International Journal of Neurology Research

ISSN Print: 2664-908X
ISSN Online: 2664-9098
Impact Factor (RJIF): 6.08
IJNR 2026; 8(1): 01-04
www.neurologyjournals.com
Received: 06-11-2025
Accepted: 08-12-2025

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Effectiveness of motor imaginary techniques on improving upper limb function in middle cerebral artery

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DOI: https://www.doi.org/10.33545/2664908X.2026.v8.i1a.39

Abstract
Background: Middle Cerebral Artery (MCA) strokes are among the most disabling types of cerebrovascular injuries, frequently resulting in profound motor deficits of the upper limb. These impairments disrupt essential daily tasks such as reaching, grasping, lifting, and manipulating objects. Traditional rehabilitation often focuses on physical task practice; however, many MCA-stroke patients struggle to execute meaningful movements due to weakness, poor motor planning, and sensory-loss. Motor Imagery (MI) the cognitive simulation of movement without actual execution—activates motor networks using internal rehearsal. Recent neuroscience research demonstrates that MI engages primary motor cortex, premotor cortex, supplementary motor areas, cerebellum, and parietal regions even in the absence of muscular activity. This makes MI a promising therapeutic strategy for individuals unable to generate effective voluntary movement early after stroke.
Objective: To compare the effectiveness of Motor Imagery Therapy (MI) with a conventional Task-Oriented Training (TOT) program on upper-limb motor recovery in patients with MCA stroke.
Methods: Thirty-six MCA stroke patients were randomly assigned into two groups: MI (N=18) and TOT (N=18). Both groups underwent a structured 12-week rehabilitation program, receiving daily sessions under therapist supervision. Upper-limb recovery was evaluated using the Fugl-Meyer Assessment-Upper Extremity (FMA-UE), Grip Strength testing, and the Modified Rankin Scale (mRS) for functional disability.
Results: The MI group demonstrated significantly larger improvements in FMA-UE scores, grip strength, and functional independence (mRS) compared to the TOT group. Statistical analysis confirmed a clear advantage of MI across all outcome domains.
Conclusions: Motor Imagery Therapy is an effective, low-cost, accessible, and neurophysiologically powerful intervention for improving upper-limb recovery after MCA stroke. It is particularly valuable for patients with limited physical movement ability, as it stimulates motor circuits even when overt movement is not possible.

Keywords: Chhani, consumption, fuel-wood, households, Lanchaan

Introduction
Middle Cerebral Artery (MCA) stroke accounts for the majority of ischemic strokes and is associated with some of the most severe and functionally limiting upper-limb impairments. The MCA supplies motor, sensory, and association areas responsible for voluntary arm and hand movements. As a result, MCA lesions often lead to a combination of:

- Profound muscle weakness
- Spasticity or altered tone
- Impaired motor planning
- Sensory loss
- Reduced hand dexterity
- Difficulty with purposeful reaching and grasping

These deficits significantly impact independence in activities such as dressing, feeding, writing, or handling household objects. For many patients, upper-limb recovery progresses slowly and remains incomplete even after intensive rehabilitation.

Traditional interventions such as Task-Oriented Training (TOT) emphasize repeated practice of functional tasks to promote motor relearning. While effective for many individuals, TOT requires a minimum degree of voluntary movement. Patients with severe paresis, minimal voluntary activation, or sensory loss often cannot benefit optimally from task-based practice in the early phase of recovery.

To address this limitation, rehabilitation science has turned toward cognitive-motor approaches. One such approach Motor Imagery (MI) involves mentally simulating a movement without actual execution. MI can be performed even when the patient has little to no voluntary motion, making it uniquely suited for early rehabilitation.

Neuroscience studies using fMRI and EEG have shown that MI activates neural pathways overlapping with those used in physical movement execution

These include

- Primary motor cortex.
- Premotor cortex.
- Supplementary motor area.
- Posterior parietal cortex.
- Cerebellum.
- Basal ganglia.

These findings suggest that MI may strengthen motor circuits, enhance synaptic efficiency, and support neuroplasticity necessary for functional recovery.

Despite its strong theoretical foundation, MI is still underutilized in many clinical settings due to misconceptions regarding its complexity or the belief that it is suitable only for motivated or cognitively intact patients. In reality, structured MI protocols guided by therapists can be easily integrated into clinical rehabilitation.

This study aims to directly compare Motor Imagery Therapy with Task-Oriented Training to determine whether MI results in greater improvements in motor recovery and functional independence in MCA stroke patients.

Methods

Study Design

A randomized comparative trial was conducted to determine the differential effects of MI and TOT on upper-limb motor recovery among MCA stroke patients. Randomization ensured unbiased allocation and equivalence between groups.

Participants

A total of 36 individuals diagnosed with MCA stroke were recruited. Selection criteria ensured participants had residual upper-limb impairment and were medically stable enough to participate in therapy.

Inclusion Criteria

- Clinical diagnosis of MCA stroke.
- Unilateral upper-limb involvement.
- Residual motor impairment of the affected limb.
- Ability to follow verbal instructions.
- 3 to 12 months post-stroke.

Exclusion Criteria

- Severe cognitive impairment.
- Uncontrolled medical conditions
- Pre-existing neurological or orthopaedic disorders affecting the upper limb
- Severe neglect or aphasia interfering with MI participation

Participants were randomly divided into

- MI Group (N=18)
- TOT Group (N=18)

Intervention

Motor Imagery Therapy (MI)

The MI group performed structured Motor Imagery exercises for 12 weeks, 5 days per week.

Motor imagery sessions included

Visual MI

- First-person perspective (seeing through one's own eyes).
- Third-person perspective (watching oneself perform the action).

Kinesthetic MI

- Feeling the movement internally.
- Imagining joint rotation, muscle tension, movement trajectory.
- Focusing on the sensation of executing the movement even if the limb is still.

MI training followed a graded structure:

- Relaxation and mental readiness.
- Simple imagined movements such as elbow flexion or hand opening.
- Complex motor sequences such as reaching, gripping, lifting.
- Task-specific imagery related to everyday functions.
- Combined MI + mild physical attempts when possible.

Sessions were therapist-guided to ensure correct use of imagery strategies, attention control, and engagement of sensory networks.

Task-Oriented Training (TOT)

The TOT group received 12 weeks of repetitive functional task practice including:

- Reaching for objects placed at different distances.
- Grasping and releasing items.
- Lifting lightweight objects.
- Simulated daily tasks (e.g., using utensils, stacking items, folding cloth).

The goal was to enhance motor performance through repetition and functional relevance.

Outcome Measures

Three standardized measures were used before and after the 12-week intervention

- **Fugl-Meyer Assessment:** Upper Extremity (FMA-UE) Evaluates motor control, reflex activity, coordination, and isolated joint movements.
- **Grip Strength:** Assessed using a calibrated dynamometer.

- **Modified Rankin Scale (mRS):** Rates functional independence and disability.

Data Analysis
Within-group (pre- vs post-intervention) and between-group comparisons were analyzed statistically. Significance was set at $p<0.05$.

Results
The MI group showed superior improvements across all parameters compared with TOT.

Key Findings
- **Motor Recovery (FMA-UE):** MI group exhibited greater gains in motor control.
- **Grip Strength:** MI participants demonstrated significantly larger increases in strength.
- **Functional Independence (mRS):** MI group achieved more substantial reduction in disability scores, indicating better real-world functional recovery.

All improvements in the MI group were statistically significant and exceeded those observed in the TOT group.

Discussion
The findings of this study highlight the superior effectiveness of Motor Imagery Therapy for upper-limb rehabilitation in MCA stroke patients.
Why Motor Imagery Works Better

MI activates motor networks without movement
MI triggers neural activation patterns similar to actual movement. This is important because many MCA-stroke patients cannot physically execute tasks early in rehabilitation. MI allows these individuals to practice movement mentally, thereby strengthening neural pathways even when muscles cannot perform effectively.

MI Enhances Neuroplasticity
Repeated motor imagery stimulates
- Corticospinal excitability
- Motor map reorganization
- Synaptic strengthening
- Improved connectivity between sensory and motor regions

These neuroplastic changes help restore voluntary movement and coordination.

MI improves motor planning
After an MCA stroke, patients often struggle with initiating movements. MI helps reorganize motor planning pathways, enabling:
- Better sequencing of tasks.
- Improved anticipatory control.
- Smoother execution when physical practice begins.

Combination of visual and kinesthetic imagery deepens learning
Visual MI helps refine movement trajectory, while kinesthetic MI strengthens the sense of movement from within. Together, they improve motor output even before overt movement is possible.

TOT requires physical capacity MI Does Not
While TOT is useful, its benefits depend on the patient's ability to move the limb. In contrast, MI can be performed:
- In severe weakness
- In early recovery
- With fatigue
- When movement is difficult or unsafe

This makes MI more versatile and universally applicable across impairment levels.

Functional Recovery (mRS Improvement)
The greater reduction in mRS scores in the MI group indicates better real-life independence. Patients likely experienced improvements in:
- Hand function.
- Coordination.
- Confidence using the affected limb.
- Ability to perform ADLs.

These functional benefits strengthen the clinical relevance of MI
Clinical Implications
- MI is cost-effective, requiring no equipment.
- Useful for patients with severe upper-limb paresis.
- Can be delivered in person or remotely.
- Enhances outcomes when combined with physical therapy.

Limitations
- Small sample size.
- No neuroimaging used to confirm cortical changes.
- Long-term effects were not measured.

Future Recommendations
- Include larger multi-center studies.
- Use fMRI, EEG, or TMS to measure neuroplastic changes.
- Explore combined MI + physical practice programs.
- Investigate home-based MI protocols for telerehabilitation.

Conclusion
Motor Imagery Therapy is a powerful, scientifically grounded intervention for upper-limb rehabilitation after MCA stroke. It produces greater improvements in motor control, grip strength, and functional independence compared with Task-Oriented Training. MI is especially beneficial for patients with severe motor deficits, offering a safe, accessible method to stimulate neuroplasticity and accelerate recovery.

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