Archives of Epilepsy

Original Article

Assessing Neurologists' Knowledge and Experience with Neurostimulation Techniques for Epilepsy: A Cross-sectional Analysis in Saudi Arabia

Zainah Al-Qahtani[1], Nawaf Najeh Almahfuth[2], Abdullah Abdulaziz Aldhabaan[2], Kouther Mutlaq Omar Alhudires[3], Noha Tashkandi[4]

[1]King Khalid University Faculty of Medicine, Department of Internal Medicine, Devision of Neurology, Abha, Saudi Arabia

[2]King Khaled University Faculty of Medicine, Abha, Saudi Arabia

[3]University of Hail Faculty of Medicine, Hail, Saudi Arabia

[4]King Saud bin Abdulaziz University for Health Sciences Faculty of Medicine, Department of Medical Research, Jeddah, Saudi Arabia

Cite this article as: Al-Qahtani Z, Almahfuth NN, Aldhabaan AA, Alhudires KMO, Tashkandi N. Assessing neurologists' knowledge and experience with neurostimulation techniques for epilepsy: a cross-sectional analysis in Saudi Arabia. *Arch Epilepsy.* 2025;31(4):134-141.

Corresponding Author: Noha Tashkandi, King Saud bin Abdulaziz University for Health Sciences Faculty of Medicine, Department of Medical Research, Jeddah, Saudi Arabia, E-mail: nohatashkandi@gmail.com

Received: 05.03.2025 **Accepted:** 23.06.2025 **Epub:** 21.08.2025 **Publication Date:** 07.11.2025

DOI: 10.4274/ArchEpilepsy.2025.25173

Abstract

Objective: This study aimed to evaluate neurologists' opinions on vagus nerve stimulation (VNS) therapy for managing all forms of epilepsy in Saudi Arabia.

Methods: This cross-sectional survey study was conducted across all five main regions of Saudi Arabia, using a structured questionnaire, and data were collected from a randomly selected sample of neurologists, with a final sample size of 229 participants. The study questionnaire was validated through a pilot study.

Results: A total of 112 Saudi neurologists were included in this study. Approximately 67.86% of neurologists reported the availability of VNS procedures at their practice, with 82.14% indicating patients undergo VNS implantation at epilepsy centers, and return for follow-up. Initial training in neurostimulation was rated excellent by 52.68%; but 10.71% reported it as poor. Clinical assessments were the most commonly used diagnostic tool (43.75%), and VNS was the primary technique for early epilepsy treatment (68.75%). VNS therapy was rated as highly effective in controlling seizures (68.75%), with significant benefits in reducing seizure frequency and improving quality of life (76.79%). Most neurologists (92.86%) encountered complications such as physical discomfort, mood changes, and device malfunctions.

Conclusion: This study highlighted that neurologists in Saudi Arabia generally recognize the effectiveness of VNS in managing drug-resistant epilepsy, though there is a need for improved training and wider availability of VNS devices. Addressing these gaps through enhanced educational programs and better access to VNS therapy could significantly improve patient outcomes and the overall management of epilepsy.

Keywords: Epilepsy, drug-resistant epilepsy, vagus nerve stimulation, neuromodulation therapy, Saudi Arabia

INTRODUCTION

Epilepsy is a neurological disorder characterized by recurrent seizures and lasting brain changes, as defined by the International League Against Epilepsy.[1] Globally, around 1 to 2 percent of the population is affected by epilepsy.[2] The World Health Organization estimated in 2019 that nearly 50 million people worldwide have epilepsy.[3] In Saudi Arabia, the prevalence is approximately 3.96 cases per 1,000 persons [95% confidence interval (CI): 2.99-5.16].[4] Individuals with epilepsy face a higher risk of injuries related to seizures, as well as significant psychological effects, including anxiety, depression, and low self-esteem, which can lead to social isolation and fear of injuries.[5,6]

Anti-seizure medications (ASMs) are the primary treatment for epilepsy, but about 25% of patients do not achieve seizure freedom with these drugs. For a third of these patients, epilepsy remains uncontrolled or drug-resistant.[7] The rate of drug-resistant epilepsy is similar globally around 30-36.5%.[8] Early identification of these patients is critical for improving their management. Patients with drug-resistant epilepsy face a greater risk of complications and comorbidities. Patients with drug-resistant epilepsy are defined as those who continue to experience seizures despite appropriate trials of two or more adequately chosen and tolerated ASMs.[8] For these patients, if they are not candidates for resective epilepsy surgery, if they have failed epilepsy surgery, or if they have contraindications to epilepsy surgery, alternative treatment options include palliative therapies such as neurostimulation. Currently, three neurostimulation techniques vagus nerve stimulation (VNS), deep brain stimulation (DBS), and responsive neurostimulation (RNS) are approved for the management of drug-resistant epilepsy.[9-11] These therapies offer seizure reduction rather than curative outcomes, making them essential options for patients who are not suitable candidates for definitive surgical interventions.

VNS, approved in 1995, stimulates the vagus nerve, leading to a 50% or greater reduction in seizures for about half of the patients, with effectiveness potentially increasing over time.[12] The anterior nucleus of the thalamus-DBS, approved in 2014 (2010 in Europe), shows similar efficacy. RNS, also approved in 2014, targets brain activity patterns preceding seizures with the aim of preventing them and achieving similar results in seizure reduction to the VNS.[13]

While these neurostimulation therapies provide relief for some, they are generally considered palliative, with only a small percentage achieving long-term seizure independence.[14] Their use is particularly significant for patients who are not candidates for curative epilepsy surgery. Neurostimulation's primary benefit is manipulating the epileptic network by delivering stimuli to specific brain regions.[15] However, further theoretical studies are needed to understand the mechanisms of neurostimulation, and epilepsy networks.

Studies have explored neurostimulation techniques, with a retrospective study finding VNS therapy to be a safe and effective adjunct for both adult and pediatric patients. They showed promising results in reducing seizure frequency using VNS and DBS in patients unresponsive to medications.[13,16] Effective epilepsy control via neurostimulation could reduce the economic burden of epilepsy by decreasing hospitalizations and emergency visits, improving patients' quality of life (QoL).[17] This study aims to evaluate neurologists' opinions on VNS for managing drug-resistant epilepsy in Saudi Arabia, providing insights to enhance patient care and develop more efficient treatment approaches.

MAIN POINTS

- **Effectiveness of VNS:** The study found vagus nerve stimulation (VNS) highly effective in reducing seizure frequency and improving quality of life in patients with drug-resistant epilepsy.
- **Training Gaps Identified:** While most neurologists rated their initial VNS training as excellent or good, a notable 10.7% reported inadequate training, highlighting the need for improved educational programs.
- **Challenges in Accessibility:** One-third of participants reported limited access to VNS devices, underscoring disparities in availability across healthcare facilities in Saudi Arabia.
- **Complications Encountered:** Common complications of VNS therapy included physical discomfort, mood changes, and device malfunctions, emphasizing the need for better patient monitoring and support systems.
- **Recommendations for Improvement:** Neurologists suggested advancements in patient monitoring, less invasive procedures, and more effective stimulation techniques to optimize VNS therapy outcomes.

METHODS

Study Design, Area, and Setting

A cross-sectional survey study was used to evaluate the perceptions of neurologists regarding neurostimulation techniques in epilepsy treatment, their commonly utilized techniques, and their opinions on the safety of these procedures. This study was conducted in Saudi Arabia, covering all five main regions: Eastern, Central, Northern, Western, and Southern. These regions included various urban and rural settings, with neurologists working in different types of healthcare facilities, such as public hospitals, private hospitals, and specialized neurology clinics. Before starting data collection, ethical approval was obtained from the King Khalid University Research Ethics Committee (approval no: HAPO-06-B-001, date: 08.11.2023). Confidentiality and security of the data were ensured, with only the research team and principal investigator having access to the data for research purposes.

Inclusion Criteria

The inclusion criteria for this study were certified neurologists currently practicing in Saudi Arabia across various healthcare facilities, including public and private hospitals, as well as specialized neurology clinics, with specific experience in neurostimulation techniques for epilepsy diagnosis and treatment. Exclusion criteria ruled out neurologists who were not currently practicing and those without experience in neurostimulation techniques.

Sample Size

The sample size was calculated using Raosoft. According to the Ministry of Health Statistical Yearbook (2021), the population size of specialized neurologists and consultants was 560. With a confidence level of 95% and a 5% margin of error, the estimated sample size was 229 neurologist participants.

Sampling Technique

Participants were selected through a random sampling technique. Saudi Arabia was divided into regions (Eastern, Central, Northern, Western, and Southern). Neurologists from each region were randomly selected from neurology clinics, ensuring an accurate representation of the entire population.

Data Collection Methods and Tools

Data were collected using a structured questionnaire developed specifically for this study. The questionnaire was administered online and comprised a mix of multiple-choice questions, 3-point Likert scale questions, and open-ended questions. The questionnaire was divided into three parts: 1) demographic information (age, gender, region, hospital center, experience with

neurostimulation techniques, initial training in neurostimulation techniques); 2) assessment of the efficacy and safety of neurostimulation techniques using a 3-point Likert scale; 3) data related to participants' perceived benefits, QoL, neurostimulation complications, and improvements.

A pilot study was conducted on a small group of neurologists to test the validity and reliability of the questionnaire. Necessary modifications were made based on the feedback received.

Data Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS; IBM Corp., Version 25). Descriptive statistics were used to summarize the basic features of the dataset. Categorical data were represented as frequencies and percentages.

RESULTS

The study included 112 neurologists (response rate 48%), with the majority (71.43%) aged between 30 and 45 years and 28.57% aged 45 or older. The gender distribution showed a higher percentage of male participants (59.82%) compared to females (40.18%). Regional representation was most significant from the Central Region (36.61%), followed by the Western Region (27.68%), the Eastern Region (19.64%), and both the Southern and Northern Regions (8.04% each). A significant proportion of participants (59.82%) were practicing neurologists at epilepsy centers. King Faisal Specialist Hospital and Research Centre had the highest representation (21.43%), followed by King Fahad Specialist Hospital (9.82%), King Fahad Medical City (8.04%), Prince Sultan Military Medical City (8.04%), Security Forces Hospital (8.04%), Prince Fahd bin Sultan Hospital (5.36%), National Guard (4.46%), and other hospitals (33.93%), as shown in Table 1.

In their current practice, 67.86% of neurologists reported that VNS procedures are available at their hospital or center, while 32.14% indicated that they refer patients elsewhere for the procedure. When patients are not at an epilepsy center, 82.14% of neurologists stated that these patients undergo VNS device implantation at an epilepsy center and then return to their clinic for follow-up and device adjustment, whereas 17.86% noted that patients schedule follow-up appointments there. Regarding their initial training in neurostimulation techniques, 52.68% of neurologists rated it as excellent, 36.61% as good, and 10.71% as poor (Table 2).

The study revealed that clinical assessments are the most commonly used diagnostic tool for detecting early signs of epilepsy, as reported by 43.75% of neurologists. Electroencephalography (EEG) was used by 18.75% of respondents, magnetic resonance imaging (MRI) by 16.07%, and computed tomography (CT) by 4.46%, while 16.96% indicated using all of these techniques. For early epilepsy diagnosis and treatment, VNS was the most commonly used technique, cited by 68.75% of neurologists, followed by RNS at 22.32%, with 8.93% indicating none of the above, or that the techniques were not available. Determining patient suitability for VNS therapy involved considering the frequency and severity of seizures (18.75%), conducting comprehensive neurological assessments (15.18%), collaborating with a multidisciplinary team (1.79%), and combining all of these methods (64.29%), as shown in Table 3.

The outcomes of VNS therapy in epilepsy patients were rated by neurologists as excellent in controlling seizures by 68.75%, good by 29.46%, and poor by 1.79%. The typical duration of VNS treatment varied, with 24.11% indicating 6 months to 1 year, 7.14%

Table 1. Demographic characteristics

Parameters		n (%)
Age	30-45 years	80 (71.43%)
	45 or older	28 (28.57%)
General	Male	67 (59.82%)
	Female	45 (40.18%)
Region	Western Region	31 (27.68%)
	Central Region	41 (36.61%)
	Southern Region	9 (8.04%)
	Eastern Region	22 (19.64%)
	Northern Region	9 (8.04%)
Are you a neurologist currently practicing at an epilepsy center?	Yes	67 (59.82%)
	No	45 (40.18%)
Please specify the name of your hospital and indicate whether it is a neuro clinic or monitoring epilepsy unit?	King Faisal Specialist Hospital	24 (21.43%)
	King Fahad Specialist Hospital	11 (9.82%)
	King Fahad Medical City	9 (8.04%)
	Prince Sultan Military Medical City	9 (8.04%)
	Security Forces Hospital	9 (8.04%)
	Prince Fahad bin Sultan Hospital	6 (5.36%)
	National Guard	5 (4.46%)
	Others	38 (33.93%)

Table 2. Availability and implementation of VNS therapy

Question	Responses	n (%)
At your current practice as a neurologist. Is VNS procedure available in your hospital/ center?	Yes	76 (67.86%)
	No, the referral is advised	36 (32.14%)
If the patient is not at an epilepsy center, do they undergo VNS device implantation at the epilepsy center and then come back to your clinic for follow-up and device adjustment if necessary?	Yes	92 (82.14%)
	No, the patient schedules a follow-up appointment at the epilepsy center	20 (17.86%)
How would you rate your initial training in neurostimulation techniques?	Excellent	59 (52.68%)
	Good	41 (36.61%)
	Poor	12 (10.71%)

VNS: Vagus nerve stimulation

indicating 2 to 5 years, 25.89% indicating it varies depending on the patient's response, and 42.86% reporting indefinite duration. The effectiveness of VNS treatment was primarily monitored through periodic device programming and patient feedback (49.11%), followed by EEG monitoring and medication adjustments (31.25%), regular follow-up visits and seizure diaries (16.07%), and clinical observation and caregiver reports (3.57%). The potential benefits of VNS treatment included a reduction in seizure frequency and severity (1.79%), improved mood and QoL (13.39%), decreased use of anti-epileptic drugs (8.06%), and a combination of these benefits (76.79%) as shown in Table 4.

When assessing the QoL for patients who have undergone neurostimulation therapy for epilepsy, 64.29% of neurologists consider all factors, including patient-reported outcomes and satisfaction, impact on daily activities and social interactions, family support and involvement, and frequency of follow-up visits. Specifically, 16.07% prioritize patient-reported outcomes and satisfaction during clinic visits, 9.82% focus on the impact on daily activities and social interactions, 7.14% emphasize family support and involvement, and 2.68% consider the frequency of follow-up visits. Managing potential side effects or adverse events related to VNS therapy typically involves three strategies: medication changes or additions (9.82%), adjusting stimulation parameters or programming settings (7.14%), and collaborating with speech and language therapists (11.61%). The majority (71.43%) of practitioners employing all these strategies.

A significant majority of neurologists (92.86%) have encountered complications or observed adverse effects following neurostimulation procedures, with the most frequently reported issues being physical discomfort (58.93%), mood changes

Table 3. Diagnostic tools and techniques for epilepsy

Question	Responses	n (%)
Which of the following techniques or diagnostic tools are most commonly used in the evaluation of epilepsy in your clinical practice?	EEG	21 (18.75%)
	Clinical assessments	49 (43.75%)
	MRI	18 (16.07%)
	CT scan	5 (4.46%)
	All of the above	19 (16.96%)
Which neurostimulation technique do you most commonly use for the management of epilepsy in your patients?	VNS	77 (68.75%)
	RNS	25 (22.32%)
	None of the above or not available	10 (8.93%)
How do you determine if a patient with epilepsy is a suitable candidate for VNS therapy?	Based on the frequency and severity of seizures	21 (18.75%)
	By conducting a comprehensive neurological assessment	17 (15.18%)
	Through collaboration with a multidisciplinary team	2 (1.79%)
	All of the above	72 (64.29%)

EEG: Electroencephalography, MRI: Magnetic resonance imaging, CT: Computed tomography, VNS: Vagus nerve stimulation, RNS: Responsive neurostimulation

Table 4. Outcomes of VNS therapy

Question	Responses	n (%)
On a scale of 1-3, how would you rate the effectiveness of neurostimulation in controlling seizures in epilepsy patients?	Excellent	77 (68.75%)
	Good	33 (29.46%)
	Poor	2 (1.79%)
What is the typical duration of VNS treatment in epilepsy patients?	6 months to 1 year	27 (24.11%)
	2 to 5 years	8 (7.14%)
	It does vary depending on the patient's response	29 (25.89%)
	Indefinite	48 (42.86%)
How is the effectiveness of VNS treatment monitored in epilepsy patients?	It is through EEG monitoring and medication adjustments	35 (31.25%)
	It is through regular follow-up visits and seizure diaries	18 (16.07%)
	It is through clinical observation and caregiver reports	4 (3.57%)
	It is through periodic device programming and patient feedback	55 (49.11%)
What are the potential benefits of VNS treatment in epilepsy?	Reduction in seizure frequency and severity	2 (1.79%)
	Improved mood and quality of life	15 (13.39%)
	Decrease in the use of anti-epileptic drugs	9 (8.06%)
	All of the above	86 (76.79%)

VNS: Vagus nerve stimulation, EEG: Electroencephalography

(41.07%), device malfunction (30.36%), hemorrhage (27.68%), infection (25.89%), and cognitive changes (25.00%) (Figure 1).

Regarding MRI scans, 46.43% noted that while complications can occur, precautions can be taken to conduct the scan safely whereas

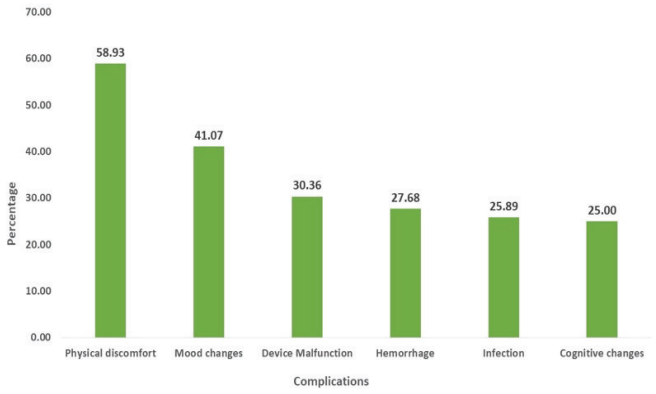

Figure 1. The most frequently reported complications encountered by the neurologists during implementation of VNS
VNS: Vagus nerve stimulation

24.11% reported that the device is entirely MRI-compatible, and 19.64% mentioned complications only if the MRI is of the head. Suggested improvements in neurostimulation techniques included better patient monitoring (51.79%), less invasive procedures (45.54%), better training programs (36.61%), and more effective stimulation techniques (32.14%). Specific patient characteristics or epilepsy types that tend to respond better to VNS treatment include patients with focal seizures (46.43%), a history of traumatic brain injury (13.39%), and drug-resistant epilepsy (10.71%), while 29.46% indicate all of the above (Table 5).

DISCUSSION

The findings of this study highlight the perceptions and experiences of neurologists in Saudi Arabia regarding the use of VNS therapy for epilepsy management. A substantial number of neurologists indicated that VNS procedures are available in their practice settings, demonstrating a favorable trend toward the adoption of this neurostimulation technique. Nevertheless, approximately 10% of participants reported inadequate training, highlighting the need for improvement in training materials and physician education programs to enhance understanding and proficiency in VNS procedures. In addition, about one-third of the participants reported that VNS devices are not available in their institutions or hospitals.

Table 5. QoL and management of adverse effects in VNS therapy

Question	Responses	n (%)
Which of the following is an important factor to consider when assessing the QoL for patients who have undergone neurostimulation therapy for epilepsy, based on follow-up visits and family responses?	Patient-reported outcomes and satisfaction (QoL assessment in clinic visit)	18 (16.07%)
	Impact on daily activities and social interactions	11 (9.82%)
	Family support and involvement	8 (7.14%)
	Frequency of follow-up visits	3 (2.68%)
	All of the above	72 (64.29%)
How do you manage potential side effects or adverse events related to VNS therapy in epilepsy patients?	Medication changes or additions	11 (9.82%)
	Adjusting stimulation parameters or programming settings	8 (7.14%)
	Collaborating with speech and language therapists	13 (11.61%)
	All of the above	80 (71.43%)
Have you encountered any complications during or observed any adverse effects after neurostimulation procedures?	Yes	104 (92.86%)
	No	8 (7.14%)
What improvements or advancements would you like to see in neurostimulation techniques? (Select all that apply)	Better patient monitoring	58 (51.79%)
	Better training programs	41 (36.61%)
	Less invasive procedures	51 (45.54%)
	More effective stimulation techniques	36 (32.14%)
Can the VNS device cause complications if a patient needs to undergo an MRI scan?	Yes, all MRI scans are contraindicated with a VNS device	11 (9.82%)
	Yes, but precautions can be taken to conduct an MRI safely	52 (46.43%)
	Yes, but only if the MRI is of the head	22 (19.64%)
	No, the device is entirely MRI-compatible	27 (24.11%)
Are there any specific patient characteristics or epilepsy types that tend to respond better to VNS treatment?	Patients with drug-resistant epilepsy	12 (10.71%)
	Patients with a history of traumatic brain injury	15 (13.39%)
	Patients with focal seizures	52 (46.43%)
	All of the above	33 (29.46%)

VNS: Vagus nerve stimulation, QoL: Quality of life, MRI: Magnetic resonance imaging

The lack of VNS devices in certain healthcare settings highlights disparities in access to advanced neurostimulation therapies. While larger, specialized epilepsy centers may have the necessary resources and expertise to offer VNS, smaller hospitals or clinics may face limitations due to budget constraints, infrastructure, or training gaps.[18] As a result, patients in underserved areas may be deprived of this potentially beneficial treatment option.[19] Neurologists working in institutions without VNS devices face a challenging dilemma. When encountering patients who could benefit from VNS, healthcare providers must decide whether to refer them to external centers or explore alternative treatment modalities.[20] This decision-making process involves weighing the potential benefits of VNS against the logistical challenges of referral and follow-up. It also underscores the need for collaborative networks and clear referral pathways to ensure seamless patient care.

Clinical evaluations by neurologists play a crucial role in diagnosing epilepsy. These assessments consider seizure semiology, medical history, and physical examination. The substantial use of clinical assessments (43.75%) reflects their importance in identifying early signs of epilepsy.[21] EEG remains a cornerstone in diagnosing epilepsy. It records electrical activity in the brain and helps identify abnormal patterns associated with seizures.[22] The utilization of EEG (18.75%) needs to be increased to align with the international and regional recommendations.[23] MRI provides detailed structural images of the brain. It helps detect underlying lesions, such as tumors or vascular malformations, which may contribute to epilepsy. CT scans are less commonly used (4.46%) due to their lower sensitivity for detecting subtle brain abnormalities associated with epilepsy. However, they may be useful in emergency situations or when MRI is contraindicated.[24] Saudi neurologists reached a consensus recommending that, before VNS implantation, a comprehensive seizure evaluation must be documented, including baseline seizure type, severity, and frequency. Each patient must have at least one documented seizure and undergo a video-EEG recording for a minimum of 24 hours. Additionally, a brain MRI (at least 1.5 Tesla) should be performed to rule out potential resective epilepsy surgery with a CT scan as an alternative if MRI is contraindicated.[25]

Identifying suitable candidates for VNS involves assessing seizure frequency, severity, and response to previous treatments. Collaboration with a multidisciplinary team ensures comprehensive evaluation and optimal patient selection. A Saudi consensus showed that patients recommended for VNS therapy must meet specific criteria, including having symptomatic localized epilepsy with multiple or bilateral independent foci; cryptogenic or symptomatic generalized epilepsy with widespread epileptogenic abnormalities such as Lennox-Gastaut syndrome; a history of failed intracranial epilepsy surgery with no viable alternative surgical options; or refractory epilepsy that is not suitable for surgical intervention.[25]

The effectiveness of VNS in controlling seizures was rated highly, with a majority of neurologists acknowledging its benefits in reducing seizure frequency and improving the QoL for patients. These results align with existing literature that underscores the efficacy of VNS in managing drug-resistant epilepsy. A meta-analysis of 74 articles showed that following VNS therapy, seizure frequency decreased by an average of 45%, with a 36% reduction observed at 3 to 12 months post-surgery and a 51% reduction after more than one year of treatment. At the final follow-up, approximately 50% of patients experienced a 50% or greater reduction in seizures. VNS predicted a reduction of 50% or more in seizures with a main effects odds ratio of 1.83 (95% CI: 1.80-1.86).[26] A more recent systematic review and meta-analysis showed that high-frequency VNS was significantly more effective than the control, with a standardized mean difference of 0.82 (95% CI: 0.39-1.24, $p<0.001$). This significance persisted across subgroup analyses comparing low-frequency VNS as the control, different VNS modalities, and, after excluding studies with moderate-to-high risk of bias. Treatment response data from 8 studies involving 758 patients also favored high-frequency VNS over control, with a risk ratio of 1.57 (95% CI: 1.19-2.07, $p<0.001$). QoL outcomes were descriptively reported in 4 studies with 363 patients, and adverse events were documented in 11 studies comprising 875 patients.[27]

The study participants identified physical discomfort, mood changes, device malfunction, hemorrhage, infection, and cognitive changes as the most commonly encountered adverse events. In a cohort study conducted by Alshehri et al.[28] 67.4% of patients undergoing VNS therapy reported experiencing side effects. The serious adverse reactions identified included dysphagia (39.5%), dyspnoea (23.3%), aspiration pneumonia (9.3%), increased secretions (7%), snoring (7%), and an increase in seizure frequency (2.3%). Mild side effects encompassed cough (23.3%), hoarseness (18.6%), and also included vomiting and fatigue.[28] Toffa et al.[29] meta-analysis detailed additional side effects of VNS, such as postoperative infection, vocal cord paresis, cough, neck pain, hoarseness, dysphonia, and snoring. High-intensity stimulation often led to withdrawals and changes in voice, including hoarseness. At lower stimulation levels, side effects such as cough, dyspnea, pain, paresthesias, nausea, and headache were noted.[29] Furthermore, as an electrical device, the electrode used in VNS therapy may pose risks such as electrode breakage, disconnection, failure, and pacemaker malfunction. Surgical complications related to electrode insertion, including infection, hematoma, vocal cord palsy, and cable discomfort, should also be considered.[30]

The survey results reflect the evolving understanding of MRI compatibility with VNS devices. While a significant proportion of respondents (46.43%) acknowledged potential complications, they also recognized that safety precautions could mitigate these risks. This aligns with current guidelines, which state that MRI can be safely performed with VNS therapy systems, provided specific guidelines are followed.[31] 24.11% of respondents reported that the device was entirely MRI-compatible, reflecting advancements in VNS technology that have expanded MRI access. However, 19.64% of respondents mentioned complications only if the MRI the head, indicating a need for further clarification and education on this topic.

The survey responses highlight several areas for improvement in neurostimulation techniques. Better patient monitoring was the most commonly suggested improvement, aligning with recent literature emphasizing the importance of personalized strategies and dynamic closed-loop assessment of neural function.[32] Less invasive procedures were also highlighted, reflecting ongoing efforts to minimize patient discomfort and risk. Better training programs and more effective stimulation techniques were also suggested, underscoring the need for continuous innovation and education in the field of neurostimulation.[33]

The survey identified specific patient characteristics or epilepsy types that tend to respond better to VNS treatment. Patients with focal seizures were most commonly identified, consistent with literature indicating that VNS is particularly effective for patients with focal seizures.[34] A history of traumatic brain injury and drug-resistant epilepsy was also noted, reflecting the broad applicability of VNS therapy.[35] Interestingly, 29.46% of respondents indicated that all of the above characteristics could predict a better response to VNS, suggesting that a comprehensive patient assessment is crucial for optimizing VNS outcomes.

Implications

The study's implications are significant for clinical practice and healthcare policy in Saudi Arabia. The high effectiveness rating of VNS therapy by neurologists suggests that it is a valuable tool in the management of drug-resistant epilepsy. Healthcare facilities should consider increasing the availability of VNS procedures and providing robust training programs for neurologists to enhance their competence in neurostimulation techniques. Furthermore, addressing the complications associated with VNS through comprehensive follow-up and patient support systems can improve patient outcomes and satisfaction. Policymakers should also consider integrating VNS therapy more broadly into national epilepsy management guidelines to ensure uniformity in treatment approaches.

Future Directions

Future research should focus on exploring alternative mechanisms by which VNS might affect epilepsy beyond its current applications. Studies should investigate the potential of VNS in modulating neural networks and their impact on cognitive and psychological outcomes in epilepsy patients. Additionally, future studies should include subgroup analyses to identify specific patient characteristics that may influence the response to VNS therapy, such as age, gender, and epilepsy type. Sensitivity analyses are also crucial to assess the robustness of findings and to account for variations in study designs and patient populations. Long-term studies with larger sample sizes and diverse demographic representation are needed to establish the sustained efficacy and safety of VNS therapy in various clinical settings. This comprehensive approach will provide deeper insights into the optimization of neurostimulation techniques for epilepsy management.

Study Limitations

This study has several limitations that need to be acknowledged. The sample size was relatively small, with only 112 neurologists participating, which may limit the generalizability of the findings. Additionally, the response rate was low at 48%, potentially introducing non-response bias and limiting the representativeness of the results. The descriptive nature of the study also restricts the ability to infer causality or explore more complex relationships between variables. Another limitation is the reliance on self-reported data, which may be subject to recall bias or social desirability bias. The assessment of neurostimulation effectiveness was based on the subjective opinions of participating neurologists, without using standardized clinical metrics such as seizure reduction rates. This reliance on subjective evaluation may have introduced variability in the reported effectiveness of neurostimulation techniques. Furthermore, the study was conducted within a specific geographic context Saudi Arabia potentially limiting the applicability of the findings to other regions with different healthcare systems and practices. Finally, variations in healthcare infrastructure and resources across the different regions included in the study may also influence the results, indicating the need for more nuanced analyses in future research.

CONCLUSION

This study provided valuable insights into the knowledge, awareness, and perceptions of neurologists in Saudi Arabia regarding the use of neurostimulation techniques, particularly VNS, for epilepsy diagnosis and management. The findings indicate a significant level of awareness and implementation of VNS procedures, with most neurologists acknowledging its effectiveness in reducing seizure frequency and improving patient QoL. However, the study also identified gaps in training, with a portion of neurologists reporting inadequate initial training in neurostimulation techniques, highlighting the need for enhanced educational programs. Neurologists' views on the efficiency and safety of VNS were generally positive, aligning with existing literature on the benefits of this therapy for drug-resistant epilepsy. Factors influencing recommendations for VNS therapy included the frequency and severity of seizures, comprehensive neurological assessments, and multidisciplinary collaboration. The study also uncovered challenges such as limited availability of VNS devices in certain healthcare settings and the occurrence of adverse events like physical discomfort and device malfunctions.

Addressing these challenges requires targeted efforts to improve access to VNS therapy, provide robust training programs, and develop comprehensive patient support systems. Future research should explore alternative mechanisms of VNS, conduct subgroup analyses to identify specific patient characteristics influencing therapy response, and undertake long-term studies to establish the sustained efficacy and safety of VNS. By addressing these areas, healthcare providers can enhance the effectiveness and safety of neurostimulation techniques, ultimately improving patient outcomes in epilepsy management.

Finally, while VNS therapy is a promising intervention for drug-resistant epilepsy, further research and improvements in training, patient monitoring, and management of adverse effects are essential to maximize its benefits. By addressing these areas, healthcare providers can enhance the effectiveness and safety of VNS therapy, ultimately improving the QoL for epilepsy patients.

Ethics

Ethics Committee Approval: Before starting data collection, ethical approval was obtained from the King Khalid University Research Ethics Committee (approval no: HAPO-06-B-001, date: 08.11.2023).

Informed Consent: Retrospective study.

Footnotes

Author Contributions

Concept: Z.A.Q., N.T., Design: Z.A.Q., N.T., Data Collection or Processing: N.N.A., A.A.A., K.M.O.A., Analysis or Interpretation: Z.A.Q., A.A.A.,

Literature Search: N.N.A., A.A.A., Writing: Z.A.Q., N.N.A., A.A.A., K.M.O.A., N.T.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Fisher RS, Acevedo C, Arzimanoglou A, et al. ILAE official report: a practical clinical definition of epilepsy. *Epilepsia*. 2014;55(4):475-482. [Crossref]
2. Falco-Walter J. Epilepsy-definition, classification, pathophysiology, and epidemiology. *Semin Neurol*. 2020;40(6):617-623. [Crossref]
3. Minghui R, Kestel D, Wiebe S, Brodie M. A public health imperative. *World Health Organization*. https://www.who.int/news-room/fact-sheets/detail/epilepsy. 2014. [Crossref]
4. Al Rumayyan A, Alharthi A, Al-Rowaili M, et al. The prevalence of active epilepsy in the Kingdom of Saudi Arabia: a cross-sectional study. *Neuroepidemiology*. 2023;57(2):78-89. [Crossref]
5. Feigin VL, Nichols E, Alam T, et al. Global, regional, and national burden of neurological disorders, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol*. 2019;18(5):459-480. [Crossref]
6. Boling W, Means M, Fletcher A. Quality of life and stigma in epilepsy, perspectives from selected regions of Asia and sub-Saharan Africa. *Brain Sci*. 2018;8(4). [Crossref]
7. Brodie MJ, Barry SJE, Bamagous GA, Norrie JD, Kwan P. Patterns of treatment response in newly diagnosed epilepsy. *Neurology*. 2012;78(20):1548-1554. [Crossref]
8. Mesraoua B, Brigo F, Lattanzi S, Abou-Khalil B, Al Hail H, Asadi-Pooya AA. Drug-resistant epilepsy: definition, pathophysiology, and management. *J Neurol Sci*. 2023;452:120766. [Crossref]
9. Piazza MG, Varga G, Welch W, Abel TJ. The utility of responsive neurostimulation for the treatment of pediatric drug-resistant epilepsy. *Brain Sci*. 2023;13(10):1455. [Crossref]
10. Li MCH, Cook MJ. Deep brain stimulation for drug-resistant epilepsy. *Epilepsia*. 2018;59(2):273-290. [Crossref]
11. Pérez-Carbonell L, Faulkner H, Higgins S, Koutroumanidis M, Leschziner G. Vagus nerve stimulation for drug-resistant epilepsy. *Pract Neurol*. 2020;20(3):189-198. [Crossref]
12. Ryvlin P, Jehi LE. Neuromodulation for refractory epilepsy. *Epilepsy Curr*. 2022;22(1):11-17. [Crossref]
13. Bouwens van der Vlis TAM, Schijns OEMG, Schaper FLWVJ, et al. Deep brain stimulation of the anterior nucleus of the thalamus for drug-resistant epilepsy. *Neurosurg Rev*. 2019;42(2):287-296. [Crossref]
14. Inaji M, Yamamoto T, Kawai K, Maehara T, Doyle WK. Responsive neurostimulation as a novel palliative option in epilepsy surgery. *Neurol Med Chir (Tokyo)*. 2021;61(1):1-11. [Crossref]
15. Rao VR, Rolston JD. Unearthing the mechanisms of responsive neurostimulation for epilepsy. *Commun Med*. 2023;3(1):166. [Crossref]
16. Morrell MJ. Responsive cortical stimulation for the treatment of medically intractable partial epilepsy. *Neurology*. 2011;77(13):1295-1304. [Crossref]
17. Raspin C, Faught E, Armand J, et al. An economic evaluation of vagus nerve stimulation as an adjunctive treatment to anti-seizure medications for the treatment of drug resistant epilepsy in the United States. *J Med Econ*. 2023;26(1):189-199. [Crossref]
18. Pan W, Hussain A, Tolba R. Disparities in access to neuromodulation therapies: what factors are at play? 2022. https://www.asra.com/news-publications/asra-newsletter/newsletter-item/asra-news/2022/02/07/disparities-in-access-to-neuromodulation-therapies-what-factors-are-at-play [Crossref]
19. Lado FA, Ahrens SM, Riker E, et al. Guidelines for Specialized Epilepsy Centers: executive summary of the report of the National Association of Epilepsy Centers Guideline Panel. *Neurology*. 2024;102(4):e208087. [Crossref]
20. Hakimi A, Spanaki M, Schuh L, Smith B, Schultz L. A survey of neurologists' views on epilepsy surgery and medically refractory epilepsy. *Epilepsy Behav*. 2008;13:96-101. [Crossref]
21. Stafstrom CE, Carmant L. Seizures and epilepsy: an overview for neuroscientists. *Cold Spring Harb Perspect Med*. 2015;5(6):a022426. [Crossref]
22. Alalayah KM, Senan EM, Atlam HF, Ahmed IA, Shatnawi HSA. Effective early detection of epileptic seizures through EEG signals using classification algorithms based on t-distributed stochastic neighbor embedding and k-means. *Diagnostics (Basel, Switzerland)*. 2023;13(11):1957. [Crossref]
23. Michel C, Murray M. Towards the utilization of EEG as a brain imaging tool. *Neuroimage*. 2011;61:371-385. [Crossref]
24. Cendes F, Theodore WH, Brinkmann BH, Sulc V, Cascino GD. Neuroimaging of epilepsy. *Handb Clin Neurol*. 2016;136:985-1014. [Crossref]
25. Alqadi K, Aldhalaan H, Alghamdi A, et al. Saudi arabian consensus statement on vagus nerve stimulation for refractory epilepsy. *Saudi J Med Med Sci*. 2021;9(1):75-81. [Crossref]
26. Englot DJ, Chang EF, Auguste KI. Vagus nerve stimulation for epilepsy: a meta-analysis of efficacy and predictors of response. *J Neurosurg*. 2011;115(6):1248-1255. [Crossref]
27. Lim MJR, Fong KY, Zheng Y, et al. Vagus nerve stimulation for treatment of drug-resistant epilepsy: a systematic review and meta-analysis. *Neurosurg Rev*. 2022;45(3):2361-2373. [Crossref]
28. Alshehri KA, Abuhulayqah SH, Asiry MA, Alyamani SA. Vagus nerve stimulation in medically refractory epilepsy: adverse effects and clinical correlates. *Neurosci J*. 2024;29(1):10-17. [Crossref]
29. Toffa DH, Touma L, El Meskine T, Bouthillier A, Nguyen DK. Learnings from 30 years of reported efficacy and safety of vagus nerve stimulation (VNS) for epilepsy treatment: a critical review. *Seizure*. 2020;83:104-123. [Crossref]
30. González HFJ, Yengo-Kahn A, Englot DJ. Vagus nerve stimulation for the treatment of epilepsy. *Neurosurg Clin N Am*. 2019;30(2):219-230. [Crossref]
31. LivaNova. MRI Safety & Scan Guidelines - VNS Therapy™ systems are MR Conditional and safe in the MR environment as long as certain conditions are met. [Internet]. 2024. [Crossref]
32. Carè M, Chiappalone M, Cota VR. Personalized strategies of neurostimulation: from static biomarkers to dynamic closed-loop assessment of neural function. *Front Neurosci*. 2024;18:1363128. [Crossref]
33. Marson F, Lasaponara S, Cavallo M. A scoping review of neuromodulation techniques in neurodegenerative diseases: a useful tool for clinical practice? *Medicina (B Aires)*. 2021;57(3):215. [Crossref]
34. McAllister-Williams RH, Sousa S, Kumar A, et al. The effects of vagus nerve stimulation on the course and outcomes of patients with bipolar disorder in a treatment-resistant depressive episode: a 5-year prospective registry. *Int J Bipolar Disord*. 2020;8(1):13. [Crossref]
35. Pires do Prado HJ, Pinto LF, Bezerra DF, et al. Predictive factors for successful vagus nerve stimulation in patients with refractory epilepsy: real-life insights from a multicenter study. *Front Neurosci*. 2023;17:1210221. [Crossref]