

Technical, social, and economic characteristics of mammography screening in Goiás: ecological study after the implementation of a mammography quality control program

Rosângela da Silveira Corrêa¹ , Ruffo Freitas-Junior¹ , Danielle Cristina Netto Rodrigues¹ ,
João Emílio Peixoto² , Suzana Alves Bastos³ , Rodrigo Massakatsu Nishiharu Tanaka⁴ ,
Lucy Aparecida Parreira Marins⁴ , Leonardo Ribeiro Soares¹ 

ABSTRACT

Objective: The aim of this study was to evaluate technical, social, and economic aspects characterizing opportunistic breast cancer screening in a state in central Brazil. **Methods:** A survey was conducted to quantify the number of mammography machines and evaluate the imaging technology, the geographical distribution of the scanners, the number of mammograms performed at each center, the cost of the exams, and sources of payment. Data from this study were compared with data from a similar study conducted in 2008. **Results:** In Goiás, 164 mammography units were operational, with 66 (40%) serving the Sistema Único de Saúde (SUS). Approximately 400,896 scans were performed in 2019, averaging 204 scans/month (ranging from 5 to 1,000), at a cost of R\$ 41,931,120.00. Screening coverage was 31.2%, with 6.4% of these scans being performed within the SUS. No correlation was found between the municipal Human Development Index (HDI) and mammography coverage in the health regions (HRs) ($p=0.10$). Compared with the 2008 results, the percentage of computed radiography systems increased from 24.3% to 86.7%, and digital radiography was introduced (7.3%). **Conclusion:** In 2019, breast cancer screening coverage in Goiás reached 31.1%, with 6.4% of scans being conducted within the SUS. The geographic distribution of mammography units is heterogeneous, and productivity is low. Compared to 2008, availability increased, and the standard of the equipment improved.

KEYWORDS: breast neoplasms; early diagnosis; mass screening; mammography; delivery of health care.

INTRODUCTION

Breast cancer screening involves the systematic application of a screening test in an asymptomatic population in order to detect and treat cancer at a preclinical stage¹. Mammography is the only detection method capable of impacting mortality, as shown by the results of randomized clinical trials that reported a 16–36% reduction in the relative risk of death from breast cancer^{2,3}. In recent decades, this strategy has contributed toward an

improvement in breast cancer-related oncologic outcomes, both in developed and in developing countries^{4,5}.

The principal benefits associated with mass screening for breast cancer are directly related to the length of time during which the screening programs are offered and to how compliant the target population is with the recommendations provided¹. As seen in other countries of continental dimensions and/or with large populations, the solution adopted in Brazil was to

¹Universidade Federal de Goiás, Teaching Hospital, Centro Avançado de Diagnóstico da Mama – Goiânia (GO), Brazil.

²Ministério da Saúde, Instituto Nacional de Câncer, Departamento de Serviço de Controle de Qualidade e Radiações Ionizantes – Rio de Janeiro (RJ), Brazil.

³Secretaria Municipal de Saúde de Goiânia, Diretoria de Vigilância Sanitária e Ambiental, Coordenação de Fiscalização de Estabelecimentos Assistenciais de Saúde – Goiânia (GO), Brazil.

⁴Superintendência de Vigilância Sanitária, Ambiental e Saúde do Trabalhador, Gerência de Vigilância Sanitária, Coordenação de Programas Especiais em Serviços de Saúde – Goiânia (GO), Brazil.

*Corresponding author: rosilveiracorreia@gmail.com

Conflict of interests: nothing to declare. **Funding:** Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG), por meio da Chamada Pública nº 04/2017 — Programa Pesquisa para o SUS: Gestão Compartilhada em Saúde — FAPEG/SES-GO/CNPq/MS-DECIT/2017; Secretaria Municipal de Saúde de Goiânia e Superintendência de Vigilância em Saúde da Secretaria de Saúde de Goiás.

Received on: 07/16/2025. **Accepted on:** 08/15/2025.

implement an opportunistic screening program; however, controversies persist regarding the targeted age group and the frequency at which screening should be performed.

The Brazilian Society of Mastology (SBM), the Brazilian College of Radiology, and the Brazilian Federation of Gynecology and Obstetrics Associations recommend annual breast screening beginning at 40 years of age⁶. However, the Ministry of Health, through the National Cancer Institute, limits screening to biennial examinations and focuses solely on the 50- to 69-year age group⁷. Despite this discrepancy, Brazil's public healthcare system (Sistema Único de Saúde [SUS]), on which around 70% of the population depends, authorizes screening mammograms for individuals aged 40 years and above⁸.

Brazil is divided into 26 states and a federal district. In the process of regionalization and hierarchy, each state, including the federal district, has a planning director who determines the provision of healthcare within health regions (HRs)⁹⁻¹¹. Nevertheless, significant geographical variations in breast cancer screening coverage and other epidemiological indicators of interest have been identified^{12,13}. Therefore, it is important to evaluate the cost-effectiveness of breast cancer screening programs throughout the country, including analyzing the number of available machines, their geographical distribution, and their productivity, as well as the quality and interpretation of the exams.

In view of Brazil's continental dimensions, access to healthcare services within the National Health Service (SUS) is decentralized and organized according to region and type of complexity⁹. Since mammography is a test of moderate complexity, each HR is expected to have at least one machine in order to guarantee access to breast cancer screening for the resident population in that area. However, few studies have been conducted on the geographical distribution of machines in the different states^{13,14}.

In 2008, a cross-sectional study was conducted in the Brazilian state of Goiás to calculate breast cancer screening coverage and to analyze the type of infrastructure installed and the services offered to women in each HR within the state¹⁵. Eleven years after that initial survey, the objective of the present study is to evaluate the characteristics of breast cancer screening in that state according to the demographic data, the number of available mammography machines and the technology used, the geographic distribution of the machines, their productivity, sources of payment, and the cost of the tests in 2019.

METHODS

This was an ecological study in which the unit of observation consisted of diagnostic centers with functioning mammography machines. Centers performing scans within the SUS network, including public and philanthropic institutes and those with a contractual agreement with the SUS, were included, as well as centers serving the private sector. The diagnostic centers were

identified from the database of the Program for Quality Control in Mammography, implemented by the institutes responsible for breast cancer control and for the inspection of healthcare establishments in the state since 2007.

Study area

The area covered by this study consists of the entire state of Goiás, located in the Central Brazilian Plateau. Goiás consists of an area of 341,289.5 square kilometers, with a population calculated at 6.9 million inhabitants, a population density of 20.4 inhabitants/km², and a life expectancy of 73.6 years¹⁶. The area is divided into 246 municipalities, which, in accordance with the health regionalization management plan, are organized into 18 HRs. The city of Goiânia, the state capital, lies approximately 200 km from the Brazilian capital city, Brasília.

The incidence of breast cancer in the state of Goiás

According to the National Cancer Institute, 1,640 new cases of breast cancer in women were expected in 2019 in the state of Goiás, with an adjusted incidence rate of 46.09 cases per 100,000 inhabitants. In the capital, Goiânia, 420 new cases were expected, with an adjusted incidence rate of 52.50 cases per 100,000 inhabitants⁵.

Data collection

Data collection involved onsite visits to each diagnostic center in Goiás, Brazil, and a review of publicly available health information systems.

During the onsite visits, data were obtained on the geographical location of the diagnostic center, the number of mammography units in use, the type of healthcare provided (SUS or private), and the mean number of scans performed per machine per month. The data collected regarding the equipment were: the year of manufacture, the year the machine was installed in the center, and the type of technology involved (conventional, computed radiography [CR], or digital radiography [DR]).

By analyzing publicly available healthcare data, information was retrieved on the number of inhabitants in each municipality¹⁷, the number of women per age group¹⁷, the number of mammograms performed within the SUS¹⁸, and the municipal Human Development Index (HDI)¹⁹, which consists of a summary index of life expectancy, education, and income. HDI is used to classify given regions into different levels of human development, taking into consideration a concept of well-being seen in terms of capacity. Municipal HDI levels range from zero (the worst) to one (the highest).

Data analysis

Based on the geographical location of the diagnostic center, the geographical distribution of the mammography units was established per municipality and then consolidated according to HR.

Next, the proportion of women in the 40-to-69-year age group was evaluated per mammography unit according to whether the machine was available to the SUS or not.

Given that each machine can perform approximately 30 scans per day^{20,21} and can operate for about 230 days each year, the HRs were classified based on their potential capacity to perform breast screening mammograms annually, biennially, or at intervals exceeding 2 years for the target population. The following categories were then assigned: *Category A*: one mammography unit per 6,000 women or fewer; *Category B*: one mammography unit per 6,001–12,000 women; and *Category C*: one mammography unit per 12,001 women or more.

To establish whether the number of machines available was sufficient, the number of mammography units required to screen the target population was calculated according to the guidelines established in Decree GM/MS 1,163 of the Brazilian Ministry of Health dated October 1, 2015, taking the recommended age group and the capacity of the machine into consideration²².

To calculate overall coverage, the number of scans reported by the diagnostic center was the number taken as performed. For the scans performed within the SUS, the data used were the numbers reported by the diagnostic centers in the outpatient data system (SIA-SUS/DATASUS) using codes 02024030030 (mammography) or 0204030188 (bilateral mammography for screening purposes)¹⁸.

Total coverage was calculated for the state of Goiás and for each HR according to the percentage ratio of the number of mammograms performed and the size of the female population of 40–69 years of age. The estimated number of mammograms in the 40- to 69-year age group was based on the data recorded in the Breast Cancer Information System (SISMAMA) for the year 2013 and corresponded to 89.3% of all the exams conducted in the state across all age groups.

The municipalities were classified according to the methodology determined in the Atlas of Human Development in Brazil, in which municipal HDIs are classified as: *very low* (0–0.499), *low* (0.500–0.599), *medium* (0.600–0.699), *high* (0.700–0.799), and *very high* (0.800–1.00). The HDI was calculated for each HR based on the weighted arithmetic mean of the municipal HDI for the municipalities composing each HR, using the Equation 1:

$$\overline{MHDI}_i = \frac{\sum_{i=1}^n (p_i * MHDI_i)}{\sum_{i=1}^n p_i} \quad (1)$$

where:

n: the number of municipalities;

pi: the population of municipality i;

MHDI: the municipal Human Development Index i.

The annual cost of all mammograms conducted in the state of Goiás in 2019 was calculated based on the unit value of R\$ 45.00 paid by the SUS, and on a value of R\$ 120.00, considered

the average amount paid by insurers or by women themselves in the private sector.

In this study, the compound annual growth rate (CAGR) was determined for some indicators obtained in 2019 compared to those obtained in a similar study conducted in 2008, using the Equation 2:

$$CAGR = [(N_f / N_i)^{1/(Y_f - Y_i)}] - 1 \quad (2)$$

where:

Nf: the value of the variable in the final year;

Ni: the value of the variable in the initial year;

Yf: the final year;

Yi: the initial year.

Statistical analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 17.0. Absolute and relative frequencies of the variables were calculated. The normality of data distribution was established using the Kolmogorov-Smirnov test. Agreement between total screening coverage, coverage within the SUS, and the municipal HDI was calculated using Pearson's correlation coefficient. Simple linear regression analysis was used to analyze the relationship between regional coverage and the HDI of each HR. The age of the mammography units available within the SUS was compared with the age of those in the private healthcare network using the Mann-Whitney test.

The indicators of the characteristics of breast cancer screening were compared based on the percentage of difference between the values found in a previous study conducted in 2008¹⁵ and the results of the present study conducted in 2019.

ETHICAL ASPECTS

In accordance with current legislation in Brazil²³, there was no need to submit the study protocol for approval by an ethics committee since the study involved equipment in operation and no data from human beings. Nevertheless, to avoid evaluation biases, all the diagnostic centers and the respective mammography units were coded and analyzed in a blinded fashion.

RESULTS

In January 2019, the database of the Goiás Program for Quality Control in Mammography contained data from 180 diagnostic centers performing the exam in Goiás. Of these, 158 (87.8%) had functioning units in use, while in 22 (12.2%), the equipment was either broken, undergoing maintenance, or out of use for reasons involving pending licensing processes with the relevant supervisory governmental agencies. In the 158 diagnostic centers that participated in the present study, six had more than

one mammography unit, making a total of 164 machines in use. Table 1 shows the number of mammography machines classified according to the type of imaging technology used (conventional, CR, or DR).

Of the 164 mammography machines in the sample, 11 (6.7%) still used analog or conventional imaging technology, while 141 (86.0%) were of the CR type, and 12 (7.3%) used DR. The majority of the mammography machines were manufactured by GE (99 units; 60.4%), followed by Philips/VMI (27 units; 16.5%), Siemens (16 units; 9.9%), and Hologic/Lorad (14 units; 8.6%). The three primary manufacturers of the 141 CR digitizers were Carestream/Kodak (57; 40.4%), Fuji (40; 28.4%), and Agfa (38; 27.0%).

Information on the year of manufacture of the machines in this sample was available for 159 units (96.9%; 159/164). In the case of the remaining five units, the year of manufacture was not found on any of their identification plates. As shown in Figure 1, the time of use of the mammography machines ranged from 1 to 31 years, with a median of 16 years.

A total of 66 functioning machines (40.2%) were used to conduct examinations for the SUS; however, of these, only 14 (21.2%) belonged directly to the SUS, with 52 (78.8%) being affiliated with the SUS network. Analysis of the distribution of mammography machines within the SUS per HR showed that in the *Nordeste I* and *Oeste I* regions, no equipment at all was available to the SUS (Table 2). Mammography units were available in 48 of the 246 state municipalities (19.5%), with all HRs there having at least one machine. However, in four of these regions (*Nordeste I*, *Oeste I*, *Pirineus*, and *Entorno Norte*), the machines were all located in the same municipality. Likewise, there was a concentration of equipment (41%) in the state capital, Goiânia.

Of the projected total number of 6,931,501 residents in the state in 2019, 1,149,302 (16.6%) were women in the 40- to 69-year age group. The HRs with the lowest proportions of women in this age group were the *Entorno Sul* (13.8%) and *Nordeste I* (14.1%) regions, while the highest proportions were found in *Oeste II* (19.0%) and *Oeste I* (19.7%). In the *Central* region, the most populous in the state, this proportion was 17.9%.

Based on annual screening for all women of 40–69 years of age in the state, the number of women per mammography unit in use was 7,008. The 164 existing mammography machines would be sufficient to serve the entire population, assuming each performs 30 exams per day and operates 230 working days per year. However, the distribution of mammography machines across the HRs is not proportional to the demand for mammography.

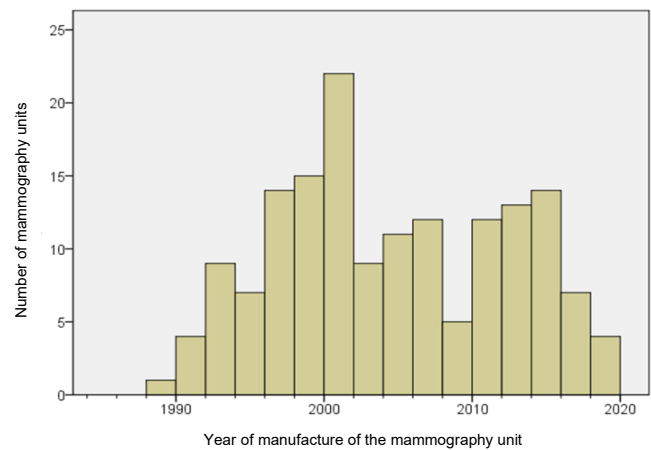


Figure 1. Breakdown of the quantity of mammography machines in use according to their year of production, State of Goiás, Brazil, 2019.

Table 1. Number of mammography machines and CR digitalizers by type of image detection technology, State of Goiás, Brazil, 2019.

Manufacturer	Type of Image Detection Technology			
	Conventional mammography machine	Digital CR Mammography machine	CR Digitalizer	Digital DR
GE	5	89	-	5
Hologic/Lorad	3	9	-	2
Siemens	-	15	-	1
Agfa	-	-	38	-
Philips/VMI	3	21	1	2
Fuji	-	-	40	2
Konica	-	-	5	-
Toshiba	-	4	-	-
Carestream/Kodak	-	-	57	-
Lotus	-	1	-	-
IMS	-	1	-	-
Bennett	-	1	-	-

Analysis of the proportion of women of 40–69 years of age per HR revealed that four HRs (*Central, São Patrício I, Serra da Mesa, and Nordeste I*) were classified as *category A*, with fewer than 6,000 women per mammography machine, while 11 HRs (*Entorno Sul, Estrada de Ferro, Nordeste II, Norte, Oeste II, Pirineus, Rio Vermelho, São Patrício II, Sudoeste I, Sudoeste II, and Sul*) were *category B* with 6,001–12,000 women per mammography unit, and three HRs (*Centro Sul, Entorno Norte, and Oeste I*) were *category C* with 12,001 or more women per mammography machine.

In 2019, 358,000 of the 400,896 mammograms performed were estimated to have been carried out in women of 40–69 years of age, with 73,540 (20.5%) of these being covered by the SUS and 284,460 (79.5%) by non-SUS providers. The total breast cancer screening coverage for the target age group in the state was 31.2%, with 6.4% of the scans being conducted within the SUS and 24.8% by non-SUS providers. The highest coverage was found in the *Central* (54.3%) and *Sul* (41.5%) regions, while the lowest was in the *Nordeste II* (9.4%) and *Entorno Norte* (8.3%) regions.

Table 3 shows the ratio between the number of mammograms performed by non-SUS providers and those performed within

the SUS according to HR and for Goiás as a whole. For the entire state, this ratio is 3.87, while for the HRs, ratios range from 0.30 in the *Centro Sul* region and 0.51 in the *Sudoeste I* region to 31.73 in *Oeste I* and 35.00 in *Nordeste I*.

Data on breast cancer screening costs for each HR and for the entire state of Goiás are shown in Table 4, discriminating between the costs covered by the SUS and those either covered by health insurance or by women who pay for the exam themselves (non-SUS). In this respect, expenditures in the *Central* HR account for 53.1% of the total expenditure in the state. The ratio between non-SUS and SUS expenditure for the state of Goiás is 10.3. For each HR, this ratio ranges from 0.8 in the *Centro Sul* region and 1.4 in the *Sudoeste I* region to 84.6 in the *Oeste I* region and 93.3 in the *Nordeste I* region.

In the state of Goiás, the municipal HDI ranged from 0.584 to 0.7990. In three municipalities, the HDI was classified as *low*, in 129 as *medium*, and in 114 as *high*. Figure 2 shows that the correlation between the mean ($\overline{M}HDI_i$) and breast cancer screening coverage for women of 40–69 years of age was moderate and positive ($r=0.393$), albeit not significant ($p=0.106$).

Table 2. Female population aged 40–69 years, mammography machines in use, exams performed, and breast cancer screening coverage, by health region, Goiás, Brazil, 2019.

Health region	Female population	Machines in use in the state		Exams performed			Coverage (%)		
	aged 40–69 years	SUS (own network)	Total	SUS	Non-SUS	Total	SUS	Non-SUS	Total
Central	338,818 (29.5%)	22 (7)	74	29,195	154,895	184,090	8.6	45.7	54.3
Centro Sul	146,140 (12.7%)	2 (1)	8	13,882	4,218	18,099	9.5	2.9	12.4
Entorno Norte	38,605 (3.4%)	1 (0)	1	142	3,073	3,215	0.4	8.0	8.3
Entorno Sul	122,511 (10.7%)	4 (0)	11	901	15,355	16,256	0.7	12.5	13.3
Estrada de Ferro	52,890 (4.6%)	3 (0)	8	1,053	16,071	17,124	2.0	30.4	32.4
Nordeste I	6,624 (0.6%)	0 (0)	2	27	938	964	0.4	14.2	14.6
Nordeste II	14,794 (1.3%)	1 (0)	2	325	1,068	1,393	2.2	7.2	9.4
Norte	24,956 (2.2%)	3 (0)	4	174	5,184	5,358	0.7	20.8	21.5
Oeste I	23,030 (2.0%)	0 (0)	1	98	3,117	3,215	0.4	13.5	14.0
Oeste II	22,061 (1.9%)	2 (1)	3	814	4,329	5,144	3.7	19.6	23.3
Pirineus	88,858 (7.7%)	10 (1)	14	5,471	22,530	28,001	6.2	25.4	31.5
Rio Vermelho	37,069 (3.2%)	2 (0)	4	413	4,784	5,197	1.1	12.9	14.0
São Patrício I	31,295 (2.7%)	3 (0)	6	1,702	9,400	11,102	5.4	30.0	35.5
São Patrício II	28,915 (2.5%)	2 (0)	4	298	9,025	9,323	1.0	31.2	32.2
Serra da Mesa	21,644 (1.9%)	3 (1)	4	884	3,563	4,447	4.1	16.5	20.5
Sudoeste I	68,445 (6.0%)	2 (0)	7	12,088	6,183	18,271	17.7	9.0	26.7
Sudoeste II	36,320 (3.2%)	2 (0)	4	2,187	10,083	12,270	6.0	27.8	33.8
Sul	46,327 (4.0%)	4 (3)	7	3,886	15,360	19,246	8.4	33.2	41.5
GOIÁS	1,149,302 (100%)	66 (14)	164	73,540	284,460	358,000	6.4	24.8	31.2

SUS: Sistema Único de Saúde.

Table 3. Ratio of exams performed within the SUS and non-SUS healthcare networks according to health region and the number of women of 40–69 years of age in the regional reference municipality, Goiás, Brazil, 2019.

Health region	Reference municipality (female population aged 40–69 years)	Non-Sus/SUS ratio of exams performed
Central	Goiânia (270,707)	5.31
Centro Sul	Aparecida de Goiânia (85,867)	0.30
Entorno Norte	Formosa (17,789)	21.64
Entorno Sul	Luziânia (29,570)	17.04
Estrada de Ferro	Catalão (17,488)	15.26
Nordeste I	Campos Belos (2,975)	35.00
Nordeste II	Posse (4,983)	3.29
Norte	Porangatú (7,598)	29.77
Oeste I	Iporá (6,582)	31.73
Oeste II	São Luiz dos Montes Belos (6,399)	5.32
Pirineus	Anápolis (67,390)	4.12
Rio Vermelho	Goiás (4,900)	11.57
São Patrício I	Ceres (4,498)	5.52
São Patrício II	Goianésia (11,179)	30.26
Serra da Mesa	Uruaçu (6,929)	4.03
Sudoeste I	Rio Verde (31,186)	0.51
Sudoeste II	Jataí (16,548)	4.61
Sul	Itumbiara (19,826)	3.95
Entire state of Goiás	-	3.87

SUS: Sistema Único de Saúde.

Table 4. Mammography-related expenses in the public and non-public healthcare sectors, total expenditure, and the ratio of public to private expenditure according to health region, Goiás, Brazil, 2019.

Health region	Mammography expenditure (R\$)			Ratio
	SUS*	Non-SUS**	Total	Non-SUS/SUS
Central	1,313,768	18,587,438	19,901,206	14.1
Centro Sul	624,676	506,117	1,130,793	0.8
Entorno Norte	6,389	368,738	375,127	57.7
Entorno Sul	40,547	1,842,616	1,883,163	45.4
Estrada de Ferro	47,378	1,928,559	1,975,937	40.7
Nordeste I	1,206	112,518	113,724	93.3
Nordeste II	14,627	128,163	142,791	8.8
Norte	7,836	622,064	629,900	79.4
Oeste I	4,420	373,988	378,409	84.6
Oeste II	36,649	519,512	556,160	14.2
Pirineus	246,173	2,703,647	2,949,820	11
Rio Vermelho	18,606	574,056	592,662	30.9
São Patrício I	76,593	1,127,966	1,204,559	14.7
São Patrício II	13,422	1,082,959	1,096,381	80.7
Serra da Mesa	39,783	427,568	467,352	10.7
Sudoeste I	543,944	741,976	1,285,920	1.4
Sudoeste II	98,413	1,209,944	1,308,357	12.3
Sul	174,885	1,843,152	2,018,037	10.5
GOIÁS	3,309,315	34,135,175	37,444,490	10.3

*Price of mammogram paid by SUS: R\$ 45.00; **average price of mammogram paid privately or through health insurance: R\$ 120.00; SUS: Sistema Único de Saúde.

Table 5 compares the breast cancer screening indicators from 2008 with those from 2019. There was a positive CAGR in the number of mammography machines in use and in the number of municipalities with mammography machines, with a mean annual increase of around 4%. The technology of the equipment has progressed considerably, with an increase in CR systems (CAGR=17.0%) and a decline in conventional systems (CAGR=-16.3%). Additionally, 12 DR mammography machines have been installed.

The CAGR for the female population of all age groups was 1.9% per year between 2008 and 2019, compared to 3.5% for the population in the 40- to 69-year age group. This finding confirms the aging of the female population and indicates a growing need for more mammography machines in the state in the years to come. During the study period, the number of women per mammography machine remained practically stable, with a CAGR of -0.8%. Finally, the annual increase of 2.5% in the number of exams was only sufficient to maintain breast cancer screening coverage in the state at around 30% (CAGR=-0.9%) between 2008 and 2019.

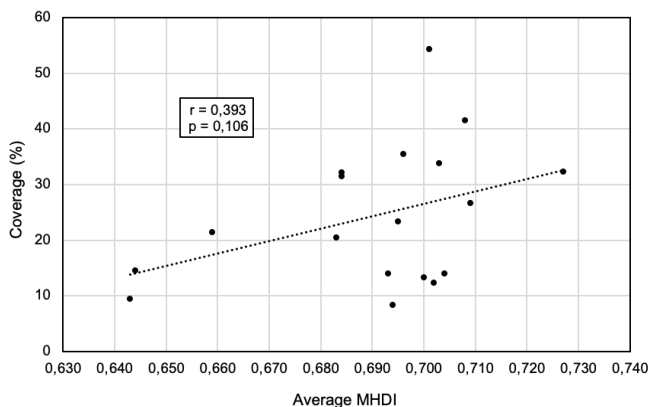


Figure 2. Linear regression between mammography coverage and the o MHI of health regions, State of Goiás, Brazil, 2019.

DISCUSSION

The present study provides valuable data on breast cancer screening in a state in midwestern Brazil, where a quality control program in mammography was set up more than 12 years ago²⁴. Each critical point reported here may prove useful when contemplating the implementation of specific public policies.

In 2008, there were 103 mammography units in use²⁴, while by 2019, this number had risen to 164, an increase of 59% in infrastructure over the period analyzed. Nevertheless, while in 2008 there were 7,677 women of 40–69 years of age per mammography unit, in 2019, this proportion was of 7,008 women per machine, representing an improvement of only 9%. These data can probably be explained by the characteristics of the population in Brazil, where an age pyramid shows a concentration in the 20- to 59-year age range²⁵. Notwithstanding, the overall number of mammography units available should be analyzed with caution, as they do not constitute an indicator of the effectiveness of breast cancer screening. In other countries, the high concentration of mammography machines has generated undesirable consequences that include an excessive number of requests for the exam and a reduction in the age at which screening is initiated²⁶.

The current number of mammography units in the state of Goiás was found to be twice that required to screen the entire target population in accordance with the Ministry of Health guidelines⁷. This information contradicts the narrative that a scarcity of equipment would account for a negative effect of mass screening on the performance of exams in the symptomatic population²⁷. In fact, the availability of mammography machines improved in relation to the number of women of 40–69 years of age, particularly in the private healthcare system. In the study conducted in 2008, only 6% of the HRs had an infrastructure that was sufficient to screen the entire population annually, while 44% were able to perform screening every 2 years and 50% at intervals that exceeded 2 years¹⁵. In 2019, the infrastructure in 22% of the HRs

Table 5. Compound annual growth rate (CAGR) for opportunistic mammography screening indicators between 2008 and 2019, Goiás, Brazil.

Indicator	2008	2019	CAGR (%)
Number of health regions	16	18	1.1
Municipalities with mammography machines in use*	31	48	4.1
Mammography machines in use	103	164	4.3
Conventional mammography machine	78	11	-16.3
Digitized mammography machine (CR)	25	141	17.0
Fully digital mammography machine (DR)	0	12	-
Female population	2,952,975	3,644,616	1.9
Female population aged 40–69 years	790,770	1,149,302	3.5
Women (aged 40–69 years)/mammography machine	7,677	7,008	-0.8
Exams performed	272,001	358,000	2.5
Coverage for ages 40–69	34	31	-0.9

*Total number of municipalities in the state of Goiás: 246

was sufficient to enable screening to be performed annually, and in 61% of cases, it was sufficient for screening to be performed every 2 years; however, 17% of the HRs were still only able to perform screening at intervals that exceeded 2 years.

A nationwide analysis of productivity showed that in 2016, only 28.5% of overall capacity was being used¹³ and that this poor productivity was directly influenced by the availability of trained professionals, consumables, the demand for screening, and other external aspects. In the present study, productivity was found to be poor, with a mean of 9 scans/day, which is well below the normal capacity of 30 scans/day per machine. Therefore, these data suggest that a new approach is required to expand access to breast cancer screening in the country, giving priority to increasing the productivity of each mammography unit at the detriment of the restrictions suggested by the National Cancer Institute⁷.

The heterogeneous distribution of mammography units in the different geographical regions constitutes another important limitation to access to breast cancer screening^{28,29}. In the current study, the equipment was found to be concentrated predominantly in the state capital, disproportionally affecting the distribution across the population. This inequality may have contributed to the low screening coverage found within the SUS, whose clients are at the lower end of the socioeconomic stratum and therefore more sensitive to geographical limitations^{9,30}. On the other hand, the importance of the network involved in providing services to the public healthcare system through contractual agreements should be emphasized, since around 80% of the equipment available within the SUS is accessible due to such contracts. In clinical practice, this amalgamation of the public and private (contracted) services bridges some of the gaps in the public healthcare system and minimizes the impact on patient flow in cases of patients with breast abnormalities³¹.

Mammography screening coverage is one of the principal indicators of the quality of population-based screening programs for breast cancer. According to the World Health Organization, to be considered effective, breast cancer screening has to reach at least 70% of the target population¹. In Brazil, progress in screening within the SUS has been monitored for more than 10 years, with different trend curves for each state over the years^{14,32}. In the state of Goiás, screening coverage within the SUS has never exceeded 20%^{14,15,32}. Nevertheless, the present study provides new data in relation to the private healthcare system, showing moderate coverage (54%) of breast exams in *Central* HR and an improvement in the percentage in other regions of the state. This positive progress could possibly be explained by the actions of continued education and awareness conducted ceaselessly with the population over the past 10 years³³.

Access to breast cancer screening programs is also influenced by the social characteristics present in each particular region^{9,30}. An ecological study reported a decline or stabilization in mortality rates from breast cancer between 1990 and 2011 in Brazilian

states with better socioeconomic levels. Conversely, mortality increased substantially in the states with lower HDIs, possibly as a result of limitations in access to healthcare services³⁴. In the present study, breast cancer screening coverage tended to be below 70% in those municipalities with lower HDIs.

The previous decade saw a worldwide transition in technology from conventional mammography to CR or DR^{35,36}. This change in technology was shown to increase breast cancer detection rates while reducing the rates of interval breast cancer, despite increasing recall rates^{35,36}. In Goiás, this transition in technology was already taking place in the previous decade, although most of the equipment in use was more than 10 years old. In 2008, 75% of the mammography units available used conventional technology¹⁵. Conversely, conventional mammography machines currently account for only 6% of the equipment in use in the state. In this respect, quality control studies are yet to be conducted to evaluate whether the advances in technology are reflected in better parameters of accuracy and efficiency.

A limitation of the present study lies in the opportunistic screening model in practice in Brazil. With this type of model, there is no control regarding the population in which mammography screening is performed. Therefore, one woman may undergo more than one scan, resulting in an overestimation of the results³⁷. Nevertheless, the present findings are in agreement with those reported from a previous study¹⁵. The pioneering nature of this study and the scope of the evaluation performed, providing a panoramic analysis of breast cancer screening in the state of Goiás, constitute strong points. Although referring to just one state, the data presented here may also reflect conditions in the other states of the country.

CONCLUSIONS

In 2019, breast cancer screening coverage in Goiás reached 31.1%, with 6.4% being conducted within the SUS. The geographic distribution of mammography units is heterogeneous, and productivity is low. Compared to 2008, availability increased, and the standard of the equipment improved.

AUTHORS' CONTRIBUTIONS

RSC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. RFJ: Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Supervisão, Validation, Visualization, Writing – review & editing. DCNR: Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. JEP: Conceptualization, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft,

Writing – review & editing. SAB: Conceptualization, Data curation, Formal Analysis, Resources, Software, Visualization, Writing – review & editing. RMNT: Conceptualization, Data curation,

Formal Analysis, Resources, Software, Visualization, Writing – review & editing. LRS: Formal analysis, Resources, Validation, Visualization, Writing – review & editing.

REFERENCES

1. World Health Organization. Early detection. Cancer control: knowledge into action: WHO guide for effective programmes; module 3 [Internet]. Geneva: WHO Press; 2007 [cited September 12, 2025]. Available at: <http://www.who.int/cancer/modules/en/>.
2. Dibden A, Offman J, Duffy SW, Gabe R. Worldwide review and meta-analysis of cohort studies measuring the effect of mammography screening programmes on incidence-based breast cancer mortality. *Cancers*. 2020;12(4):976. <https://doi.org/10.3390/cancers12040976>
3. Smith RA, Duffy SW, Gabe R, Tabar L, Yen AMF, Chen THH. The randomized trials of breast cancer screening: what have we learned? *Radiol Clin North Am*. 2004;42(5):793-806. <https://doi.org/10.1016/j.rcl.2004.06.014>
4. Giaquinto AN, Sung H, Newman LA, Freedman RA, Smith RA, Star J, et al. Breast cancer statistics 2024. *CA Cancer J Clin*. 2024;74(6):477-95. <https://doi.org/10.3322/caac.21863>
5. Brasil. Instituto Nacional de Câncer. Estimativa 2023: incidência de câncer no Brasil [Internet]. Rio de Janeiro: Instituto Nacional de Câncer; 2022 [cited September 11, 2025]. Available at: <https://www.inca.gov.br/sites/ufu.sti.inca.local/files/media/document/estimativa-2023.pdf>.
6. Urban LABD, Chala LF, Bauab SP, Schaefer MB, Santos RP, Maranhão NMA, et al. Breast cancer screening: updated recommendations of the Brazilian College of Radiology and Diagnostic Imaging, Brazilian Breast Disease Society, and Brazilian Federation of Gynecological and Obstetrical Associations. *Radiol Bras*. 2017;50(4):244-9. <https://doi.org/10.1590/0100-3984.2017-0069>
7. Migowski A, Silva GAE, Dias MBK, Diz MPE, Sant'Anna DR, Nadanovsky P. Guidelines for early detection of breast cancer in Brazil. II - New national recommendations, main evidence, and controversies. *Cad Saúde Pública*. 2018;34(6):e00074817. <https://doi.org/10.1590/0102-311X00074817>
8. Brasil. Ministério da Saúde. Legislation No. 11,664, of April 29, 2008. *Diário Oficial da União*. 2008;Section 1.
9. Castro MC, Massuda A, Almeida G, Menezes-Filho NA, Andrade MV, Noronha KVMS, et al. Brazil's unified health system: the first 30 years and prospects for the future. *Lancet*. 2019;394(10195):345-6. [https://doi.org/10.1016/S0140-6736\(19\)31243-7](https://doi.org/10.1016/S0140-6736(19)31243-7)
10. Brasil. Ministério da Saúde. Secretaria Executiva. Sistema Único de Saúde (SUS): instrumentos de gestão em saúde. Brasília: Ministério da Saúde; 2002.
11. Lima LD, Queiroz LFN, Machado CV, Viana ALD. [Decentralization and regionalization: dynamics and conditioning factors for the implementation of the Health Pact in Brazil]. *Ciênc Saúde Coletiva*. 2012;17(7):1903-14. <https://doi.org/10.1590/S1413-81232012000700030>
12. Lima LD, Viana ALA, Machado CV, Albuquerque MV, Oliveira RG, Iozzi FL, et al. [Regionalization and access to healthcare in Brazilian states: historical and political-institutional conditioning factors]. *Ciênc Saúde Coletiva*. 2012;17(11):2881-92. <https://doi.org/10.1590/S1413-81232012001100005>
13. Rodrigues DCN, Freitas-Junior R, Rahal RMS, Correa RS, Peixoto JE, Ribeiro NV, et al. Difficult access and poor productivity: mammography screening in Brazil. *Asian Pac J Cancer Prev*. 2019;20(6):1857-64. <https://doi.org/10.31557/APJCP.2019.20.6.1857>
14. Rodrigues DCN, Freitas-Junior R, Rahal RMS, Correa RS, Gouveia PA, Peixoto JE, et al. Temporal changes in breast cancer screening coverage provided under the Brazilian National Health Service between 2008 and 2017. *BMC Public Health*. 2019;19(1):959. <https://doi.org/10.1186/s12889-019-7278-z>
15. Corrêa RS, Freitas-Junior R, Peixoto JE, Rodrigues DCN, Lemos MEF, Marins LAP, et al. [Estimated mammogram coverage in Goiás State, Brazil]. *Cad Saúde Pública*. 2011;27(9):1757-67. <https://doi.org/10.1590/S0102-311X2011000900009>
16. Instituto Brasileiro de Geografia e Estatística. Resolução Nº PR-02, de 21 de junho de 2016. Aprova os valores de áreas territoriais do Brasil, Estados e Municípios. *Diário Oficial da União* [Internet]. 2016 [cited September 12, 2025];Seção 1(118):87. Available at: <https://cidades.ibge.gov.br/brasil/go/panorama>.
17. Secretaria de Estado da Saúde de Goiás. Governo do Estado de Goiás. Programas, Projetos, Ações, Atividades. Mapa da Saúde – Indicadores de Saúde [Internet]. Goiás: Secretaria de Estado da Saúde de Goiás [cited May 3, 2020]. Available at: <http://mapadasaude.saude.go.gov.br/#l=pt;v=map3>
18. Brasil. Ministério da Saúde. Departamento de Informática do SUS – DATASUS. Sistema de Informações Ambulatoriais do SUS (SIA/SUS) [Internet]. Brasília, DF: Ministério da Saúde; 2016 [cited September 12, 2025]. Available at: <https://datasus.saude.gov.br/aceso-a-informacao/producao-ambulatorial-sia-sus>.
19. Programa das Nações Unidas para o Desenvolvimento – PNUD. Atlas do Desenvolvimento Humano no Brasil. Consulta. Espacialidade. Indicadores [Internet]. PNUD [cited September 12, 2025]. Available at: <http://atlasbrasil.org.br/2013/pt/consulta/>
20. Brasil. Ministério da Saúde. Instituto Nacional de Câncer José Alencar Gomes da Silva. Diretrizes para a detecção precoce do câncer de mama no Brasil. Rio de Janeiro: Instituto Nacional de Câncer José Alencar Gomes da Silva; 2015.
21. Brasil. Ministério da Saúde. Instituto Nacional de Câncer José Alencar Gomes da Silva. Divisão de Detecção Precoce e Apoio à Organização de Rede Coordenação de Prevenção e Vigilância. Nota Técnica: revisão do parâmetro para cálculo da capacidade

- de produção do mamógrafo simples [Internet]. Rio de Janeiro: Instituto Nacional de Câncer José Alencar Gomes da Silva; 2015 [cited September 12, 2025]. Available at: https://www.inca.gov.br/sites/ufu.sti.inca.local/files//media/document/nota-revisao-capacidade-dos-mamografos-2015_0.pdf
22. Brasil. Ministério da Saúde. Gabinete do Ministro. Portaria nº 1.631 de 1 de outubro de 2015. Aprova critérios e parâmetros para o planejamento e programação de ações e serviços de saúde no âmbito do SUS. Diário Oficial da União. 2015;Seção 1(189):38.
 23. Brasil. Ministério da Saúde. Conselho Nacional de Saúde. Resolução 466 de 12 de dezembro de 2012. Aprova as diretrizes e normas regulamentadoras de pesquisas envolvendo seres humanos. Diário Oficial da União. 2013;Seção 1(59):59.
 24. Corrêa RS, Freitas-Junior R, Peixoto JE, Rodrigues DCN, Lemos MEF, Dias CM, et al. Effectiveness of a quality control program in mammography for the Brazilian National Health System. *Rev Saúde Pública*. 2012;46(5):769-76. <https://doi.org/10.1590/s0034-89102012000500002>
 25. Brasil. Instituto Brasileiro de Geografia e Estatística. Diretoria de Pesquisas. Coordenação de População e Indicadores Sociais. Gerência de Estudos e Análises da Dinâmica Demográfica. Projeção da população do Brasil e unidades da federação por sexo e idade para o período 2000–2030 [Internet]. Brasil: Instituto Brasileiro de Geografia e Estatística [cited September 12, 2025]. Available at: <http://www.ibge.gov.br/home/estatistica/populacao>
 26. Autier P, Ait Ouakrim D. Determinants of the number of mammography units in 31 countries with significant mammography screening. *Br J Cancer*. 2008;99(7):1185-90. <https://doi.org/10.1038/sj.bjc.6604657>
 27. Gonçalves R, Soares-Jr JM, Baracat EC, Filassi JR. Ethical issues surrounding breast cancer screening in Brazil. *Clinics*. 2019;74:e1573. <https://doi.org/10.6061/clinics/2019/e1573>
 28. Vieira RADC, Formenton A, Bertolini SR. Breast cancer screening in Brazil. Barriers related to the health system. *Rev Assoc Med Bras*. 2017;63(5):466-74. <https://doi.org/10.1590/1806-9282.63.05.466>
 29. Silva TB, Mauad EC, Carvalho AL, Jacobs LA, Shulman LN. Difficulties in implementing an organized screening program for breast cancer in Brazil with emphasis on diagnostic methods. *Rural Remote Health*. 2013;13(2):2321.
 30. Sandoval JL, Himsl R, Theler JM, Gaspoz J-M, Joost S, Guessous I. Spatial distribution of mammography adherence in a Swiss urban population and its association with socioeconomic status. *Cancer Med*. 2018;7(12):6299-307. <https://doi.org/10.1002/cam4.1829>
 31. Tolêdo SRS, Almeida NAM, Souza MR, Minamisava R, Freitas Júnior R. Care flow of breast cancer patients in the public health care network. *Rev Eletr Enf*. 2016;18:e1201. <https://doi.org/10.5216/ree.v18.39147>
 32. Freitas-Junior R, Rodrigues DCN, Corrêa RS, Peixoto JE, Oliveira HVCG, Rahal RMS. Contribution of the Unified Health Care System to mammography screening in Brazil, 2013. *Radiol Bras*. 2016;49(5):305-10. <https://doi.org/10.1590/0100-3984.2014.0129>
 33. Quintanilha LF, Souza LN, Sanches D, Demarco RS, Fukutani KF. The impact of cancer campaigns in Brazil: a Google Trends analysis. *Ecancermedicalscience*. 2019;13:963. <https://doi.org/10.3332/ecancer.2019.963>
 34. Gonzaga CMR, Freitas-Junior R, Curado MP, Sousa A-LL, Souza-Neto J-A, Souza MR. Temporal trends in female breast cancer mortality in Brazil and correlations with social inequalities: ecological time-series study. *BMC Public Health*. 2015;15:96. <https://doi.org/10.1186/s12889-015-1445-7>
 35. Nederend J, Duijm LE, Louwman MW, Coebergh JW, Roumen RMH, Lohle PN, et al. Impact of the transition from screen-film to digital screening mammography on interval cancer characteristics and treatment: a population based study from the Netherlands. *Eur J Cancer*. 2014;50(1):31-9. <https://doi.org/10.1016/j.ejca.2013.09.018>
 36. Sankatsing VDV, Fracheboud J, de Munck L, Broeders MJM, van Ravesteijn NT, Heijnsdijk EAM, et al. Detection and interval cancer rates during the transition from screen-film to digital mammography in population-based screening. *BMC Cancer*. 2018;18(1):256. <https://doi.org/10.1186/s12885-018-4122-2>
 37. Rodrigues TB, Stavola B, Bustamante-Teixeira MT, Guerra MR, Nogueira MC, Fayer VA, et al. [Mammographic over-screening: evaluation based on probabilistic linkage of records databases from the Breast Cancer Information System (SISMAMA)]. *Cad Saúde Pública*. 2019;35(1):e00049718. <https://doi.org/10.1590/0102-311x00049718>

