

Auditory Temporal Processing Deficits in Chronic Stroke: A Comparison of Brain Damage Lateralization Effect

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Background: There have been a few reports about the effects of chronic stroke on auditory temporal processing abilities and no reports regarding the effects of brain damage lateralization on these abilities. Our study was performed on 2 groups of chronic stroke patients to compare the effects of hemispheric lateralization of brain damage and of age on auditory temporal processing. **Methods:** Seventy persons with normal hearing, including 25 normal controls, 25 stroke patients with damage to the right brain, and 20 stroke patients with damage to the left brain, without aphasia and with an age range of 31-71 years were studied. A gap-in-noise (GIN) test and a duration pattern test (DPT) were conducted for each participant. **Results:** Significant differences were found between the 3 groups for GIN threshold, overall GIN percent score, and DPT percent score in both ears ($P \leq .001$). For all stroke patients, performance in both GIN and DPT was poorer in the ear contralateral to the damaged hemisphere, which was significant in DPT and in 2 measures of GIN ($P \leq .046$). Advanced age had a negative relationship with temporal processing abilities for all 3 groups. **Conclusions:** In cases of confirmed left- or right-side stroke involving auditory cerebrum damage, poorer auditory temporal processing is associated with the ear contralateral to the damaged cerebral hemisphere. Replication of our results and the use of GIN and DPT tests for the early diagnosis of auditory processing deficits and for monitoring the effects of aural rehabilitation interventions are recommended. **Key Words:** Stroke—brain damage—temporal processing—auditory cerebrum—gap in noise—aging.
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Introduction

Stroke is the third leading cause of death worldwide and one of the major causes of physical disabilities and cognitive deficits, particularly in the elderly.^{1,2} According to the World Health Organization's definition, stroke consists of "rapidly developing signs of focal (or global) disturbance of cerebral function, lasting longer than 24 h (unless interrupted by death) with no apparent non-vascular cause." Stroke is classified into 2 main types: ischemic (occlusion of a blood vessel) and hemorrhagic (rupture of a blood vessel). Ischemic stroke constitutes 80%-85% of all strokes.³ The middle cerebral artery (MCA) is the most common site of ischemic stroke. Several important brain areas, including the primary motor and sensory areas for the face and upper extremities, as well as Broca's and Wernicke's areas in the dominant hemisphere, are within the MCA territory. Approximately one third of patients with acute stroke present with aphasia, which may improve in the first 6 months following the stroke.⁴ Most studies that have been conducted in the fields of assessment, treatment, and/or rehabilitation of the poststroke communication difficulties have investigated disorders such as aphasia, apraxia, reading deficits, and psychological and cognitive problems. Despite the major role of auditory neuronal pathways and auditory cortical areas in decoding different types of auditory stimuli and their major roles in phonetic and phonological discrimination, few studies have addressed the consequences of chronic stroke on the auditory system in terms of processing and recognizing auditory stimuli.

Auditory perception is a complex function that involves sound analysis across temporal, spatial, and spectral dimensions. Peripheral hearing loss (HL) due to the acute phase of stroke is not very common, but chronic stroke patients might show auditory processing disorders.⁵ In 1 study, 49% of patients with hearing disorders due to unilateral cerebrovascular accidents showed difficulties in auditory perception during auditory localization and speech perception in adverse listening conditions involving multiple talkers, despite most of the participants exhibiting normal peripheral hearing.⁶ Furthermore, hearing disorders could prevent participation in physical rehabilitation programs and could adversely impact physical abilities.⁷ One of the most important forms of hearing disorders is a deficit in timing perception. Temporal processing is a critical and unique component of auditory perception because it influences other important components of auditory information transmission. Temporal processing refers to the processing of acoustic stimuli over time, and can be traced from the basic levels of auditory neural timing up to cortical processing for binaural hearing and speech perception.⁸

The 2 primary tests used to study auditory temporal perceptual ability in cases of cerebral cortical damage are the gap-in-noise (GIN) test and duration pattern test (DPT).

GIN is a sensitive test of temporal resolution that refers to the ability of the auditory system to identify rapid changes in the envelope of a sound stimulus over time.⁹ DPT is a test of auditory temporal ordering or sequencing, and refers to the ability of processing 2 or more auditory stimuli based on their temporal order.^{8,10} In a study on patients with confirmed neurological damage affecting the central auditory nervous system (CANS), the mean GIN threshold was approximately 3 milliseconds longer than that of healthy controls, while the mean overall percentage of correct scores was almost 10% lower.⁹ In another study with patients who had strokes involving the insula, the mean GIN threshold was as high as 11 milliseconds and the mean percent correct score was as low as 29% as compared to the healthy controls.¹¹ In a study by Bamiou et al¹² on patients with strokes affecting auditory processing, performance in both the DPT and GTN tests was significantly poorer in stroke patients than in control subjects. Bamiou et al reported that these tests of temporal processing have considerable diagnostic reliability in populations with central auditory disorders.¹² None of these previous studies have directly compared test performance based on the side of the stroke, although this may have been due to inadequate sample sizes. In the present study, which was performed on patients with a history of chronic stroke in the auditory cerebrum, auditory temporal processing was compared between patients with confirmed right-brain damage (RBD) due to stroke versus left-brain damage (LBD) due to stroke. The present study was designed to test the hypothesis that stroke patients would show deficits in auditory temporal processing that might differ between lateralized RBD and LBD patients. The second hypothesis tested was that older age is associated with declines in temporal processing ability for the studied groups.

Materials and Methods

Subjects

Three groups of subjects participated in the present study. The first group was composed of 25 normal control (NC) subjects (18 men; mean age: 50.52 ± 9.65 years, age range: 38-71 years). The second group included 25 poststroke subjects with confirmed unilateral ischemic RBD (19 men; mean age: 51.68 ± 10.18 years, age range: 36-68 years; 72% thrombotic stroke, 28% embolic stroke), and the third group included 20 poststroke subjects with confirmed unilateral ischemic LBD (14 men, mean age: 52.91 ± 9.74 years, age range: 36-67 years; 64% thrombotic stroke, 36% embolic stroke). All subjects were right-handed, monolingual native speakers of the Persian language without any background in music training, and with at least 9 years' formal academic education. All participants volunteered for the present study and met the institutional review board criteria for the enrollment of human subjects of the Iran

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