ISSN 2055-0286
Advances in Social Sciences Research Journal; Vol. 13 No. 04 (2026) (271-280)
https://doi.org/10.14738/assrj.1304.20215

Transcranial Magnetic Stimulation: A Scoping Review

Gian Di Feo[1], Fahdlullahi Adeniran, Kobe Gannon-Day, Anthony Zanetti, Micheal Emond, and Kassra Ghassemkhani

1. Laurentian University

Abstract: Background: Transcranial magnetic stimulation (TMS) has gained increasing recognition as a non-invasive neuromodulatory technique with potential therapeutic applications in dementia and related neurocognitive disorders. This scoping review examined the literature from 1985 through 2023 to evaluate how TMS has been applied across dementia subtypes, which forms of stimulation and neuroimaging techniques have been most frequently used, and what cognitive outcomes have been observed. Method: A systematic search of PubMed, PsycArticles, and PsycInfo yielded 184 articles, of which a subset met inclusion criteria requiring the application of TMS alongside neuropsychological testing. Results: The results demonstrated a striking predominance of Alzheimer's disease, which accounted for nearly three-quarters of included studies, while vascular dementia, frontotemporal dementia, and Lewy body dementia were rarely addressed. Neuroimaging integration was limited, with the majority of studies not incorporating it; when applied, EEG, MRI, and fMRI were most frequently paired with TMS. Cognitive outcomes were overwhelmingly positive, with 52.9% of studies reporting strong improvements and 44.1% reporting very strong improvements in standardized neuropsychological measures. Notably, no study reported null or adverse effects. Repetitive TMS emerged as the most widely used modality, followed by high-frequency rTMS, whereas deep TMS, low-frequency rTMS, intermittent theta burst stimulation, and bifocal TMS were applied only sporadically. Chi-square analyses revealed no significant associations between dementia type and TMS form or between dementia type and cognitive outcomes, suggesting that observed benefits may generalize across diagnostic subgroups. Discussion: The findings indicate that TMS may enhance cognitive function in dementia regardless of subtype or stimulation protocol, though methodological inconsistencies and limited neuroimaging integration restrict interpretability. Conclusion: TMS appears to be a robust and reproducible intervention for enhancing cognition in dementia, but standardized protocols and larger

Keywords: Transcranial Magnetic Stimulation, Dementia, Alzheimer's Disease, Neurocognitive Disorders, Cognitive Rehabilitation, Neuroimaging, Scoping Review, Neuromodulation

INTRODUCTION

In this study, the researchers examined transcranial magnetic stimulation (TMS) alongside its impacts on the performance of neuropsychological testing and disease. In 1985, Dr. Barker and his colleagues proved that it was possible to stimulate the brain through transcranial magnetic stimulation [1]. TMS is a technique for non-invasive stimulation of the human brain. Stimulation is produced by generating a brief, high-intensity magnetic field by passing a transient electric current through a magnetic coil [2], [3]. This is administered by placing an electromagnetic coil against the patient's head and activating it repeatedly to produce stimulation [4], [5].

Transcranial magnetic stimulation is a safe and non-invasive treatment technique used to address psychiatric and neurological diseases. It involves stimulating subcortical brain regions through the production of high- and low-intensity magnetic fields, which modulate cortical excitability [4]. TMS can be used to map brain function and explore the excitability of different regions. Since it can influence brain function, it has also been used for various therapeutic purposes.

TMS has provided information about cortical function across neurodegenerative disorders, including Alzheimer’s disease, frontotemporal dementia, and related extrapyramidal disorders [6]. It has been used to help alleviate symptoms of both neurological and psychiatric disease [7]. For example, repetitive TMS has been applied to post-traumatic stress disorder, Tourette’s syndrome, bipolar disorder, and Parkinson's disease [4]. The application of TMS in neurodegenerative diseases has provided important pathological insights, leading to the development of pathogenic and diagnostic biomarkers that could be used in clinical settings [8].

When TMS is applied over the motor cortex, it can measure overall excitability of the corticospinal system, somatotopic representation of muscles, and neuroplasticity changes after traumatic brain injury [9], [10]. Applied over the primary motor cortex, it can probe functions of cortical excitability and plasticity [11]. Short-latency afferent inhibition is a TMS-induced neurophysiological measure capable of probing cholinergic receptors in the central nervous system [12]. Artifact reduction can be achieved using a large single-channel radiofrequency coil with an axial imaging orientation and a 100 ms safety interval between TMS pulses and imaging acquisition [13].

Dementia and TMS

Dementia refers to a syndrome characterized by the progressive deterioration of cognitive functions. Patients diagnosed with dementia typically pass away seven to ten years after symptom onset [14]. TMS is a non-invasive brain stimulation technique used to treat neurocognitive disorders, including dementia and mild cognitive impairment.

The four main forms of progressive dementia include Alzheimer’s disease, frontotemporal dementia, vascular dementia, and Lewy body dementia. Since the 1970s, Alzheimer’s disease has been recognized as the most common form, characterized by progressive memory impairment and a decline in cognitive domains [15], [16]. It is marked by microscopic foci of degenerating neurites and amyloid plaque depositions [15]. Aging is directly related to the development of Alzheimer’s disease, and incidence rates increase exponentially with age. Dementia incidence doubles approximately every five years from age 65 to 90 [17], [18]. Global dementia rates have increased significantly since the twentieth century and continue to rise exponentially [19]. Cognitive symptoms include memory loss, disorientation, language difficulties, apraxia, and visuospatial problems, while non-cognitive symptoms include mood swings, delusions, and hallucinations.

Frontotemporal dementia results from damage to neurons in the frontal and temporal lobes [20]. It is the third most common form and is particularly frequent in patients under 65 years old [21]. Parkinson’s disease is a common secondary condition to frontotemporal dementia [21]. Frontotemporal lobar degeneration is characterized by neuronal loss, gliosis, and microvacuolar changes of the frontal and anterior temporal lobes, as well as the insular cortex [21]. Symptoms include apathy, impulsivity, and socially inappropriate behaviors [20].

Vascular dementia is the second most common form of dementia after Alzheimer's disease [22]. In vascular dementia, memory impairment is mild, but disturbances in executive functioning are common [22]. There are currently no approved pharmacological treatments for vascular dementia [23]. However, medications are prescribed to manage its symptoms. White matter changes are associated with an increased risk of post-stroke dementia [24], and cerebral microbleeds have been linked to cognitive impairment in stroke survivors [25].

Forms of TMS include single-pulse TMS, paired-pulse TMS, repetitive TMS, and theta burst stimulation. TMS is also commonly combined with electroencephalography. Single-pulse TMS delivers a brief magnetic pulse to a specific brain region. Paired-pulse TMS (ppTMS) delivers a low-intensity pulse followed by a higher-intensity one, modifying inhibitory neuron activation in the motor cortex and reducing the motor evoked potential amplitude. Repetitive TMS (rTMS) applies magnetic stimulation at a repetitive frequency over time. Theta burst stimulation (TBS) was first introduced in 2005, derived from paradigms used to induce long-term potentiation in animals [26], [27]. It involves administering three TMS pulses at 50 Hz every 200 milliseconds.

In patients with dementia, TMS is useful for identifying specific abnormalities within the cerebral cortex [28]. Brain stimulation techniques such as TMS may help identify therapeutic targets and monitor pharmacological treatments [7]. For example, changes in motor areas may be secondary to structural alterations caused by neurodegenerative diseases [29]. TMS has shown strong potential in revealing motor system impairments [30].

TMS is a powerful tool to probe in vivo brain circuits, allowing assessment of cortical excitability, plasticity, and connectivity [31]. It has been applied to patients with dementia to identify markers of pathophysiology and predictors of cognitive decline [31]. Studies have shown improvements in Alzheimer's disease and mild cognitive impairment symptoms following TMS [31]. However, its use in dementia with Lewy bodies remains limited [31]. TMS measures reveal dysfunction in intracortical inhibitory and excitatory circuits and cortical plasticity associated with frontotemporal dementia [31]. It has also shown positive effects in vascular dementia [31].

Hypotheses

In this study there were four hypotheses. For the first hypothesis, the researchers predicted that Alzheimer's disease would be the most explored form of dementia regarding the use of transcranial magnetic stimulation. This was hypothesized as Alzheimer's disease is the most researched form of dementia within scientific literature across high-, middle-, and low-income countries [32]. Additionally, the researchers chose to examine Alzheimer's disease as diagnosis rates have increased significantly since the development of its criteria and are estimated to continue increasing exponentially by the year 2050 [33]. It was also hypothesized that vascular dementia would be the least explored type of dementia within the literature, as vascular dementia has the quickest mortality rate from the onset of symptoms among all forms of progressive dementia [34]. A meta-analysis also found that vascular dementia is the least common form of progressive dementia studied in the twenty-first century [32].

For the second hypothesis, it was hypothesized that the electroencephalogram (EEG), magnetic resonance imaging (MRI), and functional magnetic resonance imaging (fMRI) would be the most prevalent neuroimaging techniques used simultaneously with transcranial magnetic stimulation. These methodologies are commonly used in medical practice alongside TMS [35]. For example, when transcranial magnetic stimulation is paired with positron emission tomography (PET), there are positive correlations between cerebral blood flow in the frontal eye field and the visual cortex of the superior parietal and medial parieto-occipital regions, and the number of TMS pulses [36]. Additionally, the use of single-photon emission computed tomography (SPECT) and PET alongside TMS pulses has been shown to reduce symptoms of depression within the left orbitofrontal cortex [36], [37]. Through the combination of transcranial magnetic stimulation and fMRI, it is possible to examine how TMS influences neural activity [38], [39].

For the third hypothesis, the researchers predicted that transcranial magnetic stimulation would have a positive impact on cognitive functions examined through neuropsychological testing. This was hypothesized as rTMS has been shown to improve working memory in patients diagnosed with mild cognitive impairment [40]. Furthermore, repetitive transcranial magnetic stimulation has shown improvements in motor function and the synaptic structure in the hippocampus of rats [41]. Additionally, the researchers examined comorbidities of dementia among participants alongside the critical sections of neuropsychological tests impacted by transcranial magnetic stimulation within the articles.

For the fourth hypothesis, the researchers predicted that repetitive transcranial magnetic stimulation would be the most applied form of this technique. It was also hypothesized that theta burst transcranial magnetic stimulation, prolonged iTBS, accelerated rTMS, deep dTMS, priming TMS, synchronized TMS, and magnetic seizure therapy would be the least applied forms of this technique and would be least effective on cognitive functions. These forms of TMS have all been developed in the twenty-first century and are applied infrequently [42]. Part of this hypothesis is that transcranial magnetic stimulation would show the greatest improvements on neuropsychological testing among patients diagnosed with any form of dementia. This was hypothesized as repetitive TMS has shown significant development among patients diagnosed with mild cognitive impairments [42].

MATERIALS AND METHODS

This review was conducted in accordance with the PRISMA guidelines [43]. Articles were included if they discussed dementia, applied neuropsychological testing alongside neuroimaging, and were published between January 1, 1985, and December 31, 2023. Articles prior to 1985 were excluded because transcranial magnetic stimulation (TMS) was first introduced in 1985 by Barker et al. [1].

A systematic search was conducted using PubMed, PsycArticles, and PsycInfo. The search terms were “neuropsychological testing,” “dementia,” and “transcranial magnetic stimulation.” The search initially yielded 274 records, of which 41 were duplicates, leaving 184 unique articles for screening. After title and abstract review, 110 articles were excluded for not meeting inclusion criteria. The full texts of the remaining 74 articles were then assessed for eligibility, resulting in the exclusion of 38 that lacked neuropsychological testing, neuroimaging, or sufficient methodological detail. Ultimately, 36 studies met all inclusion criteria and were included in the final qualitative synthesis.

For each included article, the researchers assessed the form of TMS applied (e.g., single-pulse, paired-pulse, repetitive, or theta burst stimulation). Additionally, demographic information of participants was extracted, including age, gender, and use of medications. The income level of the country from which each source article originated was also recorded.

These data allowed for examination of the prevalence of each TMS modality, participant characteristics, and trends related to country-level economic classification. No ethical approval was required for this review, as all data were obtained from previously published studies. A summary of the article selection process is presented in Figure 1 (PRISMA 2020 flow diagram).

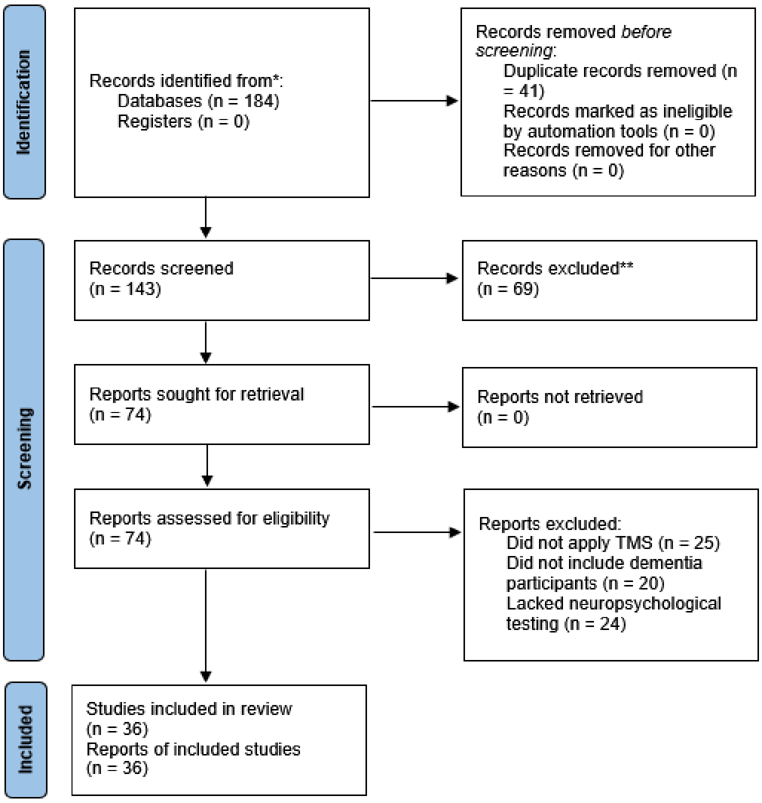

Fig. (1): Figure 1. PRISMA 2020 flow diagram illustrating the study selection process for the systematic review on transcranial magnetic stimulation in dementia. Numbers indicate records identified, screened, excluded, and included at each stage of the review.

RESULTS

rTMS (n = 17) was the most applied TMS form. Other forms included high-frequency rTMS (HFrTMS; n = 11), dTMS (n = 1), low-frequency rTMS (LFrTMS; n = 1), intermittent TBS (iTBS; n = 1), and bifocal TMS (n = 1). AD was the most studied dementia type (n = 25; 73.5%), followed by FTD (n = 4; 11.8%), VaD (n = 1; 2.9%), and LBD (n = 1; 2.9%).

Regarding neuroimaging, 76.5% of studies did not use any imaging. PET was used in five studies (14.7%), while EEG, MRI, and fMRI appeared in single studies.

TMS was consistently associated with cognitive improvements measured by neuropsychological testing: 52.9% of studies (n = 18) reported strong improvements, 44.1% (n = 15) reported very strong improvements, and one study (2.9%) reported mild improvement. No study reported null or negative effects.

Chi-square tests indicated no significant association between dementia type and TMS form (x^2 = 40.41, df = 35, p = .24) or between dementia type and cognitive outcome (x^2 = 6.49, df = 10, p = .77). Similarly, TMS modality × neuroimaging technique was not significant (x^2 = 14.63, df = 28, p = .98), suggesting imaging choice was not systematically linked to TMS form.

These results show the dominance of rTMS and HFrTMS, robust cognitive gains, and no evidence of differential pairing of TMS form by dementia type or neuroimaging modality.

DISCUSSION

This scoping review examined the application of TMS in dementia, focusing on stimulation forms, concurrent neuroimaging, cognitive outcomes, and dementia subtypes. Findings supported the hypotheses while highlighting gaps and nuances. AD emerged as the most studied subtype, consistent with research trends. VaD, FTD, and LBD were underrepresented, indicating a research gap.

EEG, MRI, and fMRI were the most commonly used imaging modalities, though many studies used none. Limited imaging restricts mechanistic insights into cortical excitability, functional connectivity, and network-level plasticity. Chi-square analyses indicated no association between TMS form and imaging technique, suggesting choice of imaging reflects resources and study design rather than stimulation parameters. Future studies should use multimodal protocols to clarify neural mechanisms underlying cognitive improvements.

TMS was consistently associated with positive cognitive outcomes: over 97% of studies reported strong or very strong improvements, with one study showing mild improvement and none showing null or negative effects. Cognitive gains did not differ significantly across dementia subtypes, although limited representation of non-AD dementias warrants caution.

rTMS was the most frequently applied modality, followed by HFrTMS. dTMS, LFrTMS, iTBS, and bifocal TMS were applied sporadically, reflecting historical precedence and the recent development of newer modalities. Chi-square analyses showed no association between dementia subtype and TMS modality, indicating research priorities rather than disorder-specific rationale drive protocol choice.

Overall, the findings highlight the promise and limitations of TMS research in dementia. Consistency of cognitive gains and dominance of rTMS suggest it is a reliable intervention. Lack of systematic associations between TMS form, dementia subtype, and imaging usage underscores the need for comparative, mechanistically informed studies. Expanding dementia subtype diversity, integrating multimodal imaging, and comparing stimulation modalities will optimize TMS application and advance clinical utility.

CONCLUSION

This review provides strong evidence that TMS, particularly rTMS and HFrTMS, can improve cognitive function in dementia. While AD remains the primary focus, there is a clear need for research on underrepresented dementias, including VaD, FTD, and LBD. Future studies should integrate multimodal neuroimaging and directly compare stimulation protocols to elucidate mechanisms and optimize therapeutic outcomes. These steps will be essential in translating TMS from a promising research tool into a standardized component of dementia care.

Availability of Data and Materials

The source of data and materials should be mentioned in the manuscript, in support of the findings. If the data source is not revealed, the authors need to clearly state the reasons. Authors who do not wish to share their data should clearly state that the data will not be shared, and give the reasons.

The statement relating to the data should be presented in the following format under a separate ‘Availability of Data and Materials’ section in the manuscript:

"The data supporting the findings of the article is available in the [repository name] at [URL], reference number [reference number]”.

Funding: None

Conflict of Interest: The authors declare no conflict of interest, financial or otherwise.

Acknowledgements: Declared none.

REFERENCES

[1] A. T. Barker, R. Jalinous, and I. L. Freeston, “Non-invasive magnetic stimulation of human motor cortex,” *Lancet Lond. Engl.*, vol. 1, no. 8437, pp. 1106–1107, May 1985, doi: 10.1016/s0140-6736(85)92413-4.

[2] M. Hallett, “Transcranial magnetic stimulation: a primer,” *Neuron*, vol. 55, no. 2, pp. 187–199, July 2007, doi: 10.1016/j.neuron.2007.06.026.

[3] S. Rossi *et al.*, “Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines,” *Clin. Neurophysiol. Off. J. Int. Fed. Clin. Neurophysiol.*, vol. 132, no. 1, pp. 269–306, Jan. 2021, doi: 10.1016/j.clinph.2020.10.003.

[4] S. K. Mann and N. K. Malhi, “Repetitive Transcranial Magnetic Stimulation,” in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2025. Accessed: Oct. 31, 2025. [Online]. Available: http://www.ncbi.nlm.nih.gov/books/NBK568715/

[5] J.-P. Lefaucheur *et al.*, “Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): An update (2014-2018),” *Clin. Neurophysiol. Off. J. Int. Fed. Clin. Neurophysiol.*, vol. 131, no. 2, pp. 474–528, Feb. 2020, doi: 10.1016/j.clinph.2019.11.002.

[6] S. Vucic and M. C. Kiernan, “Transcranial Magnetic Stimulation for the Assessment of Neurodegenerative Disease,” *Neurother. J. Am. Soc. Exp. Neurother.*, vol. 14, no. 1, pp. 91–106, Jan. 2017, doi: 10.1007/s13311-016-0487-6.

[7] J. Antczak, G. Rusin, and A. Słowik, “Transcranial Magnetic Stimulation as a Diagnostic and Therapeutic Tool in Various Types of Dementia,” *J. Clin. Med.*, vol. 10, no. 13, p. 2875, June 2021, doi: 10.3390/jcm10132875.

[8] G. Koch, A. Martorana, and C. Caltagirone, “Transcranial magnetic stimulation: Emerging biomarkers and novel therapeutics in Alzheimer’s disease,” *Neurosci. Lett.*, vol. 719, p. 134355, Feb. 2020, doi: 10.1016/j.neulet.2019.134355.

[9] N. Lapitskaya, M. R. Coleman, J. F. Nielsen, O. Gosseries, and A. M. de Noordhout, “Disorders of consciousness: further pathophysiological insights using motor cortex transcranial magnetic stimulation,” *Prog. Brain Res.*, vol. 177, pp. 191–200, 2009, doi: 10.1016/S0079-6123(09)17713-0.

[10] A. Jannati, L. M. Oberman, A. Rotenberg, and A. Pascual-Leone, “Assessing the mechanisms of brain plasticity by transcranial magnetic stimulation,” *Neuropsychopharmacology*, vol. 48, no. 1, pp. 191–208, Jan. 2023, doi: 10.1038/s41386-022-01453-8.

[11] Y.-H. Chou, M. Sundman, V. Ton That, J. Green, and C. Trapani, “Cortical excitability and plasticity in Alzheimer’s disease and mild cognitive impairment: A systematic review and meta-analysis of transcranial magnetic stimulation studies,” *Ageing Res. Rev.*, vol. 79, p. 101660, Aug. 2022, doi: 10.1016/j.arr.2022.101660.

[12] C. V. Turco, J. El-Sayes, M. J. Savoie, H. J. Fassett, M. B. Locke, and A. J. Nelson, “Short- and long-latency afferent inhibition; uses, mechanisms and influencing factors,” *Brain Stimulat.*, vol. 11, no. 1, pp. 59–74, 2018, doi: 10.1016/j.brs.2017.09.009.

[13] B. Zhang, X. Luo, Y. Ning, J. Wang, and Y.-F. Zang, “Editorial: Investigating the Mechanism of TMS Using Brain Imaging Methods,” *Front. Neurosci.*, vol. 16, p. 936219, 2022, doi: 10.3389/fnins.2022.936219.

[14] W. M. van der Flier and P. Scheltens, “Epidemiology and risk factors of dementia,” *J. Neurol. Neurosurg. Psychiatry*, vol. 76 Suppl 5, no. Suppl 5, pp. v2-7, Dec. 2005, doi: 10.1136/jnnp.2005.082867.

[15] M. Weiler, K. C. Stieger, J. M. Long, and P. R. Rapp, “Transcranial Magnetic Stimulation in Alzheimer’s Disease: Are We Ready?,” *eNeuro*, vol. 7, no. 1, p. ENEURO.0235-19.2019, 2020, doi: 10.1523/ENEURO.0235-19.2019.

[16] G. C. Román, “Stroke, Cognitive Decline and Vascular Dementia: The Silent Epidemic of the 21st Century,” *Neuroepidemiology*, vol. 22, no. 3, pp. 161–164, Apr. 2003, doi: 10.1159/000069885.

[17] M. M. Corrada, R. Brookmeyer, A. Paganini-Hill, D. Berlau, and C. H. Kawas, “Dementia incidence continues to increase with age in the oldest old: the 90+ study,” *Ann. Neurol.*, vol. 67, no. 1, pp. 114–121, Jan. 2010, doi: 10.1002/ana.21915.

[18] E. Nichols *et al.*, “Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019,” *Lancet Public Health*, vol. 7, no. 2, pp. e105–e125, Feb. 2022, doi: 10.1016/S2468-2667(21)00249-8.

[19] C. A. Derby, “Trends in the public health significance, definitions of disease, and implications for prevention of Alzheimer’s disease,” *Curr. Epidemiol. Rep.*, vol. 7, no. 2, pp. 68–76, June 2020, doi: 10.1007/s40471-020-00231-8.

[20] M. A. Rouse, R. J. Binney, K. Patterson, J. B. Rowe, and M. A. Lambon Ralph, “A neuroanatomical and cognitive model of impaired social behaviour in frontotemporal dementia,” *Brain*, vol. 147, no. 6, pp. 1953–1966, June 2024, doi: 10.1093/brain/awae040.

[21] I. Khan and O. De Jesus, “Frontotemporal Lobe Dementia,” in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2025. Accessed: Nov. 02, 2025. [Online]. Available: http://www.ncbi.nlm.nih.gov/books/NBK559286/

[22] Kai Sin Chin, “Pathophysiology of dementia,” *Aust. J. Gen. Pract.*, vol. 52, no. 8, Aug. 2023, doi: 10.31128/AJGP-02-23-6736.

[23] C. Dang *et al.*, “Pharmacological treatments for vascular dementia: a systematic review and Bayesian network meta-analysis,” *Front. Pharmacol.*, vol. 15, Aug. 2024, doi: 10.3389/fphar.2024.1451032.

[24] N. S. Rost *et al.*, “Post-Stroke Cognitive Impairment and Dementia,” *Circ. Res.*, vol. 130, no. 8, pp. 1252–1271, Apr. 2022, doi: 10.1161/CIRCRESAHA.122.319951.

[25] M. M. F. Poels *et al.*, “Cerebral microbleeds are associated with worse cognitive function,” *Neurology*, vol. 78, no. 5, pp. 326–333, Jan. 2012, doi: 10.1212/WNL.0b013e3182452928.

[26] E. Demeter, J. L. Mirdamadi, S. K. Meehan, and S. F. Taylor, “Short theta burst stimulation to left frontal cortex prior to encoding enhances subsequent recognition memory,” *Cogn. Affect. Behav. Neurosci.*, vol. 16, no. 4, pp. 724–735, Aug. 2016, doi: 10.3758/s13415-016-0426-3.

[27] Y. Huang *et al.*, “Theta-burst direct electrical stimulation remodels human brain networks,” *Nat. Commun.*, vol. 15, no. 1, p. 6982, Aug. 2024, doi: 10.1038/s41467-024-51443-1.

[28] M. Cantone *et al.*, “The contribution of transcranial magnetic stimulation in the diagnosis and in the management of dementia,” *Clin. Neurophysiol. Off. J. Int. Fed. Clin. Neurophysiol.*, vol. 125, no. 8, pp. 1509–1532, Aug. 2014, doi: 10.1016/j.clinph.2014.04.010.

[29] G. Tesco and S. Lomoio, “Pathophysiology of neurodegenerative diseases: an interplay among axonal transport failure, oxidative stress, and inflammation?,” *Semin. Immunol.*, vol. 59, p. 101628, Jan. 2022, doi: 10.1016/j.smim.2022.101628.

[30] D. A. Spampinato, J. Ibanez, L. Rocchi, and J. Rothwell, “Motor potentials evoked by transcranial magnetic stimulation: interpreting a simple measure of a complex system,” *J. Physiol.*, vol. 601, no. 14, pp. 2827–2851, 2023, doi: 10.1113/JP281885.

[31] V. Di Lazzaro *et al.*, “Diagnostic contribution and therapeutic perspectives of transcranial magnetic stimulation in dementia,” *Clin. Neurophysiol. Off. J. Int. Fed. Clin. Neurophysiol.*, vol. 132, no. 10, pp. 2568–2607, Oct. 2021, doi: 10.1016/j.clinph.2021.05.035.

[32] G. M. D. Feo, M. Emond, and K. Ghassemkhani, “Dementia and its Relations Between the Late 20th and 21st Century,” *Adv. Soc. Sci. Res. J.*, vol. 10, no. 7, pp. 129–141, July 2023, doi: 10.14738/assrj.107.15071.

[33] P. D. Sloane *et al.*, “The public health impact of Alzheimer’s disease, 2000-2050: potential implication of treatment advances,” *Annu. Rev. Public Health*, vol. 23, pp. 213–231, 2002, doi: 10.1146/annurev.publhealth.23.100901.140525.

[34] J. Keene, T. Hope, C. G. Fairburn, and R. Jacoby, “Death and dementia,” *Int. J. Geriatr. Psychiatry*, vol. 16, no. 10, pp. 969–974, 2001, doi: 10.1002/gps.474.

[35] E. C. Caparelli, T. Zhai, and Y. Yang, “Simultaneous Transcranial Magnetic Stimulation and Functional Magnetic Resonance Imaging: Aspects of Technical Implementation,” *Front. Neurosci.*, vol. 14, Sept. 2020, doi: 10.3389/fnins.2020.554714.

[36] K. P. Ebmeier, “Transcranial magnetic stimulation and neuroimaging,” *Bipolar Disord.*, vol. 4 Suppl 1, pp. 96–97, 2002, doi: 10.1034/j.1399-5618.4.s1.42.x.

[37] L. Aceves-Serrano, J. L. Neva, and D. J. Doudet, “Insight Into the Effects of Clinical Repetitive Transcranial Magnetic Stimulation on the Brain From Positron Emission Tomography and Magnetic Resonance Imaging Studies: A Narrative Review,” *Front. Neurosci.*, vol. 16, Feb. 2022, doi: 10.3389/fnins.2022.787403.

[38] D. J. Oathes *et al.*, “Combining transcranial magnetic stimulation with functional magnetic resonance imaging for probing and modulating neural circuits relevant to affective

disorders," *Wiley Interdiscip. Rev. Cogn. Sci.*, vol. 12, no. 4, p. e1553, July 2021, doi: 10.1002/wcs.1553.

[39] J. Jung, A. Bungert, R. Bowtell, and S. R. Jackson, "Vertex Stimulation as a Control Site for Transcranial Magnetic Stimulation: A Concurrent TMS/fMRI Study," *Brain Stimulat.*, vol. 9, no. 1, pp. 58–64, Jan. 2016, doi: 10.1016/j.brs.2015.09.008.

[40] A. Senczyszyn *et al.*, "Improvement of working memory in older adults with mild cognitive impairment after repetitive transcranial magnetic stimulation – a randomized controlled pilot study," *Front. Psychiatry*, vol. 14, Nov. 2023, doi: 10.3389/fpsyt.2023.1196478.

[41] J. Yang, R. Liang, L. Wang, C. Zheng, X. Xiao, and D. Ming, "Repetitive Transcranial Magnetic Stimulation (rTMS) Improves the Gait Disorders of Rats Under Simulated Microgravity Conditions Associated With the Regulation of Motor Cortex," *Front. Physiol.*, vol. 12, p. 587515, 2021, doi: 10.3389/fphys.2021.587515.

[42] C.-M. Cheng, C.-T. Li, and S.-J. Tsai, "Current Updates on Newer Forms of Transcranial Magnetic Stimulation in Major Depression," *Adv. Exp. Med. Biol.*, vol. 1305, pp. 333–349, 2021, doi: 10.1007/978-981-33-6044-0_18.

[43] M. J. Page *et al.*, "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews," *Syst. Rev.*, vol. 10, no. 1, p. 89, Mar. 2021, doi: 10.1186/s13643-021-01626-4.