Mental Practice

Applying Motor PRACTICE and Neuroplasticity Principles to Increase Upper Extremity Function

Stephen J. Page, PhD, MS, MOT, OTR/L; Heather Peters, MOT

The vast majority of stroke survivors exhibit residual impairments, with most reporting-associated quality of life decrements. The prevalence of these poststroke motor deficits and the overall burden of stroke are likely to rise exponentially attributable to an aging population and increases in the prevalence of many risk factors (eg, obesity, diabetes mellitus, smoking). In light of these trends, several promising motor interventions have been introduced, with many targeting upper extremity (UE) hemiparesis, given its widely appreciated impact. Yet, although several of these approaches appear efficacious, few therapeutic approaches showing promise in animal or early human trials are fully translated to regular clinical practice. Consistently, many contemporary motor rehabilitation strategies require high duration contact time and costly equipment, preventing their widespread clinical application, except among specialized rehabilitation and academic medical centers.

Mental practice involves repetitive cognitive rehearsal of physical movements in the absence of physical, voluntary attempts. From a practical perspective, mental practice constitutes an attractive alternative to other rehabilitative approaches because it does not require physical rehearsal, can be performed without direct supervision, and requires minimal expense and equipment, facilitating ease of use. The brain’s ability to respond to repetitive, learning-based strategies even years after injury and well into adulthood also makes mental practice a favorable match for stroke, which tends to be a disease of the aged and because survivors frequently exhibit residual impairments for years postictus.

We speculated that repetitive mental practice use, shown to trigger the same neural areas and musculature as physical practice of the same tasks, would cause substantive neural and motor changes in stroke survivors with UE deficits. Although used for decades in sport and exercise settings, this laboratory was the first to apply mental practice to increase learning and outcomes in stroke, later showing that mental practice use increases paretic UE use and function. More recently, our work has shown that mental practice use causes the same cortical changes as physical practice in survivors of stroke. Given these promising findings, its robust scientific bases and its easy clinical integration, this article first briefly summarizes some of the major evidence supporting mental practice use in stroke, with an emphasis on UE hemiparesis. Because motor learning-based physical practice is ideally coupled with mental practice of the same activities, this article also reviews aspects of the motor practice regimens that we integrate with mental practice, and introduces the PRACTICE principles. These discussions are intended to provide an overview of the framework that we apply to structure the motor practice regimens that we integrate with mental practice, and introduces the PRACTICE principles. Finally, we identify and describe the mechanisms thought to be responsible for the mental practice treatment effect.

What Is Mental Practice and Why Apply It to Poststroke Movement?

Mental practice is most effective when combined with physical practice of the same skill, likely because it incorporates already-established motor schema from physical practice of the same tasks. From a practical standpoint, skills that have been previously performed are likely more salient and easy to mentally rehearse for clients with stroke. Consequently, accelerated motor learning and improved movement have been reported when mental practice is combined with physical practice in a variety of contexts. Moreover, the same neural and muscular areas are activated during mental practice as during physical practice of the same skill, including in individuals years poststroke (discussed later in this article). Thus, mental practice provides the opportunity to noninvasively gain additional motor skill practice by recreating similar neural and muscular conditions as are observed during physical practice. This facet of mental practice is particularly advantageous in stroke rehabilitative settings because of the following: (1) certain motor skills may be difficult and unsafe to physically practice, making it useful to be able to approximate physical practice conditions. Mental practice alone is not as efficacious as mental practice coupled with physical practice, but does elicit cortical and neuromuscular activations as if the activity...
is being physically performed\textsuperscript{10-14}; (2) stroke survivors spend considerable time inactive and alone,\textsuperscript{20} necessitating strategies that allow them to practice in such circumstances; and (3) repetitive task-specific practice (RTP) appears to be a prerequisite for cortical plasticity and subsequent motor changes poststroke.\textsuperscript{21}

The primary emphasis of poststroke mental practice has been the paretic UE. However, some pilot studies have examined the impact of mental practice on lower extremity (LE) function.\textsuperscript{22-26} Additionally, this laboratory proposed a model of learned nonuse of speech\textsuperscript{27} and suggested that mental practice may be a strategy to encourage individuals with non fluent aphasia to resume functional communication and experience accelerated outcomes. However, the larger body of mental practice evidence emphasizes poststroke UE motor performance. Specifically, evidence points to the efficacy of mental practice as an adjunctive physical rehabilitation strategy as compared with the provision of physical rehabilitation alone. For example, we found that mental practice, when combined with standard UE rehabilitation, resulted in increased function.\textsuperscript{18} We also showed that motor imagery use improves UE movement kinematics in patients years poststroke with stable motor deficits,\textsuperscript{16} although this was a noncontrolled study in which all patients received mental practice and physical rehabilitation. Stroke survivors engaging in both physical and mental practice also display greater generalization of skill learning to new environments and skills than those who only physically practice.\textsuperscript{28} This is important because not every skill that is important to community independence can be repeatedly rehearsed before discharge. In our own laboratory, mental practice has also been combined with other stroke therapies targeting the paretic UE, such as modified constraint-induced therapy, a reimbursable, outpatient therapy shown efficacious in the days, months, and years after stroke. Specifically, our results showed that combining mental practice with modified constraint-induced therapy resulted in greater gains in UE function when compared with modified constraint-induced therapy alone,\textsuperscript{29} an important discovery that could heighten the impact of this easily-integrated clinical regimen. Additionally, other work by our group suggests that participants maintain motor gains several months after mental practice treatment,\textsuperscript{30} indicating that mental practice may have promising long-term effects when used as an adjunctive intervention.

A summary of the methods and outcomes of selected UE mental practice studies is provided in Table 1. In light of the evidence from aforementioned studies and others, mental practice was reported in a recent meta-analysis to have a pooled treatment effect size of 0.51 (95\% confidence interval, 0.27-0.750) in controlled clinical studies, indicating a moderate effect.\textsuperscript{33}

Studies Integrating Mental Practice Into Clinical Stroke Rehabilitation

In light of mental practice’s efficacy as an adjunctive UE treatment strategy in controlled trials, several other studies have integrated mental practice into clinical rehabilitative efforts among people with stroke and other neurological impairments. Although potentially important, in most cases, the heterogeneity of patients encountered in regular clinical practice, a lack of rigorous study criteria, and other methodological shortfalls were noted: (1) Bovend’Eerdt et al\textsuperscript{31} administered mental practice to people with stroke, brain injury, and multiple sclerosis. No statistically significant differences were reported between those who did and did not receive mental practice, likely attributable to heterogeneity of the subjects’ injuries and impairment levels and low therapist and patient adherence to the therapy protocol. (2) In one of the largest mental practice trials to date, Ietswaart et al\textsuperscript{32} investigated the effect of inpatient rehabilitation augmented by either mental practice, nonmotor rehearsal, or no mental rehearsal component in 121 stroke survivors. As with Bovend’Eerdt et al,\textsuperscript{31} results showed no differences in UE function changes between groups. However, these outcomes should, again, be taken with caution given the high heterogeneity of subjects in the sample (ie, individuals with scores of 3–51 on the Action Research Arm Test were included, meaning that individuals with severe, moderate, and minor UE deficits were all included in the study). This is problematic because the size and location of their lesions, their resultant motor recovery trajectories, the amount and diversity of adjunctive treatments, and ability to actively, fully, participate in physical practice attempts and tests that were administered will all greatly vary), resulting in likely type II errors. Additionally, the researchers did not control for the multitude of treatments that are coadministered during a typical inpatient rehabilitative stay, which constitutes a contaminant and likely threat to the validity of the findings. Moreover, one must consider the comorbidities that are commonly seen during the acute and subacute phases, which could have washed out the impact of mental practice in this study, resulting in type II errors. The study’s sole use of first person and kinesthetically based mental practice techniques may also be a minor shortfall and was certainly inconsistent with previous mental practice studies that this and other groups have conducted. (3) An additional study by Timmermans et al\textsuperscript{34} provided either a regimen of therapy and mental practice or a control intervention of neurodevelopmental therapy only to 42 subjects with stroke who were 2 to 6 weeks poststroke. Although both groups showed UE motor changes on the Fugl-Meyer and Wolf Motor Function Test, the authors reported no differences between the 2 groups. Again, though, the results may be taken with caution because there was no control for other therapies and medications that were coadministered as part of routine clinical care, little control for spontaneous recovery that is commonly observed during this period, and because the only motor inclusion criterion was that subjects exhibit a Medical Research Council grades 1 to 3, a considerable degree of heterogeneity in UE motor function that, again, introduces the possibility of type II errors and other challenges noted with the study by Ietswaart et al\textsuperscript{32} mentioned above. (4) Finally, Braun et al\textsuperscript{35} randomly added mental practice to regular care in nursing homes in the Netherlands, with some of the measures that were administered focusing on UE motor function. As with the work by Timmermans et al,\textsuperscript{34} all eligible subjects encountered at the facility and meeting study criteria were enrolled. Again, although nonstringent study criteria were applied (clinically diagnosed stroke occurring between...
Table 1. Selected, Relevant Randomized Controlled Trials Examining Mental Practice Efficacy for the Paretic Upper Extremity

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Purpose</th>
<th>Study Design, Participants</th>
<th>Intervention, Outcome Measures</th>
<th>Results</th>
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<tr>
<td>Page et al, 200718</td>
<td>Determine efficacy of MI in increasing function and use of affected upper extremity in chronic stroke</td>
<td>Design: Randomized, placebo-controlled trial</td>
<td>Intervention: 30-min standard therapy 2 d/wk for 6 wk and either 30-min MI sessions or 30-min relaxation exercises</td>
<td>MI group improved significantly on the FM (+6.7 vs +1.0; P&lt;0.0001) and ARA (+7.8 vs +0.44; P&lt;0.0001).</td>
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<td>Liu et al, 200928</td>
<td>Determine effect of MI on generalization of learned task skills to trained and untrained tasks in new environments</td>
<td>Design: Randomized controlled trial</td>
<td>Intervention: Either MI or conventional rehabilitation, both provided 1 h/d for 3 wk</td>
<td>MI participants improved performance on 4 of 5 trained tasks vs improvement on 1 trained task in control group. MI participants also improved performance on 3 trained and 2 untrained tasks in new environment.</td>
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<tr>
<td>Page et al, 200929</td>
<td>Determine efficacy of MI when combined with mCIT on upper extremity function</td>
<td>Design: Randomized controlled trial</td>
<td>Intervention: Either mCIT only or MI (30 min/d) and mCIT, both interventions 3x/week for 10 wk</td>
<td>mCIT+MI group members had significantly greater improvements on the FM (+7.8 vs +4.1; P=0.01) and ARA (+15.4 vs 8.4; P&lt;0.001) immediately post and 3-mo postintervention.</td>
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<td>Bovend’Eerdt et al, 201031</td>
<td>Examine feasibility of the integration of MI into occupational and physical therapy rehabilitation</td>
<td>Design: Single-blind, randomized controlled trial</td>
<td>Intervention: 6 wk of conventional therapy+MI or conventional therapy only</td>
<td>Gains measured in both groups, but no significant differences in outcome measures between groups.</td>
</tr>
<tr>
<td>Ietswaart et al, 201132</td>
<td>Examine the effect of MI on upper extremity function in stroke</td>
<td>Design: Multicenter, randomized controlled trial</td>
<td>Intervention: All participants received treatment 3 d/wk for 45 min. Participants additionally received either MI (motor mental rehearsal), attention placebo control (nonmotor mental rehearsal) or usual care with no mental rehearsal component.</td>
<td>No significant changes were seen in any outcome measures.</td>
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<tr>
<td>Page et al, 201130</td>
<td>To compare 20-, 40-, and 60-minute sessions of MI on upper extremity function poststroke</td>
<td>Design: Single-blind, multiple baseline, randomized controlled trial</td>
<td>Intervention: 30-min task-specific training 3 d/wk for 10 wk. Participants were randomized to receive 20-, 40-, or 60-min MI sessions or an audiotaped sham intervention.</td>
<td>Duration of MI predicted changes in FM scores, with the 60-min duration yielding the largest significant increase (+5.4). A nonsignificant trend was measured in ARA scores, with the 20-min duration showing the greatest gains. Subjects who received MI (regardless of dose) showed larger increases than those in the control group, but differences were not statistically significant.</td>
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ADL indicates activities of daily living; ARA, Action Research Arm test; FM, Fugl-Meyer Assessment; mCIT, modified constraint-induced therapy; and MI, motor imagery.
Two components are commonly applied to maximize mental practice’s efficacy: (1) RTP and (2) the mental practice itself.

Repetitive Task-Specific Practice
During the past decade, the RTP that is coadministered with mental practice has changed little. The motor therapy sessions are usually administered on an outpatient basis in 45- to 60-minute increments and occur 3 days per week, for a 10-week intervention period. These frequency and duration levels were chosen based on the typical outpatient therapy durations and frequency usually offered in clinical environments and on the frequency and duration of therapies that we had used for other UE protocols. These parameters also allow the motor practice to remain practical and easily integrated into existing clinical pathways, overcoming limitations of other motor practice regimens that have been advocated in the literature, and increasing likelihood of client compliance and attendance.

As with virtually all motor rehabilitative programs, the physical practice regimen typically begins with evaluation. In addition to administering the aforementioned outcome measures, and as has long been advocated in the occupational therapy literature, we obtain an occupational profile. This includes asking the client and caregiver about valued occupations in which they engaged premorbidly, roles and performance patterns in these activities that have been compromised by UE impairments, tasks that are critical to resumption of these roles and to gaining independence, and, ultimately, tasks that the client may wish to physically and mentally practice. In part, we obtain this information using formalized assessments of occupational interests (eg, the Canadian Occupational Performance Measure), with the Canadian Occupational Performance Measure being advantageous because it asks clients to rate their most valued activities and determines clients’ satisfaction with these activities and their perceived performance of those activities. The end result of the evaluation process is a list of ≤5 to 6 tasks the patient most wants to carry out during clinical sessions, with one of the tasks noted as a priority task on which we conduct regular measurements and emphasize proficiency. With the therapist’s guidance, the chosen tasks ideally equally reflect tasks using the paretic extremity unilaterally, bilateral performance, strength, and dexterity. Task and movement analyses are also performed to identify the most pressing impairments that undermine performance, the movement components that need to be remediated so that part-whole practice can effectively occur, and to determine the level of just right challenge needed for each task so that progression can occur. Thus, the training regimen is client driven in that the patient identifies the most salient and important tasks to practice and, during actual practice attempts, drives his/her own central nervous system to recover through repeated, progressively more difficult attempts. We think that motivation, as well as other psychosocial and affective processes, influences the client’s ultimate success with the rehabilitative process, and we regularly assess psychosocial constructs (for a discussion see Ma et al). Thus, during the evaluation session, we also collaborate with the caregiver to identify motivational strategies that may cause the client to have more buy in into the rehabilitative process. This may include the environment(s) in which practice occurs, the people with whom it occurs, and the type and timing of feedback provided. We also administer a behavior contract, which we have described elsewhere, as an additional motivational strategy and as a context to orient the client to the collaborative role that we expect him/her to assume during the rehabilitative process, including participation in formulating home exercises. Lastly, during this time, we familiarize the participant with the mental practice audio file and how it will be integrated into the therapeutic process.

During clinical sessions, the therapist interacts with the client to assure that the therapy tasks being practiced continue to be meaningful, to identify the most pressing difficulties that
Table 2. Description of PRACTICE Principles for Neurorehabilitation

<table>
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<tr>
<th>Principle</th>
<th>Description</th>
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<tr>
<td>Part-whole practice should be used</td>
<td>Break the desired task down into its smallest components and repetitively practice those components that are deficient as well as practicing the task in its entirety.</td>
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<td>Repetitive and goal focused</td>
<td>The paretic body part (eg, paretic limb) and region (eg, paretic hand) should be integrated into repetitive practice focused on a particular task or task component. Strategies to encourage paretic limb use (eg, a mitt worn on the less affected limb) can be used to maximize repetitive use and integration.</td>
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<tr>
<td>Activities should be meaningful to the client</td>
<td>The tasks chosen to be repetitively practiced should be meaningful to the client, either because they are of high interest or because they are necessary (eg, feeding, washing).</td>
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<tr>
<td>Client driven</td>
<td>Allow the client to drive the therapy content and his/her nervous system changes by identifying goals, engaging in error reporting and correction, and self-directing the therapy or trials when possible and appropriate.</td>
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<tr>
<td>Train in a practical way</td>
<td>The regimen should use techniques, tools, a training schedule, and practice environments that are easy to follow and easy to implement for the patient and his/her care partners.</td>
</tr>
<tr>
<td>Impairments should be addressed</td>
<td>If a patient exhibits modifiable impairments that impede progress in attaining the tasks (eg, deconditioning, spasticity), address them.</td>
</tr>
<tr>
<td>Challenge regularly and appropriately</td>
<td>Grade the task regularly. Frequently integrate trials in which most or all of the movement is attempted (ie, part-whole practice) to assess progress and identify opportunities to grade up or down.</td>
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<tr>
<td>Emphasize accomplishments</td>
<td>Use voluminous, patient-specific, verbal and written encouragement and choose tasks that have inherent rewards (eg, feeding oneself). This facilitates patient buy in, compliance, self-efficacy, and encourages reintegration of the ability being emphasized (eg, paretic limb use; speaking [in the case of nonfluent aphasia]). Other strategies that engender awareness of knowledge of performance and knowledge of results, as well as accomplishments, should be integrated when possible.</td>
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</table>

The PRACTICE Principles

Based on converging findings from neuroscience and motor learning research,21,41 our UE motor therapy studies during the past decade, common therapy practices (eg, use of homework; use of strategies to encourage compliance and motivation; use of occupation-based, salient activities), and the important work of others,7,8 we developed a set of organizing principles that govern the way in which UE motor practice is adjunctively provided to mental practice in the clinic, as well as other therapies that we provide. These tenets, called the PRACTICE principles, speak to the nature of RTP, the practice regimen’s structure, the practicality of the RTP regimen, and the ways in which tasks are chosen and broken down to facilitate learning, compliance, self-efficacy, and, ultimately, reintegration of skills learned in therapy to clients’ real-world environments. Reduction of impairments that may obstruct attempts paretic UE use (eg, muscle deconditioning) are also addressed when plausible. We have routinely applied the PRACTICE principles shown in Table 2 to a variety of approaches targeting function in people with motor, language, and other neurological impairments and conditions. Many of these techniques are used concurrently or sequentially with the RTP principles described in the preceding paragraphs. Some of these strategies may be more efficacious on certain groups of patients (eg, those with relatively intact cognitive function, less UE impairment, higher levels of caregiver support) or in concert with specific therapeutic strategies. Discerning the impact of these strategies (both individually and collectively), which of these strategies are the most potent, on whom, and at what point(s) in the rehabilitative process is a fertile and important area of research being explored in this laboratory and others.8,18,27,42 These principles, their practical application in clinical stroke rehabilitation, and their full rationale are beyond the scope of this article and will be discussed elsewhere. For the purposes of this article, they provide a framework for the RTP that we integrate with mental practice in the clinic.

Mental Practice

Mental practice is usually provided directly after motor therapy sessions and thus occurs 3 days per week during the same 10-week period as the physical practice sessions. We have not yet explored whether also providing mental practice on days when clinical motor practice does not occur renders a larger treatment effect. However, it does seem clear that providing mental rehearsal of the same activities that are being physically practiced during clinical sessions and providing them at a time that proximal to the occurrence of the physical practice sessions is integral to the regimen’s efficacy.
After entering a quiet room adjacent to our treatment area, clients are seated and provided with an mp3 player and headphones. They then listen to a mp3 file lasting ≈30 minutes and containing the following elements: (1) ≈ 3 to 5 minutes during which the patients are asked to imagine themselves in a warm, relaxing place (eg, a beach) and to contract and relax their muscles (ie, progressive relaxation). (2) ≈ 20 minutes during which the patients mentally rehearse the task that was physically practiced during RTP occurring earlier that day. For example, when mentally practicing reaching for a favorite coffee cup, the recording first describes the setting in which the patient was seated, followed by the visual image of reaching for the cup from first and third person perspectives, as well as the sensations associated with reaching for it (eg, the feeling of extending the elbow and fingers, the feeling of the cup in their hand). Several trials of each task are mentally practiced, using various physical and sensory cues and perspectives. (3) Finally, patients are provided ≈3 to 5 minutes to refocus into the room.

Hypothesized Mechanisms Responsible for the Mental Practice Treatment Effect

The 2 primary mechanisms hypothesized to be responsible for the treatment effect are as follows: (1) use-dependent cortical organizations and (2) overcoming nonuse of the paretic UE.

Use-Dependent Cortical Reorganization

Although the body of evidence showing cortical activations during mental practice is sizable, only a handful of studies have examined whether cortical organizations occur as a result of mental practice participation. We have administered a battery of paretic UE functional activities followed by physical and mental practice of the same activities during a 10-week period. After participating in the regimen, subjects typically displayed new movements in their paretic wrists and fingers that enable them to resume valued activities (eg, typing on a computer keyboard) that they have not performed in months. Across our motor imagery studies, postintervention functional MRI data have shown reduced activation in contralateral primary motor and parietal areas and increased activation in ipsilateral primary motor, premotor, and supplementary motor areas. Concurrently, activation increases have included an expansion of activation and an increase in activation magnitude. Subjects in this work have been several years poststroke and thus were medically and neurologically stable and receiving no rehabilitative therapies. Moreover, their clinicians had reported that these individuals had plateaued, meaning that no additional motor responses were elicited when subjects were administered rehabilitative therapies.

Nonuse of the Paretic UE

For almost 100 years,41 patients with UE hemiparesis have been reported to not use their paretic limbs even when capable of doing so. Concurrently, because of diminishing lengths of inpatient stay, stroke survivors are often encouraged to learn compensatory strategies integrating the intact UE (eg, one handed tying of shoes, eating with the less affected UE), even if this necessitates that the client use the nondominant limb. These patterns are thought to become habits and, as a result, become more difficult to overcome over time.

In our early work, we informally found that stroke survivors reported that they valued the opportunity to gain additional practice attempts rehearsing skills performed during therapy sessions, but outside of the clinic. They also stated that mental practice use outside of the clinic made integration of the paretic UE into activities during practice sessions easier and more palatable to them. We also have suspected that the behavioral techniques used during the mental practice regimen, including discussing the use of the paretic limb in the home environment and mentally rehearsing functional use of the paretic UE in the client’s own environment, also contribute to the impact of the regimen on overcoming limb nonuse. Our data have supported these findings, showing that mental practice use significantly increases paretic UE use even years poststroke, as measured by the Motor Activity Log,37 as well as activity monitors. Preliminary data from a recently completed, subacute study conducted by our group seem to provide additional support for this finding but are still being analyzed at time of this writing.

Conclusions

Motor weakness is frequently exhibited poststroke and is particularly disabling. Mental practice shows promise for increasing UE use and function and is advantageous given that it requires few resources and can be performed virtually anywhere. Moreover, it seems that repetitive mental practice use causes use-dependent cortical reorganizations and changes in paretic UE use that are commonly reported when other efficacious UE regimens have been implemented poststroke. However, there also remains much still to be answered in this area of research, including at what point in the rehabilitative process mental practice should be administered, what other adjunctive components might maximize its efficacy, and in which clients mental practice is likely to be most efficacious. Nonetheless, given that formalized opportunities to practice and rehabilitative lengths of stay are each diminishing, the possibility of being able to simulate practice and gain function are promising and warrant additional attention in the future.

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Disclosures

None.

References


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