

ORIGINAL ARTICLE

Status of neurosonology in Spain. A study from the Spanish Society of Neurosonology (SONES)

J. Rodríguez-Pardo^{a,*}, J. Carneado-Ruiz^b, M. Martínez-Martínez^c, J.M. Moltó-Jordá^d, P. Irimia^e, J. Serena-Leal^f, Ó. Ayo-Martín^g, P. Martínez-Sánchez^h, J. Pagolaⁱ, J. Fernández-Domínguez^j, on behalf of the Spanish Society of Neurosonology (SONES)

^a Servicio de Neurología y Centro de Ictus, Hospital Universitario La Paz, Universidad Autónoma de Madrid, Instituto de Investigación IdiPaz, Madrid, Spain

^b Servicio de Neurología, Hospital Universitario Puerta de Hierro, Universidad Autónoma de Madrid, Majadahonda, Madrid, Spain

^c Servicio de Neurología, Hospital Universitario Infanta Sofía, Universidad Europea de Madrid, San Sebastián de los Reyes, Madrid, Spain

^d Servicio de Neurología, Hospital Virgen de los Lirios, Alcoy, Alicante, Spain

^e Servicio de Neurología, Clínica Universidad de Navarra, Pamplona, Navarra, Spain

^f Servicio de Neurología, Hospital Josep Trueta, Girona, Spain

^g Servicio de Neurología, Complejo Hospitalario Universitario de Albacete, Albacete, Spain

^h Servicio de Neurología, Hospital Universitario Torrecárdenas, Universidad de Almería, Almería, Spain

ⁱ Unitat d'Ictus, Servei de Neurologia, Hospital Universitari Vall d'Hebron, Vall d'Hebron Institut de Recerca, Universitat Oberta de Catalunya, Barcelona, Spain

^j Servicio de Neurología, Centro Médico Asturias, Oviedo, Asturias, Spain

Received 22 February 2023; accepted 18 June 2023

Available online 21 June 2025

KEYWORDS

Neurosonology;
Echography;
Doppler;
Ultrasound

Abstract

Introduction: Neurosonology is the field of study of the ultrasound techniques applied to neurological diseases. The Spanish Society of Neurosonology (SONES) was funded in 1997 to promote training and education in these techniques, especially focused on the study of cerebrovascular diseases. After 25 years, the increased use of other advanced neurovascular imaging techniques and the emergence of novel applications of ultrasound in other fields of neurology, have modified the classic role of neurosonology. From the SONES we aimed to evaluate the current status of neurosonology in Spain.

Methods: Cross-sectional survey of neurologists and neurology residents working in Spain regarding training, education, and local daily practice, including a strengths, weaknesses, opportunities and threats (SWOT) analysis.

DOI of refers to article: <https://doi.org/10.1016/j.nrl.2023.06.012>.

* Corresponding author.

E-mail address: jrpardodedonlebung@salud.madrid.org (J. Rodríguez-Pardo).

<https://doi.org/10.1016/j.nrleng.2025.06.003>

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PALABRAS CLAVE

Neurosonología;
Ecografía;
Doppler;
Ultrasonidos

Results: One-hundred seventy-eight neurologists and thirty-four neurology residents participated in the survey. A wide experience in vascular neurosonology (90% of respondents' Neurology departments) and limited experience in brain parenchyma sonography (34%), cardiac echoscopy (25%), ultrasound-guided techniques (24%), and nerve ultrasound (14%) was reported. Fifty-three percent of the participants reported to have a full-time neurosonology lab in their department and only 14% reported to have neurologists dedicated exclusively to neurosonology. Most participants (54%) reported to lack continuous learning opportunities, and 97% to need training in one or more neurosonology techniques. Main SWOT were respectively requiring expertise, shortage of time, versatility and comprehensive management of the neurological patient.

Conclusion: Vascular neurosonology is widely instituted in Spain, but the implementation of full-time neurosonology labs and training in non-vascular neurosonology techniques is yet scarce.

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Estado de la neurosonología en España. Un estudio de la Sociedad Española de Neurosonología (SONES)

Resumen

Introducción: La neurosonología es la disciplina que estudia las técnicas ultrasonográficas aplicadas a la neurología. En 1997 se fundó la Sociedad Española de Neurosonología (SONES) con el objetivo de promover la formación de neurólogos en estas técnicas, especialmente en el campo de las enfermedades cerebrovasculares. Veinticinco años después, la generalización de otras técnicas más avanzadas de neuroimagen vascular, y el desarrollo de la ultrasonografía en otros campos de la neurología, han modificado el papel que clásicamente se ha atribuido a esta disciplina. Desde la SONES analizamos el estado actual de la neurosonología en España.

Métodos: Estudio transversal mediante una encuesta en línea dirigida a residentes de neurología y neurólogos ejercientes en España, abordando cuestiones de formación y práctica diaria, incluyendo un análisis de debilidades, amenazas, fortalezas y oportunidades (DAFO).

Resultados: Participaron 178 neurólogos y 34 residentes. Reflejaron una amplia experiencia en neurosonología vascular (90% de los Servicios) y escasa en parénquima cerebral (34%), ecocardiografía (25%), técnicas ecoguiadas (24%), y ecografía de nervio (14%). El 53% afirmó disponer de un laboratorio de Neurosonología a tiempo completo y solo el 14% de facultativos dedicados en exclusiva a la neurosonología. La mayoría afirmó que la formación continuada en neurosonología es escasa, y el 97% creen necesario potenciar alguna de las técnicas. Las principales DAFO fueron respectivamente la necesidad de experiencia, la falta de tiempo, la versatilidad y el manejo integral del paciente neurológico.

Conclusiones: La neurosonología vascular está ampliamente implantada en España, pero la implementación de laboratorios dedicados y formación en técnicas no vasculares es aún escasa.

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Introduction

Neurosonology emerged early in Spain; however, it initially had little impact on neurology, which at the time (save for a few exceptions) showed little interest in the diagnosis and treatment of stroke.

By the 1980s, the study of the carotid, cervical, and periorbital arteries with continuous-wave Doppler ultrasound was widespread among neurologists.^{1–3} Combined B-mode and Doppler ultrasound was also beginning to spread, particularly in the fields of radiology and vascular surgery, although it was largely limited to carotid studies. At that time, and with a few notable exceptions, neurologists had very limited access to B-mode imaging. A breakthrough in this field, and particularly in cerebrovascular disease, came with the

development of transcranial Doppler ultrasound, a technique that attracted little interest from other specialties but which became an essential tool in stroke management.

Transcranial Doppler ultrasound was introduced by Aaslid et al.⁴ in 1982. Its usefulness in cerebrovascular disease had already been demonstrated by 1986, as it enabled the assessment of cerebral haemodynamics in carotid stenosis, intracranial stenosis, and subarachnoid haemorrhage.⁵ This facilitated its rapid adoption in our setting.

In Spain, transcranial Doppler ultrasound was introduced in 1989, with the creation of the first dedicated ultrasonography unit under Dr Alberto Gil Peralta. With a focus on vascular disease, this unit became a reference in the training of many neurologists, who

played a pivotal role in the spread of neurosonology within the field of neurology, the development of vascular neurology training programmes, and the application of the technique in both the clinical and research settings.

From the 1990s onwards, the use of neurosonology became widespread thanks to the support of the Spanish Society of Neurology's (SEN) Stroke Study Group.⁶ Efforts were made to implement transcranial and carotid Doppler ultrasonography in all stroke units, with these studies to be performed by trained neurologists as part of acute stroke management, as well as to provide neurosonology training. These efforts culminated in the foundation of the Spanish Society of Neurosonology (SONES, for its Spanish initials) in 1997, with the aim of promoting and advancing training in ultrasound techniques applied to neurology. In 2003, the SONES became an affiliated society of the SEN. The official Spanish neurology training programme, published in 2007, highlights the importance of neurosonology and includes mandatory training in ultrasound techniques.⁷

In parallel, new technologies also became increasingly widespread, such as the combination of B-mode ultrasound with colour Doppler in transcranial studies (duplex sonography).⁸ In 2010, the SEN developed the Neurosonology Competency Examination, certifying neurologists trained and qualified to perform vascular neurosonology techniques. Meanwhile, ultrasound techniques began to attract attention for the assessment of non-vascular neurological diseases, such as in the differential diagnosis of parkinsonism⁹ or the study of peripheral neuropathy.¹⁰ In 2011, the SONES published the first comprehensive neurosonology manual, with the collaboration of Spain's leading neurosonology experts.¹¹ In addition to vascular studies, the manual addresses ultrasound evaluation of the brain parenchyma, peripheral nerves, and orbit. Other relevant SONES publications include recommendations on the use of transcranial Doppler ultrasound to support the diagnosis of brain death¹² and recommendations on the ultrasonographic assessment of carotid artery stenosis.¹³ In 2016, the term echocardiography was introduced to describe a cardiac ultrasound study used to complement the physical examination (also known as focused cardiac ultrasound [FOCUS]).¹⁴ In 2018, the SEN/SONES and the Spanish Society of Cardiology published a joint consensus statement establishing the definition, objectives, and training requirements for neurologist certification in FOCUS.¹⁵ In 2019, the first edition of the University Expert Course in Neurosonology was launched with the endorsement of the SONES; the course not only includes the aforementioned techniques but also training in muscle ultrasound and ultrasound-guided treatments.

The COVID-19 pandemic represented a significant setback to the development of neurosonology in Spain. In addition to the collapse of the healthcare system, neurosonology techniques were put on a back seat due to COVID-19 prevention protocols, as they require close contact between patient and physician.¹⁶ However, the SONES drafted a set of recommendations for the practice of neurosonology during the pandemic.¹⁷

In parallel to the generalisation of neurosonology for the diagnosis and follow-up of degenerative and neuromuscular diseases, as well as other non-vascular neurological applications, the field of acute stroke care experienced a shift toward advanced neuroimaging techniques, which gradually replaced Doppler ultrasound as the preferred tool for assessing the cerebral circulation.¹⁸ The widespread implementation of mechanical thrombectomy and the expansion of indications for revascularisation treatments in acute stroke brought to light the need to perform early radiology tests, such as CT angiography, MRI, and diffusion/perfusion imaging. The above underscores the importance of understanding the current state of neurosonology in Spain, its role in daily clinical practice, and the tools available to support its promotion and advancement.

Methods

We conducted a cross-sectional study through an online survey aimed at neurology residents and practising neurologists in Spain, addressing their experience with neurosonology. The survey was designed using Research Electronic Data Capture (REDCap),^{19,20} a data collection tool certified for use in research. It was subsequently distributed via e-mail to all SEN members and shared via the SONES Twitter account (@neurosonologia) and through independent distribution lists. To prevent duplicate responses, only one submission per person was allowed. We gathered data on demographic variables (professional category, region, hospital level) and prior neurosonology training (certification). Information was also gathered about the activity at the respondents' departments: types of neurosonology studies routinely performed; role of the neurology department in relation to the radiology and vascular surgery departments in conducting duplex ultrasound of the supra-aortic trunks; role of the neurology department in relation to the cardiology department in the detection of right-to-left shunt and performance of FOCUS; administrative resources (neurosonology laboratory, schedules, image viewer/storage system), human resources (dedicated staff); continuing education and training needs; needs that may be addressed by the SONES; and future challenges. Regarding neurology residents, the questions about positioning and administrative resources were replaced with questions on their training (year of first specific rotation, duration of rotation in months, level of understanding of each technique). A SWOT analysis was subsequently performed to determine the strengths, opportunities, weaknesses, and threats of today's neurosonology.²¹ The aim was to identify opportunities and establish the most appropriate strategy for the SONES to support different clinical settings. A statistical analysis was performed to evaluate differences in training needs between neurology residents and neurologists using the chi-square test; the level of significance was established at $P < .05$. Analysis was conducted using SPSS Statistics 21.0 (IBM®; Armonk, NY, USA).

Results

The target population for our survey comprised 2914 full members of the SEN and 340 trainee members. However, we were unable to determine the real number of survey recipients for several reasons, including lack of confirmation of receipt and ineligibility (e.g., not currently practising neurology in Spain). We received 193 survey responses from SEN members and 24 from Twitter users. Five incomplete responses were excluded from the analysis, resulting in a final sample of 212 respondents: 178 neurologists (19 of whom were heads of department or unit) and 34 neurology residents. The geographical distribution of the participants was highly heterogeneous: a significant proportion was based in Madrid (34%), followed by Andalusia (10%) and Valencia (7%), although the sample included neurologists from all Spanish regions (Fig. 1). Most respondents practised neurology at tertiary hospitals (68%), although the sample also included respondents working at secondary (22%) and primary hospitals (5%), as well as private hospitals (5%).

Regarding neurosonology certification, only 49% of neurologists reported having completed a course accredited by the Continuing Education Commission for Healthcare Professionals of the Spanish health system; 38% held a neurosonology certification issued by the SEN, and 7% held a certification issued by an international institution.

Regarding the activity of neurology departments, 90% of neurologists reported that their departments perform neurosonology

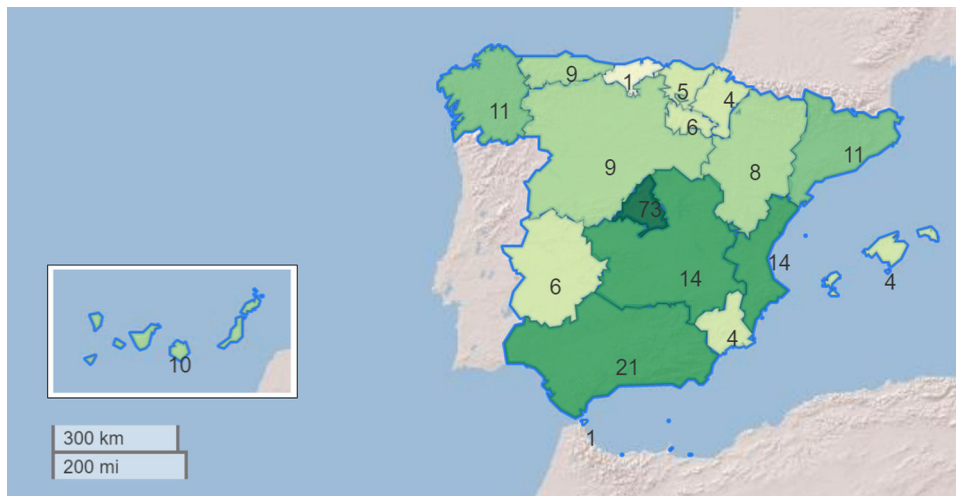


Figure 1 Distribution of participants by autonomous community (information not available from one participant).

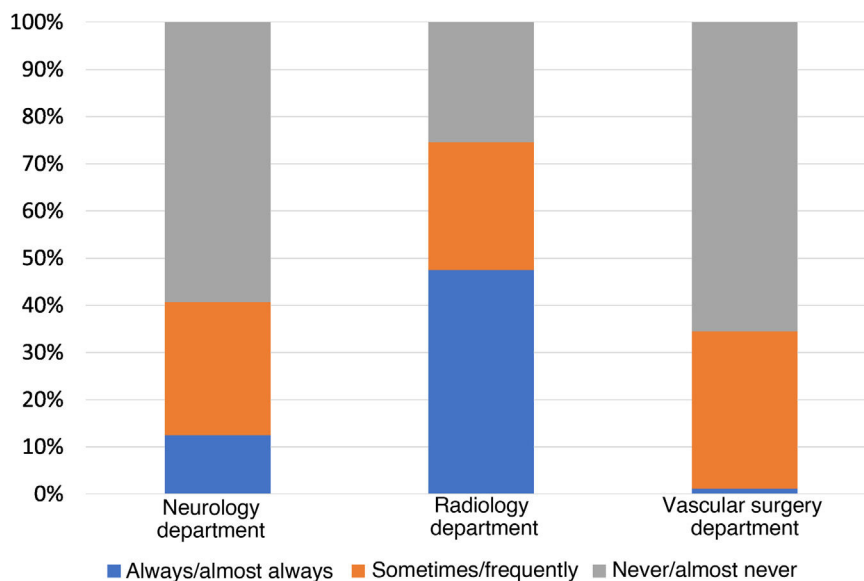


Figure 2 Hospital departments responsible for performing Doppler ultrasound of the supra-aortic trunks. The survey enquired about each department separately.

studies, although most duplex ultrasound studies of the supra-aortic trunks requested by other departments are performed by the radiology department (Fig. 2). Parenchymal sonography (34%), FOCUS (25%), ultrasound-guided techniques (24%), and nerve ultrasound (14%) were much less frequently available (Fig. 3). Detection of right-to-left shunts was performed by the neurology department according to 51% of neurologists, while 46% reported that the test was typically performed by the cardiology department, and 3% indicated that the test was not performed by any department at their hospital. FOCUS was available at the neurology department according to 45 neurologists (25%). Of these, 16 (36%) reported that the procedure was performed in specific cases, 15 (33%) reported performing it frequently but always followed by a standard transthoracic echocardiogram (TTE), 12 (27%) used it as a screening tool

(with TTE only performed when alterations are detected), and 2 (4%) reported using it to replace TTE.

Regarding the availability of a neurosonology laboratory, only 53% of neurologists reported having a dedicated space for this purpose at their hospital, while 19% reported that their centre did not have a neurosonology laboratory (Fig. 4). Only 14% of neurologists reported having physicians dedicated to neurosonology in their departments. With respect to neurosonology image viewing and storage, 23% of neurologists reported that images were not stored in any format, 55% reported that images were saved only on the ultrasound machine or internal servers, and only 22% indicated that images were available for review through a clinical workstation or a radiology image viewer.

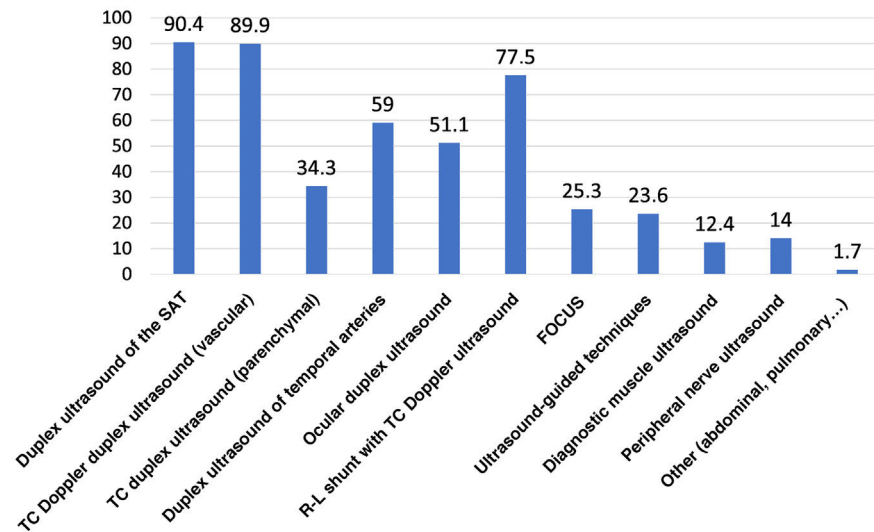


Figure 3 Neurosonology techniques offered by neurology departments. Survey respondents were asked to indicate all the techniques routinely performed in their departments.

FOCUS: focused cardiac ultrasound; R-L: right-to-left; SAT: supra-aortic trunks; TC: transcranial.

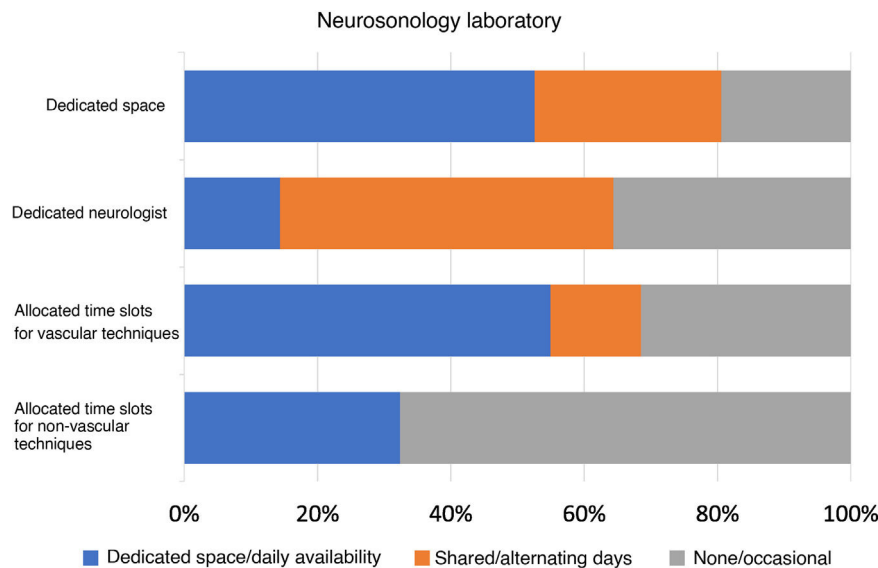


Figure 4 Resources available at neurosonology laboratories. The survey enquired about facilities, time slots, and human resources separately.

Neurosonology during residency training

Our sample included 34 neurology residents from 13 Spanish autonomous communities (no responses were received from residents in Murcia, Extremadura, Castile-Leon, or Cantabria). The most represented region was Madrid (38%), followed by Castile-La Mancha (12%) and Andalusia (9%). Most residents (52%) reported having completed their first rotation in neurosonology during the second year of residency training, 33% during the first year, and 15% during the

third year. Fifteen percent of residents indicated that specific neurosonology training lasted one month or less (Fig. 5). All residents reported having contact with neurosonology outside of the specific rotation, although only 32% characterised this contact as frequent. Regarding technical skills, 82% of residents rated their practical knowledge with vascular neurosonology as good or very good, while only 9% rated their skills with non-vascular neurosonology as good or very good.

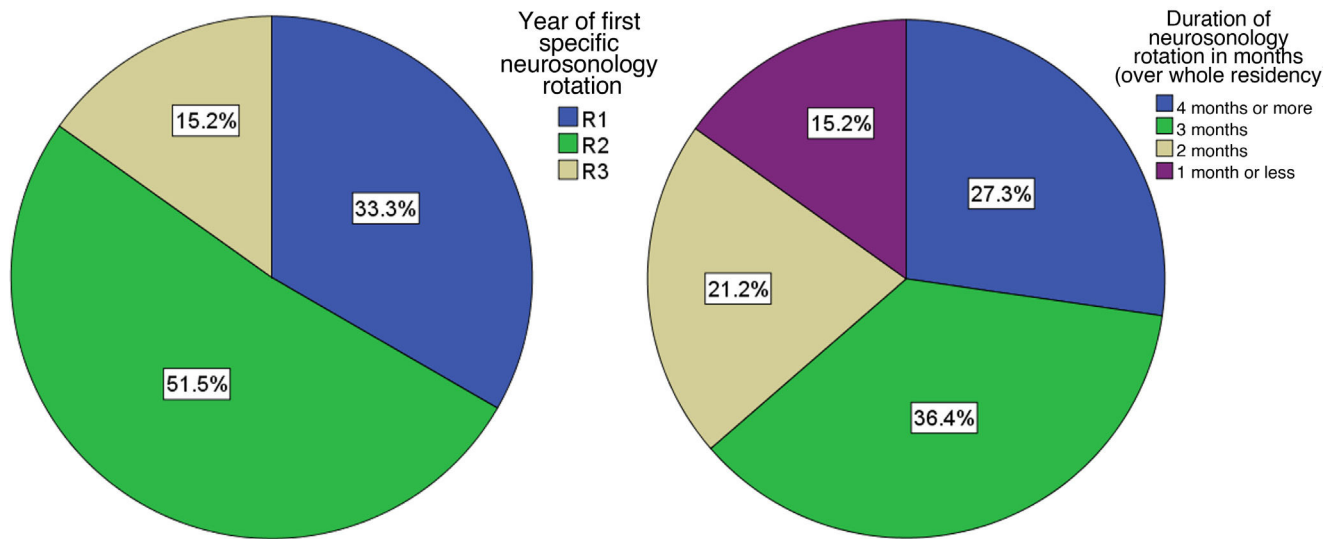


Figure 5 Neurosonology training during the neurology residency training.

Training needs

Regarding the availability of neurosonology training, 28% of survey respondents reported that specific courses were available at their own hospitals and 19% at nearby hospitals, while 53% reported that they would need to travel to attend a course. In 12 autonomous communities, over 80% of respondents would need to travel to attend a course; this percentage was significantly higher among neurologists than among neurology residents (57% vs 38%, $P = .04$). Regarding continuing education for neurologists, 53% reported that their hospitals offered little continuing education, 33% reported that continuing education was available at their hospitals but that it targeted specific techniques or physicians, and only 14% reported that training targeted all neurologists in their department. Up to 97% of the participating neurologists reported needing further training in at least one neurosonology technique, particularly in non-vascular techniques, even if this required them to travel to another centre (Fig. 6). In contrast, only 10% believed that their own hospitals could provide training in non-vascular techniques to specialists from other centres (57% in the case of vascular techniques). No statistically significant differences were observed between neurologists and neurology residents in the training most frequently requested, except in the case of nerve ultrasound, which was more frequently requested by residents (74% vs 53%; $P = .03$). Regarding the strategies that the SONES could implement to improve neurosonology training, 83% of survey respondents supported the implementation of periodic in-person courses (especially residents [97%, vs 80% of neurologists; $P = .02$]), while 60% preferred periodic online courses, and 47% were interested in external rotations (particularly neurologists [51%, vs 27% of residents; $P = .01$]).

SWOT analysis

Tables 1 and 2 summarise the results of the SWOT analysis. The most frequently cited weaknesses of neurosonology were the need for extensive training and experience (76% of respondents) and the fact that neurosonology techniques are time-consuming (35%). Impor-

tant threats were the difficulty scheduling dedicated neurosonology time slots (66%) and competitive pressure due to advances in the development of other diagnostic techniques (42%). The most commonly reported strengths were its versatility (62%), as it can be applied as part of the bedside neurological examination, and its cost-effectiveness (43%), given its low cost and similar effectiveness to other diagnostic tests, improving neurologists' autonomy and resource management. Finally, the analysis identified the following opportunities: comprehensive neurological patient management (72%), as occurs in transient ischaemic attack clinics based on neurosonology techniques, and the expanding range of applications (52%), including FOCUS, parenchymal ultrasound, and ultrasound-guided botulinum toxin injection.

Future challenges

Based on the SWOT analysis, the most appropriate strategies in the current circumstances are the following: 1) publishing comprehensive examination protocols (e.g., a protocol for use in transient ischaemic attack clinics and at emergency departments) as well as abbreviated protocols for targeted studies (e.g., for the follow-up of patients with carotid artery stenosis and stenting; 2) promoting the efficiency of neurosonology through cost-effectiveness studies; and 3) promoting neurosonology training programmes and continuing education courses.

Discussion

Our study is the first to analyse the current state of neurosonology in Spain. Participation was higher than expected, considering the nature of the survey (distributed via mass email and focused on a highly specific discipline), and responses were received from all Spanish regions. However, our results do not allow for in-depth analysis, due to the over-representation of some regions (such as Madrid) and the limited participation of others. Although the required sample size was not pre-established, the number of responses from neurologists ($n = 178$) corresponds to a 7% margin of error for

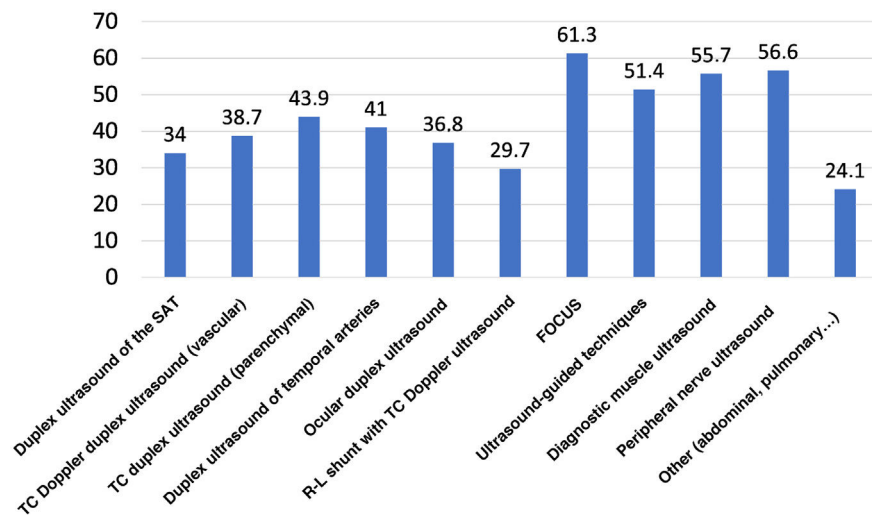


Figure 6 Training needs. Survey respondents were asked to indicate all the training resources they deemed necessary to improve or update their knowledge on neurosonology, even when this forced them to receive training at another centre. FOCUS: focused cardiac ultrasound; R-L: right-to-left; SAT: supra-aortic trunks; TC: transcranial.

Table 1 SWOT analysis of neurosonology practice (part 1): weaknesses, threats, and risk assessment.

	Description of the risk	Severity (1–3)	Likelihood (1–3)	Impact (1–3)	Level of risk (1–27)
Weaknesses	The neurosonology examination is time-consuming.	2	1	3	9
	The technique requires costly equipment.	2	2	1	4
	Confirmatory tests are needed.	1	1	1	2
	Extensive training is required.	3	2	3	15
Threats	Lack of available time during clinical practice	3	3	2	12
	Need for neurosonology experts	2	2	3	12
	Advances in other diagnostic techniques	3	3	1	6
	Hospital management often assigns ultrasound to the radiology department.	3	2	1	5

the target population, with a 95% confidence level; this is considered acceptable in terms of representativeness. This was not the case for the group of residents ($n = 34$), which presented a 16% margin of error. Despite the long history of neurosonology training, the inclusion of the discipline in the neurology residency programme, and the efforts made by both the SEN and the SONES

to promote a certification in the field, only 38% of the participating neurologists held a neurosonology certification, and fewer than half reported having completed a certified continuing education course. Regarding clinical practice, the vast majority of neurology departments perform vascular neurosonology techniques (Duplex-Doppler ultrasound of the supra-aortic trunks and transcranial).

Table 2 SWOT analysis of neurosonology practice (part 2): strengths, opportunities, and opportunity assessment.

	Description of the opportunity	Severity (1–3)	Likelihood (1–3)	Impact (1–3)	Level of importance (1–27)
Strengths	The technique can be performed at the patient's bedside.	3	3	3	18
	It is the ideal screening tool.	3	1	3	12
	It provides complete autonomy to neurologists.	2	2	3	12
	Neurosonology equipment is increasingly portable.	1	1	1	2
Opportunities	Protocols for the comprehensive management of neurological patients	3	3	3	18
	Expanding applications	1	2	2	6
	Its use as a screening tool will become more necessary than ever in the future.	2	1	1	3
	Technical advances in neurosonology equipment will enable new protocols.	2	1	1	3

nial Doppler ultrasound), but few offer non-vascular techniques, such as parenchymal or neuromuscular ultrasound. We were surprised by the underutilisation (or lack of awareness) of transcranial Doppler ultrasound for detecting right-to-left shunts; despite its higher sensitivity than TTE,²² the former test is used to replace TTE by only 51% of survey respondents. Likewise, while FOCUS is a thriving technique, only 25% of participants use it frequently, and its use seems to be even more limited in daily practice. Another surprising finding is the limited availability of neurosonology laboratories, with daily activity reported by only 53% of respondents; 31% reported that their hospitals either did not have a dedicated schedule for vascular studies or performed them only occasionally. Nearly all neurologists practising neurosonology combine this activity with other healthcare activities. Only 14% exclusively practise neurosonology, and up to 36% of respondents reported that no physician at their centres was dedicated exclusively to neurosonology. These findings reflect an imbalance between the role neurosonology should play in daily clinical practice and the material and human resources available at neurology departments allocated to it. For example, considering that over 80% of hospitals offering neurology residency training in 2022 have a stroke unit,²³ the percentage of hospitals with dedicated neurosonology laboratories should be at least comparable. Another obvious weakness of current neurosonology practice is the limited use of neurosonology image storage systems, with only 22% of respondents reporting use of clinical image viewers. We believe that it is essential for neurosonology laboratory activity to be systematically recorded using dedicated systems, and for study results to be accessible to other health-

care professionals working at the neurology and other departments. Increasing the visibility of neurosonology laboratories is essential in obtaining more material, human, and training resources. Regarding neurosonology training among residents, the importance placed on vascular neurosonology was as expected. However, it is concerning that 15% spent one month or less of their residency in a dedicated neurosonology rotation, especially considering that neurosonology is a mandatory part of the neurology residency programme. This may be explained by the lack of dedicated spaces and time slots, which forces residents (and neurologists) to combine neurosonology training with other training activities. Continuing education opportunities for neurologists are also limited, according to survey respondents. Greater efforts should be made to improve access to neurosonology courses and workshops across Spain, given that most respondents reported a lack of local training opportunities. There is a significant imbalance between the demand for neurosonology training and the availability of training opportunities at neurology departments, particularly with respect to non-vascular neurosonology techniques. One of the SONES' objectives for the coming years is to increase the number and improve the geographical distribution of training courses in different techniques, although human and economic resources are limited. Based on SWOT analysis results, other strategies to be considered include the publication of standardised protocols for different neurosonology techniques and the performance of cost-effectiveness studies. This study presents several limitations, including the survey format, which prevented us from tracking the number of recipients, the geographical distribution of respondents, and the insufficient number of par-

ticipating residents to consider our findings representative of this group.

Conclusions

Neurosonology is widely used across Spanish hospitals, but the implementation of dedicated neurosonology laboratories remains limited. There is growing interest in non-vascular neurosonology techniques among neurologists and neurology residents, but training options are currently insufficient. Increased efforts should be made to draw greater attention to this discipline, demanding more material and human resources for its development. The SONES should facilitate access to continuing training in neurosonology for neurologists.

Funding

This study has received no specific funding from any public, commercial, or non-profit organisation.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Acknowledgements

We would like to thank Dr Alberto Gil Peralta, Dr Carlos Jiménez Ortiz, Dr Jaime Gallego Cullere, Dr Gabriel Delgado Bona, Dr Antoni Dávalos Herrando, Dr Carlos Molina, Dr Antonio Alayón, Dr José Antonio Egido Herrero, Dr Jorge Matías-Guiu, Dr Eduardo Martínez Vila, Dr José Álvarez Sabin, Dr Exuperio Díez Tejedor, Dr Ángel Chamorro, Dr Mariano Rebollo Álvarez-Amandi, Dr Tomás Segura, and Dr José M. Tembl for their significant contributions to the development of neurosonology. We also wish to thank Henar Martín Santos for her help in designing the infographic.

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.nrleng.2025.06.003>.

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