Role of Auricular Vagus Nerve Stimulation in Improving Upper Limb Functional Recovery Among Stroke Survivors

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Abstract:

- ***Background and Need***

Stroke is one of the most common causes of long term disability and often leaves a patient with upper limb motor loss, affecting both function and independence as well as impacting on QOL. The conventional rehabilitation usually restores only a limited arm hand function. In recent years, transcutaneous auricular vagus nerve stimulation (taVNS) is a form of non-invasive neuromodulation method that might facilitate neuroplasticity and promote motor recovery after stroke.

- ***Methods***

About 458 articles were searched by database viz. PubMed, Science Direct and Google Scholar. Based on the inclusion and exclusion criteria, seven studies were included consisting of interventional and prospective studies.

- ***Results***

Two randomized controlled trials found significant Improved upper limb motor function, functional independence, and motor recovery, one prospective study and three randomized pilot study.

- ***Conclusion***

Transcutaneous auricular vagus nerve stimulation is a viable and realistic complementary technique to boost upper limb motor recovery poststroke. Despite minor heterogeneity in stimulation parameters, treatment duration and outcome measures among the persistence of positive findings suggest a therapeutic potential for taVNS.

Keywords: *"Post-Stroke", "Upper Limb Function", "Upper Limb Motor Rehabilitation", "Transcutaneous Auricular Vagus Nerve Stimulation", "taVNS"*

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I. INTRODUCTION

Ischemic stroke is brain tissue death from blocked blood flow, with high incidence, mortality, and disability. Upper limb motor impairment is the most common poststroke deficit. Lower limb gross motor function recovers faster, while upper limb recovery is slower due to its reliance on fine, coordinated movement.[1,10,11]

Upper limb recovery is slow because the movements are fine, complex, and use large cortical areas. This limits daily tasks like eating, dressing, and reaching. Chronic deficits also increase anxiety and depression, slowing rehab. Early effective treatment can speed motor recovery and improve function.2,12,13,14,16

In 1997, the FDA approved cervical implanted VNS for a number of disorders, including heart failure, depression, cluster headaches, and drug-resistant epilepsy.

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According to recent research, VNS can also enhance motor function in the upper limbs following a stroke. However, the use of implanted VNS is limited since it necessitates surgery and carries a risk of arrhythmia, peritracheal hemorrhage, and vocal cord dysfunction.12, 14, 15

By activating the vagus nerve's auricular branch at the cymba conchae, transcutaneous auricular VNS (taVNS) prevents surgery. With improved safety and tolerability, it provides advantages comparable to those of implanted VNS.[1,2,3]

Implanted VNS improves post-stroke upper limb function but requires surgery with risks. taVNS stimulates the auricular branch of the vagus nerve non-invasively and shows similar brain activation with better safety. Studies pair taVNS with rehab to aid upper limb recovery, though the mechanism is unclear. This study tested taVNS + taskoriented training in subacute stroke using fNIRS and TMS to explore effects and mechanisms on upper limb function[3,4].

Animal and human studies show VNS boosts neuroplasticity and enhances repetitive task practice. In stroke rats, VNS paired with lever-pulling sped forelimb recovery and enlarged motor cortex. VNS with tones can also reduce

tinnitus.4,5,

Mechanisms include increased BDNF, IL-B, acetylcholine, and noradrenaline. In mice, blocking cholinergic projections from the nucleus basalis eliminated VNS motor benefits, indicating ACh is key to VNS-induced plasticity.[5]

Stroke disrupts key neurotransmitters like acetylcholine, dopamine, GABA, and norepinephrine, impairing cognition and plasticity, taVNS delivers TENS to the auricular vagus nerve, activating the locus coeruleus and nucleus of the solitary tract to regulate acetylcholine, GABA, and norepinephrine. This modulates brain regions tied to cognition. For motor recovery, tVNS boosts acetylcholine and norepinephrine to drive corticospinal reorganization. tSCS raises motor neuron excitability, improves muscle coordination via Ia-inhibitory interneurons, and enhances sensory gating through GABA interneurons.[3,4,5,6,]

taVNS mechanisms for motor cortex plasticity post-stroke are unclear but likely involve adrenergic-cholinergic balance. Recovery models include compensation, interhemispheric competition, and Di Pino's bimodal model, which ties predictions to structural preservation, with a Fugl-Meyer score of 43 as a potential threshold.[6,7]

II. METHODOLOGY

- Search Strategy

Databases used for this review were PubMed, Science Direct, cochrane, and google Scholar. The following keywords were used: “post-stroke”, “upper limb function”, “Upper Limb Motor Rehabilitation”, “Transcutaneous Auricular Vagus Nerve Stimulation”, “taVNS”

- Study Selection

Studies were considered for inclusion if they met the following criteria: (a) articles in English language (b) articles that include Transcutaneous Auricular Vagus Nerve Stimulation (c) articles that were published from 2018 to 2026 and (d) studies done on human. Studies were considered for exclusion if they met the following criteria: (a) articles whose full text was not available (b) articles published before 2018 (c) articles that used taVNS for conditions other than Post-Stroke Patients.

- Examined Variables

The variables examined in the study were: (a) Upper Limb Motor Function, (b) Muscle Strength, (c) Functional Independence, (d) Spasticity, (e) ROM, (f) Neuroplasticity (g) Sensory Function

- Search of Literature

238 duplicates were eliminated from the 458 items that the database's literature search turned up. Following preliminary screening, 41 papers were left for abstract review after 179 were eliminated. Only seven papers that satisfied all the inclusion criteria were taken into consideration for additional examination after a total of 34 articles that did not satisfy the remaining inclusion criteria were eliminated. (Figure 1)

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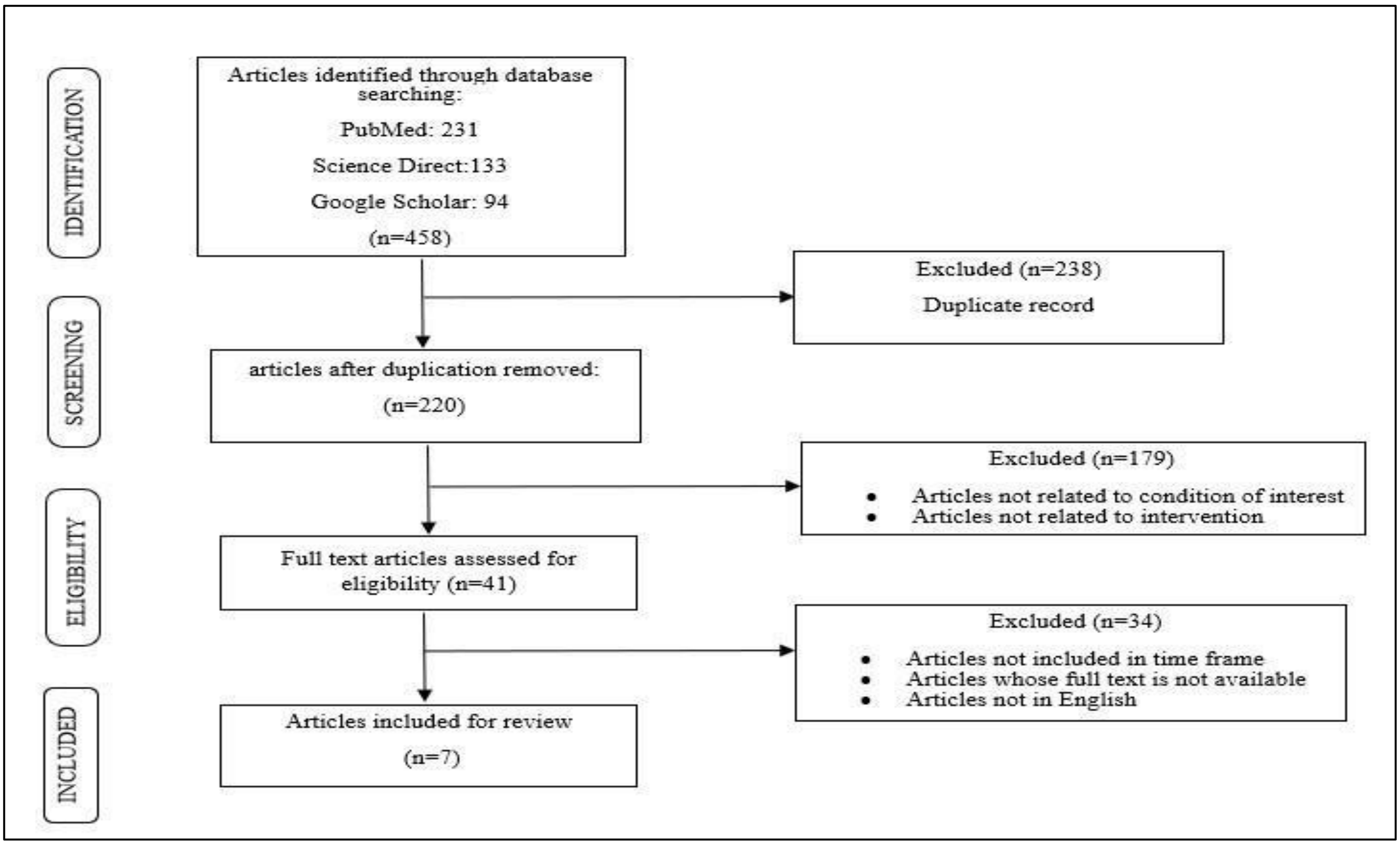

Fig 1 The Prisma Flow Diagram, Which Shows Each Stage of the Procedure for Choosing the Final Set of Studies to be Reviewed.

III. RESULTS

➢ *Sample*

Adults with post-stroke symptoms made up the study samples. According to the Brunnstrom Recovery Stages, the majority of research involved participants who were post-stroke patients in Stages 2 through 5.

➢ *Methodological Quality of Trials*

Only seven studies were ultimately approved for the current investigation based on the selection and rejection criteria (Figure 1). Given that Meng-Huan Wang et al. (4) and Long Chen et al. (9) employed the design of a randomized controlled trial (Level 2), the quality of these trials was evaluated using the PEDro scale, which yielded scores of 8/10 and 7/10, respectively, for one prospective study and three randomized pilot studies.

➢ *Interventions*

The TaVNS group received 600 pulses (intratrain pulse frequency = 20 Hz, pulse duration = 0.3 ms) lasting 30 seconds each, stimulating once every five minutes, at an intensity of 30 minutes each day for 15 consecutive days.. Ruiling Xue et al[2] TENS-200A auricular vagus nerve electrical stimulator. Each session lasted 60 min, 6 times per week, and both groups were treated for a total of 4 weeks output pulse frequency of 20 Hz for 10 s alternating with 4 Hz for 5 s, with a pulse width of 0.3 ms. Hui-Lin li et al[3] sessions ranged from 9 to 20. One study treated continuously for 15 days. 3 times/week or 5 times/week Pulse width: 300 µs for all studies Frequency: 20 Hz in 3 studies ; 30 Hz in 1 study Duty cycle: Stimulation trains lasted 0.5–30 s, with off-time 10 s–5 min, Current intensity: Active taVNS: set to individual sensory threshold. (Table 1).

Table 1 Brief Description of Included Studies

No	Author & Year	Sample size	Intervention/Device	Duration, Frequency, Intensity of Intervention	Dependent variables	Evaluation/ reassessment	Results
1	Ruiling Xue et al2	N=139 taVNS group=70 rehabilitation	TENS-200A electrical stimulator for the auricular vagus nerve group for	Six times a week, for 60 minutes each, both groups received treatment.	Serum biomarker levels (brainderived neurotrophic factor,	Baseline and 4th week of intervention	In terms of MEP latency and amplitude, ARAT, FMA-UE, MBI scores,

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	2025	group=69	rehabilitation The use of traditional rehabilitative training was made. Patients were guided to undertake range-of-motion exercises, sit training in bed, and arrange their limbs correctly.	output pulse frequency of 20 Hz for 10 s, alternating with 4 Hz for 5 s, and pulse width of 0.3 ms for a total of 4 weeks.	S100), clinical functional assessments (Action Research Arm Test, Fugl-Meyer Assessment for Upper Extremity, Modified Barthel Index), and motor evoked potential latency and amplitude calcium-binding protein (β)		BDNF, and S100-β, the taVNS group outperformed the rehabilitation group by a substantial margin. Clinically, both groups improved, but the gains in taVNS were greater.
2.	Nga Huen Chan e t al6 2025	N=90 tVNS group=30 tSCS group=30 Sham group=30	Neurostimulator TENS device	The study was conducted for 6 weeks *3 session/week.Each 60mins session included passive stretching followed by stimulation combined with upper limb exercises. The tVNS and tSCS groups received active stimulation with intensity of tolerate level, while sham group received no active stimulation. Exercise includes grasping, reaching and strengthening exercise.	The Montreal Cognitive Assessment (MoCA), Fugl-Meyer Assessment of Upper Extremities (FMA-UE), Rivermead Behavioural Memory Test (RBMI), and Wolf Motor performance Test (WMFT) are among the outcome measures used to evaluate upper limb and cognitive performance. A handhelf dynamometer was used to assess muscle strength.	Mid intervention assessment Post intervention assessment 1-month follow up assessment	Results are pending completion of the trial. The study aims to evaluate: 1. Effects of tVNS vs sham stimulation 2. Effects of tSCS vs sham stimulation 3. Effects of tVNS vs tSCS

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3.	Meng-Huan Wang et al4 2024	N=40 VNS group=20 Sham group=20	taVNS combined with task oriented training auricular vagus nerve stimulator	500 µs square pulses at 25 Hz for 30 s, with a duty cycle of 1:1, five days a week for four weeks. The intensity of the current was tailored to each patient's tolerated level, making sure it didn't go over 10 mA.	The Action and the Fugl-Meyer Assessment-Upper Extremity (FMA-UE) The hemiplegic upper extremity function was assessed using the Research Arm Test (ARAT) and the modified Barthel Index (MBI).	Before and After the treatment session	And in the study taVNS improved upper limb function, neurophysiology, cortical activation, and autonomic balance vs sham.
4.	Long Chen al9 2023 et	N=38	Invasive VNS (iVNS), transcutaneous auricular VNS(taVNS). these stimulation were combined with upper limb rehabilitation exercises such as task - specific training, repetitive functional movements. iVNS used as an implanted device connected to cervical vagus nerve, while taVNS used surface electrode placed on left ear. taVNS therapy using low frequency pulse elecrtostimulator	The intervention sessions lasted between 45 mins to 2 hrs, with total duration ranging from 6 to 18 weeks. Studies showedtreatment 3 times/ week for 6 weeks. Total of 18 sessions, while some studies used daily session for 15 days up to 18 weeks. Stimulation has been given according to the tolerated level (0.38mA). studies shown 0.8 mA at 30 Hz. 30 min per taVNS session.	Fugl-Meyer Assessment-Upper Extremity (FMA-UE). Wolf Motor Function Test (WMFT) - functional performance. Grip and pinch strength. Box and Block Test. Functional Independence Measure (FIM). Sensory recovery: Light touch, proprioception from UFM	Baseline: Before intervention, after consent - Midintervention: After 9 sessions in some protocols - Postintervention: Day 1, day 7, day 30, day 90 after 6-week clinical treatment - Longterm followup: 8 months	VNS paired with rehab increased motor cortex plasticity and forelimb strength, reduced infarct volume and boosted angiogenesis. Clinical trials showed both invasive VNS and non-invasive taVNS are safe and effective across acute, subacute and chronic stroke.
5.	Liki Wang et al7202 3	N=27 taVNS left hemiplegia= 15 taVNS right hemiplegia= 12	Functional near infrared spectroscopy data recorded using	Single session only. Pre-fNIRS → taVNS → PostfNIRS. 25 Hz, 300 µs, biphasic sinusoidal.	Fugl-Meyer Assessment Upper Extremity (FMA-UE) Simplified upper limb function test	Baseline and post treatment	Across both groups, taVNS significantly enhanced right and left motor cortical network activation. The

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			34multichannel fNIRS instrument device	Current increased to pain threshold,	(STEF)		Laterality Index remained stable, indicating balanced gains in both hemispheres
6.	Dandong Wu et al1 2020	N=44 N=21 taVNS group=10 Sham taVNS group=11	The BHD-1A transcutaneous electrical stimulation therapy device was used to administer taVNS. Sham group The modified dot-like electrodes attached to the cymba conchae stimulated the left auricular branch.	30 minutes every day for fifteen days in a row taVNS group 600 pulses, each lasting 30 seconds and stimulating once every five minutes, with an intratrain pulse frequency of 20 Hz and a length of 0.3 ms. Conventional rehabilitation was used in the sham TaVNS group based on the patients' abilities.	Upper limb Fugl-Meyer assessment (FMA-U), Wolf motor function test (WMFT), Functional independence measure (FIM)upper limb burnnstorm stage	Baseline, end of intervention	At baseline, the two groups' FMA-U, WMFT, FIM, and Brunnstrom scores did not differ significantly. At follow-up, there were notable improvements in both groups' FMA-U scores...
7.	Redgrave et al5 2018	N=13	Cerbomed taVNS stimulator,	6 weeks total 3 times per week Pulse width 0.1 ms, frequency 25 Hz. Current intensity: Increased by 0.1 mA increments to participant's maximum tolerable level; that level used for rest of session	Action Recovery Arm Test (ARAT), Upper Limb Fugl-Meyer (UFM) 14, Barthel Index, Stroke Impact Scale (SIS), Generalized Anxiety Disorder 7 (GAD7) 22, and the Fatigue Assessment Scale 23. The top Scales for limb assessment Framework for the International Classification of Functioning (impairment, function, and participation)	After treatment	Thirteen individuals with chronic stroke finished the intervention, according to the results. ARAT, MAL, and SIS scores showed less significant gains. There was little to no change in other outcome metrics.

N: Sample Size; taVNS : Transcutaneous Auricular Vagus Nerve Stimulation ; UFM : Upper Limb Fugl-Meyer, SIS : Stroke Impact

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III. DISCUSSION

Ischemia stroke is characterized by morbidity, high mortality, and severe disability. It is described as localized ischemia necrosis brought on by a blood circulation abnormality in the brain. The most prevalent impairment after an ischemic stroke is limb motor dysfunction. Gross motor lower limb function in patients with cerebral infraction in a clinical environment. While upper limb motions are mainly made up of flexible and coordinated skills, hemiplegia heals more quickly. The motions are challenging and slow. The goal of the current review was to assess how well transcutaneous auricular vagus nerve stimulation improves upper limb motor function in stroke patients.

This review included seven papers in all, including three randomized pilot studies, one prospective research, and two randomized controlled trials. According to the included studies, stroke patients' upper limb motor recovery, functional independence, cortical activation, and neuroplasticity all improved when taVNS was combined with conventional therapy or task-oriented training. The Fugl-Meyer Assessment-Upper Extremity (FMA-UE), Wolf Motor Function Test (WMFT), Action Research Arm Test (ARAT), Functional Independence Measure (FIM), and Modified Barthel Index (MBI) all showed notable improvements in most of the reviewed studies. These findings suggest that taVNS may be a useful adjunctive approach in stroke recovery.

The results of this assessment are in line with past studies that support the use of vagus nerve stimulation in stroke recovery.According to Xue et al. (2025), taVNS outperformed rehabilitation alone in improving motor evoked potentials, FMA-UE, ARAT, and MBI scores. These results imply that taVNS may enhance daily activities and neurophysiological performance in addition to improving motor recovery. In a similar vein, Wang et al. (2024) discovered that, in comparison to sham stimulation, taVNS in conjunction with task-oriented training greatly enhanced upper extremity function and brain activation.

Several research included in this review found improvements in neuroplasticity-related outcomes. Wang et al. (2023) employed functional near-infrared spectroscopy (fNIRS) to detect increased bilateral motor cortex activation after taVNS. Long Chen et al. (2023) found that vagus nerve stimulation increased angiogenesis, decreased infarct volume, and improved motor cortical plasticity. These findings lend support to the idea that taVNS may help with recovery by reorganising the central nervous system.

Redgrave et al. (2018) conducted a pilot study that looked into transcutaneous auricular vagus nerve stimulation paired with repetitive upper limb task practice in chronic stroke patients. The study found that participants handled the intervention well and experienced improvements in upper limb motor outcomes after therapy.

Although the majority of research yielded excellent results, some limitations were noted. Some research used small sample sizes, which may limit the generalisability of the findings. Several studies were pilot trials or study procedures that yielded inconclusive data. In addition, methodological quality varied amongst research, with PEDro values ranging from moderate to high. The heterogeneity of participant characteristics, stroke chronicity, intervention duration, and outcome measures made cross-study comparisons difficult. Furthermore, longterm follow-up data were inadequate, making it impossible to establish the long-term effectiveness of treatment.

Despite these limitations, this analysis provides data to support the efficacy of taVNS as an additional therapy for upper limb rehabilitation following stroke. The continuous gains in motor function, functional independence, and brain activity suggest that taVNS may aid recovery when combined with traditional physiotherapy and task-oriented rehabilitation. Future research should focus on bigger randomised controlled studies with standardised stimulation protocols, longer follow-up periods, and evaluation of optimal stimulation parameters to create stronger clinical guidelines for using taVNS in stroke rehabilitation.

V. CONCLUSION

Transcutaneous auricular vagus nerve stimulation (taVNS) has been shown to improve upper limb motor function in stroke patients. TaVNS, especially when combined with traditional, task-oriented, or high-repetition upper limb rehabilitation, consistently produced better motor recovery outcomes than sham stimulation or rehabilitation alone across studies with different sample sizes, stroke chronicity, stimulation protocols, and rehabilitation approaches. Widely recognized clinical outcome measures, including the FuglMeyer Assessment–Upper Extremity (FMA-UE), Wolf Motor Function Test (WMFT), Action Research Arm Test (ARAT), Functional Independence Measure (FIM), and Modified Barthel Index (MBI), were used to measure improvements. These measures showed significant improvements in motor impairment, functional performance, and activities of daily living. To sum up, the information that is currently available indicates that transcutaneous auricular vagus nerve stimulation is a potential and successful supplementaryg. In conclusion, the available evidence suggests that transcutaneous auricular vagus nerve stimulation is an effective and promising adjunctive therpy for enhancing upper limb motor recovery after stroke. While heterogeneity exists in stimulation parameters, treatment duration, and outcome measures, the overall consistency of positive findings underscores the therapeutic potential of taVNS.

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