Neurología 38 (2023) 591—598

NEUROLOGÍA

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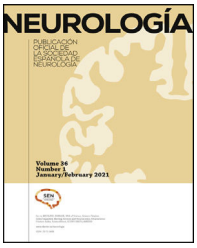

REVIEW ARTICLE

Impact of new technologies on neurology in Spain. Review by the New Technologies Ad-Hoc Committee of the Spanish Society of Neurology☆

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Received 30 September 2020; accepted 10 October 2020

KEYWORDS
Technology;
Biomedical technology;
Neurology;
Spain

Abstract
Introduction: New technologies are increasingly widespread in biomedicine. Using the consensus definition of new technologies established by the New Technologies Ad-Hoc Committee of the Spanish Society of Neurology (SEN), we evaluated the impact of these technologies on Spanish neurology, based on communications presented at Annual Meetings of the SEN.
Material and methods: We defined the concept of new technology in neurology as a novel technology or novel application of an existing technology, characterised by a certain degree of coherence persisting over time, with the potential to have an impact on the present and/or future of neurology. We conducted a descriptive study of scientific communications presented at the SEN's annual meetings from 2012 to 2018, analysing the type of technology, the field of neurology, and the geographical provenance of the studies.

DOI of refers to article: https://doi.org/10.1016/j.nrl.2020.10.015.
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https://doi.org/10.1016/j.nrleng.2020.10.011

Results: We identified 299 communications related with new technologies from a total of 8139 (3.7%), including 120 posters and 179 oral communications, ranging from 1.6% of all communications in 2012 to 6.8% in 2018. The technologies most commonly addressed were advanced neuroimaging (24.7%), biosensors (17.1%), electrophysiology and neurostimulation (14.7%), and telemedicine (13.7%). The neurological fields where new technologies were most widely employed were movement disorders (18.4%), cerebrovascular diseases (15.7%), and dementia (13.4%). Madrid was the region presenting the highest number of communications related to new technologies (32.8%), followed by Catalonia (26.8%) and Andalusia (9.0%).
Conclusions: The number of communications addressing new technologies follows an upward trend. The number of technologies used in neurology has increased in parallel with their availability. We found scientific communications in all neurological subspecialties, with a heterogeneous geographical distribution.

PALABRAS CLAVE
Tecnología;
Tecnología biomédica;
Neurología;
España

Impacto de las nuevas tecnologías en la neurología en España. Revisión del Comité Ad-Hoc de Nuevas Tecnologías de la Sociedad Española de Neurología

Resumen
Introducción: Las nuevas tecnologías (NT) están cada vez más presentes en el ámbito biomédico. Utilizando la definición de consenso de NT del Comité Ad-Hoc de Nuevas Tecnologías de la SEN, se evalúa su impacto en la Neurología española a través de las comunicaciones de las reuniones anuales de la SEN.
Material y métodos: Se define el concepto de NT en neurología, como una tecnología novedosa o aplicación de una tecnología anterior, caracterizada por un cierto grado de coherencia persistente en el tiempo, con potencial de tener impacto en el presente y futuro de la neurología. Se plantea un estudio descriptivo tomando como fuente las comunicaciones de las reuniones de la SEN desde 2012-2018 y analizando los tipos de NT empleadas, la subespecialidad, así como su distribución territorial.
Resultados: De las 8139 comunicaciones presentadas, 299 estaban relacionadas con NT [3.7%], incluyendo 120 pósteres y 179 comunicaciones orales, variando desde el 1.6% en 2012 hasta el 6.8% en 2018. Los tipos de tecnología mayormente representados fueron neuroimagen avanzada [24.7%], biosensores [17.1%], electrofisiología y neuroestimulación [14.7%] y telemedicina [13.7%]. Las áreas neurológicas con mayor empleo de NT fueron trastornos del movimiento [18.4%], enfermedades cerebrovasculares [15.7%] y demencias [13.4%]. Madrid fue la comunidad que presentó más comunicaciones [32.8%], seguida por Cataluña [26.8%] y Andalucía [9.0%].
Conclusiones: Las comunicaciones sobre NT siguen una tendencia creciente. El número de NT empleadas han ido aumentando de manera paralela a la disponibilidad tecnológica. Se encontraron comunicaciones en todas las subespecialidades neurológicas con una distribución geográfica heterogénea.

Introduction

Technology is defined as a set of theories and techniques enabling the application of scientific knowledge for practical purposes.[1] In the field of healthcare, technology is enriching the traditional approaches of modern medicine.[2,3] It offers new tools for training, recording, analysis, and dissemination of objective knowledge, both in research and in clinical practice, and has great potential for growth in the coming years.

In the context of the current digital revolution, the emergence of new information technology systems and devices, and innovative applications and software, together with the advancement of telecommunications technology, has enabled the development of new technologies applied to healthcare. Defining a technology as novel is controversial due to the wide range of criteria used. However, new technologies are increasingly present in biomedicine in general, and in neurology in particular.

This study reviews several of the transformative technologies that characterise the digital revolution. One

example is mobile health, or mHealth,[4–7] that is the use of such mobile devices as smartphones and tablets to provide healthcare or health information. These devices are portable, readily accessible in developed countries, and versatile due to the incorporation of various sensors and applications.[4,5,8] We should also mention technological advances in information systems and the development of big data analytics technologies, such as machine learning, deep learning, and artificial intelligence. These technologies have enormous potential in the study of neurological diseases.[9,10]

Wearable devices equipped with inertial biosensors also constitute promising tools for a wide range of neurological conditions and purposes,[7,11–14] including movement disorders, cerebrovascular diseases, sleep disorders, cognitive impairment, epilepsy, demyelinating diseases, and neurorehabilitation.

Likewise, improvements in telecommunications technologies, with internet access through portable devices, represent a huge step forward in teleneurology.[15–17] On the other hand, advances in neuroradiology[18,19] and neurophysiology[20,21] provide a deeper knowledge of human neuroanatomy, neurophysiology, and neuropathology in vivo.

Virtual reality and robotics constitute promising technologies for the neurorehabilitation of patients with impaired mobility.[22,23]

The study of new materials and the miniaturisation of devices, which could be manufactured through 3D printing, opens up new possibilities in neurology.[24,25]

The development and clinical validation of these and other emerging technologies is a long process,[13,26] resulting in a delay between the creation of a tool and its application in clinical practice.[27] The great diversity and constant emergence of new tools makes it difficult to study new technologies as a whole and delays their potential implementation in clinical practice. Thus, during clinical validation, new technologies continue to undergo improvements which at the same time also need to be validated clinically, widening this temporal gap. Efforts should be made to facilitate and shorten this process, reducing the distance between the parties involved. The confluence of clinical and technical knowledge, despite differences in the languages used, has become a reality, with several collaborative studies being published and the development of technological tools for neurological patients both in the public and the private spheres.[28] Close interdisciplinary collaboration between technicians and clinicians is to be expected in the following years.

In view of the need to deepen our understanding of new technologies for application in such clinical disciplines as neurology, several initiatives to study new technologies have been launched by several scientific societies, including the Spanish Society of Neurology, the American Academy of Neurology, and the International Parkinson and Movement Disorder Society.[29–31] These aim to bring technical knowledge to clinicians, and vice versa, with a view to the generation of advances and improvements in healthcare. These clinical initiatives are complemented by technological initiatives such as university courses on biomedical and healthcare applications of technology.

Our study aims to analyse the impact of new technologies on current neurological care in Spain. To this end, the Spanish Society of Neurology's (SEN) New Technologies Ad-Hoc Committee has established a consensus definition for the concept of ''new technology'' and evaluated the impact of these technologies on neurological care in Spain over the years, based on the information provided in communications presented at the SEN's Annual Meeting.

Material and methods

Due to the lack of a formal definition for ''new technology,'' a consensus definition was established by a panel of experts from the SEN's New Technologies Ad-Hoc Committee. New technology in neurology was defined as ''a novel technology or a new application of an existing technology, characterised by a certain degree of coherence that persists in time, and with the potential to have a substantial impact on the present and future of neurology.'' According to this definition, electroencephalography (EEG) is an existing technology whose use is well established in clinical practice, and is therefore not considered a new technology. However, virtual network analysis based on EEG signals with neural mass models represents a new application of an existing technology and is therefore considered a new technology.

Subsequently, to develop a panoramic view of the status of these technologies in the neurological community, we performed a descriptive study of all communications presented at the SEN's Annual Meetings held between 2012 and 2018, selecting those analysing the use of new technologies according to our consensus definition.

The selection process included 2 phases, both of which involved 2 raters, with any disagreements resolved by consensus: (1) initial selection: review of the titles of the communications according to the consensus criteria (ASR and MM), and (2) review of the abstracts of the selected communications (RLB and MM), excluding all communications that provided insufficient information on the technology used or focused on technologies that belong to another biomedical discipline (genetics, molecular biology, immunology, etc) (Fig. 1).

We gathered data on the following main variables: type of new technology according to a set of pre-established categories (communications may focus on more than one type of technology), neurology subspecialty, and type of communication. Secondary variables included distribution of the research groups by autonomous community in absolute and relative numbers with regard to population size (official population count according to the local population register on 1 January 2019, published by Spain's National Statistics Institute),[32] cooperation between research centres, participation of technology institutes (e.g., polytechnic universities, non-clinical research institutes), and the participation of the healthcare industry.

Results

Of a total of 8139 communications presented between 2012 and 2018, 299 (3.7%) were related to new technologies (Fig. 1). Of these, 120 were presented in poster format and

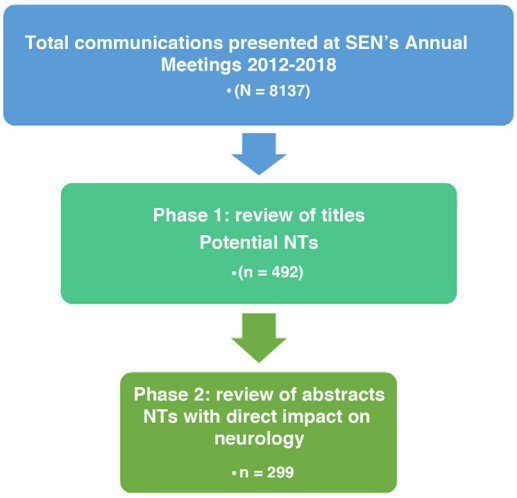

Figure 1 Flow chart of the selection process and inclusion criteria. NT: new technologies; SEN: Spanish Society of Neurology.

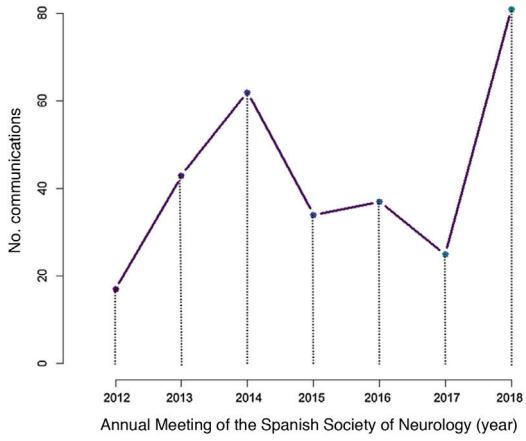

Figure 2 Trend in the number of communications on new technologies presented at the SEN's Annual Meetings between 2012 and 2018.

179 were oral communications. The number of communications presented ranges from 17 in 2012 (1.6% of a total of 1056) to 81 in 2018 (6.8% of a total of 1185). The number of communications on new technologies increased considerably in the last year (Fig. 2).

The types of new technologies used are as follows: advanced neuroimaging (novel neuroimaging techniques, including recently developed MRI sequences or advanced neuroimaging analysis techniques, such as principal component analysis or classification using artificial intelligence) (n = 74; 24.7%); biosensors (n = 51; 17.1%); electrophysiology and neurostimulation (n = 44; 14.7%); telemedicine (n = 41; 13.7%); apps (n = 28; 9.4%); artificial intelligence, machine learning, and deep learning (n = 26; 8.7%); virtual reality (n = 14; 4.7%); robotics (n = 13; 4.3%); and other (2.7%) (Fig. 3).

The neurology subspecialty most frequently using new technologies was movement disorders (n = 55; 18.4%), fol-

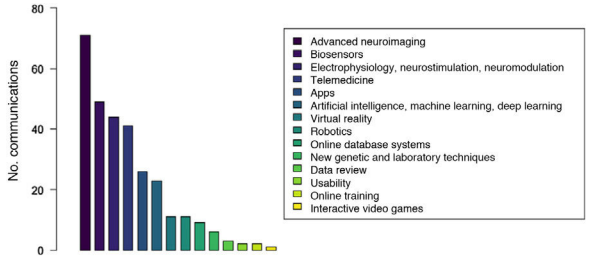

Figure 3 Types of new technologies analysed in the communications.

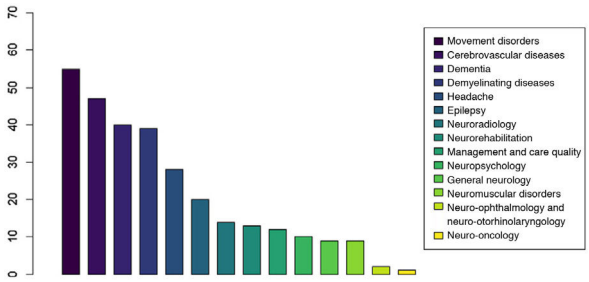

Figure 4 Neurological subspecialties where new technologies have been applied.

lowed by cerebrovascular diseases (n = 47; 15.7%), dementia (n = 40; 13.4%), demyelinating diseases (n = 39; 13.0%), headache (n = 28; 9.4%), epilepsy (n = 20; 6.7%), and other areas (23.4%) (Fig. 4).

By geographical location, the research groups presenting communications were distributed as follows: 98 in Madrid (32.8%), 80 in Catalonia (26.8%), 27 in Andalusia (9.0%), 23 in the Valencian Community (7.7%), 14 in Navarre (4.7%), and 57 in other autonomous communities (19%) (Fig. 5A). The highest ratios of communications by million population were found in the autonomous communities of Navarre (21.4/million population), Madrid (14.7/million population), Cantabria (12.0/million population), and Catalonia (10.4/million population) (Fig. 5B). More detailed demographic information is provided in the Supplementary Material.

Twenty-two percent of communications resulted from collaborations between centres: 12.3% between Spanish centres and 9.7% between Spanish centres and centres abroad. Collaboration with the healthcare industry was not disclosed in 77% of the communications; 11% did disclose the participation of the healthcare industry; and the remaining 12% declared that there was no collaboration with the healthcare industry. In 31.1% of the communications, research groups collaborated with technology institutes.

Discussion

The consensus definition of new technology proposed in this study provides an initial framework for evaluating the impact of new technologies on neurology in Spain. To this

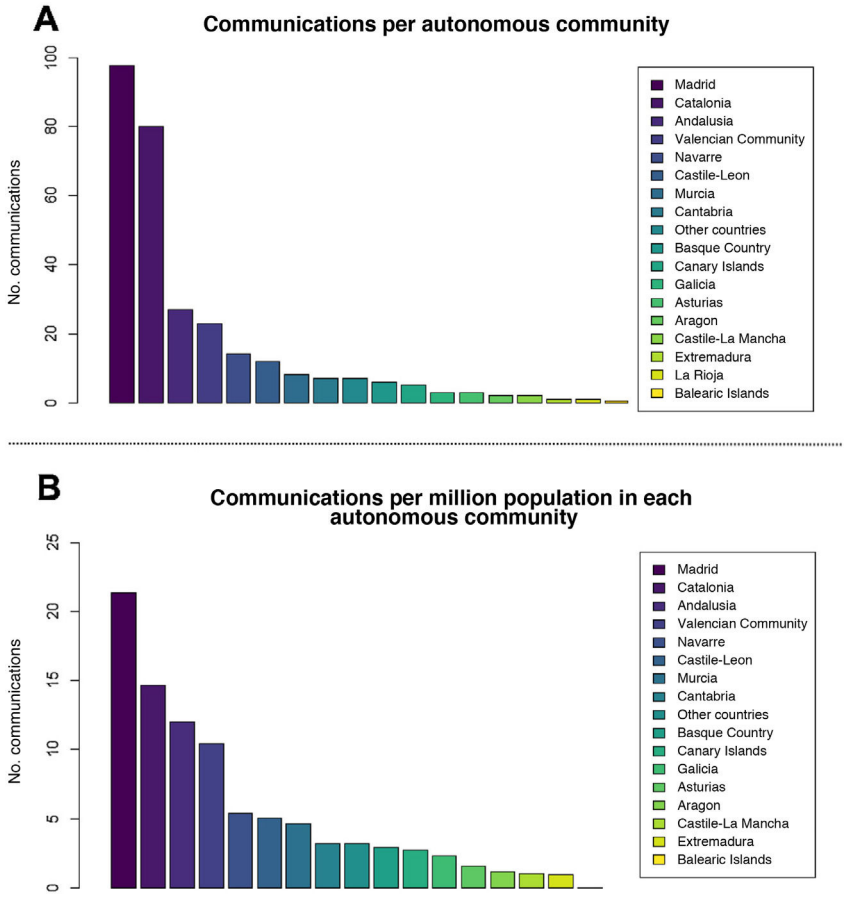

Figure 5 Communications presented by autonomous community. A) Number of communications presented by autonomous community. B) Number of communications presented in each autonomous community per million population.

end, we evaluated the communications presented at the SEN's Annual Meetings held between 2012 and 2018. The impact of new technologies on research shows an upward, though fluctuating, trend over the period analysed. The types of technology most frequently used are advanced neuroimaging, biosensors, electrophysiology/neurostimulation, and telemedicine and information applications, whereas the neurology subspecialties most benefiting from new technologies are movement disorders, cerebrovascular diseases, and dementia.

The technologies mentioned have generated advances in such fields as neuroradiology and neurophysiology, which constitute fundamental pillars of neurological diagnosis and are also beginning to play a relevant role in the treatment of neurological diseases.[33,34] These advances are therefore expected to have a substantial impact on neurological practice in the coming years. Research on biosensors is developing rapidly,[13] and this new technology is emerging as an objective and potentially minimally invasive tool for the assessment of neurological diseases.[11] Telemedicine and information applications are emerging as essential tools in the digitalisation of healthcare, representing a unique opportunity to facilitate access to specialised care.[3,16] Research into this field is therefore expected to increase, further promoted by social distancing measures implemented in the context of the COVID-19 pandemic.[35—37]

The autonomous communities presenting the highest numbers of communications were Madrid, Catalonia, and Andalusia. However, when the distribution was adjusted for the population of each community, Navarre was identified as the autonomous community with the highest number of communications per million population, followed by Madrid, Cantabria, and Catalonia. The association between the population of different regions and the number of communications presented is not linear. Other factors involved include strategic relationships with the healthcare industry, universities, or research centres, and the implementation of local policies for technological development, which may promote the use of these tools (see Supplementary Material).

Nearly a quarter of the communications involved several research centres, whether in Spain or abroad, and nearly one-third of the communications involved a technology institute. This reflects the importance of scientific collaboration and multidisciplinarity, as well as the ease of data sharing with these new tools. Furthermore, 48% of the communica-

tions stating in the abstract whether there was collaboration with the healthcare industry disclosed that the industry did participate; however, this should be interpreted with caution as a large percentage of the communications did not specify this information.

This is the first study to describe the situation of new technologies in Spanish neurology from a cross-sectional, integrative perspective. However, it does present some limitations. First of all, not all research studies conducted in Spain are presented at the SEN's Annual Meetings. Therefore, our study does not include data from studies presented at other regional or international congresses of neurology or other non-clinical disciplines (engineering, physics, information technology, etc) or studies published in scientific journals. Furthermore, research into the application of new technologies in clinical practice does not always result in a scientific communication. Our results may therefore underestimate the real impact of new technologies on Spanish neurology, and the geographical distribution of research groups presented in this study may not be accurate. Secondly, the inclusion of studies into new technologies was based on the subjective interpretation of the raters. However, the fact that all communications were reviewed by 2 raters helped to minimise the possibility of a selection bias. Thirdly, not all subspecialties produce the same number of communications; therefore, in some areas with a smaller number of communications, new technologies may have a greater impact than described (eg, in neurorehabilitation). Furthermore, a single study may analyse multiple technologies, hindering the classification of studies by type of technology. However, in our case, this limitation had little impact, as we treated each new technology as an individual item for analysis. Lastly, the analysis by geographical distribution did not consider such other key factors as sociological, political, and economic variables, which may at least in part explain the geographical differences.

Future studies into the impact of new technologies on Spanish neurology should gather data from a wider range of sources, including regional and international congresses of neurology and other disciplines, as well as scientific journals. Collaboration with national and international research centres, and even with technology institutes, is a trend that may become even more widespread in the future, as multidisciplinarity promotes biomedical progress. The involvement of the healthcare industry in studies into the use of new technologies in neurology is also a reality, although future research should aim to better determine the scope of this involvement.

Conclusions

New technologies have a growing impact on Spanish neurology, as reflected by the increasing number of communications on new technologies presented at SEN's Annual Meetings in recent years. In addition to the advances made in technological areas that have historically had an impact on neurology (eg, neuroimaging, electrophysiology), new technologies and approaches (eg, biosensors, mobile apps, artificial intelligence) present great potential for translation into clinical practice in the coming years.

This trend affects all neurology subspecialties, but most importantly movement disorders, cerebrovascular diseases, dementia, and neurocognitive disorders.

The geographical distribution of research groups interested in these new technologies is heterogeneous. However, the regions producing the greatest numbers of communications are Madrid, Catalonia, and Andalusia; or Navarre, Madrid, and Cantabria after adjusting for population. These variations may reflect the influence of such other factors as sociological, political, and economic variables, which have an impact on research groups' collaboration with the healthcare industry, technology institutes, and biomedical universities.

This study provides a preliminary overview of this promising field; our results may be useful for future studies monitoring the incorporation of new technologies in Spanish neurology.

Funding

None.

Conflicts of interest

None.

Acknowledgements

We wish to thank the authors of the communications on new technologies presented at the SEN's Annual Meetings held between 2012 and 2018.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.nrl.2020.10.015.

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