



Patterns and trends in outpatient diagnostic imaging studies of the Brazilian public healthcare system, 2002–2014

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ABSTRACT

Objectives: The use of medical imaging examinations has been increasing in the developed world, mainly due to the increasing use of high-radiation dose procedures, such as computed tomography. Information on diagnostic imaging examination trend in developing countries is scarce. We evaluated the patterns and trends of diagnostic imaging among outpatients of the public healthcare system in Brazil for the period of 2002 to 2014.

Methods: We collected the annual number of diagnostic imaging procedures among SUS outpatients and the number of diagnostic imaging machines (in use in Brazil and available to SUS) from an on-line database managed by SUS. Usage rates of procedures among the SUS-dependent population were estimated using demographic data and the proportion of the population not covered by private health insurance.

Results: Diagnostic imaging usage increased dramatically in the Brazilian public healthcare system over the study period, mainly for computed tomography (CT) and magnetic resonance imaging (MRI), which increased by 12% and 19% per year, respectively. Usage rates for radiography, ultrasound, CT, MRI, nuclear medicine and fluoroscopy in 2014 were: 367, 103, 24, 6, 3 and 2 procedures per thousand SUS-dependent population, respectively. Increased usage rates were accompanied by increased availability of machines in SUS and/or increased number of procedures per machine.

Conclusions: The use of diagnostic imaging in SUS-Brazil greatly increased since 2002, but was still much lower than in developed countries, mainly for advanced imaging modalities. Nevertheless, the steep growth in CT use in Brazil raises concerns regarding its potential radiation-related risks, mainly among children.

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Introduction

Medical radiation exposure has increased, worldwide, over the last two decades. This is mainly attributed to an increased use of relatively high dose imaging modalities such as computed tomography (CT) [1–5]. Although this has contributed to improve health-care, allowing for earlier and more accurate diagnosis and follow up of a variety of diseases, it has also raised concerns about the radiation-related cancer risk [6–8].

The trends and patterns of distribution of examinations by imaging modality and imaged anatomical region differ significantly

among countries [1,2,4,5]. Literature review showed that there is no readily available published data information on diagnostic imaging examination trends in developing countries [1,2].

Brazil, a middle income-country with around 200 million inhabitants, is one of the five largest countries in the world [9,10]. In 2008, through a National Household Sample Survey, the Brazilian population self-reported their race as white (48%), multiracial (44%), black (7%) or indigenous (<1%) [11]. More than 80% of Brazilians live in urban areas, with an illiteracy rate of 8% among people older than 15 years. Nevertheless, Brazil is a country with widespread internal inequalities, in which the wealthiest 10% receive 40.4% of per head family income, while the poorest 20% receive 3.6% [10].

The Brazilian healthcare system is made up of both private and government funded subsystems. The public subsystem, the Unified

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Health System (Sistema Único de Saúde, SUS), is a free universal coverage system that is one of the largest healthcare providers in the world [9]. SUS plays an important role in Brazil, as about 75% of the Brazilian population depends only on SUS to receive any healthcare [9], although this percentage varies geographically.

We evaluated the patterns and trends of diagnostic imaging among outpatients of the public healthcare system in Brazil for the period of 2002 to 2014.

Methods

This retrospective database analysis used online data from the System of Health Information [12] of the Information Technology Department (DATASUS) of SUS, which gathers a number of databases with information on SUS health assistance, human and physical health resources in Brazil, and demographic and socio-economic data for the Brazilian population [12]. All data are secondary, anonymous and publicly available on the Internet.

Annual numbers of each type of SUS outpatient diagnostic imaging procedures performed in Brazil were collected for all ages and both sexes for the period of 2002 and 2014 (period with data available for use). Data from inpatients were not included as they were not available for the whole study period. Inpatients examinations represent roughly circa of 9% of all examinations performed in SUS, with CT and interventional radiology examinations representing a higher proportion (25% and 40%, respectively) [12]. Diagnostic imaging procedures were grouped into modalities (general radiography, fluoroscopy, dental radiology, mammography, bone densitometry, CT, nuclear medicine, magnetic resonance imaging – MRI, and ultrasound) and imaged body region (head, abdomen/pelvis, spine, chest and extremities). In a number of situations, grouping was done for other body parts (urinary tract, digestive tract, heart, thyroid, eyes and breast) or more specific types of examination (hysterosalpingography, arthrography, angiography, musculoskeletal, obstetric, and gynaecological).

We also collected the total number of diagnostic imaging machines in use in the country (from private, public and philanthropic institutions) and the number of machines available to SUS patients for 2002 and 2014. Diagnostic machines available to SUS include those located in public radiology services and those located in private and philanthropic institutions providing SUS assistance. Machines for fluoroscopy also include units for hemodynamic examinations.

Demographic data from the Brazilian Vital Statistics System, and the proportion of people with private health insurance coverage in Brazil from the National Agency of Supplementary Health were also gathered from the System of Health Information website [12].

The SUS-dependent population size was estimated by applying the proportion of the uninsured population to the overall population in Brazil for each year of the study. The number of examinations per million SUS-dependents was calculated using the annual number of SUS outpatient procedures and the respective SUS-dependent population. For mammography and breast, gynaecological and obstetric examinations by ultrasound we considered only the female population, since these procedures were undergone almost exclusively by women [13].

The number of machines in use per million people, and the number of machines available to SUS per million SUS-dependent population, were calculated using the respective number of machines and population figures, for each year.

Average compound annual growth rates (CAGR) were calculated using Eq. (1), below, where N_{t_0} and N_{t_1} represent the number of procedures in the first and in the last year of the time period, respectively, and t_0 and t_1 represent the first and the last year of the

corresponding time period, respectively.

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

Results

The SUS-dependent population underwent almost 900 million outpatient diagnostic imaging procedures between 2002 and 2014. General radiography was the most frequently performed examination, followed by ultrasound, mammography, dental X-rays, CT, and fluoroscopy (Table 1). Nuclear medicine, MRI and bone densitometry each represented less than 1.0% of the procedures. During the study period, there was an upward trend in the overall use of most types of diagnostic imaging, except for fluoroscopy (Table 1, Fig. 1). The greatest rise was for MRI, which increased almost eight-fold, followed by bone densitometry, CT and mammography (annual growth rates of 18.7%, 13.4%, 12.2% and 7.5%, respectively).

Table 2 shows the distribution of diagnostic procedures among SUS outpatients by imaged body part in 2002 and 2014. An increasing rate was seen for all forms of general radiography, except head/neck X-rays. Positive growth rates were also observed for CT and MRI of all body parts, especially abdominal/pelvic scans. Head scans were the most frequent CT examination, although the relative increase throughout the study period was lower than for other body parts. The increasing use of nuclear medicine for diagnostic purposes was mainly driven by cardiac scintigraphy and musculoskeletal examinations, while the use of scintigraphy for the examination of the thyroid was greatly reduced.

The availability of diagnostic imaging machines has increased over the study period for the whole Brazilian population and also for the SUS-dependent population for most modalities (Table 3). The greatest growth rate was observed for MRI scanners (14.2% per year), while the number of radiography, fluoroscopy and nuclear medicine units remained stable or slightly decreased. The number of procedures per machine available to SUS also increased over the study period for radiography, nuclear medicine, CT, MRI and bone densitometry, but it decreased for fluoroscopic, dental and ultrasound examinations, as well as for mammography.

Discussion

In this study, we have evaluated the patterns and trends of outpatient diagnostic imaging studies performed between 2002 and 2014 in SUS, the Brazilian public healthcare system. The number of examinations increased over this period for all modalities except fluoroscopy. There was an accentuated growth in the use of MRI (all body parts), CT (mainly abdomen/pelvis) and some types of ultrasound examinations (eyes, extremities, and thyroid). These patterns can partly be explained by the greater availability of imaging machines to SUS, along with an increase in the number of procedures per machine.

Growth rates for most diagnostic imaging modalities in SUS outpatients were similar to, or even higher than those reported for developed countries during similar periods. Comparison with other developing countries is hampered by the scarcity of data on the use of diagnostic imaging procedures in these countries. CT and MRI use in the United States increased by around 15% per year between 2000 and 2005, after which usage began to level off [3]. In patients enrolled in large integrated health care systems in the United States, CT and MRI examinations increased annually by 7.8% and 10%, respectively, between 1996 and 2010 [4]. In the same period, the growth rates for radiography (including breast imaging) and ultrasound were 1.2% and 3.9%, respectively, while the use of nuclear medicine decreased (–3% per year) [4]. Interestingly, while the growth in CT and MRI usage in the United States tended to level off or even decline around 2005–2010 [3,4], the

Table 1
Usage rate of selected diagnostic imaging procedures^a per 1000 SUS-dependent population^b, in 2002 and 2014.

Year	Imaging modality									
	Radiography	Fluoroscopy	Dental radiology	Mammography ^c	Bone densitometry	CT	Nuclear medicine	MRI	Ultrasound	
2002	N 227.9 (%) (67.2)	4.2 (1.2)	14.3 (4.2)	26.0 (7.7)	0.8 (0.2)	6.2 (1.8)	1.6 (0.5)	0.8 (0.2)	57.3 (16.9)	
2014	N 367.1 (%) (62.1)	2.0 (0.3)	19.7 (3.3)	61.9 (10.5)	3.6 (0.6)	24.5 (4.1)	2.9 (0.5)	6.2 (0.1)	103.0 (17.4)	
CAGR ^d	% +4.1	-6.1	+2.7	+7.5	+13.4	+12.2	+4.8	+18.7	+5.0	

Abbreviations: CT – computed tomography, MRI – magnetic resonance imaging.

^a Other diagnostic imaging modalities, such as PET-CT, angio-CT, angio-MRI and others, were not listed in DATASUS databases.

^b SUS dependent population is the proportion of the Brazilian population that is not covered by private health insurance (82% in 2002 and 74% in 2014).

^c Mammography rates were calculated only among women.

^d CAGR: Compound Annual Growth Rate as described in the methods section.

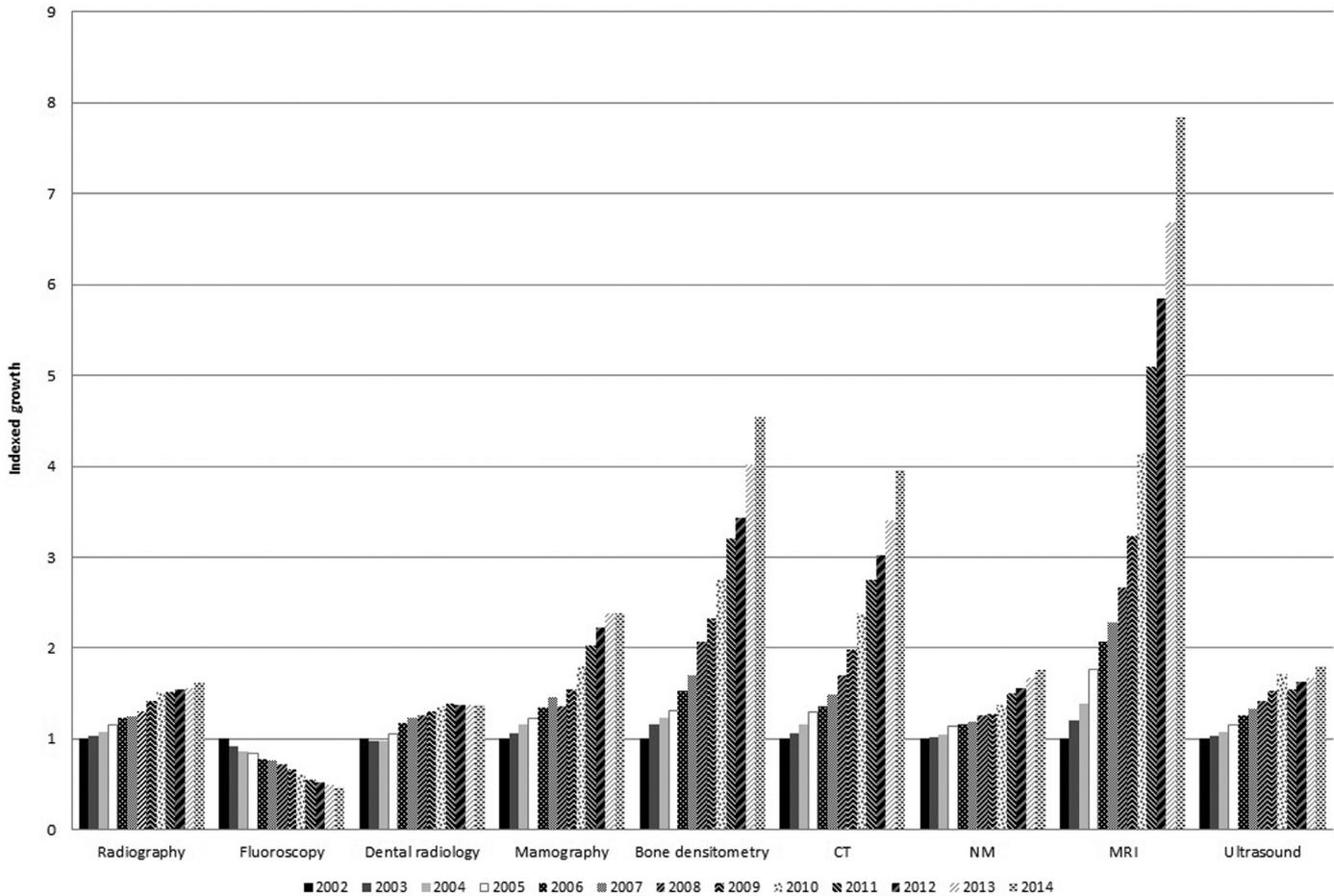


Fig. 1. Indexed growth rate of diagnostic imaging procedures per 1000 SUS-dependent population. Indexed growth rate was calculated for each modality as the quotient between the usage rate for a given year relative to the usage rate in 2002. SUS dependent population is the proportion of the Brazilian population that is not covered by any private health insurance. Mammography rates were calculated among women. CT: computed tomography, MRI: magnetic resonance imaging.

use of these imaging modalities seemed to remain on an upward trend in Brazil. Also, the rise in the use of diagnostic imaging was higher in Brazil than in England, where between 2000–2001 and 2012–2013, the annual growth rates for MRI, CT, radiography, ultrasound and nuclear medicine were around 12%, 10%, 1%, 5% and 1%, respectively [5]. In contrast, the drop in fluoroscopy use was steeper among SUS outpatients in Brazil (–6.1% per year) than in the United States (–1.3% per year) [4], while its use in England remained relatively stable over time (0.4% per year) [5].

Nevertheless, despite the great increase in the usage of diagnostic medical imaging in the Brazilian public healthcare system over the last decade, the absolute number of diagnostic imaging procedures per thousand population was still low, compared to

developed countries, such as United States and England (Table 4) [4,5,14]. Differences were more striking for CT, MRI, nuclear medicine and fluoroscopy, for which usage rates in the United States and England were much higher than the corresponding figures in SUS outpatients in Brazil.

Many of the changes observed in the pattern of diagnostic imaging can be explained by changes in the modality chosen for the diagnosis of a number of pathologies. These include the replacement of general radiography for head imaging by CT and MRI [15,16], the use of CT and ultrasound for imaging of kidney stones [16], the introduction of faster MRI scan times allowing imaging of the chest and abdomen [17], the replacement of barium enemas by CT colonography, and improved Doppler ultrasound

Table 2Usage rates of diagnostic imaging procedures per 1000 SUS dependent population^a, by imaged body region, in 2002 and 2014.

Examination	2002		2014		CAGR ^c %
	N	(%)	N	(%)	
Radiography	227.9	(100.0)	367.1	(100.0)	+4.1
Chest	76.1	(33.4)	119.0	(32.4)	+3.8
Extremities	59.6	(26.1)	114.5	(31.2)	+5.6
Head/neck	34.3	(15.1)	33.9	(9.2)	-0.1
Spine	25.6	(11.2)	41.7	(11.4)	+4.1
Abdomen/pelvis	13.8	(6.1)	24.3	(6.6)	+4.8
Other	18.4	(8.1)	33.9	(9.2)	+5.2
Fluoroscopy	4.2	(100.0)	2.0	(100.0)	-6.1
Digestive tract	1.9	(45.5)	0.8	(42.8)	-6.6
Urinary tract	1.7	(40.8)	0.6	(30.5)	-8.4
Angiography	0.3	(6.8)	0.4	(19.1)	+2.4
Histerosalpingography	0.2	(4.4)	0.1	(5.8)	-4.0
Artrography	0.0	(1.1)	0.0	(0.5)	-12.0
Other	0.1	(1.4)	0.0	(1.3)	-7.0
CT	6.2	(100.0)	24.5	(100.0)	+12.2
Head/neck	3.7	(59.7)	10.3	(42.3)	+9.0
Spine	0.9	(13.9)	2.9	(11.8)	+10.6
Abdomen/pelvis	0.9	(14.2)	7.4	(30.1)	+19.4
Chest	0.6	(9.9)	3.2	(13.1)	+14.8
Extremities	0.1	(2.3)	0.7	(2.7)	+13.9
Nuclear medicine	1.6	(100.0)	2.9	(100.0)	+4.8
Heart	0.6	(36.8)	1.6	(56.2)	+8.5
Musculoskeletal	0.5	(31.0)	0.8	(28.6)	+4.1
Urinary tract	0.2	(14.0)	0.2	(8.3)	+0.3
Thyroid	0.2	(9.6)	0.1	(3.1)	-4.5
Other	0.1	(8.5)	0.1	(3.8)	-2.0
MRI	0.8	(100.0)	6.2	(100.0)	+18.7
Spine	0.3	(34.6)	2.3	(36.5)	+19.3
Head	0.3	(37.3)	1.6	(25.3)	+15.0
Extremities	0.2	(20.6)	1.6	(25.5)	+20.9
Abdomen/pelvis	0.0	(6.1)	0.7	(11.3)	+25.0
Chest	0.0	(1.5)	0.1	(1.4)	+18.3
Ultrasound	21.7	(100.0)	58.7	(100.0)	+8.6
Abdomen/pelvis	13.0	(59.7)	24.2	(41.2)	+5.3
Extremities	0.9	(4.2)	12.8	(21.9)	+24.6
Heart	4.2	(19.4)	8.5	(14.5)	+6.1
Thyroid	0.8	(3.5)	3.1	(5.3)	+12.5
Eyes	0.4	(1.8)	5.7	(9.6)	+24.8
Other	2.5	(11.3)	4.4	(7.4)	+4.9
Obstetric, gynaecological and breast ultrasound^b	71.8	(100.0)	88.6	(100.0)	+1.8
Obstetric	26.9	(37.4)	28.7	(32.3)	+0.5
Gynaecological (pelvic)	24.9	(34.7)	6.8	(7.7)	-10.3
Gynaecological (transvaginal)	13.4	(18.7)	37.5	(42.3)	+9.0
Breast	6.6	(9.3)	15.7	(17.7)	+7.4

Abbreviations: CT-computed tomography, MRI-magnetic resonance imaging.

^a SUS dependent population is the proportion of the Brazilian population that is not covered by private health insurance (82% in 2002 and 74% in 2014).^b Rates were calculated among SUS-dependent women.^c CAGR: Compound Annual Growth Rate as described in the methods section.

capabilities for vascular imaging [18,19]. Ultrasound has become the preferred modality for investigating thyroid nodules and for fine needle aspiration cytology guidance [16], which may explain the apparent shift from nuclear medicine to ultrasound for thyroid imaging. Indeed, the pattern of increasing thyroid cancer incidence in Brazil [20,21] might be partially explained by a diagnostic effect caused by the increased use of thyroid ultrasound and fine needle biopsy. Obstetric ultrasound use remained relatively stable over the study period, which was unsurprising since birth rates decreased in Brazil between 2002 and 2014 (19.7 and 14.5 per 1000, respectively) [22].

A number of other factors may have contributed to the changing patterns of diagnostic imaging use among SUS outpatients, including changing demographic and socio-economic status, better access to health care, higher demand for examinations by patients and physicians, and financial incentives for selected tests [3,4]. The relatively low availability of machines to the Brazilian public health system, as opposed to private healthcare, may explain the relatively low use of diagnostic imaging in SUS. Funding for the

SUS comes mostly from tax revenues and social contributions from the federal, state, and municipal budgets. Nevertheless, it has not been enough to ensure adequate or stable financial resources for the public system implying in poor quality services which has a great impact on sustainability of the free coverage health service. The number of all CT scanners in use per million people in Brazil in 2014 (17.6) was comparable to figures estimated by the OECD [23] for some developed countries in 2014 (17.1 for New Zealand, 16.7 for Ireland and 17.6 for Spain), and even higher than for others countries (9.5 for the United Kingdom and 13.4 for the Netherlands) [23]. Nevertheless, only about 61% of these machines were available to SUS. The scenario was similar for MRI, for which the number of all machines per million people in Brazil in 2014 (8.4) was close to the number in the United Kingdom (7.2) [23]. However, only about half of the MRI scanners in use in Brazil were available to SUS in 2014.

Accordingly, the increasing number of imaging procedures in the SUS-dependent population was accompanied by increased availability of the respective machines and/or higher rates of

Table 3

Rates of diagnostic imaging machines per million Brazilian population^a, machines available to SUS per million population dependent on SUS^b, and rates of procedures per machine available to SUS, by imaging modality in 2002 and 2014.

Year	Imaging modality										
		Radiography	Fluoroscopy	Dental radiology	Mammography	Bone densitometry	CT	Nuclear Medicine	MRI	Ultrasound	
Machines/million people ^a											
2002	N	92.3	9.0	38.0	27.8	5.2	9.1	3.8	2.4	66.5	
2014	N	108.0	10.8	215.2	48.7	9.5	17.6	4.4	8.4	151.8	
	CAGR ^c	%	+1.3	+1.5	+15.6	+4.8	+5.1	+1.2	+10.9	+7.1	
Machines available to SUS/million SUS dependent population ^b											
2002	N	62.2	5.7	17.3	11.9	1.3	4.8	2.3	0.9	28.9	
2014	N	63.6	5.6	43.9	30.5	4.1	10.8	2.2	4.2	72.8	
	CAGR ^c	%	+0.2	-0.1	+8.1	+8.2	+9.9	+7.0	-0.3	+14.2	+8.0
Procedures per machine available to SUS											
2002	N	3662	729	827	2193	612	1292	714	911	1984	
2014	N	5773	346	449	2025	891	2266	1304	1458	1415	
	CAGR ^c	%	+3.9	-6.0	-5.0	-0.7	+3.2	+4.8	+5.2	+4.0	-2.8

Abbreviations: CT – computed tomography, MRI – magnetic resonance imaging.

^a The rate of machines per million Brazilian population was calculated considering the number of diagnostic machine in use for each imaging modality and the respective Brazilian population for each year.

^b The rate of machines available to SUS per million dependent on SUS was calculated considering the number of diagnostic machines for each imaging modality available to SUS and the SUS dependent population in each year (82% in 2002 and 74% in 2014). For mammography only the female population was considered.

^c CAGR: Compound Annual Growth Rate as described in the methods section.

Table 4

Usage rates of diagnostic imaging examinations per thousand population in Brazil, the United States and England.

Procedures	Number of examinations/1000		
	Brazil, 2008 ^a	USA, 2008 ^b	England, 2008 ^c
Radiography	297	783	414
Ultrasound	82	271	149
Nuclear medicine	2	53	12
Angiography/fluoroscopy	3	64	25
Computed tomography	11	177	65
Magnetic resonance imaging	2	72	34

^a This study – rounded values for usage rates per thousand SUS-dependent population.

^b Data are from reference 4. Usage rates were standardized by sex and age. Radiography also includes mammography.

^c Data are from references 5 and 14. Usage rates were estimated by dividing the annual number of examinations by the resident population for the same year.

examinations per machine. For CT, the number of scanners per million dependent on SUS increased 2.3-fold between 2002 and 2014 and was accompanied by a 1.8-fold increase in the number of procedures per scanner. The availability to SUS and the rate of examinations per machine also greatly increased over the study period for MRI (4.9- and 1.6-fold, respectively). The number of procedures per CT or MRI scanner in SUS was lower than in many developed countries, however. While in the United Kingdom and the United States in 2011 there were 8708 and 6694 exams per CT scanner, respectively, and 7017 and 3260 examinations per MRI unit [23], respectively, the number of exams per machine available to SUS was only 2266 and 1458 exams per CT or MRI scanner, respectively, in 2014. Although we are unable to identify manufacturers and models of imaging machines or imaging protocols used in SUS, it is possible that more modern machines and techniques were introduced later in Brazil. This may also have contributed to the relatively low numbers of CT and MRI examinations per machine in SUS. Conversely, the increase in the number of radiographic and nuclear medicine examinations in SUS outpatients over time was due to the increasing number of procedures per machine rather than by the rise in the number of machines available to SUS, since the number of both X-ray generators and gamma cameras for nuclear medicine was almost unchanged over the study. Potential reasons for this include the introduction of digital detectors

in general radiography, and dual-headed gamma cameras in nuclear medicine, both of which are associated with reduced imaging times [24].

Although the number of ultrasound machines available to SUS, per million dependents, more than doubled over the study period, the number of ultrasound examinations per machine dropped by a factor of 0.7. Ultrasonography is a highly skilled imaging technique, requiring extensive training. Therefore, it may be suggested that at least part of this decrease was a result of the increasing availability of ultrasound units without a corresponding growth in the number of machine operators.

Demographic changes over the study period may have also contributed to the increasing rates of diagnostic imaging use among SUS outpatients, as usage of diagnostic imaging tends to increase with age [4,25]. The Brazilian population is aging rapidly as shown by the fall in birth rate (19.7 to 14.5 births per 1000 inhabitants in 2002 and 2014, respectively), and the increased life expectancy at birth (70.7 to 75.1 years in the same period) [22]. Also, many economic and human development indicators have improved over recent decades in Brazil, including a decrease in the Gini coefficient for income concentration and increasing gross domestic product per head and adult literacy [26]. Importantly, access to healthcare has increased, but is still very unequal and lags behind that in developed countries [26]. These improvements were accompanied by a shift in the main health problems of the Brazilian population. While infectious diseases and injuries related to violence were still an important health problem, there were decreases in the rates of chronic non-communicable diseases, mainly cardiovascular and chronic respiratory diseases. Conversely, hypertension, obesity and diabetes have all risen [26–29]. All these changes may have affected the patterns and trends of diagnostic examinations in SUS.

We hypothesize that the increasing use of advanced diagnostic imaging such as MRI and CT in Brazil might be associated with better medical care. However, it raises some concerns regarding the increasing cost of healthcare services and, for CT, increased ionizing radiation exposure. There are reports of misuse and overuse of imaging procedures [30–32], and it is uncertain to what extent the rise in diagnostic imaging usage over the last decade has contributed to improved health status [33]. MRI and CT were the most rapidly growing of all medical services in the North-American Medicare population between 2000 and 2006, and had a significant impact on the increasing cost of health-

care [3,34,35]. Additionally, there is direct epidemiological evidence linking CT scans in childhood to subsequent increased cancer risk [7,8]. This is particularly important considering a recent publication which reported a relatively high proportion of CT procedures in children and young adults among SUS outpatients in Brazil (about 13%) [36]. It has been also reported an inappropriate use of mammography examinations among SUS patients in Brazil, where screening rates were lower than recommended in target age groups and both screening and diagnostic mammograms were recorded for women younger than usually [37].

The use of diagnostic imaging in Brazil is regulated by health authorities, both at national and local levels. All nuclear medicine examinations throughout the country are also under the control of the National Nuclear Energy Commission (CNEN), which however does not regulate the use of X-rays. The regulatory framework is generally in line with international recommendations, including the requirements for quality control and quality assurance procedures established by the International Atomic Energy Agency (IAEA) [38]. In developed countries, radiation concerns have led to initiatives aiming to increase awareness about potential CT doses and risks, such as the Image Wisely [39] and Image Gently [40] campaigns of the American College of Radiologists. These campaigns concentrated efforts to avoid inappropriate use and to promote the most efficient and cost-effective use of diagnostic imaging services. This includes the development of guidelines and appropriateness criteria [16,41], and the introduction of constraints to the payment of advanced imaging studies. As a result, there has been a reduction in the usage of advanced imaging in the United States [3,4,42]. Only very recently such campaigns were introduced in Brazil [43]. The use of newer and more expensive technologies, such as CT and MRI, greatly increased in SUS, without a corresponding decrease in use of older and cheaper modalities, which would be expected when new imaging technologies are introduced [35,44]. Noteworthy, we do not have information on the quality of diagnostic imaging equipment in SUS and therefore we were not able to evaluate imaging quality over time.

Strengths of our study include using data from a public health care system, which covers about 75% of Brazilian population and is one of the largest public healthcare systems in the world. We used information from a complete and comprehensive automated information system (DATASUS), which is of relatively good quality [45]. Furthermore, this is the first study, to our knowledge, to document the patterns of diagnostic imaging over time and across different modalities in a developing country, from where information is scarce. Limitations of our study include the restriction of data only to outpatients of the public healthcare system, which may be not representative of the patterns and trends for all Brazil. In particular, diagnostic imaging usage may greatly differ among outpatients from the private setting, as financial incentives and greater expenditures *per capita* might encourage increasing imaging in the latter [35]. Also, more recent data could not be used as they were still under revision. Another limitation to be considered, was the poor comparison of the trend and pattern of diagnostic imaging observed the Brazilian Public Health system with other developing countries, mostly due to the scarcity of data in developing countries.

In conclusion, this is the first study to present extensive data on the patterns and trends of diagnostic imaging usage in Brazil. The use of diagnostic imaging increased dramatically in Brazil over the study period, mainly for those modalities associated with high costs or high radiation doses (i.e. MRI and CT, respectively). Although several factors might have contributed to this increase, including wider availability of these modalities to the public health care system, overuse of some procedures cannot be ruled out. The increasing use of CT in Brazil raises concerns regarding the potential radiation-related risks due to the relatively high radiation

dose delivered by this examination [6–8]. A proper assessment of the corresponding benefits is required in order to develop imaging guidelines in Brazil. This is particularly important in developing countries where population ageing is taking place, increasing the demand for medical services in a set of limited healthcare resources.

Author statements

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Competing interests

None declared.

Ethical approval

Not required.

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