

Telemedicine in neurology: advances and possibilities

Telemedicina em neurologia: avanços e possibilidades

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ABSTRACT

Background: Telemedicine develops from technology that offers opportunities for knowledge transfer and information sharing and allows the provision of health services at a distance. **Objective:** To evaluate the number of publications on teleneurology in the last two decades in PubMed and the available evidence on the use of this technology in neurological clinical conditions. **Methods:** A quantitative assessment of publications related to telemedicine and neurology in the last two decades. A search was performed on the PubMed database for the descriptors (“Telemedicine”[Mesh]) AND “Neurology”[Mesh]). A review of the articles retrieved on the topic was carried out to evaluate the innovation processes used and applications in various clinical conditions involving teleneurology. **Results:** The search performed on March 14th 2022 resulted in 229 publications involving the topic of telemedicine and neurology between 1999 and 2022. Since 2000, there has been an increase in publications related to this topic, with a peak of 71 articles published in 2020, the year in which the World Health Organization defined the COVID-19 pandemic status. **Conclusion:** In the last two decades, teleneurology has been developing through the expansion of technological resources and the COVID-19 pandemic intensified this process. Different modalities of teleneurology are studied in several neurology subfields and include teleconsultation (between healthcare professionals or between healthcare professionals and patients), telerehabilitation, telemonitoring and tele-education. The advances achieved by teleneurology in this period encouraged technological innovations and health processes that developed opportunities to improve the care provided in a mechanism of constant evolution.

Keywords: Telemedicine; Neurology; Remote Consultation; COVID-19; Delivery of health care.

RESUMO

Antecedentes: A telemedicina se desenvolve a partir da tecnologia que permite a transferência de conhecimento e o compartilhamento de informações, possibilitando a prestação de serviços de saúde à distância. **Objetivo:** Avaliar o número de publicações sobre teleneurologia nas últimas duas décadas no PubMed e as evidências disponíveis sobre o uso desta tecnologia em diferentes quadros clínicos neurológicos. **Métodos:** Avaliação quantitativa das publicações relacionadas à telemedicina e neurologia nas últimas duas décadas. O levantamento dos artigos ocorreu a partir de busca no PubMed com os descritores (“Telemedicine”[Mesh]) AND “Neurology” [Mesh]). Foi realizada uma revisão dos artigos relacionados ao tema para avaliar os processos de inovação utilizados e aplicações em diversas condições clínicas envolvendo a teleneurologia. **Resultados:** A busca realizada no PubMed em 14 de março de 2022 resultou em 229 publicações envolvendo o tema telemedicina e neurologia entre 1999 e 2022. Desde 2000, houve um aumento de publicações relacionadas a esse tema, com um pico de 71 artigos publicados em 2020, ano em que a Organização Mundial da Saúde definiu o status de pandemia da COVID-19. **Conclusão:** Nas últimas duas décadas, a teleneurologia vem se desenvolvendo com a expansão dos recursos tecnológicos e a pandemia de COVID-19 intensificou esse processo. São estudadas diferentes modalidades de telemedicina em diversas áreas da neurologia, incluindo teleconsulta e teleconsultoria, telereabilitação, telemonitorização e teleeducação. Os avanços alcançados pela teleneurologia nesse período estimularam inovações tecnológicas e processos de saúde que criaram oportunidades para melhorar a assistência prestada em um mecanismo de constante evolução.

Palavras-chave: Telemedicina; Neurologia; Consulta Remota; COVID 19; Atenção à saúde.



INTRODUCTION

Telemedicine in neurology has developed with the advent of technology, which provided an opportunity for knowledge transfer and information sharing. The applications of technology

enable patient care, teaching and training of professionals and research development¹. Telemedicine allows the provision of health services at a distance using technologies for connectivity, including telephone and internet, and may involve teleconsultation, teleconference, or even tele-education. Contact can

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be initiated by healthcare professionals or patients and can be synchronous (in real-time) or asynchronous (store and forward)².

In December 2019, a new type of coronavirus, now known as SARS-CoV-2, was identified in China. SARS-CoV-2 infection (COVID-19) caused severe respiratory conditions and was associated with ICU admission and high mortality³. On March 11 2020 the World Health Organization characterized COVID-19 as a pandemic⁴. The pandemic has had a major socio-economic impact and caused collapses in health systems around the world. Social distancing and the lockdown promoted a change in the offer of health care and the development of telemedicine. The COVID-19 pandemic highlights how neurological care was provided and how the mode of delivery needed to adapt quickly during this period, and how technology was fundamental in this process⁵.

The aim of this study was to evaluate the number of publications on telemedicine in neurology in the last two decades in PubMed and the available evidence on the use of this technology in neurological clinical conditions.

METHODS

This study carried out a quantitative survey of publications related to telemedicine and neurology in the last two decades. The survey of articles consisted of a PubMed search on telemedicine in neurology in the last two decades with the descriptors (“Telemedicine”[Mesh]) AND “Neurology”[Mesh]. For the proper identification of publications/year, articles were classified by publication date as described in Table 1.

A review of the articles related to the topic was carried out to evaluate the innovation processes used and applications in various clinical conditions involving teleneurology.

This study was not submitted for approval by the Research Ethics Committee, as it is a non-systematic literature review to assess the development of telemedicine in neurology.

RESULTS

The search performed on March 14, 2022 resulted in 229 publications involving the topic of telemedicine and neurology between 1999 and 2022. Since 2000 there has been an increase in publications related to this topic, with a peak of 71 articles published in 2020, the year when the World Health Organization declared COVID-19 a pandemic. The year 2021 presented a reduction in the number of publications, reaching 32, but maintaining a higher level of publications compared to the last 2 decades. The results are presented in Table 1 and in Figure 1.

DISCUSSION

The emergence and consolidation of teleneurology is closely linked to the evidence for the benefit of stroke reperfusion therapies published in the 1990s⁶. The perception that every minute of delay in thrombolysis decreases the effectiveness of treatment and increases the risk of complications is promoted

Table 1. Number of publications / year.

Year	Publications
1999	1
2000	5
2001	2
2002	4
2003	4
2004	4
2005	8
2006	2
2007	2
2008	4
2009	6
2010	6
2011	4
2012	4
2013	7
2014	7
2015	8
2016	7
2017	12
2018	15
2019	9
2020	71
2021	32
2022	5
Total	229

with the slogan “time is brain”⁷. In this context, where every effort is made to reduce the time between the onset of symptoms and the start of reperfusion therapy, telestroke allows remote specialists to indicate thrombolysis through information provided by the hospital physician, close to the patient⁸.

During the last two decades, the telestroke concept has spread around the world and been refined. Mobile stroke units were developed to optimize pre-hospital care. They are ambulances specially equipped with computed tomography, a point-of-care laboratory for blood analysis, medication and an interdisciplinary team. Telemedicine allows the support of a stroke specialist and, if indicated, thrombolysis can be started in the ambulance, before arrival at the hospital⁹.

Scientific evidence shows that stroke treatment has benefited from the digital health revolution. The use of teleneurology for stroke has significantly impacted the acute treatment of cerebrovascular diseases in many areas¹⁰.

Several experiences and a few randomized trials have been published on remote consultation between neurologists and patients with chronic neurological diseases. Patients suffering from headache were evaluated and studies showed that the use of telemedicine was not inferior to face-to-face care in terms of reducing attacks and recognizing secondary headaches¹¹⁻¹³.

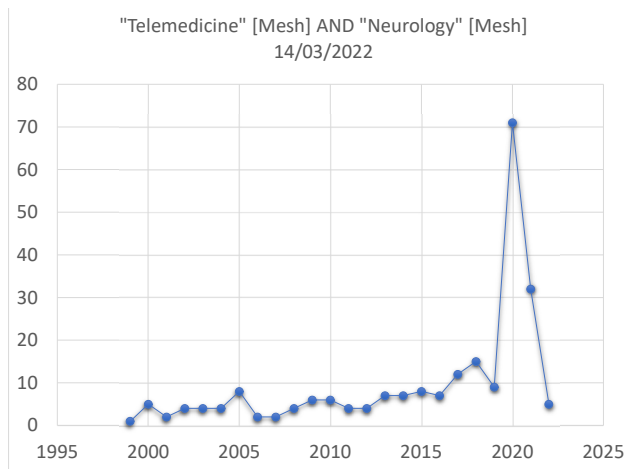


Figure 1. Number of publications in PubMed in the last 20 years.

Evidence in the literature demonstrates that telemedicine care, through video or telephone interviews, is suitable for people with epilepsy. Outpatient epilepsy follow-up consultations depend essentially on phenomenological interviews, adherence to treatment and counseling, and not on physical examination. Studies have shown similar patterns of seizure control and medication adherence among patients with face-to-face and remote care^{14,15}.

An important aspect evaluated in studies with telemedicine and cognitive impairment includes the diagnostic reliability of the administration of cognitive tests, such as the Montreal Cognitive Assessment (MoCA) and the Mini-Mental State Examination, showing that scores obtained remotely and face-to-face are comparable¹⁶⁻¹⁹.

Other studies indicate that telemedicine is a useful tool on the management of patients with dementia²⁰⁻²², movement disorders^{23,24}, including deep brain stimulation (DBS)^{25,26} follow-up, and in the attention of their caregivers²⁷.

The neurological examination involved in neuromuscular diseases has some items that are difficult to access by telemedicine, such as reflexes and vibratory sense. The same happens with vestibular disorders, with positional maneuvers, for example²⁸. Before the COVID-19 pandemic, remote consultation in these areas was less consolidated. In the last two years, however, experience with this type of care has increased and telemedicine has been encouraged²⁹. Current evidence indicates that telemedicine is a potential tool to be used as a complement to face-to-face consultations in numerous areas of neurology³⁰.

The development of telemedicine in neurology for chronic diseases is mainly motivated by the difficulty of access to the specialists in some regions. In several countries, there is a greater supply of specialists in capitals or tertiary services, which makes access difficult for rural populations or locations with greater distances from large centers. Access to care is also limited by patients' disabilities, as many neurologic conditions impair mobility and driving abilities.

Telemedicine can have a positive impact on ensuring timely neurological care in inpatient or outpatient across different

healthcare systems. The impact of the distance of access to the neurologist and the use of real-time video to promote timely access was the subject of the cohort study developed by Craig et al. in 2004. The study highlighted the difficulty of accessing specialist neurology consultations at two rural hospitals in Northern Ireland, with general physicians providing local care and referring patients to specialists when needed. Offering an early neurological consultation through real-time video was an alternative to promote access in a shorter waiting time for the neurologist with reduced hospitalization time³¹.

Reducing the waiting time for consultation with the neurologist was also the subject of the retrospective cohort by Constanzo et al. in 2020, involving analysis of primary and secondary care referrals of 8269 patients to neurology. Waiting time for the first consultation was 60% shorter for patients enrolled in the Teleneurology program in Chile, a country with great distances from some locations to access the capital, Santiago, the city with the highest concentration of neurologists³².

A program that allows primary care providers (PCP) to maintain direct contact with neurologists (eConsult service) in Canada has reduced the need for specialist consultation by more than 30%. The neurologist's answers to PCP questions can guide the management of patients with neurological complaints in primary care, which reduces the waiting time for patients who need a formal consultation with a neurologist³³.

There is evidence showing benefits of telerehabilitation specially in patients after stroke³⁴⁻³⁶, but also in other neurological conditions, such as Parkinson disease³⁷, vestibular disorders³⁸ and multiple sclerosis³⁹. Telerehabilitation is characterized not only by video contact between patient and physical therapist, but can include virtual reality and applications for self-managed exercises^{36,38}, without therapist guidance. Telemedicine is useful in improving access to rehabilitation therapy and reducing travel time and costs.

Telemonitoring is already a reality and an increasingly promising area. It is possible to use portable vital signs measurement devices⁴⁰, wearable sensors and smartphone apps to detect information and send to the doctor synchronously, 24 hours a day. It helps in the diagnosis, the assessment of the severity of neurological diseases and supports clinical decision making. Smartphones can capture voice and tremor and, through machine learning, we can monitor or even diagnose Parkinson's disease⁴¹⁻⁴³. Assessing balance and risk of falls using a validated smartphone app can increase safety and reduce the number of falls in older adults⁴⁴.

In the near future, a set of quantitative measures derived from wearables or apps could be considered digital biomarkers of a disease, contributing to early diagnosis, stratification of subgroups and prediction of treatment outcomes⁴⁵.

In addition to the application of telemedicine among healthcare professionals and between healthcare professionals and patients, teleneurology is also useful in education. An experience has shown that supervising neurology training with robot⁴⁶ telepresence is feasible and remote consultations can be more

comfortable for students and patients for teaching anamnesis and neurological diagnosis⁴⁷.

The COVID-19 pandemic, with the recommendation of social distancing and the implementation of lockdown in several countries, was an important factor in the development of telemedicine to guarantee access to the first consultation and maintenance of patient follow-up. Ganapathy highlighted in its descriptive study in 2020, about telemedicine and neurological practice in the period of COVID-19, that real-time video synchronous queries or asynchronous digital store-and-forward services can be used. The latter includes text messages, WhatsApp communication and email. Remote monitoring of patient data can include viewing images and neurophysiological parameters⁵.

The pandemic has certainly made Digital Health a necessity and no longer an exception. Technological advances that seemed distant possibilities and futuristic concepts came to fruition in a short period of time due to the needs imposed by the COVID-19 pandemic¹⁰.

Teleneurology in Brazil

There are few Brazilian publications about teleneurology. A recent survey³⁰ showed that before the pandemic only 18.5% of Brazilian neurologists worked with telemedicine and 31.7% studied telemedicine, while 63.6% reported working with telemedicine during the first year of pandemic³⁰.

Telestroke is a reality in some Brazilian cities, but it is necessary to improve stroke care in all regions of the country, and the implementation of telemedicine support is recommended for hospitals without neurologists available 24 hours a day^{48,49}.

Several medical specialties have been included in government telemedicine programs with the aim of supporting primary care physicians and optimizing referrals for each specialty^{50,51}. Mantese et al. evaluated 1,687 teleconsultations on patients

with neurological complaints and showed that telehealth support could avoid 29% of referrals for neurology. The main reason for teleconsultation was epilepsy or seizure (25%), followed by headache (20%), stroke (10%), tremor or parkinsonism (7%) and cognitive disorders (6%)⁵².

In Brazil, some telemedicine procedures, such as remote consultations, were not regulated until ordinance 467 of the Ministry of Health⁵³ and Law 13.989, of April 2020⁵⁴, during the COVID-19 pandemic. After regulation, public and private health services organized remote consultations and several studies are now being submitted for publication. A descriptive study on telehealth in Recife during the COVID-19 pandemic included 126 remote neurological consultations and showed that in 68 the patient did not need to be referred to specialized face-to-face care after the consultation, with follow-up possible in primary care⁵⁵. The authors are aware of different initiatives in teleneurology during the pandemic and we believe that Brazilian publications on telemedicine will increase significantly soon.

In conclusion, in the last two decades, teleneurology has been developing through the expansion of technological resources. The COVID-19 pandemic intensified this process and allowed for greater use of teleneurology to assist patients and to discuss cases between doctors at different levels of health care. Different modalities of teleneurology are studied in several neurology subfields and include teleconsultation (between healthcare professionals or between healthcare professional and patient), telerehabilitation, telemonitoring, tele-education.

The last two years have certainly made Digital Health a necessity and no longer an exception. Technological advances that seemed distant possibilities and futuristic concepts came to fruition in a short period of time due to the needs imposed by the pandemic. The advances achieved by teleneurology in this period encouraged technological innovations and health processes that developed opportunities to improve the care provided in a mechanism of constant evolution.

References

1. Misra UK, Kalita J, Mishra SK, Yadav RK. Telemedicine in neurology: underutilized potential. *Neurol India*. 2005 Mar;53(1):27-31. <https://doi.org/10.4103/0028-3886.15047>
2. Larner AJ. Teleneurology: an overview of current status. *Pract Neurol*. 2011 Oct;11(5):283-8. <https://doi.org/10.1136/practneurol-2011-000090>
3. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020 Feb 15;395(10223):497-506. [https://doi.org/10.1016/S0140-6736\(20\)30183-5](https://doi.org/10.1016/S0140-6736(20)30183-5)
4. Organização Pan-Americana da Saúde (OPAS). [Internet]. Histórico da pandemia de COVID-19/OPAS; 2020 [cited 2020 Aug 26]. Available from: <https://www.paho.org/pt/covid19/historico-da-pandemia-covid-19#:~:text=A%20Organiza%C3%A7%C3%A3o%20Pan%2DAmericana%20da,infetados%20com%20o%20novo%20coronav%C3%ADrus>.
5. Ganapathy K. Telemedicine and Neurological Practice in the COVID-19 Era. *Neurol India*. 2020 May-Jun;68(3):555-9. <https://doi.org/10.4103/0028-3886.288994>
6. Tissue Plasminogen Activator for Acute Ischemic Stroke. *N Engl J Med*. 1995 Dec 14;333(24):1581-7. <https://doi.org/10.1056/nejm199512143332401>
7. Gomez CR. Editorial: Time is brain! *J Stroke Cerebrovasc Dis*. 1993;3(1):1-2. [https://doi.org/10.1016/s1052-3057\(10\)80125-9](https://doi.org/10.1016/s1052-3057(10)80125-9)
8. Levine SR, Gorman M. "Telestroke": The Application of Telemedicine for Stroke. *Stroke*. 1999;30(2):464-9. <https://doi.org/10.1161/01.str.30.2.464>
9. Hariharan P, Tariq MB, Grotta JC, Czup AL. Mobile stroke units: Current evidence and impact. *Curr Neurol Neurosci Rep*. 2022 Jan;22(1):71-81. <https://doi.org/10.1007/s11910-022-01170-1>
10. Silva GS, Schwamm LH. Advances in stroke: Digital health. *Stroke*. 2021 Jan;52(1):351-5. <https://doi.org/10.1161/strokeaha.120.033239>
11. Müller KI, Alstadhaug KB, Bekkelund SI. A randomized trial of telemedicine efficacy and safety for nonacute headaches. *Neurology*. 2017 Jul 11;89(2):159-162. <https://doi.org/10.1212/wnl.0000000000004085>
12. Müller KI, Alstadhaug KB, Bekkelund SI. Telemedicine in the management of non-acute headaches: A prospective, open-

- labelled non-inferiority, randomised clinical trial. *Cephalalgia*. 2017 Aug;37(9):855-63. <https://doi.org/10.1177%2F0333102416654885>
13. Friedman DI, Rajan B, Seidmann A. A randomized trial of telemedicine for migraine management. *Cephalalgia*. 2019 Oct;39(12):1577-85. <https://doi.org/10.1177/0333102419868250>
 14. Rasmussen KA, Hartshorn JC. A comparison of epilepsy patients in a traditional ambulatory clinic and a telemedicine clinic. *Epilepsia*. 2005 May;46(5):767-70. <https://doi.org/10.1111/j.1528-1167.2005.44804.x>
 15. Bahrani, K, Singh MB, Bathia R, Prasad K, Vibha D, Shukla G, et al. Telephonic review for outpatients with epilepsy - A prospective randomized, parallel group study. *Seizure*. 2017 Dec;53:55-61. <https://doi.org/10.1016/j.seizure.2017.11.003>
 16. Ciemins EL, Holloway B, Jay Coon P, McClosky-Armstrong T, Min S. Telemedicine and the Mini-Mental State Examination: Assessment from a Distance. *Telemed J E Health*. 2009 Jun;15(5):476-8. <https://doi.org/10.1089/tmj.2008.0144>
 17. Jennings LA, Araujo KLB, Meng C, Peduzzi P, Charpentier P, Reuben DB. Utility of a short, telephone administered version of the Montreal Cognitive Assessment. *J Am Geriatr Soc*. 2021 Oct;69(10):2741-4. <https://doi.org/10.1111/jgs.17318>
 18. Loh P, Donaldson M, Flicker L, Maher S, Goldswain P. Development of a telemedicine protocol for the diagnosis of Alzheimer's disease. *J Telemed Telecare*. 2007;13(2):90-4. <https://doi.org/10.1258%2F135763307780096159>
 19. Shores MM, Ryan-Dykes P, Williams RM, Mamerto B, Sadak T, Pascualy M, et al. Identifying undiagnosed dementia in residential care veterans: comparing telemedicine to in-person clinical examination. *Int J Geriatr Psychiatry*. 2004 Feb;19(2):101-8. <https://doi.org/10.1002/gps.1029>
 20. Kim H, Jhoo JH, Jang J-W. The effect of telemedicine on cognitive decline in patients with dementia. *J Telemed Telecare*. 2017 Jan;23(1):149-54. <https://doi.org/10.1177%2F1357633X15615049>
 21. Cheong C-K, Lim K-H, Jang J-W, Jhoo JH. The effect of telemedicine on the duration of treatment in dementia patients. *J Telemed Telecare*. 2015 Jun;21(4):214-8. <https://doi.org/10.1177%2F1357633X14566571>
 22. Nkodo JA, Gana W, Debaq C, Aidoud A, Poupin P, Camus V, et al. The Role of Telemedicine in the Management of the Behavioral and Psychological Symptoms of Dementia: A Systematic Review. *Am J Geriatr Psychiatry*. 2022 Feb 3. <https://doi.org/10.1016/j.jagp.2022.01.013>
 23. Tarolli CG, Andrzejewski K, Zimmerman G, Bull M, Goldenthal S, Auinger P, et al. Feasibility, reliability, and value of remote video-based trial visits in Parkinson's Disease. *J Parkinsons Dis*. 2020;10(4):1779-86. <https://doi.org/10.3233/jpd-202163>
 24. Bull MT, Darwin K, Venkataraman V, Wagner J, Beck CA, Dorsey ER, et al. A pilot study of virtual visits in huntington disease. *J Huntingtons Dis*. 2014;3(2):189-95. <https://doi.org/10.3233/jhd-140102>
 25. Esper CD, Merola A, Himes L, Patel N, Bezchlibnyk YB, Falconer D, et al. Necessity and feasibility of remote tele-programming of deep brain stimulation systems in Parkinson's disease. *Parkinsonism Relat Disord*. 2022 Mar;96:38-42. <https://doi.org/10.1016/j.parkrelidis.2022.01.017>
 26. Xu X, Zeng Z, Qi Y, Ren K, Zhang C, Sun B, et al. Remote video-based outcome measures of patients with Parkinson's disease after deep brain stimulation using smartphones: a pilot study. *Neurosurg Focus*. 2021 Nov;51(5):E2. <https://doi.org/10.3171/2021.8.focus21383>
 27. Lai, FH-Y, Yan EW-H, Yu KK-Y, Tsui W-S, Chan DT-H, Yee BK. The protective impact of telemedicine on persons with dementia and their caregivers during the COVID-19 Pandemic. *Am J Geriatr Psychiatry*. 2020 Nov;28(11):1175-84. <https://doi.org/10.1016/j.jagp.2020.07.019>
 28. Govindarajan R, Anderson ER, Hesselbrock RR, Madhavan R, Moo LR, Mowzoon N, et al. Developing an outline for teleneurology curriculum: AAN Telemedicine Work Group recommendations. *Neurology*. 2017 Aug 29;89(9):951-9. <https://doi.org/10.1212/wnl.0000000000004285>
 29. Shaikh AG, Bronstein A, Carmona S, Cha Y-H, Cho C, Ghasia SS, et al. Consensus on virtual management of vestibular disorders: Urgent versus expedited care. *Cerebellum*. 2021 Feb;20(1):4-8. <https://doi.org/10.1007/s12311-020-01178-8>
 30. Aquino ERDS, Domingues RB, Mantese CE, Fantini FGMM, Nitrini R, Prado GFD. Telemedicine use among neurologists before and during COVID-19 pandemic. *Arq Neuropsiquiatr*. 2021 Jul;79(7):658-64. <https://doi.org/10.1590/0004-282x-anp-2020-0488>
 31. Craig J, Chua R, Russell C, Wootton R, Chant D, Patterson V. A cohort study of early neurological consultation by telemedicine on the care of neurological inpatients. *J Neurol Neurosurg Psychiatry*. 2004 Jul;75(7):1031-5. <https://doi.org/10.1136/jnnp.2002.001651>
 32. Constanzo F, Aracena-Sherck P, Hidalgo JP, Peña L, Marrugo M, Gonzalez J, et al. Contribution of a synchronic teleneurology program to decrease the patient number waiting for a first consultation and their waiting time in Chile. *BMC Med Inform Decis Mak*. 2020 Feb 5;20(1):20. <https://doi.org/10.1186/s12911-020-1034-2>
 33. Bradi AC, Sitwell L, Liddy C, Afkham A, Keely E. Ask a neurologist: What primary care providers ask, and reducing referrals through eConsults. *Neurol Clin Pract*. 2018 Jun;8(3):186-91. <https://doi.org/10.1212/cpj.0000000000000458>
 34. Chen J, Sun D, Zhang S, Shi Y, Qiao F, Zhou Y, et al. Effects of home-based telerehabilitation in patients with stroke: A randomized controlled trial. *Neurology*. 2020 Oct 27;95(17):e2318-e2330. <https://doi.org/10.1212/wnl.0000000000010821>
 35. Tchero H, Tabue Teguio M, Lannuzel A, Rusch E. Telerehabilitation for stroke survivors: Systematic review and meta-analysis. *J Med Internet Res*. 2018 Oct 26;20(10):e10867.
 36. Gauthier LV, Nichols-Larsen DS, Uswatte G, Strahl N, Simeo M, Proffitt R, et al. Video game rehabilitation for outpatient stroke (VIGOROUS): A multi-site randomized controlled trial of in-home, self-managed, upper-extremity therapy. *EClinicalMedicine*. 2021 Dec 17;43:101239. <https://doi.org/10.1016/j.eclinm.2021.101239>
 37. Gandolfi M, Geroi C, Dimitrova E, Boldrini P, Waldner A, Bonadiman S, et al. Virtual reality telerehabilitation for postural instability in Parkinson's Disease: A multicenter, single-blind, randomized, controlled trial. *Biomed Res Int*. 2017;2017:7962826. <https://doi.org/10.1155/2017/7962826>
 38. van Vugt VA, van der Wouden J, Essery R, Yardley L, Twisk JWR, van der Horst HE, et al. Internet based vestibular rehabilitation with and without physiotherapy support for adults aged 50 and older with a chronic vestibular syndrome in general practice: Three armed randomised controlled trial. *BMJ*. 2019 Nov 5;367:l5922. <https://doi.org/10.1136/bmj.l5922>
 39. Chanpimol S, Benson K, Maloni H, Conroy S, Wallin M. Acceptability and outcomes of an individualized exergaming telePT program for veterans with multiple sclerosis: a pilot study. *Arch Physiother*. 2020 Oct 1;10:18. <https://doi.org/10.1186/s40945-020-00089-5>
 40. Ajčević M, Furlanis G, Naccarato M, Caruso P, Polverino P, Marsich A, et al. e-Health solution for home patient telemonitoring in early post-acute TIA/Minor stroke during COVID-19 pandemic. *Int J Med Inf*. 2021 Aug;152:104442. <https://doi.org/10.1016/j.ijmedinf.2021.104442>
 41. Sajal MSR, Ehsan MT, Vaidyanathan R, Wang S, Aziz T, Al Mamun KA. Telemonitoring Parkinson's disease using machine learning by combining tremor and voice analysis. *Brain Inform*. 2020 Oct 22;7(1):12. <https://doi.org/10.1186/s40708-020-00113-1>
 42. Zhang L, Qu Y, Jin B, Jing L, Gao Z, Liang Z. An intelligent mobile-enabled system for diagnosing Parkinson disease: Development and validation of a speech impairment detection system. *JMIR Med Inform*. 2020 Sep 16;8(9):e18689. <https://doi.org/10.2196/18689>
 43. Deng K, Li Y, Zhang H, Wang J, Albin RL, Guan Y. Heterogeneous digital biomarker integration out-performs patient self-reports in predicting Parkinson's disease. *Commun Biol*. 2022 Jan 17;5(1):58. <https://doi.org/10.1038/s42003-022-03002-x>
 44. Greene BR, McManus K, Ader LGM, Caulfield B. Unsupervised assessment of balance and Falls Risk Using a Smartphone and

- Machine Learning, *Sensors* (Basel). 2021 Jul 13;21(14):4770. <https://doi.org/10.3390/s21144770>
45. Fröhlich H, Bontridder N, Petrovska-Delacréta D, Glaab E, Kluge F, El Yakoubi M, et al. Leveraging the potential of digital technology for better individualized treatment of Parkinson's disease. *Front Neurol*. 2022 Feb 28;13:788427. <https://doi.org/10.3389/fneur.2022.788427>
 46. Kramer NM, Demaerschalk BM. A novel application of teleneurology: Robotic telepresence in supervision of neurology trainees. *Telemed J E Health*. 2014 Dec;20(14):1087-92. <https://doi.org/10.1089/tmj.2014.0043>
 47. Patterson V, Gormley S. Teaching neurology by videolink. *Med Educ*. 2008 Nov;42(11):1116-7. <https://doi.org/10.1111/j.1365-2923.2008.03187.x>
 48. Martins SCO, Pontes-Neto OM, Alves CV, Freitas GRd, Oliveira Filho J, Cabral NL, et al. Past, present, and future of stroke in middle-income countries: The Brazilian experience. *Int J Stroke*. 2013 Oct;8(Suppl A100):106-11. <https://doi.org/10.1111/ijs.12062>
 49. Silva GS, Schwamm LH. Use of telemedicine and other strategies to increase the number of patients that may be treated with intravenous thrombolysis. *Curr Neurol Neurosci Rep*. 2012 Feb;12(1):10-6. <https://doi.org/10.1007/s11910-011-0235-6>
 50. de Melo MdCB, Nunes MV, Resende R, Figueiredo RR, Ruas SSM, Santos AdFd, et al. Belo Horizonte telehealth: Incorporation of teleconsultations in a health primary care system. *Telemed J E Health*. 2018 Aug;24(8):631-8. <https://doi.org/10.1089/tmj.2017.0165>
 51. Harzheim E, Gonçalves MR, Umpierre RN, Siqueira ACdS, Katz N, Agostinho MR, et al. Telehealth in Rio Grande do Sul, Brazil: Bridging the gaps. *Telemed J E Health*. 2016 Nov;22(11):938-44. <https://doi.org/10.1089/tmj.2015.0210>
 52. Mantese CE, Aquino ERdS, Figueira MD, Rodrigues L, Basso J, da Rosa PR. Telemedicine as support for primary care referrals to neurologists: decision-making between different specialists when guiding the case over the phone. *Arq Neuropsiquiatr*. 2021 Apr;79(4):299-304. <https://doi.org/10.1590/0004-282x-anp-2020-0137>
 53. Ministry of Health. Ordinance No. 467, of March 20, 2020. [Internet]. Brasília: Diário Oficial da União; 2020 [cited 2020 Aug 26]. Available from: <https://www.in.gov.br/en/web/dou/-/portaria-n-467-de-20-de-marco-de-2020-249312996>.
 54. Brazil. Brazil. Law No. 13,989, of April 15, 2020. [Internet]. Brasília: Diário Oficial da União; 2020 [cited 2020 Aug 26]. Available from: <https://www.in.gov.br/en/web/dou/-/lei-n-13.989-de-15-de-abril-de-2020-252726328>.
 55. Sperling S, Andretta CRL, Basso J, Batista CEA, Borysow IdC, Cabral FC, et al. Telehealth for supporting referrals to specialized care during COVID-19. *Telemed J E Health*. 2022 Apr;28(4):544-50. <https://doi.org/10.1089/tmj.2021.0208>