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Original

Radiation exposure in patients during COVID-19 pandemic

Thailane Marie Feitosa Chaves[1], Mariana Luiza de Acioly Rodrigues[1], Emídio Cavalcanti de Albuquerque[2], Maria Carolina Martins de Lima[1]

[1]Universidade Federal de Pernambuco, Recife, Brazil
[2]Instituto de Medicina Integral Professor Fernando Figueira - IMIP

Introduction
Despite advances in knowledge about COVID-19, it remains a multifaceted disease, with several aspects still requiring further investigation. There is an ongoing need to access and understand long-term, lasting effects of COVID-19 or its clinical handling. The main objective is to analyze risks associated with the radiological investigation performed in patients with neurological symptoms and COVID-19 during the initial pandemic.

Methods
A group of 116 patients, referred to a Neurological-Unit during the initial semester (Apr-Sep/2020) of the pandemic in Pernambuco, Brazil, and positivity (SARS-CoV-2 RT-PCR) for COVID-19 was compared to a similar group, conducted under the same institutional protocols, in a pre-pandemic period. All investigation data used are part of Institutional-Clinical-Image-Databank (BIC-HPS), which automatically stores all imaging performed at the Unit. Groups were similar (in age, p=0.73; sex, p=0.78; and main comorbidities at admission: hypertension p=0.30, diabetes-2, p=0.09).

Results
The COVID-19-group was submitted to a significantly greater number of investigations (medical imaging: p<0.001, radiological exams: p<0.001, and number of tomographic scans: on average: 3.4, 1-12, ±2.0, p<0.001), surpassing safety-limits for radiation exposure.

Conclusions
The study points out the elevated number of clinical investigations undertaken in COVID-19 patients during early pandemic and highlights risks associated – including long-term health risks associated with radiation exposure.

Keywords
Coronavirus, COVID-19, Tomography, Radiation Exposure, Radiation.

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Marcelo Moraes Valença

Thailane Marie Feitosa Chaves
thailanemarie@gmail.com

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Introduction

Although severe acute respiratory syndrome (SARS-type 2) is the best-known manifestation of COVID-19, neurological symptoms have been observed in COVID-19, with or without respiratory illness (1, 2). In non-specialized hospitals, around 36.4% of patients with COVID-19 display neurological symptoms, ranging from alteration of level of consciousness to acute cerebrovascular disease, including skeletal muscle dysfunction (3). Therefore, it is not uncommon that this patient requires investigation of the nervous system (4). Furthermore, in the beginning of pandemic, facing an unknown virus, when specific diagnostic methods were not yet available, imaging - particularly computed tomography (CT) of the thorax - were used to ascertain diagnosis, when suspicion of COVID-19 existed, and this practice has persisted in some locations, in parallel to and despite the development and availability of genomic and serological tests (5).

This study utilizes a Bank-of-Clinical-Images from a Neurological-Unit (BIC-HPS), which automatically stores all imaging performed, without deletion, with the objective of comparing the policy of exam acquisition in neurological patients with positivity for COVID-19 with that performed in similar patients, treated under same institutional protocols, but in a period in which COVID-19 was not a Public-Health concern, seeking, in rethinking past actions, prepare the Health-System and its users for future demands.

Methods

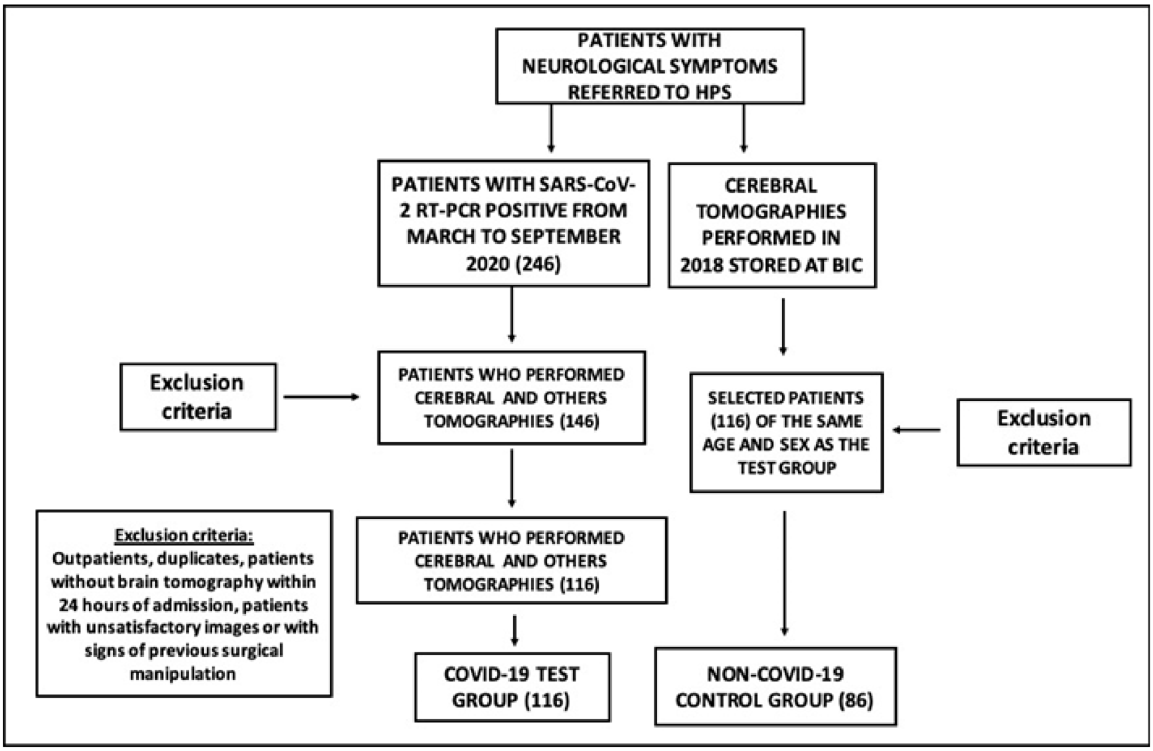
The work was performed in Hospital Metropolitano Oeste Pelópidas Silveira IMIP/SES/SUS, Recife, Pernambuco, Brazil

Retrospective study, comparing number and type of imaging exams performed during hospitalization of neurological patients with and without COVID-19 (Diagram 1). All medical images were accessed through BIC-HPS.

Considering the state of knowledge about diagnostic tests of infection at the time, a choice was made to select control-group from a chronological moment prior to COVID-19 pandemic and not from synchronic patients with negative RT-PCR.

The following clinical images were accounted for: a) non-contrast cranial computed-tomography (CCT-NC), b) contrast-enhanced cranial computed-tomography (CCT-CE), c) computed-tomography of other regions (CT-OR), d) total computed-tomographies (CT-T), e) ultrasounds (US), f) echocardiograms (ECHO), g) angiography (ANG), h) Holter-24h.

Diagram 1. Summary of the study design



Source: The author (2020).

Ethical Approval

Study was enrolled in HPS under number PAPP-HPS-2020-71-37 and subsequently approved by Research Ethical Committee (CAAE 37330720.7.0000.5201).

Place of study

The research was conducted in a Specialized-Tertiary-Unit of Brazilian-Public-Health-System, whose primary profile at inauguration (2011-2012) was to serve as a Cardiological/ Cerebrovascular Reference Unit in the state of Pernambuco.

The Unit possesses a clinical archive, the BIC-HPS, in continuous function since 2014, interfacing for research (anonymized) and assistance (non-anonymized), without deletions, thus making up a continuous database, being distinct from a sample by convenience or even from *Picture Archive and Communicating Systems* (PACS) available in the region, which suffers periodic programmed deletion.

Criteria for inclusion

Patients with positivity (SARS-CoV-2 RT-PCR) for COVID-19 treated at HPS, who performed CCT from March until September/2020 were included in test-group. Control-group included patients who performed CCT in 2018, but similar in age and sex to test-group and randomly selected from BIC-HPS.

Criteria for exclusion

Non-hospitalized patients were excluded. Since this study is part of larger initiatives (including outcome evaluation and neuroimaging findings) patients who have not performed CCT within 24 hours of admission (6), images with artifacts and with signs of previous surgical manipulation were excluded.

Statistics

Softwares Excel 2019 and STATA-SE 12.0 were used. All tests considered 95% confidence interval.

Characteristics of sample

Groups were similar in age, gender and main comorbidities at time-of-admission (Table 1). Age ranged between 22-99y, in both groups.

Table 1. Sample characteristics

	COVID-19 Group	Non-COVID-19 Group	p
Age (average)	64.1 anos (±14.9)	63.4 (±14.8)	0.73
Elderly (≥65 years old)	55.2%	52.3%	0.69
Women	37.9%	36%	0.78
Systemic arterial hypertension	90.9%	96.6%	0.30
Diabetes	68.2%	85.7%	0.09

Source: The author (2020).

Results

Exams:
Frequency and Type (Table 2)

Table 2. Number of individualized exams (by type) performed on each group

Exam	COVID-19			NON-COVID-19			p
	Average	n	SD	Average	n	SD	
CCT-NC	1.9	1-7	±1.2	1.8	1-6	±1.1	0.37
CCT-CE	0.1	0-1	±0.3	0.03	0-1	±0.2	0.02
CT-OR	1.3	0-5	±1.1	0.2	0-3	±0.5	<0.001*
CT-T	3.4	1-12	±2.0	2.0	1-8	±1.4	<0.001*
MR	0.1	0-2	±0.3	0.1	0-1	±0.2	0.61
US	0.6	0-3	±0.7	0.6	0-4	±0.7	0.75
ECHO	0.3	0-2	±0.5	0.1	0-1	±0.3	0.004*
ANG	0.1	1-2	±0.3	0.03	0-1	±0.2	0.14
Holter-24h	0.02	0-1	±0.1	-	-	-	0.22

CT: computed tomography; CCT: cranial computed tomography; NC: non-contrast; CE: contrast-enhanced; OR: other regions; T: total; MR: magnetic resonance; US: ultrasound; ECHO: echocardiogram; ANG: angiography. "-": not performed. Please note that MR numbers presented here were acquired elsewhere and inserted at BIC-HPS at request of the therapeutic team at patients` admission, since no MR equipment is available at the Unit.

In grouping all the radiological exams (only the ones which emit ionizing radiation (IR) it was possible to construct Table 3. When all imaging exams were grouped, Table 4 was obtained. The groupings showed difference between groups, with statistical significance (p<0.0001).

Table 3. Overview of radiological exams by group

Group	Minimum number of exams	Maximum number of exams	Average	SD	P
COVID-19	1	12	3.5	±2.0	**<0.001**
Non-COVID-19	1	9	1.4	±2.1	

The table above presents the global number of radiological exams (CCT-NC, CCT-CE, CT-OR and ANG) for each group, considering all exams registered in the BIC-HPS. Numbers do not include radiographies, since those were not included in the BIC-HPS at the time.

Table 4. Overview of imaging exams by group

Group	Minimum number of exams	Maximum number of exams	Average	SD	p
COVID-19	1	15	4.40	±2.6	**<0.001**
Non-COVID-19	1	12	2.80	±2.0	

The table above presents the global number of imaging exams (CCT-NC, CCT-CE, CT-OR, ANG, US, ECHO and Holter-24h) for each group, considering all exams registered (and not only exams involving IR, as depicted in Table 3). Numbers do not include radiographies, since those were not included in BIC-HPS at the time.

Discussion

In face of the challenges of a new disease, potentially fatal and causing a pandemic, as has been the case with COVID-19, imaging became essential to handling patients. However, an increase in number of such exams have implications both economical and biological. In the latter context, due to it being a contagious disease, the logistics to performing imaging require modification, since it involves patient´s transportation, which can risk isolation protocol, with a variety of immediate consequences. However, delayed biological complications must also be kept in focus, particularly when considering exams involving ionizing radiation (IR).

Biological Effects Of Radiation In Neuroimaging

Imaging can be grouped according to emission, or lack thereof, of IR.

Biological effects due to low-dose and/or chronic radiation exposure may lead to diseases such as cancer after a latency period, which will depend on radiation dose, irradiated organ and type of effect considered, and reparative mechanisms available (7). The severity of effects to low-doses does not depend, therefore, on dose absorbed - however, the larger the dose absorbed, the higher the probability will be of effects` occurrence. Due to all these characteristics and factors involved throughout the latency period, proving direct causality relation between exposure and disease is virtually impossible (8).

CT scans have revolutionized medical investigation for allowing tridimensional and anatomical evaluation, with progressively better definition. Its use, thereafter, has rapidly increased in the last decades. Today, around 50% of median radiation dose for the population comes from medical exposure, with around one-quarter due only to CTs (9). CT scans utilize around 10-100 times more radiation than conventional radiographies and, therefore, doses absorbed through the former are within the highest observed in diagnostic radiology (10-100mGy) (9). Considering the tendency to repeat CTs, doses may exceed safety-limits and increase risk of cancer (10). Around one-third of CTs in adults are cranial, with about 75% obtained in hospitals (11).

Most of what is known about quantitative amounts of radiation capable of generating biological effects (radiation-threshold) has been based in studies of subgroups of survivors of atomic bombs. There was a significant increase in general risk of cancer in the subgroup of survivors who received low-doses of radiation, varying from five to 150mSv (12-14). Average dose in this subgroup was of around 40mSv, which is approximately the absorption dose of two or three regular, adult´s CT scans (11). Another study with survivors supports the evidence that doses above 100mSv have increased the occurrence of various types of cancers compared to the occurrence in the non-exposed population. It is, however, worth remembering that survivors received instant, full-body exposure to a mixture of radiation more complex than x-ray beams used in CT (9).

However, a study conducted with 400.000 workers of a nuclear industry who were exposed to an average dose of approximately 20mSv (the approximate dose of a single, adult CT scan) has shown significant increase in cancer in workers who received doses between 5-150mSv - consistent with studies of bomb survivors (11, 15, 16). Therefore, there is evidence that exposure to doses of radiation corresponding to two or three CT scans (resulting in an average dose of 30-90mSv) results in an increased risk of cancer (11).

Number Of Exams And Exposure To Radiation In Covid-19

In COVID-19, neuroimaging studies have highlighted types of findings, potential patterns, and the importance of those for diagnosis and handling of infected patients, but rarely do they address the implications of number of exams performed.

In a 2020 study, the number of imaging exams performed is evaluated, however without comments on risks to safety (17). Another study, involving neuroradiology experts, establishes recommendations for neuroimaging in COVID-19, however it does not comment on exposure to radiation and how the proposed investigation protocols might minimize such risks (4).

Concerns about radiation exposure in COVID-19 appears in a study published in early 2021, in Turkey, in the initial stages of the pandemic (5). These authors point out that many CTs of the thorax were initially performed, due to the lack of diagnostic tests (5).

After the completed sequencing of the genome of SARS-CoV-2 and the development of the first protocol of RT-PCR for diagnosis of COVID-19, the World Health Organization (WHO) recommended RT-PCR as gold standard for diagnosis of SARS-CoV-2 due to its being highly sensitive and able to detect infections with minimal levels of pathogens present in patient´s sample (18, 19). But, methods based on RT-PCR require sophisticated equipment and specialized labs, which has limited widespread use, in several parts of the world (20). At HPS, as of April 13th, 2020, the institutional protocol (derived from government recommendations), instructed swab for RT-PCR of SARS-Cov-2 in symptomatic patients, preferably up to seven days after the start of symptoms (21). In this study, all patients included in COVID-19 group were diagnosed based on RT-PCR, eliminating the potential confounding effect of an increase in numbers of radiological tests to fill a void of laboratorial diagnostic tests, as have occurred in other parts of the world (5).

This study demonstrates that, although there was not a tendency to an increased number of CCT in the neurological patients with COVID-19 (Table 2), when compared to control-group; the number of CT-OR in COVID-19 group was markedly superior. There was also a tendency in COVID-19 group to present a higher number of CT-T. This difference had statistical significance ($p<0.001$ for CT-OR and CT-T).

Comparing that with control-group, the tendency of there having been a concentration of higher number of exams on a smaller number of patients was noted. It is observed that, in COVID-19 group (n=116) there was an average of 3.47 (varying from one to 12, ±2.0) radiological exams and 4.41 (varying from one to 15, ±2.6) imaging exams (which includes exams without IR, as described on Tables 3 and 4), compared to an average of 2.07 (varying from one to nine, ±1.4) radiological exams and 2.8 (varying from one to 12, ±2.0) imaging exams in the non-COVID-19 group (n=86). This difference has statistical significance ($p<0.001$). It thus demonstrates that radiation exposure was accentuated, since there was higher number of exams on a smaller number of patients (Tables 3 and 4).

Estimating the degree of exposure involves knowing the average effective doses associated with different exams.

Having established the equivalent and effective doses after a particular exam, combined with data of hazardous doses of radiation, it is possible to estimate the risk of cancer from exposure to imaging exams. Based on this data, Table 5 was produced. From that it is possible to conclude that, with anything above two cranial CT scans, patients start being at risk of delayed complications from IR.

Table 5. Effective doses and limit of exposure to radiation emitted by the main exams of CT scans

Exam	Effective dose (mSv)	Number of exams to reach hazardous effective dose of 5mSv	Number of exams to reach hazardous effective dose of 100mSv
Abdominal CT	10	0.2	10
Cranial CT	2	2.5	50
Thoracic CT	8	0.62	12.5
Pelvic CT	10	0.2	10

Table 5 summarizes the exposure to IR (effective dose) during performance of CTs, as well as the number of exams necessary for exposure to hazardous doses (between 5mSv and 100mSv) associated with deleterious long-term biological effects (11, 12, 14-18).

It is noted that regular investigation of a neurological patient already approaches this safety-limit - an understanding not universally present among specialists who request this exam. However, when COVID-19 is added to patients' picture, and due to the need of tomographic investigation of other regions, this safety-limit is exceeded.

It is observed in COVID-19 patients the performance of a superior number of total exams, when compared to other patients of same profile (Table 3). This may be explained by it being a new disease; nonetheless, the therapeutic team - which requests and analyzes this data – is bound to account for the different requirements - as of logistics involving pre- and post-performance of these exams and potentially environmental and direct patient risks.

Evaluating now the summation of radiological (Table 3) and imaging exams (Table 4), the significant increase of exams performed in patients with COVID-19 was maintained, with statistical significance ($p<0.001$ in comparison between groups in both tables), emphasizing long-term risks previously mentioned. It should be emphasized that this data does not account for the number of radiographies performed - being, therefore, an underestimation.

If careful assessment of the need for the examination by a conscientious therapeutic team is one way to avoid exposure, there are other ways of minimizing radiation during imaging that cannot be avoided. Radiologists must, in inter-consultation, recommend alternatives. Radiology technicians must be trained in reducing radiation-dose. Reductions of over 50% in dose is possible, by adjusting technical parameters and quality-control checking (10).

Despite importance, delayed biological complications of radiation derived from medical investigation, is still an under-discussed topic. Many healthcare professionals are unaware of it. In 2003, 130 doctors, including ten radiologists were interviewed, about radiation dose of main imaging utilized in medical practice (22). Results demonstrated that 97% underestimated radiation exposure from exams and correct answers ranged from 0-59%. Still, five and eight percent of phisicians, respectively, were unaware that US and MR are IR-free. This points out to insufficient knowledge about IR among doctors - not only the opinion-making tier among healthcare professionals, but also those who request these investigations daily (22).

In the context of COVID-19, it was expected that, due to it being a novel disease, the necessity for additional clarifying exams would manifest. However, this study demonstrates that, for the investigation of a neurological patient - already on the limit of the safety-threshold for long-term effects - safe alternatives must be prioritized.

Furthermore, an alert must be made about long-term effects derived from increased number of clinical exams with IR, performed all over the world during COVID-19 pandemic. Data from this study points out that patients with COVID-19 and neurological manifestations are the focus of concern.

Due to its nature as a Specialized-Unit in a Public-Health-System, the results of this study must be extrapolated to other scenarios with caution. The absence of MR device in the Unit and the non-computation of X-rays at the time of the study are limitations inherent to the Unit´s historical moment, and its potential impacts on the results of this study have been debated. Even so, similar clinical and working situations are not unique to this Health Unit, being, in fact, reasonably common considering a world-based scenario, which make this study results valid and pertinent.

It seems imperative, at present, to: a) raise awareness among healthcare professionals involved in care of these patients about judicious use of exams and b) develop investigation protocols favoring modalities IR-free and, in the future, to continue following up these patients for understanding the belated lessons from COVID-19 pandemic.

References

1. Payus AO, Liew Sat Lin C, Mohd Noh M, Jeffree MS, Ali RA. SARS-CoV-2 infection of the nervous system: A review of the literature on neurological involvement in novel coronavirus disease (COVID-19). Bosnian Journal of Basic Medical Sciences. 2020.Doi 10.17305/bjbms.2020.4860
2. Archie SR, Cucullo L. Cerebrovascular and Neurological Dysfunction under the Threat of COVID-19: Is There a Comorbid Role for Smoking and Vaping? International Journal of Molecular Sciences. 2020;21(11).Doi 10.3390/ijms21113916
3. Mao L, Jin H, Wang M, Hu Y, Chen S, He Q, et al. Neurologic Manifestations of Hospitalized Patients With Coronavirus Disease 2019 in Wuhan, China. JAMA Neurology. 2020;77(6). Doi 10.1001/jamaneurol.2020.1127
4. Kremer S, Gerevini S, Ramos A, Lersy F, Yousry T, Vernooij MW, et al. Neuroimaging in patients with COVID-19: a neuroradiology expert group consensus. European Radiology. 2022;32(6):3716-25.Doi 10.1007/s00330-021-08499-0
5. Yurdaisik I, Nurili F, Aksoy SH, Agirman AG, Aktan A. Ionizing Radiation Exposure in Patients with Covid-19: More Than Needed. Radiation Protection Dosimetry. 2021;194(2-3):135-43.Doi 10.1093/rpd/ncab092
6. Achados da tomografia computadorizada de crânio de pacientes com COVID-19 na admissão em Unidade Terciária de perfil Neurovascular: estudo comparativo com pacientes admitidos antes da pandemia Tese de Mestrado em Neuropsiquiatria e Ciências do Comportamento [Internet]. 2022.
7. (UNEP) UNEP. Radiation - Effects and Sources. United Nations Scientific Commitee on the Effects of Atomic Radiation (UNSCEAR) 2016.
8. PC V. Efeitos da radiação X e níveis de exposição em exames imagiológicos: inquéritos a clínicos gerais ,Tese de Mestrado em Saúde Pública. Coimbra: Faculdade de Medicina da Universidade de Coimbra. 2011.Doi
9. Boone JM, Hendee WR, McNitt-Gray MF, Seltzer SE. Radiation Exposure from CT Scans: How to Close Our Knowledge Gaps, Monitor and Safeguard Exposure—Proceedings and Recommendations of the Radiation Dose Summit, Sponsored by NIBIB, February 24–25, 2011. Radiology. 2012;265(2):544-54.Doi 10.1148/radiol.12112201
10. International Commission on Radiological Protection [Internet]. 2000.
11. Brenner DJ, Hall EJ. Computed Tomography — An Increasing Source of Radiation Exposure. New England Journal of Medicine. 2007;357(22):2277-84.Doi 10.1056/NEJMra072149
12. Pierce DA, Preston DL. Radiation-Related Cancer Risks at Low Doses among Atomic Bomb Survivors. Radiation Research. 2000;154(2):178-86.Doi 10.1667/0033-7587(2000)154[0178:Rrcral]2.0.Co;2
13. Preston DL, Shimizu Y, Pierce DA, Suyama A, Mabuchi K. Studies of Mortality of Atomic Bomb Survivors. Report 13: Solid Cancer and Noncancer Disease Mortality: 1950–1997. Radiation Research. 2003;160(4):381-407.Doi 10.1667/rr3049
14. Preston DL, Ron E, Tokuoka S, Funamoto S, Nishi N, Soda M, et al. Solid Cancer Incidence in Atomic Bomb Survivors: 1958–1998. Radiation Research. 2007;168(1):1-64.Doi 10.1667/rr0763.1
15. Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, et al. Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. Bmj. 2005;331(7508).Doi 10.1136/bmj.38499.599861.E0
16. Cardis E, Vrijheid M, Blettner M, Gilbert E, Hakama M, Hill C, et al. The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: Estimates of Radiation-Related Cancer Risks. Radiation Research. 2007;167(4):396-416.Doi 10.1667/rr0553.1
17. Jain R, Young M, Dogra S, Kennedy H, Nguyen V, Jones S, et al. COVID-19 related neuroimaging findings: A signal of thromboembolic complications and a strong prognostic marker of poor patient outcome. Journal of the Neurological Sciences. 2020;414.Doi 10.1016/j.jns.2020.116923
18. Islam KU, Iqbal J. An Update on Molecular Diagnostics for COVID-19. Frontiers in Cellular and Infection Microbiology. 2020;10.Doi 10.3389/fcimb.2020.560616
19. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. New England Journal of Medicine. 2020;382(8):727-33.Doi 10.1056/NEJMoa2001017
20. Notomi T. Loop-mediated isothermal amplification of DNA. Nucleic Acids Research. 2000;28(12):63e-.Doi 10.1093/nar/28.12.e63
21. (SES-PE) SdSdGdEdP. Orientações para a rede assistencial – Manejo Clínico do paciente com COVID-19. 2020 [Available from: http://portal.saude.pe.gov.br/noticias/secretaria/covid-19-ses-pe-atualiza-protocolo-de-manejo-clinico.
22. Shiralkar S. Doctors' knowledge of radiation exposure: questionnaire study. Bmj. 2003;327(7411):371-2.Doi 10.1136/bmj.327.7411.371

Thailane Marie Feitosa Chaves
https://orcid.org/0000-0002-4039-0280
Mariana Luiza de Acioly Rodrigues
https://orcid.org/0000-0002-8968-3623
Emídio Cavalcanti de Albuquerque
https://orcid.org/0000-0002-4231-3115
Maria Carolina Martins de Lima
https://orcid.org/0000-0002-0197-3520

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