The cost/effectiveness relationship of imaging exams in the efficiency of covid diagnosis

A relação custo/efetividade de exames de imagem na eficiência do diagnóstico da covid

La relación costo/eficacia de los exámenes por imágenes en la eficiencia del diagnóstico de covid

RESUMO

Analisar a relação custo-efetividade de métodos de imagem radiológica, radiografia e tomografias, no diagnóstico de pneumonias adquiridas na comunidade em unidade de saúde em São Luís, Maranhão, durante a epidemia da COVID-19. Pesquisa quantitativa, com diagnósticos do agravo estudado e custos efetivos. Discutiu-se a necessidade de exames de baixo e alto custo no diagnóstico com vistas à qualificação da Análise de Custo-Efetividade. Foram analisados 511 laudos, com análise comparativa radiografia/tomografia, para as grandes opacidades, a concordância entre as duas técnicas ocorreu em 177 laudos, sendo 103 (58,19%) do gênero masculino, com predominância nas idades entre 33 e 53 anos (51,4%). Ao comparar as duas técnicas, o sistema de radiografia mostrou-se tão eficaz quanto a tomografia. Nessa análise de custo efetividade, observou-se a necessidade em avançar, não apenas na produção de evidência, mas sobretudo no uso dessa metodologia, na redução de custo do sistema de saúde e ampliação em quantidade/ qualidade.

DESCRITORES: Custo-Efetividade; Economia da Saúde; Sistema Único de Saúde; Radiologia, Pneumonia.

ABSTRACT

To analyze the cost-effectiveness of radiological imaging methods, radiography and CT scans, in the diagnosis of community-acquired pneumonias in a health care facility in São Luís, Maranhão, during the COVID-19 epidemic. Quantitative research, with diagnoses of the grievance studied and cost effectiveness. The need for low and high cost tests in diagnosis was discussed with a view to qualifying the Cost-Effectiveness Analysis. A total of 511 reports were analyzed, with comparative radiography/tomography analysis for large opacities. Agreement between the two techniques occurred in 177 reports, 103 (58.19%) of male patients, with a predominance in the age range between 33 and 53 years (51.4%). When comparing the two techniques, the radiography system proved to be as effective as the tomography. In this cost-effectiveness analysis, it was observed the need to advance, not only in the production of evidence, but especially in the use of this methodology, in the reduction of health system costs and expansion in quantity/quality.

DESCRIPTORS: Cost-effectiveness; Health Economics; Unified Health System; Radiology, Pneumonia.

RESUMEN

Analizar la rentabilidad de los métodos de imagen radiológica, radiografías y tomografías computarizadas, en el diagnóstico de la neumonía adquirida en la comunidad en un centro de salud de São Luís, Maranhão, Brasil, durante la epidemia de COVID-19. Investigación cuantitativa, con diagnósticos del agravio estudiado y rentabilidad. Se discutió la necesidad de exámenes de baja y alta custodia en el diagnóstico con vistas a la cualificación de la Análise de Custo-Efetividade. Foram analisados 511 laudos, com análise comparativa radiografia/tomografia, para as grandes opacidades, a concordância entre as duas técnicas ocorreu em 177 laudos, sendo 103 (58,19%) do gênero masculino, com predominância nas idades entre 33 e 53 anos (51,4%). Al comparar las dos técnicas, el sistema de radiografía demostró ser tan eficaz como la tomografía. En este análisis de coste-efectividad, se observó la necesidad de avanzar, no sólo en la producción de evidencias, sino especialmente en el uso de esta metodología, en la reducción de costes del sistema sanitario y en la expansión en cantidad/calidad.

DESCRIPTORES: Coste-efectividad; Economía de la Salud; Sistema Único de Salud; Radiología, Neumonía.

RECEBIDO EM: 22/12/2022 **APROVADO EM:** 03/04/2023

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DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

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INTRODUCTION

Health financing is a subject that always generates debate in order to better determine the use and allocation of resources for society as a whole. When it comes to health care, most countries are faced with rising costs, both in absolute and relative terms, regardless of whether the financing model adopted is public or private, based on tax collection or direct user funding[1].

Since the 1980s, emphasis has been placed on better management of health resources in the United States, through a group of activities aimed at reducing the cost of providing health services, as well as improving the quality of this care, known as managed care, which has been the basis of the health system. This system focuses on the fact that healthcare professionals must always be concerned with both the cost and the benefit of providing services. Vassalo[2] and Eldenburg[3] defend managed care, arguing that cost control reduces the high prices previously imposed on society. Baker[4] criticizes managed-care, as he believes it is detrimental to the quality of patient care and can be a limiting factor in technological progress.

The relevant findings found in this research on community-acquired pneumonia (CAP) will contribute to a better understanding and identification of the costs and benefits of imaging methods - Computed Tomography (CT) and X-ray (XR) - for this pathology. It is intended that the investigation of the prevalence, radiological and clinical findings in a sample of the population of Maranhão will arouse the interest of health services at regional and national level, so that greater efforts can be made to ensure the correct and balanced use of the diagnosis and treatment of this entity.

The problem to be addressed is: How can the SUS exercise its constitutional role of contributing to a better cost-effectiveness ratio of imaging tests - X-ray and CT - as a parameter of efficiency in health services for the diagnosis and treatment of community-acquired pneumonia (CAP), with rational use of resources?

CAP has an eminently clinical and imaging (radiological) diagnosis, using chest X-rays, as mentioned above. Chest tomography is considered to be a high-cost exam for the Unified Health System (SUS), and is carried out in only a few public imaging services in Maranhão.

A previous review of published articles, master's dissertations and doctoral theses on the subject carried out in postgraduate programs in Public Health and Health Sciences in the state of Maranhão from 2009 to 2019 has shown that there is no scientific production on the cost-effectiveness of imaging tests as an efficiency parameter in SUS health services in Maranhão, hence its relevance.

The aim is also to contextualize this master's work, providing valuable information to the SUS on the frequency of this lung disorder in a reference service in the state, contributing to strategic planning in the SUS in the field of epidemiological surveillance of lung diseases.

Health economics plays a major role throughout the world, with the resources used to provide medical care playing a growing role in the new actions that the procedure offers, thus justifying the need for studies and practices in the area[5]. In Brazil's political and financial scenario, the health sector has sought new management alternatives, focusing on the need for health organizations to adapt to an increasingly competitive market. The need to guarantee positive results and satisfied customers requires organi-

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

zations to learn how to combine low costs with excellent quality for their customers[6].

The high cost index in health care has led professionals to invest in this knowledge in order to rationalize the process of allocating resources, balancing financial resources and optimizing results[7].

On the other hand, the exponential increase in these costs is entirely related to a series of factors, such as the use of new technologies; the growth in demand; the scarcity of qualified workers, resulting in low productivity; the poor management of organizations due to the administrative incapacity of health professionals; the failure to implement control systems; waste in the production chain, among others[8].

At the end of the 1990s, in the context of state reform, driven by the neoliberal wave, some states adopted the policy of social health organizations (OSS). The OSS are non-profit private entities with recognized expertise in health management, which manage public hospitals and outpatient clinics, with state resources and control9. The OSS were formalized by Complementary Law No. 846 of June 4, 1998.

It is true to say that when a health institution is well managed, it starts to offer classified and controlled responsibility in order to achieve goals in the most skillful and effective way. It is at this time that the health professional is extremely necessary for monitoring decisions in technical areas, offering a quality service so that the institution has improved in counting expenses, specialization, economics, finances and organizational assumptions, containing understanding and human relationships[7].

In our research, we carried out a comparative study between the effectiveness of chest X-rays and computed tomography in the diagnostic evaluation of inflammatory/infectious pulmonary processes (pneumonia), which is the purpose of this research. A retrospective review of medical records and test reports of patients with a clinical diagnosis of pneumonia was also carried out, comparing the cost-effectiveness of the imaging methods9.

Pneumonia is an infection in the lungs caused by various infectious or irritating agents (bacteria, viruses, fungi and allergic reactions). Symptoms vary and can include fever, runny nose, shortness of breath, listlessness, back pain, among others. Unlike viruses, which are highly infectious, the other infectious agents of pneumonia are not usually easily transmitted. Diagnosis should be made through anamnesis, physical examination with lung auscultation and the aid of diagnostic tests, primarily chest X-rays and, in selected cases, chest CT scans[10].

In Brazil, although the pneumonia mortality rate is falling (25.5% reduction between 1990 and 2015), the number of hospitalizations and the high cost of treatment are still challenges for public health and society as a whole. Between January and August 2018, in Brazil, 417,924 patients were hospitalized because of pneumonia, totaling more than R$378 million spent on hospital services[11]. However, an entirely new scenario has emerged with the COVID-19 epidemic among us. Considering that the main affection of the disease is the viral pneumonia that results from it[12].

Community-acquired pneumonia (CAP) continues to be an ongoing challenge for primary health care services around the world[13]. In the context of increasing expectations that health systems provide care based on a rational cost-effectiveness ratio, the financial burden of diagnosing CAP, especially in the local use of imaging methods, has attracted the attention of health professionals and managers[14]. Various measures have been proposed and implemented to contain costs related to the care of patients with CAP, while preserving satisfactory clinical outcomes[15].

Cost assessment is therefore a key element in supporting healthcare decisions. Thus, assessing the costs of adverse events is relevant for two essential reasons[16]:

a) On the one hand, together with the assessment of the prevalence of these events, it highlights the economic weight of the disease for society and, therefore, its preferential nature for health policies. In practice, it is not enough to prove the high prevalence or incidence of a disease in order to persuade political decision-makers to intervene; its economic weight is also highlighted, in terms of costs for the state and society, and losses related to economic growth and development.
b) On the other hand, evaluating the cost of adverse events (AEs) is a fundamental pillar for evaluating alternative interventions to reduce AEs, or comparing these interventions with others in the health field.

Chest X-rays (PA + profile) can vary from R$45.00 to R$90.00 (from popular clinics to private ones). CT scans range from R$400.00 to R$600.00. Evidence shows that CAP is also a pathology whose curative treatment is clinical. The SUS prices are R$6.88 for a chest X-ray and R$136.41 for a chest CT scan[17].

It is assumed that the health services market has its flaws, which implies the need for intervention. Savedoff[18] supports Kenneth Arrow in the discussion on the adoption of cost-effectiveness, with the publication of the article "The welfare of health economics" in 1963, considered the milestone in the creation of the discipline of Health Economics. Regarding Arrow's article, Savedoff considers it to be well up to date as it

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

touches on the central characteristic of debates on public health policy, such as market and non-market institutions that play their role in the provision and distribution of health care services, assessing that the essence of uncertainty regarding the incidence of diseases and the effectiveness of treatment can lead to an inefficient allocation of resources, even in competitive (health) markets.

Faced with the need to justify health care with a view to efficiency, economic evaluations of health interventions have emerged as an important tool to support decision-making, as they allow for the comparative analysis of optional actions in terms of costs and consequences[19].

The aim of this study was to highlight the cost-effectiveness of imaging tests for diagnosing Community-Acquired Pneumonia, to carry out a literature review on health economics based on the efficiency of imaging tests; to diagnose pneumonia foci using different methods and show the accuracy between them, and to discuss the probable consequences of using cost-effectiveness parameters when incorporating technologies into the SUS.

METHODS

The proposed research design was a retrospective observational study, using data from medical records and other documents related to imaging exams, such as reports, opinions and requisitions.

The research was carried out at the Imaging Unit of the UDI Hospital, located at Avenida Prof. Carlos Cunha, 2000 - Jaracati. It is part of the Rede D'Or in São Luís and has an adult and pediatric emergency department, a humanized Intensive Care Unit (ICU) and 24-hour medical and surgical clinics. It performs high-tech tests, such as cardiology, endoscopy, hemodynamics and diagnostic imaging. It has a special IT and management system (TASY) through which all patients' medical records and test results and images are available online to all the doctors on the UDI team.

The inclusion criteria were: reports from patients with CAP results. The exclusion criteria were patients who underwent X-rays and CT scans, but who were not diagnosed with pneumonia using different methods and whose accuracy was not confirmed.

Data was collected on exams carried out between March 1st and May 30th 2020. In the first phase, all the reports and images of the CT and X-ray exams carried out in the period were analyzed, checking the diagnoses and main radiological findings, seeking to identify patients with a diagnosis of CAP through imaging. All patients whose CT and X-ray reports and images showed the presence of CAP were entered into the database. Specifically, those individuals whose diagnosis of CAP was demonstrated by X-ray or CT.

As for the reason for the examination, all the indications were checked, not excluding any of them, so that we could base ourselves on whether the professional's conduct was consistent with the result. The following radiological signs were collected from the reports and images: consolidation, lung extension, pleural effusion and alveolar opacities. The data collected on the above radiological signs, associated with the main pathology, was also uploaded to the database.

In the last phase of data collection, the medical records of patients who underwent CT and X-ray in the period were analyzed for clinical and epidemiological data. The following information was actively searched for in the medical records: age; gender; pre-hospital medication; clinical complaints; hospitalization; death and COVID-19 testing. All the data obtained was consecutively stored in a digital spreadsheet.

At first, a descriptive analysis was carried out on the data found, which could be presented in tables or graphs. Descriptive statistics were used to evaluate the results obtained over the course of the study. Microsoft Excel 2003® software was used for data storage, calculations and the creation of graphs and tables.

After sampling, the data collected was summarized in Microsoft Office Excel® spreadsheets. As the research period was the same as the COVID-19 pandemic, the following variables were investigated: gender, age, occurrence of CT and X-ray findings, COVID-19 testing, hospitalization, death and pulmonary extension. Age was analyzed using the mean and standard deviation.

The other variables were studied using the absolute and relative frequency of occurrence. A table was created containing data on the variables age and gender in relation to the patients' lung extension.

In order to provide an overview, albeit brief, of gender inequalities, the study sought to cover a range of essential information in order to address the domains established by the research20. Thus, a principal component analysis was carried out in order to understand the ordering of patients through their impact on pulmonary findings and the extent to which the lungs were affected.

All the CT and chest X-ray exams and their respective reports were only analyzed after the project had been approved by the Research Ethics Committee of the University of Ceuma and duly authorized by the governing body responsible for the institution where the research was carried out and by its respective local Ethics Committee, whose Opinion number is 4.657.170. Likewise, the medical records of patients who underwent tests at the research site were only reviewed after approval and authorization by the head of the institution.

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

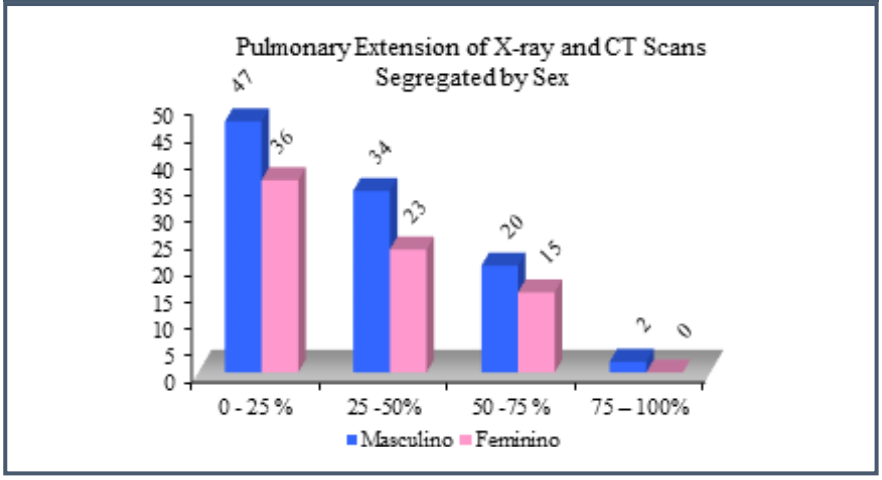
Table 1. Characterization of patients according to sociodemographic data, according to individual variables and lung extension. (*) no data available, 2020.

Variables	Pulmonary extension (n/%)				
	0 - 25 %	25 -50%	50 -75 %	75 – 100%	General
Gender	**83 (n° / %)**	**57 (n° / %)**	**35 (n° / %)**	**2 (n° / %)**	**177 (n° / %)**
Male	47 (56,63)	34 (59,65)	20 (57,14)	2 (100,00)	103 (58,19)
Female	36 (43,37)	23 (40,35)	15 (42,86)	-	74 (41,81)
Age					
13 a 33	10 (12,05)	9 (15,79)	6 (17,14)	-	25 (14,12)
33 a 53	44 (53,01)	32 (56,14)	16 (45,71)	-	92 (51,98)
53 a 73	20 (24,10)	13 (22,81)	8 (22,86)	2 (100,00)	43 (24,29)
73 a 93	8 (9,64)	3 (5,26)	5 (14,29)	-	16 (9,04)
X-ray (+) covid					
Sim	25 (30,12)	55 (96,49)	35 (100,00)	2 (100,00)	117 (66,10)
Não	58 (69,88)	2 (3,51)	-	-	60 (33,90)
X-ray					
Sim	83 (100,00)	57 (100,00)	35 (100,00)	2 (100,00)	177 (100,00)
Não	-	-	-	-	-
PCR (+)					
Yes	69 (83,13)	54 (94,74)	33 (94,29)	1 (50,00)	157 (88,70)
No	4 (4,82)	2 (3,51)	-	-	6 (3,39)
Not requested	10 (12,05)	1 (1,75)	2 (5,71)	1 (50,00)	14 (7,91)
Exams					
PCR (+)	68 (81,93)	54 (94,74)	33 (94,29)	1 (50,00)	156 (88,14)
PCR (-)	4 (4,82)	2 (3,51)	-	-	6 (3,39)
Not requested	11 (13,25)	1 (1,75)	2 (5,71)	1 (50,00)	15 (8,47)
Intubation					
Yes	2 (2,41)	6 (10,53)	21 (60,00)	1 (50,00)	30 (16,95)
No	80 (96,39)	51 (89,47)	14 (40,00)	1 (50,00)	146 (82,49)
No data	1 (1,20)	-	-	-	1 (0,56)
Azithromycin					
Yes	17 (20,48)	23 (40,35)	11 (31,43)	-	51 (28,81)
No	10 (12,05)	6 (10,53)	3 (8,57)	-	19 (10,73)
No data	56 (67,47)	28 (49,12)	21 (60,00)	2 (100,00)	107 (60,45)
Chloroquine					
Yes	43 (51,81)	39 (68,42)	26 (74,29)	1 (50,00)	109 (61,58)
No	14 (16,87)	8 (14,04)	5 (14,29)	-	27 (15,25)
No data	26 (31,33)	10 (17,54)	4 (11,43)	1 (50,00)	41 (23,16)
Deaths					
Yes	1 (1,20)	3 (5,26)	7 (20,00)	1 (50,00)	12 (6,78)
No	80 (96,39)	54 (94,74)	28 (80,00)	1 (50,00)	163 (92,09)
No data	2 (2,41)	-	-		2 (1,13)

Source: Research data, 2020.

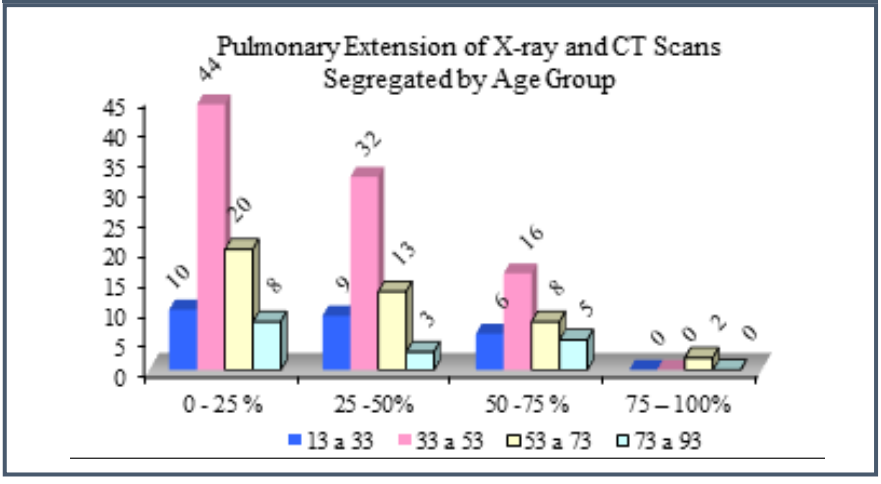
DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

Graph 1. Characterization of patients by gender, according to individual variables and lung extension. (*) no data



available, 2020. Source: Research data, 2020.

Graph 2. Characterization of patients by age group, according to individual variables and lung extension. (*) no data available, 2020.



Source: Survey data, 2020.

RESULTS

The clinical and demographic characteristics of the 177 hospitalized CAP cases are shown in Table 1.

The cases were categorized by severity, with 103 (58.19%) male patients, 92 (51.98%) of whom were aged between 33 and 53 (45.71%). Of these 177 patients, 117 underwent a covid (+) X-ray. PCR (+) was requested for 157 (88.70%) patients, of whom 156 (88.14%) were positive.

The health resources and respective quantities used by the 177 patients with CAP are detailed in Table 1, where it can be seen that 30 (16.95%) patients were intubated. During the period prior to hospitalization, 109 (61.58%) patients received more than one medication, and the most prescribed medications were Azithromycin (28.81%) and Chloroquine (61.58%). As for the clinical outcome, 12 (6.78%) died.

When evaluating each variable individually, it can be seen that male patients were more prevalent (Graph 1)

The findings in relation to age range showed that the majority of patients were between 33 and 53 years old, as shown in Graph 2.

Graph 3 shows that a large number of patients underwent X-rays to check whether lung extension was related to COVID-19.

In order to assess the patients' monetary notions in relation to the cost of the tests, the sociodemographic variables were asked about which diagnostic methods had been requested, indicating X-ray and CT.

The CT findings were grouped into six distinct categories. Ground glass was the most common finding (56%), followed by septal thickening (19%) and consolidations (18%). The variations in the findings that could not be included in the categories are shown in the graph below. They were grouped together in the other category (1%), which had a low frequency of occurrences (Graph 4).

The chosen methods were implemented in order to compare and evaluate the diagnoses of the two techniques in relation to the segmentation carried out by the experts. The properties of the segmentations to be compared are area and perimeter and, in addition to these two characteristics, information on abnormalities suggestive of diseases was used in real time and with a sensitivity percentage in the diagnosis of CAP (Figures 8, 9 and 10).

In the concordance analysis (positive or negative), all those who underwent the test were diagnosed with CRP (+), with a predominance of between 25-50% pulmonary extension (Graph 5).

Graph 6 shows the clinical outcome of the patients, where it was clear that the majority were discharged from hospital, although there were still 12 deaths.

Figures 8, 9 and 10 show that CT scans offer similar sensitivity to a lower-cost scan, in this case X-rays. Both allow image formation, but CT is a more sophisticated method and re-

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

quires greater cost-effectiveness (Table 2).

The minimization cost analysis (MCA) is justified, represented by the difference in costs between the alternatives Computed Tomography and X-Ray, therefore, R$ 7,605.00 - R 24,000.00 = - R$ 16,395.00. Therefore, by opting for X-ray to screen for CAP in this sample of 177 reports, the cost was 17,000.00 less.

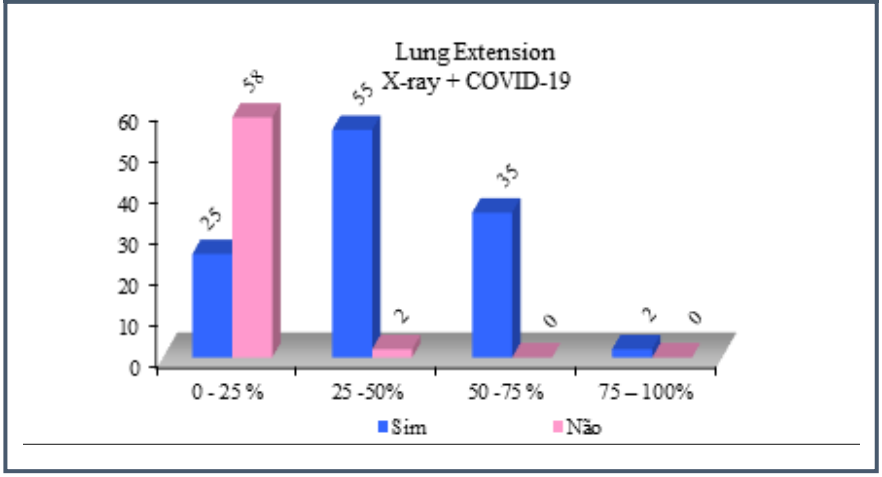
DISCUSSION

Gender is a relevant characteristic and in a review carried out by Li et al.[21] in China, around 60% of those infected with SARS-CoV-2 were men. The same occurred in a study by Zhou et al.[22] in which both the patients who were discharged (59%) and the patients who died (70%) were men. However, the relationship between gender and COVID-19 has not yet been clarified, but it could be that the worse outcome in men may be related to the greater number of comorbidities present in men or a different immune system response to that observed in the female population.

It was noted that the highest recorded mortality rates are among men compared to women. This notification is observed in the reports of a significant number of countries and raises important questions about the spread and clinical impact of this pandemic[23]. According to Scully et al,[24] data collected in 38 countries reveals that the lethality rate among men is 1.7 times higher than among women. Thus, gender can be considered a risk factor for greater severity and mortality in COVID-19 patients, regardless of age and susceptibility, and the higher case of the disease may be correlated with the shorter life expectancy of men compared to women[25].

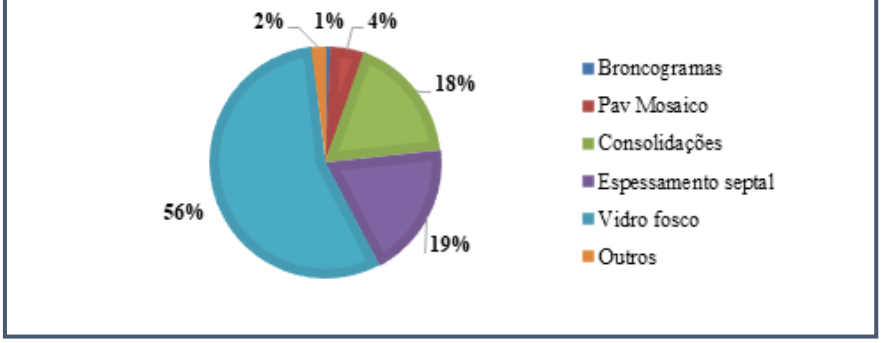
It is possible to state that the likelihood of falling ill from this pandemic was lower in Santa Catarina than in Brazil as a whole, during the period

Graph 3. Characterization of patients according to X-ray + COVID-19, according to individual variables and lung extension. (*) no data available, 2020.



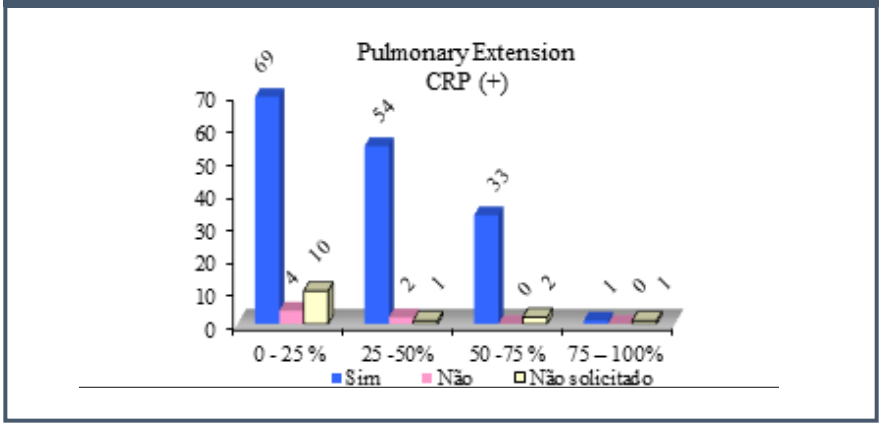
Source: Survey data, 2020.

Graph 4. Findings observed through Computed Tomography, according to six different categories, 2020.



Source: Research data, 2020.

Graph 5. Characterization of patients according to CA (+), according to individual variables and lung extension. (*) no data available, 2020.



Source: Research data, 2020.

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

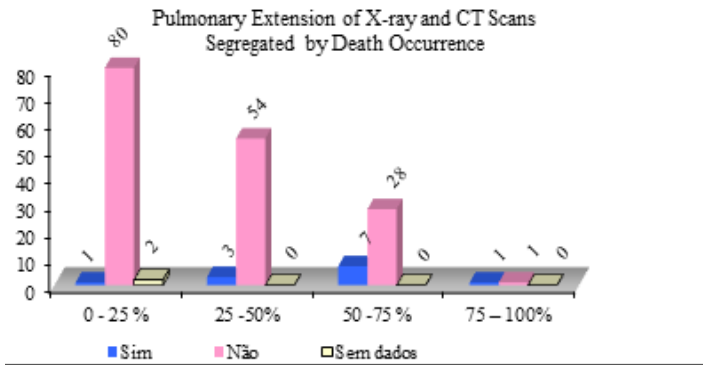
analyzed, indicating that the control of containment of the disease was more marked in the territory of Santa Catarina. The risk of incidence is lower for children and adolescents, but increases rapidly for adults. For adults over 40, the risk is greater than 0.9 when they have total exposure to the virus[21].

Nunes et al.[26] demonstrated the magnitude of the occurrence of multiple morbidities related to the risk of developing clinically severe forms of COVID-19 among the aging Brazilian population. It is estimated that at least 34 million individuals aged ≥ 50 years came with some type of morbidity assessed, highlighting the considerable number of individuals at risk of severe COVID-19, thus representing a greater number of the population of South American countries, except Colombia and Argentina.

According to Bomfim[27], chest radiography is the imaging test of choice in the initial approach to CAP, due to its excellent cost-effectiveness, low radiation doses and wide availability. As well as being essential for diagnosis, chest X-rays help to assess severity, identify multilobar involvement and can suggest alternative etiologies. It can also indicate associated conditions, such as pleural effusion, as well as monitoring the response to treatment. CT should be requested if the professional has any doubts about the infiltrate on plain radiology, to detect complications and differentiate it from neoplasia.

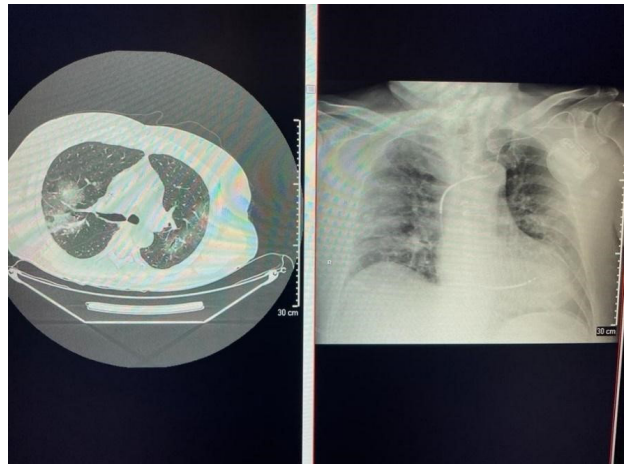
Brazil does not have an explicit threshold for the incremental cost-effectiveness ratio for the incorporation of technologies, which is why we opted to use the WHO proposal for countries that do not have it. The WHO suggests two classifications of limits for incorporating a technology. In the first, disbursement for technology below a country's GDP per capita is highly cost-effective. In the second, disbursement of less than three times the GDP per capita is considered cost-effective[28].

Graph 6. Characterization of patients according to CA(+), according to individual variables and lung extension. (*) no data available, 2020.



Source: Survey data, 2020.

Figure 8. A - Axial computed tomography image showing foci of consolidation, thickening of inter- and intralobular septa associated with ground-glass opacities, typical findings of COVID-19 viral pneumonia, extending to between 25% and 50% of the lung parenchyma; B - AP chest X-ray of the same patient, showing bilateral and peripheral alveolar pulmonary opacities, with a predominance in the lower third of both hemithoraxes, corresponding to a CT scan, adapted by the researcher, 2020.



Source: Research data, 2020.

In the study carried out by Xie et al.[29] with 167 patients, 5 of them were not diagnosed with COVID-19 in the RT-PCR, although the patients had viral pneumonia confirmed by chest CT. However, after repeating the test, the patients received a positive diagnosis of COVID-19 and were isolated for treatment. Hao et al.[30] reported in their research the case of a patient with suspected COVID-19 who, after undergoing two RT-PCR tests, had a negative result and even with the presence of a slight ground-glass opacity in the apical segment of the right upper lobe observed on the chest CT, the patient was discharged

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

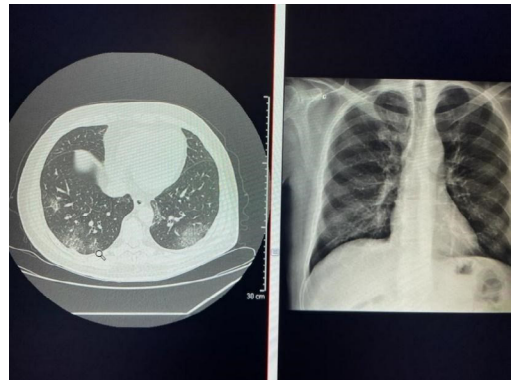
from hospital. However, due to recurring symptoms of fever, dry cough and fatigue, the patient returned to hospital on the same day as discharge and repeated the test, with a positive result for the disease.

In Brazil, as of April 16, 2020, equivalent to the ninth week of the pandemic, there have been 1,924 deaths from COVID-19. Of these, 72% occurred in people aged 60 or over[31]. In China, more than 80% of deaths among adult patients occurred in individuals aged over 65.6 years. Elderly patients and those with comorbidities were found to have the highest risk of serious illness and death[32].

On the one hand, there is the subjectivity of the preference offered by the patient or society when faced with two mutually exclusive alternatives. On the other, there is the assertiveness and reproducibility of science, assessing that the cost of a new technology needs to be regulated. In cost-effectiveness evaluation, costs are checked against clinical outcomes in order to understand the impact of different options, identifying those with better treatment results, generally in exchange for a lower cost. The reason for cost-effectiveness, one of the phases for determining whether a program or treatment should be practiced or not, is defined as the difference between the cost of two interventions divided by the difference between their effects in terms of health (effectiveness)[33].

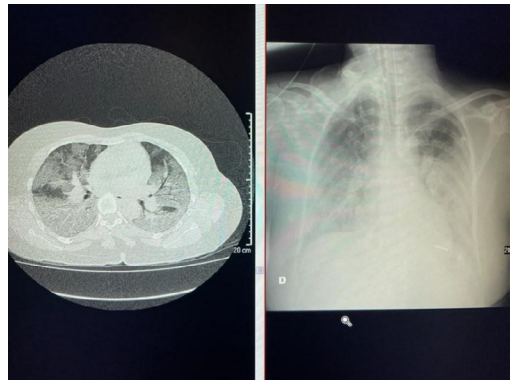
Cost estimates are defined using billing values corresponding to the expectations adopted by the healthcare institution. This is important

Figure 9. A - Axial computed tomography image showing ground-glass opacities, typical findings of COVID-19 viral pneumonia, extending to less than 25% of the lung parenchyma; B - PA chest X-ray of the same patient, showing bilateral and peripheral alveolar pulmonary opacities, with a predominance in the lower lobes, corresponding to computed tomography, adapted by the researcher, 2020.



Source: Research data, 2020.

Figure 10. A - Axial computed tomography image showing foci of consolidation, thickening of inter- and intralobular septa associated with ground-glass opacities, typical findings of COVID-19 viral pneumonia, extending to more than 50% of the lung parenchyma; B - AP chest X-ray of the same patient, showing bilateral and diffuse alveolar pulmonary opacities, corresponding to computed tomography, data adapted by the researcher, 2020.



Source: Research data, 2020.

Table 2. Distribution of total costs considering 177 exams and effectiveness of performing, viewing/interpreting CT scans compared to X-rays, 2020.

Alternative	Cost per exam	Qdt	Total cost
Computerized Tomography	**400,00**	**60**	**24.000,00**
X-ray	65,00	117	7.605,00

Source: Research data, 2020.

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

for analyzing cost-effectiveness from the perspective of the health system, making it possible to incorporate the scope of the country's institutional and regional variability. On the other hand, although micro-costing allows for more detailed spending and individual measurement of the items consumed per patient and by the promoting institution[34].

A cost-of-illness study based on primary data collected from a sample of 59 patients with bacterial pneumonia considered direct medical and non-medical costs and used three costing methods: micro-costing based on a review of medical records, micro-costing based on therapeutic guidelines and gross costing based on reimbursement rates from the Unified Health System. The cost estimates for the different methods were compared using the Friedman test, where the cost estimates for cases of hospitalization for severe pneumonia totaled R$ 780.70 (medical record review), R$ 641.90 (therapeutic guidelines) and R$ 594.80 (SUS reimbursement rates). Brazilian SUS costs estimated using different costing methods differ significantly, with gross costing generating lower cost estimates[35].

When comparing options in order to choose the most cost-effective one, an important concept that must be taken into account is that of opportunity cost. The act of choosing means sacrificing an alternative. In economics, the concept of cost refers to the value of the benefits not obtained by making one decision instead of another[36].

This reduces the opportunity cost of other interventions, which could be replaced by innovation, due to budgetary constraints. In view of this, estimating the opportunity cost has not yet been an estimated criterion in favorable recommendations, which is essential for health economics[37].

CONCLUSION

This study found two areas of important questioning, health and cost-effectiveness, with the aim of analyzing the cost-effectiveness of imaging tests as a parameter of efficiency in health services, with financial and diagnostic comparisons between Radiography and Computed Tomography.

The intention of the study was initially to evaluate only patients affected by Community Acquired Pneumonia. However, due to the COVID-19 pandemic, the world is now in a state of crisis.

One of the biggest challenges in dealing with pneumonia today is the assimilation of the etiological agent since, during collection, the sample may be contaminated with material from the upper respiratory tract that may be colonized by pathogenic microorganisms, but which do not cause infections.

Several published studies have failed to identify the etiology of pneumonia cases, despite various diagnostic resources such as serology, antigen research and the detection of genetic material using the polymerase chain reaction method, in this case PCR. Most of the time, it is not possible to distinguish COVID-19 from CAP based on signs and symptoms alone.

In a study carried out by Levi et al. (2020), it was observed that patients with bacterial pneumonia are more likely to develop symptoms quickly, presenting with purulent sputum and pleuritic pain. Secondary pneumonia usually occurs after the initial phase of the viral respiratory infection, or can also occur during the recovery phase, whose etiological agent can be identified through bacterial cultures of bronchoalveolar lavage and/or bronchial brushings in sick patients with COVID-19.

In order to make an effective diagnosis, the doctor suggests examinations and diagnostic tests, such as laboratory and imaging tests. Generally, a chest X-ray is indicated to assess patients undergoing outpatient treatment. However, due to the pandemic, computed tomography has been added to the diagnostic efficiency of pneumonia.

The result of the analysis shows that the implementation of the chosen methods, both in the comparison and evaluation of the diagnoses of the two techniques (X-ray and CT), leads to a conclusive result. The properties of the segmentations that were compared used information on abnormalities suggestive of diseases in real time and with a percentage of sensitivity in the diagnosis of CAP. In other words, given the many questions raised in the research, it can be seen that when comparing the two imaging techniques, the X-ray system is just as effective as CT. The fact is that there is no doubt that great technological advances have been made when it comes to quality Cost-Effectiveness Analysis (CEA).

Because it requires more data and obtains better results, it is possible that CEA can obtain questionable results, hence the need to be careful with the methodology, which is extremely important for carrying out various sensitivity analyses. However, it is recommended that ACE has a significant impact on changes in efficiency and budget over time, recognizing the equity characteristics of patients in terms of opportunity cost.

Furthermore, further studies comparing costing methodologies could be carried out to corroborate our findings, as these results could support other research into the economic evaluation of interventions for the prevention and control of CAP. However, after analyzing the data presented here, the place and importance of chest X-rays in the diagnosis of CAP is clear.

DOI: 10.36489/saudecoletiva.2023v13i87p12955-12976

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