Magnetic Resonance-guided Focused Ultrasound (MRgFUS) for Patients with Essential Tremor

A Scandinavian Movement Disorder Society (ScandMODIS) Consensus Document

April 2026

Introduction

- Therapeutic ultrasound treatment has long been explored as a treatment modality in movement disorders [1]. This document oulines the use of Magnetic Resonance-guided Focused Ultrasound (MRgFUS) for treating essential tremor (ET).
- MRgFUS is an incisionless stereotactic neurosurgical procedure that uses ultrasound energy to generate a permanent lesion in specific brain areas.
- Patients with advanced ET should be referred to a Movement Disorder Clinic for comprehensive and unbiased evaluation by neurologists specialized in movement disorders with experience in pharmacological treatment and advanced surgical intervetions, including deep brain stimulation (DBS).

Background

- Essential tremor (ET) is a chronic progressive movement disoders, predominantly affecting the upper extremities and head/neck region, and not attributable to conditions such as Parkinson's disease (PD).
- ET is the most common movement disorder, with incidence rising with age and familial predisposition. The average onset is around 45 years of age [2,3].
- While most patients experience only mild, slowly progressive symptoms, a subset – particularly older individuals- develop disabling tremor that significantly impairs daily activities. Many patients live for a long time with untreated symptoms and only seek medical attention when the symptoms progress to a degree that impairs daily life.
- If pharmacological therapies fail to provide adequate symptom control, DBS is typically the preferred advanced therapy. However, a substantial proportion of patients are either ineligible or decline DBS. Since 2022, MRgFUS has emerged as an approved alternative treatment option in Scandinavia [5,6,7,8,9,10].

Medical treatment

- Medical treatment is the first choice in the treatment of ET. Initially, treatment with beta-blockers (propranolol, metoprolol) can be tried. Alternatively, there is evidence of the effect of primidone (barbiturate). Preparations with less evidence are antiepileptics such as gabapentin and topiramate.

- Treatment with benzodiazepine has been shown to have some effect but carries a risk of addiction. Finally, clozapine treatment or local treatment with botulinum toxin can be considered.
- Most treatments offer modest benefits, and side-effects often limit long-term use [26].
- Country-specific treatment guidelines are available:
    - The Danish Neurological Society has published a guide [19] to medical treatment of tremor: https://neuro.dk/wordpress/nnbv/tremor/ (in Danish)
    - Finnish guides for the treatment of tremor: https://www.duodecim.fi/tuotteet-ja-palvelut/terveysportti/laakarin-tietokannat/ (in Finnish)
    - Swedish guides…
    - Norwegian guides…

Deep brain stimulation (DBS)

- DBS involves implantation of uni – or bilateral electrodes, typically targeting the ventral intermediate nucleus (VIM) of the thalamus [11,12,13].
- Refer to the ScandMODIS consensus document (April 2024) on DBS for technical and procedural details: **Deep Brain Stimulation (DBS) in patients with Parkinson´s disease, A Scandinavian Movement Disorder Society (ScandMODIS) Consensus Document**.

MRgFUS

- MRgFUS delivers incisionless unilateral focal lesions, targeting the thalamic VIM.
- The procedure involves stereotactic controlled local heating using ultrasound energy of the target area, which results in a permanent lesion to the brain tissue.
- The technique requires expertise in stereotactic neurosurgery, neuroanatomy, and complication management, especially considering the irreversible nature of the lesion.
- MRI thermometry is used to monitor tissue temperature and guide treatment. The head is secured in an MRA-compatible helmet with ultrasound transducers.
- Brain tissue temperature is monitored on the MRI scan.
- The procedure is conducted while the patient is awake, allowing real-time evaluation of tremor reduction before final lesioning. [14-22].

Indications for MRgFUS

- MRgFUS may be considered in patients with:
    - Insufficient response or intolerable side effects from pharmacological treatment
    - Contraindication to DBS or patient preference against an implantable device

- While no head-to-head randomized trials have directly compared DBS and MRgFUS, both are effective. DBS remains the more established treatment with tunability and reversibility, whereas MRgFUS offers a less invasive alternative.

Patient Evaluation and Eligibility

- Patient selection for advanced treatments should be based on scientific evidence. However, there are no currently available evidence-based guidelines for the selection of patients with ET for DBS or MRgFUS.
- Assessment of indications and contraindications for DBS and MRgFUS, is therefore currently primarily based on the clinical expertise of the evaluator, and the relevant ET literature in the field. The choice of surgical treatment thus depends on a specific professional assessment and dialogue with the patient.
- DBS can be performed after MRgFUS but not the other way round.
- Patients with previous ischemic changes, severe cognitive defects, and severely affected gait and balance are typically excluded from DBS and require careful evaluation also before an offer is made for MRgFUS. There is increased focus on these conditions during the clinical for assessment of MRgFUS.
- Marked claustrofobia is an exclusion criterium for MRgFUS as the procedure is performed with a MRI scanner and the patient is awake
- A small proportion of patients is excluded due to low skull density ratio (SDR, evaluated by CT scan), which in some patients makes treatment with MRgFUS impossible.
- Patient evaluation guideline will continue to be adjusted on an ongoing basis as evidence for best practices increases.

Indication for neuromodulation for ET (MRgFUS or DBS)

Patients who meet diagnostic criteria for ET according to the MDS consensus definition, assessed by a neurologist with expertise in movement disorders.

- The tremor must be moderate-severe, i.e. upper limb tremor that affects quality of life and activities of daily living to a moderate to severe degree (based on medical history, clinical testing, patient interview of quality of life, and expert neurological assessment).

and

- No response, to drug treatment with propranolol/primidone/gabapentin /topiramate in sufficient doses. Requiring two medications but recommending four if possible.

or

- the above-mentioned drugs are contraindicated, or the treatment causes unacceptable side effects that prevent adequate doses.

Recommendations for the use of MRgFUS

Indication and patient selection:

- MRgFUS should be used as part of an overall strategy for neuromodulation treatment for patients with essential tremor, especially in severe cases where medical treatment is not sufficient.
- Neuromodulation treatment with MRgFUS should be provided in centers with DBS competencies.
- Staged bilateral treatment may be considered in patients who have undergone unilateral MRgFUS. Retreatment on the contralateral side may be considered after stabilization of the initial treatment. The risk of side effects in the form of speech, gait and balance problems must be carefully assessed. There are limited data and recommendations on bilateral treatment [29,30].

Contraindications for neuromodulation with MRgFUS

Absolute Contraindications

- Contraindications for 3T MRI
- Previous stereotactic lesioning (DBS, thalamotomy)
- Low SDR
- Severe claustrophobia unrelieved by mild sedative medication
- Patients who cannot lie in an MRI scanner for several hours
- Pacemakers, other electronic heart implants, neurostimulators and cochlear implants due to safety considerations for 3T MRI scanning (unless the implanted device is approved for 3T MRI)
- Structural brain changes that prevent correct ablation or placement of electrodes
- Intracranial aneurysm
- Severe neurodegenerative disease
- Active alcohol or drug abuse
- Pregnancy

Relative contraindication

- Body width or body shape that makes it impossible to place in an MRI scanner, metal implants, foreign bodies of metal, e.g. clips, stents, coils, alloplastics / prostheses, shot, etc. (depends on location, type and manufacturer).
- Cerebrovascular disease, brain tumor, epilepsy (relative contraindication)
- Certain chronic diseases, including unstable heart disease, severe hypertension, advanced kidney disease/hemodialysis
- Increased risk of bleeding (hemorrhage, coagulopathy) due to medical conditions or blood thinning medication. Treatment with anticoagulant medication must be stopped before MRgFUS treatment

- Psychiatric comorbidity or cognitive deficits, including moderate or severe dementia, that prevent adequate information about the procedure, effectiveness and risks and thus informed consent (relative contraindication)

Adverse Effects

- Side effects of the treatment are divided into procedure-related, immediate side effects, most of which are transient, such as headache and nausea, and neurological side effects, where there is a significant incidence of sensory disturbances (14%) and gait problems (9%), which are present one year after treatment [17,30]. A study of 133 treated patients at five different centers showed that among those who still have discomfort because of treatment one year after treatment, 91% were considered mild (such as non-disruptive sensory disturbances), while 1.6% developed severe neurological symptoms (gait or balance disturbances). Side effects are thus rarely serious [22-23-24-25, 27].
- After MRgFUS, local cerebral edema occurs around the sonication site. This can cause transient symptoms affecting gait, balance and require short-term treatment with steroids and physiotherapeutic rehabilitation.
- After regulation of the treatment cannot take place and the follow-up is primarily for subsequent assessment of the treatment effect, side effects and need for medication.
- Transient surgery-related side effects:
    - Dizziness: 8-45.5%
    - Nausea and vomiting: 8-45.4%
    - Headache
    - Scalp warming
- Postoperative side effects:
    - Paresthesia and numbness: 38%
    - Gait and balance problems: 36%
- Long-term side effects (12 months postoperatively):
    - Paresthesia and numbness: 14%
    - Gait and balance problems: 7-9%
    - Contralateral limb weakness: 2%

Key Considerations [31]

- ET is currently a heterogeneous disorder. Up to 30–50% of patients require surgical interventions due to poor pharmacological response.
- As of now, DBS remains the gold standard for adjustability, reversibility, bilateral control and the possibility of incorporation of emerging DBS technologies.

- DBS is invasive, requires general anesthesia for pulse generator's implantation, maintenance, a stricter selection process and has higher risk of procedure-related complications.
- MRgFUS allows brain lesions without skin, skull, or brain penetration, has no risk of bleeding or infections, and is less expensive. Also, staged bilateral MRgFUS thalamotomy for ET has been recently approved by the FDA and EU (CE mark).
- MRgFUS cannot be adjusted in tremor worsening, tremor recurrence or side effects, and is contraindicated in cases of skull specifics (i.e. low SDR) and intolerance to MRI.
- The final selection of treatment modality should be driven by the medical team along with the patient and caregiver preferences.

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