

Jun 30, 2025

Protocol for the Reporting of Transcranial Ultrasound Stimulation

DOI

<https://dx.doi.org/10.17504/protocols.io.4r3l21mo3g1y/v1>

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Protocol Citation: Martin E, Aubry JF, Schafer M, Verhagen L, Treeby B, Pauly KB, Paola Di Maio 2025. Protocol for the Reporting of Transcranial Ultrasound Stimulation. **protocols.io** <https://dx.doi.org/10.17504/protocols.io.4r3l21mo3g1y/v1>

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Protocol status: Working

We use this protocol and it's working

Created: June 30, 2025

Last Modified: June 30, 2025

Protocol Integer ID: 221291

Keywords: transcranial ultrasound stimulation, transcranial ultrasound stimulation as transcranial ultrasound stimulation, ultrasound aspect, transducer, acoustic parameter, free field acoustic parameter, ultrasound

Abstract

As transcranial ultrasound stimulation (TUS) advances as a precise, non-invasive neuromodulatory method, the scope of the protocol is limited to reporting the ultrasound aspects. The guide and supplementary material provide a simple checklist covering the reporting of: (1) the transducer and drive system, (2) the drive system settings, (3) the free field acoustic parameters, (4) the pulse timing parameters, (5) in situ estimates of exposure parameters in the brain, and (6) intensity parameters. Detailed explanations for each of the parameters, including discussions on assumptions, measurements, and calculations, are also provided.

Guidelines

Transcranial ultrasound stimulation (TUS) is a non-invasive neuromodulation technique that employs focused ultrasound waves to modulate neuronal activity within the brain. TUS offers a promising avenue for therapeutic and research applications due to its spatial precision and ability to target deep neural structures. As the field transitions to more widespread human studies, the time is upon us to standardize the reporting of such studies to aid understanding and reproducibility.

Materials

Transducer and drive system description:

- Transducer manufacturer and model number
- Transducer center frequency
- Transducer geometry (e.g., radius of curvature and aperture diameter)
- Drive system components, including manufacturer and model number (e.g., signal generator and amplifier or integrated driving system)

Drive system settings:

- Operating frequency
- Output level settings
- Focal position settings
- Description of transducer coupling method

Free field acoustic parameters:

- Reference position for measurements
- Spatial-peak pressure amplitude
- Position of spatial-peak pressure amplitude (relative to reference position)
- Size of focal volume (–3 dB and –6 dB axial and lateral widths)
- Position of center of focal volume (center of –3 dB relative to reference position)
- Description of how free field parameters were obtained (including details of measurement equipment)

Pulse timing parameters:

- Pulse timing table

In situ estimates of exposure parameters:

- Estimated in situ spatial-peak pressure amplitude
- Estimated in situ pressure amplitude at the target
- Estimated in situ mechanical index
- One of the following thermal metrics: temperature rise, thermal index, or thermal dose
- Description of how in situ estimates were obtained

Intensity parameters (optional):

- Spatial-peak pulse-average intensity
- Spatial-peak time-average intensities
- The acoustic impedance used for the conversion

System and Free Field Acoustic Pressure Parameters

- 1 System parameters describe the type and geometry of the transducer, and the signal chain or system used to drive the transducer in order to generate the acoustic field. The free field acoustic pressure parameters provide a description of the generated ultrasound field under reference conditions. The term 'free field' refers to the field generated when a transducer is radiating continuously (or with the comparatively long pulses used in TUS studies) into water without any obstruction by reflectors, scatterers, or aberrators. See Section B for details of how this is implemented during measurements.
- 2 Reporting free field acoustic parameters allows comparison of the transducer output at the chosen output level and focal settings under standardized conditions, serving as a baseline for comparison between studies. In this guide, the term output level refers to the amplitude of the acoustic pressure output, which is governed by settings on the drive system such as voltage, power or intensity. The focal position setting refers to the position of the focal region where this can be steered to different positions. It may be fixed for a particular transducer, or set by the operator, for example, by selecting a distance setting, or by setting the relative phases applied to the transducer elements. The free field parameters described in this section should be reported at the output and focal settings used during exposure of participants during studies.

Transducer and Drive System

- 3 Transducer description: A description of the ultrasound transducer should be given, including the manufacturer and model number, and the operating frequency of the transducer. For spherically focusing transducers, the geometry is described by the radius of curvature and aperture diameter. In some cases, the exact geometry may not be known, for example, if the transducer construction includes a lens or permanently attached coupling medium, in which case, any other information such as the nominal position of the focus relative to the transducer face should be reported. For multi-element transducers, the number of elements and information about their shape, size, and positions should be given if available. The exact size and position of elements may not be available for commercial transducers, so a brief description accompanied by the model number is sufficient. Any other features of the transducer such as permanently attached coupling media, or lenses should be described, including a description of the material, its thickness and shape/geometry, and properties of the material such as the sound speed, density and attenuation coefficient where known.
- 4 Drive system description: The input signal used to drive the transducer may be generated by an integrated drive system, or using a signal generator and radio frequency amplifier. All components of the system, including manufacturer and model numbers and any external electrical impedance matching networks used to couple the drive signal to the transducer should be reported.



- 5 Drive system settings: All drive system settings used during studies should be described, including the operating frequency, output level settings (e.g., displayed electrical power, focal intensity, voltage etc.), and for multi-element transducers, focal distance or position settings applied. The method of coupling the transducer to the participant forms part of the in situ acoustic transmission path, so the materials and methods used should be described.