

## Impact of using teleneurology on reducing referrals in the single health system

### *Impacto da utilização da teleneurologia na redução de encaminhamentos no sistema único de saúde*

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#### ABSTRACT

**Introduction:** Telemedicine, when applied to neurology, allows for better diagnosis and more specific and appropriate procedures, as well as a highly economical outcome due to the reduction in unnecessary referrals.

**Objectives:** To analyze the impact of using teleneurology on reducing referrals in the Unified Health System (SUS) and verify the associated variables that impacted referrals.

**Method:** Documentary, quantitative, descriptive and cross-sectional research, which was carried out using information contained in a database, constructed from services included in a platform that provides teleneurology services in Brazil. Analysis was performed to examine the relationship between the binary dependent variable (emergency referral) and a set of five independent variables (age, sex, treatment unit, clinical history and tomography results).

**Results:** The study comprised 2,165 medical records of patients who required neurological care via telemedicine between April 2019 and October 2022. After analysis, it was observed that the logistic regression model was statistically significant ( $p < 0.05$ ) for the healthcare unit, treatment, clinical history and tomography results, indicating that these variables were related to the probability of emergency referral. When examining the estimated coefficients in the care units, the chance of being referred via emergency was 0.59 times greater when in hospital than in SAMU, that is, those in the hospital are 41.01% less likely to be referred via emergency. However, those in the UPA are 39.17% less likely to be referred via emergency than in the SAMU.

**Conclusion:** The innovative approach to care provided greater diagnostic efficiency and therapeutic guidance, resulting in substantial savings for the SUS.

**KEYWORDS:** Brazilian Unified Health System. Sus. Referrals. Telemedicine. Teleneurology.

#### Central message

Telemedicine, when applied to neurology, enables better diagnosis and more specific and appropriate conducts, as well as a very economical outcome due to the reduction of unnecessary referrals. Thus, analyzing the impact of the use of teleneurology on the reduction of SUS referrals and verifying the variables associated with them is opportune with a view to speeding up care, reducing unnecessary referrals and lowering the costs of neurological care as a whole.

#### Perspective

This study demonstrated that the use of teleneurology reduced the number of unnecessary referrals in the SUS. After analyzing the associated variables collected, statistical significance was found in the independent variables, i.e., treatment units, clinical history and CT scan results, concluding that they have an impact on the occurrence of emergency referral. The use of teleneurology is beneficial to patients, the health system and the economic expenditure on treatment.

#### RESUMO

**Introdução:** A telemedicina quando aplicada à neurologia, possibilita melhor diagnóstico e condutas mais específicas e adequadas, bem como desfecho com grande economicidade devido à diminuição de encaminhamentos desnecessários.

**Objetivos:** Analisar o impacto da utilização da teleneurologia na redução de encaminhamentos no Sistema Único de Saúde (SUS) e verificar as variáveis associadas que impactaram no encaminhamento.

**Método:** Pesquisa documental, quantitativa, descritiva e transversal, que foi realizada a partir da utilização de informações contidas em banco de dados, construído de atendimentos inclusos em plataforma que presta serviços de teleneurologia no Brasil. Foi efetuada análise para examinar a relação entre a variável dependente binária (encaminhamento via emergência) e um conjunto de cinco variáveis independentes (idade, sexo, unidade de tratamento, história clínica e resultado da tomografia).

**Resultado:** O estudo compreendeu 2.165 prontuários de pacientes que demandaram atendimento neurológico via telemedicina entre abril de 2019 e outubro de 2022. Após a análise, observou-se que o modelo de regressão logística foi estatisticamente significativo ( $p < 0,05$ ) para unidade de tratamento, história clínica e resultado da tomografia, indicando que essas variáveis estavam relacionadas à probabilidade de encaminhamento emergencial. Ao examinar os coeficientes estimados nas unidades de atendimento, a chance de ter encaminhamento via emergencial foi 0,59 vezes maior estando no hospital do que no SAMU, ou seja, quem está no hospital tem 41,01% menos chances de ser encaminhado via emergencial. Contudo, quem está na UPA tem 39,17% menos chances de ser encaminhado via emergencial do que no SAMU.

**Conclusão:** A abordagem inovadora de atendimento proporcionou maior eficiência diagnóstica e orientação terapêutica, resultando em economia substancial ao SUS.

**PALAVRAS-CHAVE:** Encaminhamentos. Sistema Único de Saúde. SUS. Telemedicina. Teleneurologia.

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## INTRODUCTION

The discussion about variations in the methods of care and referral of patients has been relevant for many years in the health area. This is due to the persistence of several issues and divergences related to both the excessive transfer of patients to more complex hospital institutions and the deficiencies in directing which individuals truly require this type of care.

The processes of care flows and clinical management have become progressively more challenging as population changes are established. Due to this situation, better attention to the form and availability of services offered becomes a priority.<sup>1</sup>

The advancement of technologies in patient care has significantly revolutionized the provision of health care. Several technological innovations have contributed to improving the efficiency, accuracy, and accessibility of health services, especially telemedicine. It emerges as a transformative innovation in the field of health care delivery, representing a significant advance in the form of care delivery. This modality of care is becoming increasingly important, offering a variety of benefits that transcend geographical and temporal borders. By delving deeper into the analysis of these benefits, it becomes evident that telemedicine not only facilitates access to healthcare but also promotes operational efficiency.<sup>2</sup>

The growing demand for specialized neurology services has generated significant challenges in terms of access and efficiency in the Unified Health System (SUS), especially considering the complexity of neurological diagnoses and the shortage of specialized professionals in some regions of the country. In this context, teleurology is inserted as a strategic and innovative tool.<sup>2,3</sup>

Thus, the objectives of this study were to analyze the impact of the use of teleurology on the reduction of referrals in the SUS and to verify the associated variables that impacted referrals.

## METHOD

This study was approved by the Human Research Ethics Committee of the Faculdade Evangélica Mackenzie do Paraná, Curitiba, PR, Brazil CAAE: 65591122.4.0000.0103. The research was carried out based on the use of information contained in a database, built of services included in the CEANNE telemedicine platform, which provided teleurology services in 21 units in Brazil to SUS users. The study comprised 2,165 medical records of patients who required neurological care via telemedicine between April 2019 and October 2022. The data were analyzed through descriptive statistics, through the description of absolute and relative frequencies for categorical variables and measures of relative trend and dispersion for numerical variables, in addition to univariate and multivariate statistical analysis. Ethical aspects were respected according to CNS Resolution No. 510/2016.

## Sample selection and data collection

The database used was prepared using 2165 medical records of patients who were SUS users who required care neurological via telemedicine in the 21 Brazilian units where the service was offered. Data collection occurred anonymously, without identifying the patients, with their consent form for the study. All consultations had a series of mandatory information that had to be provided by the physician who was performing the care and some complementary data at the discretion of those who used the service.

Complete medical records were included with information on patients who used teleurology as a form of care, and excluded those that were incomplete or inconclusive, which would make the statistical analysis unfeasible, and those that were not related to the teleurology service.

## Operation of the Ceanne telemedicine platform

In this study, care took place remotely, by a specialized medical team, available 24 hours a day, together with the local professional who performed the initial evaluation of the patient, thus ensuring qualified and adequate care in the 21 units included in the study (Table 1).

**TABLE 1** — List of teleurology care units included in the research

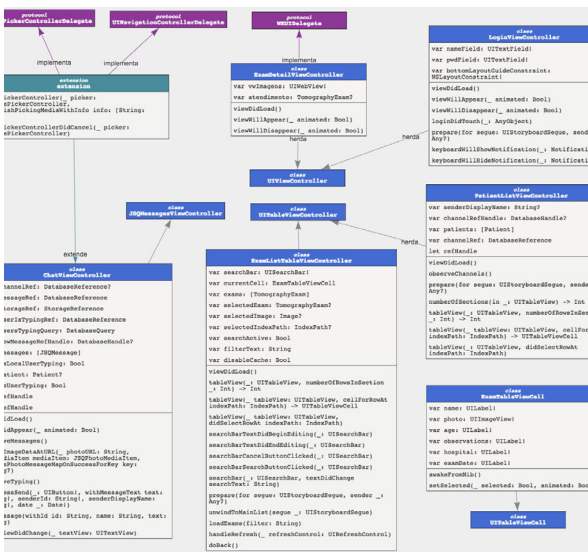
No.	Service Unit
1	Campo Belo
2	Canoas Psychosocial Care Center
3	Psychosocial Care Center Porto Alegre
4	Santa Terezinha de Erechim Hospital Foundation
5	University Foundation of Cardiology
6	São Vicente Charity Hospital
7	Santo Ângelo Charity Hospital
8	Hospital Regional de Santa Maria
9	Senhora Aparecida Hospital in Luz
10	IB Health
11	Manoel Gonçalves
12	SAMU Divinópolis
13	Santa Casa de Misericórdia São Vicente de Paulo
14	Santa Casa de Misericórdia de Santo Antônio do Monte
15	Divinópolis Basic Health Unit - Central Base
16	24-Hour Emergency Care Unit Father Roberto Cordeiro Martins
17	Antônio José dos Santos Emergency Care Unit
18	Nova Serrana Emergency Care Unit
19	Padre Roberto Emergency Care Unit
20	Rio Grande Emergency Care Unit
21	Lagoa da Prata Emergency Care Unit

The specialists evaluated each case by associating the interview data provided by the team with the tests provided by the local physician; in addition, the care relied on several protocols and diagrams provided by the system, always ensuring the necessary expertise for each case associated with the optimization of the communication channel between the remote specialist physician and the team present at the hospital of origin (Figures 1,2,3,4,5).



Source: Isolan et al., 2021<sup>4</sup>

FIGURE 1 – Class diagram of the Ceanne Médico application



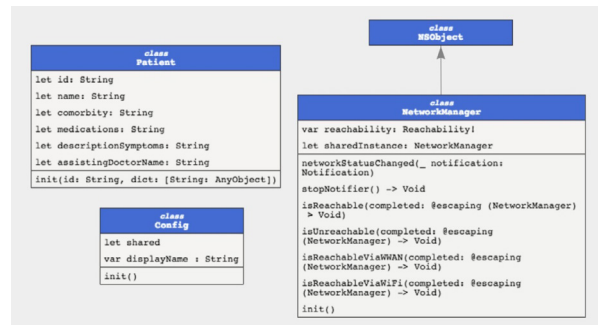
Source: Isolan et al., 2021<sup>4</sup>

FIGURE 2 – Class diagram of the Ceanne Médico application interface



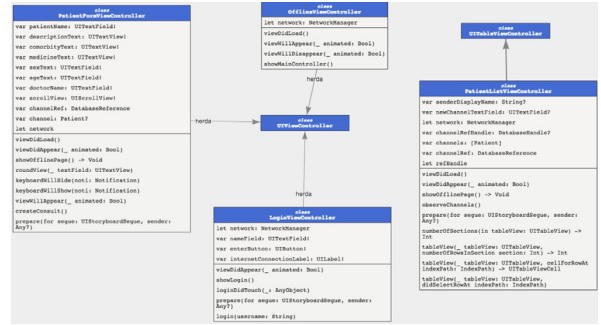
Source: Isolan et al., 2021<sup>4</sup>

FIGURE 3 – Access screen to the Ceanne Hospital system



Source: Isolan et al., 2021<sup>4</sup>

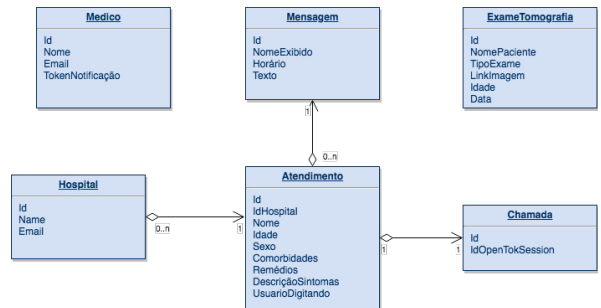
FIGURE 4 – Class diagram of the Ceanne Hospital application



Source: Isolan et al., 2021<sup>4</sup>

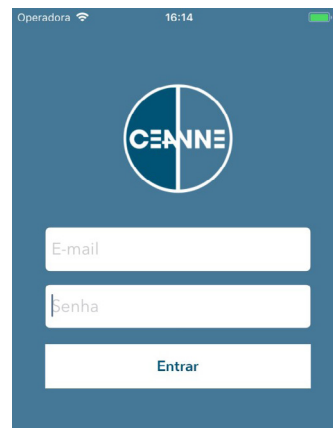
FIGURE 5 – Class diagram of the Ceanne Hospital application interface

The analysis of the cases occurred in an agile, safe and effective interphase, due to the use of a class diagram that provided interconnected processing of clinical and imaging data (Figures 6,7,8,9,10).



Source: Isolan et al., 2021<sup>4</sup>

FIGURE 6 – Entity-relationship diagram of the Ceanne system database



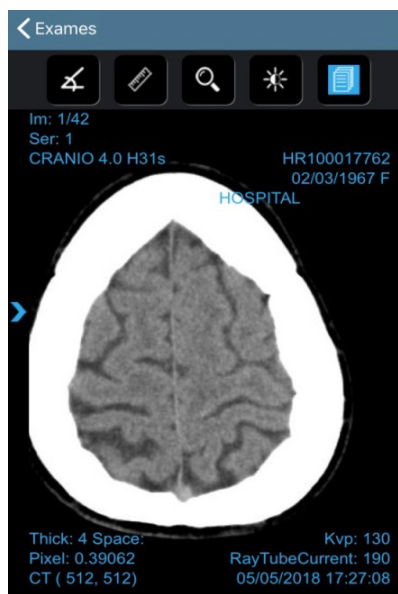
Source: Isolan et al., 2021<sup>4</sup>

FIGURE 7 – Access screen to the Ceanne call center system



Source: Isolan et al., 2021<sup>4</sup>

**FIGURE 8** – Screen for entering patient information for teleservice in the Ceanne application



Source: Isolan et al., 2021<sup>4</sup>

**FIGURE 9** – Image of the tomography interface on the Ceanne teleservice platform



Source: Isolan et al., 2021<sup>4</sup>

**FIGURE 10** – Illustrative screen of the list of exams performed by the patient connected to the Ceanne teleservice platform

### Statistical analysis

The independent variables were age, gender, treatment unit, clinical history, and CT scan results, and were included in the analysis based on sample number and clinical importance. The dependent variable was emergency referral, being binary with yes or no answers. For the descriptive analysis of the qualitative variables, absolute and relative frequencies were used. Due to the qualitative nominal binary character of the dependent variable, a logistic regression model was used to determine whether there was a significant relationship between the independent variables and the probability of emergency referral. Before performing the logistic regression analysis, the assumptions of multicollinearity (VIF), presence of outliers, and linear logarithmic relationship between the continuous independent variables age and the dependent variable were verified. These checks ensured that the assumptions of logistic regression were met and that the results were reliable. The maximum likelihood method was used to estimate the regression coefficients and the respective confidence intervals. Based on the estimated coefficients, it was possible to obtain Odds Ratio (OR) associated with each category of the independent variables. In addition, the R<sup>2</sup>Nagelkerke was used as an adjustment measure to evaluate the overall quality of the logistic regression model. It is an adaptation of the coefficient of determination R<sup>2</sup>, originally used in linear regression models, for the context of logistic regression. All analyses were performed in Software R (R Core Team, 2022), with a significance level of 5%.

### RESULT

This study presented a detailed analysis of the profile of neurological care via telemedicine of SUS users, focusing on the relationship between emergency referral and relevant variables. Tables 2,3,4 provide a comprehensive overview of the characteristics of the patients, the referral units, the observed tomographic alterations, and the factors associated with emergency referral.

**TABLE 2** – Frequency table of the evaluated data profile

Variable	Absolute frequency	Relative frequency (%)
<b>Sex</b>		
Female	864	39,91
Male	1301	60,09
<b>Service units</b>		
Hospitals	285	13,16
SAMU	1139	52,61
UPA	741	34,23
<b>Clinical history</b>		
Headache	1121	51,78
Clinical complaint	129	5,96
Progressive neurological symptoms	290	13,39
Sudden neurological symptoms	165	7,62
TEC	448	20,69
TRAIN	12	0,55
<b>CT scan result</b>		
With amendment	1314	60,69
No change	851	39,31
<b>Emergency referral</b>		
Yes	684	31,59
No	1481	68,41

**TABLE 3** – Table of frequency of tomographic alterations

Variable	Absolute frequency	Relative frequency (%)
Hemorrhagic stroke	234	10,81
Old ischemic stroke	139	6,42
New ischemic stroke	165	7,62
Skull subsidence fracture	3	0,14
Stable spine fracture	4	0,18
Osteodegenerative changes of the spine	2	0,09
Unstable spine fracture	8	0,37
Skull fracture	36	1,66
Hydrocephalus	50	2,31
Aneurysmal SAH	37	1,71
Traumatic SAH	36	1,66
Other	129	5,96
No change	800	36,95
TBI with multiple findings	89	4,11
TBI with extradural hematoma	32	1,48
TBI with acute subdural hematoma	77	3,56
TBI with chronic subdural hematoma	101	4,67
TBI with contusion	173	7,99
TCE for gunshot wound	2	0,09
Brain tumor	48	2,22
Total	2165	100

**TABLE 4** – Frequency table of the evaluated data profile

Variable	Emergency referral	
	No	Yes
<b>Sex</b>		
Female	596 (27.53%)	268 (12.38%)
Male	885 (40.88%)	416 (19.21%)
<b>Care unit</b>		
SAMU	670 (30.95%)	469 (21.66%)
Hospitals	217 (10.02%)	68 (3.14%)
UPA	594 (27.44%)	147 (6.79%)
<b>Clinical history</b>		
Headache	846 (39.08%)	275 (12.70%)
Clinical complaint	85 (3.93%)	44 (2.03%)
Progressive neurological symptoms	145 (6.70%)	145 (6.70%)
Sudden neurological symptoms	135 (6.24%)	30 (1.39%)
TEC	268 (12.38%)	180 (8.31%)
TRAIN	2 (0.09%)	10 (0.46%)
<b>CT scan result</b>		
With amendment	714 (32.98%)	600 (27.71%)
No change	767 (35.43%)	84 (3.88%)

Logistic regression analysis was performed to examine the relationship between the binary dependent variable (emergency referral) and a set of 5 independent variables (age, gender, treatment unit, clinical history, and CT scan results). The objective was to determine whether the independent variables (factors) were associated with the probability of occurrence of emergency referral.

After the analysis, it was observed that the logistic regression model was statistically significant ( $p < 0.05$ ) for some categories of the independent variables: treatment unit, clinical history, and CT scan results (Table 5), indicating that these independent variables were related to the probability of occurrence of emergency referral. By examining the estimated coefficients, the Odds Ratios (ORs) for each category were calculated in relation to the reference category.

**TABLE 5** – Results of multiple logistic regression regarding emergency referral in relation to the significant factors included in the model

Variable	$\beta$ (EP)	P-value	OR (95% CI)
<b>Age</b>			
Age	-0.01 (0.01)	0.07	-
<b>Sex</b>			
Female (reference)	-	-	-
Male	-0.11 (0.24)	0.32	-
<b>Care unit</b>			
SAMU (reference)	-	-	-
Hospitals	-0.53 (0.16)	0.001	0.59 (0.43-0.81)
UPA	-0.50 (0.12)	0.001	0.61 (0.48-0.78)
<b>Clinical history</b>			
Headache (reference)	-	-	-
Clinical complaint	-0.85 (0.22)	0.001	0.43 (0.28-0.66)
Progressive neurological symptoms	-0.26 (0.17)	0.12	-
Sudden neurological symptoms	-1.63 (0.23)	0.001	0.20 (0.12-0.31)
TEC	-0.74 (0.15)	0.001	0.48 (0.36-0.64)
TRAIN	1.17 (0.78)	0.14	-
<b>CT scan result</b>			
With modification (reference)	-	-	-
No change	-2.41 (0.16)	0.001	0.09 (0.07-0.12)

EP=standard error; CI 95%=95% confidence interval; OR=odds ratio

In the care units, the chance of having been referred via emergency was 0.59 times higher when in the hospital than in the SAMU. In other words, those who were in the hospital were 41.01% less likely to be referred via emergency than those treated by SAMU. In turn, those who were in the UPA would be 39.17% less likely to be referred via emergency than those treated at SAMU. The relationship between hospital and UPA was not significant.

When analyzing the frequency of tomographic alterations, other CT scans that had artifacts or conditions of low incidence were included, for a better analysis of the statistical coefficients. Considering the CT scan result factor, the chance of having been referred via emergency was 91.03% lower among those who did not have CT abnormalities than among patients with CT.

In the clinical history, isolated reports of malaise, weakness and fatigue were grouped under the item clinical complaints, after analysis and medical evaluation that primary neurological causes for the symptoms were ruled out and to facilitate statistical analysis. In clinical history, headache complaints stood out as the highest proportion of emergency referrals. Clinical complaints, neurological symptoms, and TBI were, respectively, 57.47%, 80.48% and 52.31% lower in emergency room referral compared to headache.

## DISCUSSION

Historically, telemedicine began in 1970 in Boston, in the United States of America, with the purpose of serving rural areas. Since then, it has been used as an assistance tool for regions lacking specialists.<sup>5</sup>

Telemedicine, as defined by the World Health Organization, refers to the provision of health services by professionals who make use of information and communication technologies. These tools are not only

limited to the validation of diagnoses, treatments, and preventive measures, but also extend to research and the provision of continuing education, training professionals for this purpose.<sup>6</sup>

Regarding the implementation of remote care, the studies identified several facilitating factors and barriers to the use of telemedicine in clinical practice. The facilitators included the support of managers, professionals and patients, the availability and adequacy of technological resources, the integration with existing systems, and the capacity building and training of those involved. Barriers included resistance to changing the form of care, lack of financial incentives, legal and ethical issues, usability and reliability of equipment, and technical and organizational challenges.<sup>7</sup>

Based on the remote care modality, it was possible to provide health services at a distance that could involve in an integrated way not only teleconsultations, but also teleeducation of the user.<sup>2</sup>

From the teleservice, it was also possible to offer users who had difficulty in accessing evaluation by specialists and greater complexity of care. In addition, the use of telemedicine was safe for the outpatient follow-up of some patients, especially in the postoperative period or who had difficulty moving, as occurred in the coronavirus pandemic, or also for those with low purchasing power.<sup>8</sup>

The scientifically proven advantages of teleconsultation were diverse, including the reduction of the need for patient travel, facilitated access to specialized care, reduction of the burden on the patient and caregiver, improved patient satisfaction, better family engagement in the care process, and reduced costs to the health system.<sup>9</sup>

According to the Ontario Telemedicine Network (OTN), a Canadian global platform for tracking, technology and data management via telemedicine, it has saved around US\$ 1.3 billion in healthcare costs per year since the beginning of the use of teleservice. According to Canada Health Infoway, 77% of Canadian physicians reported using some type of digital health technology in 2018, up 14% from 2016. A 2017 Accenture report reported that telemedicine could save up to \$10 billion in healthcare costs in the United States. OTN also reported that virtual visits can save up to 4 hours of travel time for patients living in rural areas.<sup>10</sup>

Corroborating this, other studies have historically proven the cost reduction to health services with the use of remote care. Telemedicine can reduce healthcare costs by up to 20% by reducing hospital admissions, patient transfers, face-to-face consultations, and unnecessary tests. Telemedicine can increase patients' quality of life by up to 30% by improving access to services, reducing waiting times, avoiding commuting, and facilitating follow-up. Teleconsultation has also increased the accuracy of the diagnosis of neurological diseases by up to 40% by allowing the evaluation of specialists at a distance, has proven better adherence to the treatment of neurological diseases by up to

50% by offering continuous support and guidance to patients, increased satisfaction with health services by up to 70% by providing greater autonomy and participation in therapeutic decisions, as well as the satisfaction of health professionals with their work by up to 80% by facilitating communication, collaboration and continuing education.<sup>11</sup>

Regarding clinical effectiveness, several studies have found that telemedicine was at least as effective as face-to-face care, and some have shown that it improved the clinical outcomes of patients, especially when comparing data from neurological diseases requiring brief intervention, as in the case of stroke.<sup>7</sup>

Current evidence indicates that telemedicine was an indispensable tool used as a complement to face-to-face consultations in various areas of neurology and the expansion of technological resources developed together. The coronavirus pandemic has notably intensified this process.

Different modalities of telemedicine in the various areas of neurology were studied, including teleconsultation, teleconsulting, telerehabilitation, telemonitoring and teleeducation. The advances achieved by teleneurology in this period stimulated technological innovations and health processes that created opportunities to improve the care provided to patients treated through this system.<sup>2</sup>

Teleneurology is of great importance to counteract the unequal dispersion of the number of neurologists per inhabitant in the various centers around the world.<sup>6</sup>

The importance of telemedicine care for the care of neurological diseases has already been well established in the literature. Remarkable progress in information and communication technologies has been witnessed, and telemedicine has emerged as a tool to expand access to medical care for different age groups, especially the elderly, overcoming physical and geographical obstacles.<sup>12</sup>

In this study, the results revealed that the average age of those treated via telemedicine was  $55.52 \pm 22.63$ , with a minimum of 0 and a maximum of 109 years, which allowed us to conclude that all age groups were well represented in the study and that their analyses could be inferred regardless of age.

Study conducted between April 2020 and March 2021, in which <sup>15,548</sup> users were assisted via telemedicine, 64% were women (9,953) and 36% were men (5,595).<sup>13</sup> On the other hand, in this study, when analyzing the data in terms of gender, there was a predominance of men (60.09%).

In general, the care units had a great impact on the referral of emergency cases. Patients admitted to small/medium-sized hospitals had a higher probability of death, regardless of the time of arrival, especially due to the difficulty of brief specialized evaluation.<sup>14</sup>

In agreement with the above, this study demonstrated that the distribution of patients among the different care units was remarkable, with SAMU representing the largest proportion (52.61%) and the logistic regression analysis highlighted a significant association between emergency referral and hospital

units and UPA, indicating the influence of the care unit in relation to patient referral.

This analysis raised relevant questions about the growing role of telemedicine in the initial triage of these cases. Given the predominance of referral of patients who were primarily cared for by SAMU and the often urgent nature of neurological conditions, the effective integration of telemedicine in these units can accelerate diagnoses and optimize emergency referral.

The patient's clinical history, as an essential component of medical practice, has taken on a critical role in the emerging era of telemedicine. This modality of health care transformed the way health professionals interacted with patients, and consequently, raised fundamental questions about how telemedicine was essential for the evaluation of patients with an individual clinical history of atypical chronic headache, for example, who were on some occasions unequivocally referred to specialized evaluation.<sup>15</sup>

Headache has a high prevalence globally and relevance in the context of emergency care, being among the 10 most prevalent causes in the world and one of the 5 years lived with disability.<sup>16</sup>

In this context, headache stood out among the emergency complaints, as a prevalent symptom in both severe and common cases in medical practice, reiterating the importance of accurate diagnosis and brief referral in the case of acute cause.<sup>17</sup>

According to this series, headache stood out as the most evidenced report after analyzing the proportion of emergency referrals. Clinical complaints, sudden neurological symptoms, and TBI were, respectively, 57.47%, 80.48%, and 52.31% lower in the emergency room referral item in relation to headache.

The efficacy of telemedicine and teleradiology, compared to telephone consultations, was evaluated through prospective, randomized, blinded clinical trials, known as STRoKE DOC (STRoKE DOC and STRoKE DOC-AZ TIME). Together with other studies, this analysis confirmed that the remote evaluation of cranial CTs for decision-making on rt-PA treatment in cases of acute stroke, by means of telemedicine, was a reliable method. This study contributed significantly to the validation and implementation of these telecare modalities in clinical practice, highlighting the importance of remote assessment for the effectiveness of treatment in critical situations such as acute stroke.<sup>18</sup>

In addition, the use of teleradiology stood out as an effective mechanism that avoided unnecessary referrals to specialists, allowing evaluations of radiological exams, such as CTs, by neurosurgeons or neurologists in hospitals that did not have these services in person. Results of a study focused on the pattern of transfer of patients with head trauma from a type II trauma center, without neurosurgery services, to a hospital that works with this type of care showed that consultations with neurosurgeons using teleradiology was a viable alternative in the management of patients with head trauma, since only 4% of the patients – initially hospitalized in the level II trauma center and not later indicated for referral to hospitals with specialized

services – have evolved negatively and needed late transfer.<sup>19</sup>

Therefore, the analysis of brain CT changes became valuable, as they denoted statistical relevance in increasing the probability of emergency referral. Considering the CT scan result factor, the chance of being referred via emergency in this study was 91.03% lower among those who did not present CT changes compared to those with it.

Based on the above, it has traditionally become essential to analyze the pattern of patients with neurological diseases treated via telemedicine and referred to specialized centers, since it was observed excessive transfer of individuals to hospitals of greater complexity, as well as failures in these referrals because many of these patients did not need care in a specialized center, thus unnecessarily burdening the unified health system. The processes of diagnosis and clinical management have become progressively more challenging as population changes are established, and consequently, an increase in morbidity and mortality rates, which has become indispensable for the accurate diagnosis and referral of acute diseases, such as neurological diseases.

In summary, this study analyzed the number of SUS patients with neurological diseases treated via telemedicine and the impact of its use on the reduction of referrals via SUS, as well as the associated variables (age, gender, care unit, clinical history, and CT scan results).

Regarding the independent variables - treatment units, clinical history and CT scan results - it was concluded that the logistic regression model was statistically significant, indicating a relationship between them and the probability of occurrence of emergency referral. Analyzing the estimated coefficients, the ORs for each category were calculated in relation to the reference category, since OR is a measure of the change in the odds ratio of the occurrence of the emergency referral event associated with the given category, in comparison with the reference category. It is important to note that an OR greater than 1 indicates a positive association between the independent variable and the occurrence of the emergency referral event, while an OR greater than 1 indicates a negative association. In addition, it is important to consider the confidence intervals associated with the OR. Confidence intervals provide range of values within which the true OR is likely to be contained.

In general, the logistic regression model provided good adequacy to the data ( $R^2$ Nagelkerke=0.26), indicating that it was able to explain part of the variability in the occurrence of the event of emergency referrals. However, it is important to emphasize that logistic regression does not provide information on causality, only on the association between variables.

This study did not have a control group for two reasons: the first was the originality of teleneuroregulation by specialists and, therefore, it was not possible to have an objective and comparative historical measure of referrals by non-specialists; What is observed in

practice is that most patients with alterations in their CT scans are referred to neurologists/neurosurgeons in medium and high complexity reference units. The second was that there would be an ethical bias if we divided our sample into two groups, with and without teleneuroregulation, because we could not fail to offer neurological teleconsulting on purpose (control group) with it available to the patient.

## CONCLUSION

This study demonstrated that the use of teleneurology reduced the number of unnecessary referrals in the SUS. After analyzing the associated variables collected, statistical significance was found in the independent variables, i.e., treatment units, clinical history and CT results, concluding that they have an impact on the occurrence of emergency referrals.

### Authors' contributions

Rafaela Fernandes Gonçalves: Conceptualization  
 Guilherme Batista do Nascimento: Investigation  
 Allan Fernando Giovanini: Methodology, Writing (review and editing)  
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 Gustavo Rassier Isolan: Project administration, Writing (original draft)  
 José Fernando Polanski: Writing (original draft)  
 Marcos Sigwalt: Writing (review and editing)

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