability

of more modern imaging machines in the public setting, where financial resources are more limited [27, 28, 39-41], may difficult body scans, contributing to a higher proportion of head/neck scans. Accordingly, the proportion of pediatric head/neck CT in SUS (72.6%) was similar to the proportion in less resourced countries (72%) [26], but higher than those reported in developed countries (66% in Japan [13], 62% in Switzerland [15] and 60% in Great Britain [19]). Nevertheless, we can probably anticipate an increase in the proportion of scans of others part of the body among SUS outpatients in the following years. Abdomen/pelvis CT scans increased more than head/neck examinations (21.9% and 8.5% per year, respectively) among pediatric and young adult patients from SUS between 2008 and 2014 (results not shown), as reported previously for the period 2008-2011 [27].

CT is used not only for diagnostic purposes, but also to assess disease progress and/or the course of therapy [1]. Oncologic follow up, for instance, can account for around one third of all CT examinations in children [25]. Therefore, multiple examinations on the same patient over a time period are not uncommon. In this study almost one third of pediatric and young adult patients had more than one CT examination between 2008 and 2014, with about 4% having 4 or more CT scans. Similar proportions of multiple CT in young people were reported in Great Britain [19] and Israel [18], while a slightly lower proportion (22.9%) was observed in Japan [13]. However, the proportion of multiple CT examinations in this study may be an underestimation since only CT scans underwent in the CT services enrolled in this study were considered, excluding any examination done in other CT services. Although individual doses from CT scans are usually low, patients undergoing multiple CT scans can receive total radiation doses at levels for what increased risk for radiation-induced cataracts [42] and cancer [43] have been shown. The type of examination with higher proportion of more than one examination in the same patient over the study period was spine CT (60%, not shown), which delivers relatively high doses and has been reported as a frequently unjustified examination in young patients [44].

This was the first comprehensive report on the patterns and trends of both public and privately funded pediatric CT use in Brazil. However, our study has some limitations. First, data on privately funded pediatric CT were obtained from a sample of CT services, most of which were reference CT services, localized at developed cities, where health resources, including CT scanners, are more easily available [27, 28]. Thus, data for the private setting in this study may not be representative of

CT use in the whole country. This limitation was even sharper when we analyzed CT trends over time, since exclusion of CT services without data for the whole study period resulted in a more reduced sample. Other limitation is that analysis on CT use on SUS included only outpatients. However, CT scans underwent by inpatients in SUS were much less frequent and have a similar distribution pattern by type of examination [45].

5. CONCLUSION

CT use in children and young adults had increased between 2008 and 2014 both in public and private healthcare systems in Brazil. Nevertheless, annual growth rates were less pronounced in privately than in public funded healthcare system. Head/neck was the main type of CT examination in both settings and around one third of the patients in the private setting had more than one CT examination over the period investigated. Although CT examinations may improve life quality, avoiding more invasive and costly procedures for the detection, diagnosis and treatment of a variety of diseases and injuries, CT overuse and/or misuse, which increase health costs and may harm patient's health, might also be driving this increase, mainly in the private setting. Efforts to improve radiation protection in pediatric CT in Brazil should include dissemination of appropriateness criteria and education and training of referring physicians and radiologists. Initiatives to optimize pediatric CT protocols, as the establishment of reference levels and quality assurance programs are also needed.

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