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Music as an Auditory Stimulus in Stroke Patients

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A B S T R A C T

Auditory stimulation increases mean blood flow velocity (MBFV) in the middle cerebral artery (MCA) in healthy individuals. Our aim was to monitor such changes in the affected MCA of patients with acute ischemic stroke (AIS). The study included 66 non-thrombolysed patients with AIS who were divided into groups according to National Institutes of Health Stroke Scale (NIHSS) score. Group I consisted of patients with NIHSS score ≤ 10 and group II with NIHSS score ≥11. Affected MCA was insonated with transcranial Doppler (TCD). MCA MBFVs were monitored during listening to music for 30 minutes. The first response of MBFV increase was measured as time (Tmax) and percentage of amplitude change (Amax). Pearson Chi-Square test was used. In 78.85% of patients there was a significant increase in MBFV compared to baseline values as a reaction to the music. There was no significant difference in Tmax or Amax between the two groups. However, a trend of longer Tmax was observed with every 2 NIHSS score increase. Music is an auditory stimulus in stroke patients and can be measured with TCD as MCA MBFV increase. Although our study showed no significant change of reaction time with the severity of stroke, a trend of prolonged Tmax was observed with NIHSS score increase.

Key words: *functional transcranial Doppler, Music, Stroke, Auditory stimulus*

Introduction

The psychological effects of music have been well established, including its ability to induce and modify cognitive states, moods and emotions. Obviously enough, there is a close relation between brain activity, metabolism and blood flow, thus any changes in blood flow velocities (BFV) in large basal cerebral arteries reflect changes in cognitive activity. Increase in cerebral BFV usually corresponds to an increase in cerebral metabolism due to brain activation through motor, sensory or cognitive tasks[1–3]. The relevant parameter for functional studies is a change in BFV that occurs when there is a switch from a resting state to one of cognitive activity. For more than two decades transcranial Doppler (TCD) has been used in the assessment of cerebral haemodynamics, but in recent studies researchers have also begun to explore its efficiency in the evaluation of mean blood flow velocity (MBFV) changes in vasomotor or stress tests as well as cognitive testing[4–9]. Apart of its noninvasiveness, the advantages of functional TCD (fTCD) are high temporal resolution enabling real time monitoring of blood flow changes and in combination with easy equipment transportation facilitate high accessibility. However, the correlation between music and brain function is one that has not been sufficiently explored yet, and hence it presents a challenge in modern neuroscience.

Several studies have shown that the perception of musical information involves both cerebral hemispheres in healthy individuals[10]. Different researchers described different brain hemisphere activation depending on musical education[11,12].

In our previous study we have determined the amplitude of change (8.16±6.77%) and time of reaction (9.34± 6.16%) for healthy individuals during auditory stimulation[10]. Yet, music stimulation recorded by means of TCD was never investigated on patients with neurovascular diseases. So far blood flow changes in stroke patients during rehabilitation were measured only by means of near-infrared spectroscopy[13]. Since stroke is neurological disease caused by compromised vessel perfusion the aim of our study was to monitor changes in mean blood flow velocity (MBFV) by means of TCD in the affected middle

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cerebral artery (MCA) during auditory stimulation in patients with acute ischemic stroke (AIS).

Material and Methods

We included 66 non-thrombolysed patients admitted to the hospital between November 2006 and January 2007, within 24 hours of the onset of AIS symptoms. Affected MCA was insonated by means of transcranial Doppler (TCD). Fourteen were excluded due to insufficient temporal bone window. The severity of stroke was assessed by National Institutes of Health Stroke Scale (NIHSS)[14]. Patients (24 female and 28 male) were divided into groups according to NIHSS score at the time of admission. Following the example of previous studies dealing with the dependance of stroke outcome on baseline NIHSS score[15], we chose a cutoff value of ten therefore group I consisted of patients with NIHSS score ≤10 (68±12.6yrs) and group II with NIHSS score ≥11 (71.5± 12.9yrs) (Table 1). None of the subjects showed impairment of auditory acuity. Informed consent was obtained from all subjects prior to their participation in the study.

Transcranial Doppler ultrasound was performed with a DWL MultiDop X4. One 2-MHz probe was attached to a headband and placed on the temporal bone window. The MCA was identified and insonated in all patients at the depth of 52 mm. The best signal, with maximum velocity was obtained and recorded. Insonation and identification of the MCA was performed according to the previously established criteria[16].

The AIS patients were neurologically examined and the NIHSS score was taken at the time of their admission to the hospital. Examination of the response to music stimulation was performed in supine position in a darkened room with a minimum of acoustical stimulation coming from the surroundings. After a 10 min relaxation to allow blood pressure and heart rate to stabilize the patients were instructed not to speak, move or chew during the examination and the headband with the probe and the earphones were placed. Baseline TCD was recorded without acoustical stimulation. The TCD examination was performed once, on the first day after the patient's admission, as part of a continuing musical stimulation study. We began recording the affected MCA. The instrumental relaxing music (Mozart sonatas) was presented to the patients. The musical piece consisted of harmonic sounds and no language or singing, lasted for 30 min, and was presented in stereo with a commercially available portable CD player (First Austria) via earphones. Patients were not exposed to any acoustical feedback from the ultrasound signals. During the first minute of each cycle (baseline, music, rest) the registration of MBFVs was performed every 5 seconds whereby relative MBFV was calculated for these 5 seconds using the Fast Fourrier transformation. Afterwards registration was performed every 20 seconds. Finally, after the 30 minute music stimulation, MBFVs in the MCA were recorded during the following minute of acoustic relaxation.

MBVF was calculated for the first 2 min during the baseline measurement according to the formula:

$$MBFV = \Sigma\ BFV\ (t)/n$$

in which n is the number of either 5 or 20 second cycles. This value is defined as relative blood flow value (RBFV) = 0%. All values taken during the measurement were put in relation to that blood flow velocity with the formula:

$$RBFV = (BFV(t)\text{-}MBFV)/MBFV*100$$

so that RBFV is expressed as a change in percentage (Δ%). A typical curve was obtained and the first response of MBFV increase was measured as time (Tmax) and percentage of change in amplitude (Amax). The graphical illustration of mentioned changes can be seen in Figure 1.

A change of 5% or more in amplitude was considered significant. Data were analyzed by means of non-parametric methods. Pearsons Chi-Square test was used to

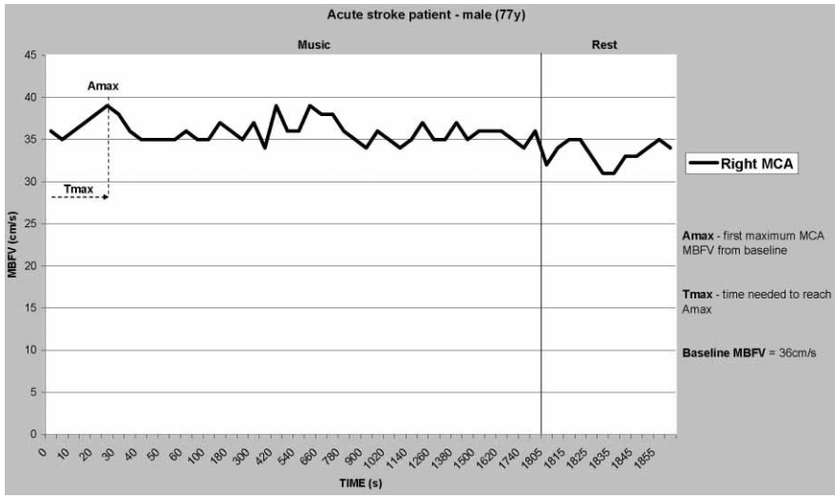

Fig. 1. Changes in middle cerebral artery (MCA) activation indexes in male patient with acute ischemic stroke.

reveal differences between the groups as a reaction to music. P-values were not corrected due to the descriptive character of the study. A p-value of 0.05 or less was considered significant.

Results

Out of 66 non-thrombolysed patients admitted to the hospital in this period, fourteen had to be excluded due to insufficient temporal bone window. The mean age of included subjects was 68.75±12.91 years (range 27 to 91 years). Our patients (24 female and 28 male) were divided into two groups according to NIHSS score at the time of admission, ranging from 2 to 19 (Table 1). Group I consisted of patients with NIHSS score 0–10 and group II 11–19. In 78.85% of patients there was a significant increase in MBFV, as a reaction to the music, compared to baseline values. In group I Tmax was 15.83±7.20s and in group II was 16.50±8.60s. Amax in group I was 10.95± 8.89% and in group II was 10.45±5.65%. There was no statistically significant difference in Tmax (p=0.269) or Amax (p=0.398) between the two groups. These results are shown in Table 2. However, a trend of longer Tmax was observed with every 2 NIHSS score increase, as shown in Table 3. During 30 minutes of auditory stimulation the MCA MBFVs fluctuated but generally remained above baseline values. This curve can be seen in Figure 1. After the music stimulation and during the period of rest, within the first 30 seconds 59.62% of listeners had a significant decrease in MCA MBFVs. After the initial decrease, the MBFVs gradually rose up to baseline values and entered a steady state.

TABLE 1
THE DISTRIBUTION OF PATIENTS IN EACH GROUP

		NIHSS score ≤10 Group I	NIHSS score ≥11 Group II	Total
Number of patients		31	21	52
Gender	Female	12	12	24
	Male	19	9	28
Age	≤65 years	15	6	21
	>65 years	16	15	30
Afected MCA	Right	15	9	24
	Left	16	12	28

MCA – middle cerebral artery

TABLE 2
DIFFERENCE IN MIDDLE CEREBRAL ARTERY (MCA) ACTIVATION INDEXES BETWEEN ACUTE STROKE PATIENTS ACCORDING TO NIHSS SCORE

	NIHSS score ≤10 Group I	NIHSS score ≥11 Group II	p
Amax (%)	10.95±8.89	10.45±5.65	0.269
Tmax (s)	15.83±7.20	16.50±8.60	0.398

Amax – first maximum middle cerebral artery mean blood flow velocity from baseline Tmax – time needed to reach Amax, statistically significant difference (p<0.05)

TABLE 3
DIFFERENCE IN MIDDLE CEREBRAL ARTERY (MCA) ACTIVATION INDEXES BETWEEN PATIENTS EVERY 2 NIHSS SCORE INCREASE

NIHSS score	Amax (%)	Tmax(s)
0–2	7.70±4.80	12.50±5.24
3–4	11.41±5.26	16.67±9.57
5–6	13.48±13.58	18.75±9.54
7–8	11.63±8.45	15.00±6.55
9–10	9.50±7.15	14.17±4.92
11–12	11.25±5.87	20.00±10.80
13–14	13.30±5.54	11.00±5.16
15–16	12.74±4.43	22.00±7.58
16–19	11.23±11.72	22.50±3.54

Amax – first maximum middle cerebral artery mean blood flow velocity from baseline Tmax – time needed to reach Amax

Discussion

The results of our study show that music is an auditory stimulus in stroke patients. In 78.85% of patients there was a significant increase in MBFV in MCA compared to baseline values as a reaction to the music, with the same reaction curve reported in healthy individuals[10–12,17–19]. This concurs with results of Saitou et al. who reported that listening to music, as a passive mental task during rehabilitation of post stroke patients, has an effect on cerebral activation, thus inducing changes in cerebral haemodynamic measured by near-infrared spectroscopy[13]. In comparison to our previously published data on music as an auditory stimulus in healthy individuals, the AIS patients showed prolonged response. Healthy individuals had a Tmax of 9.34±6.16 seconds in comparison to AIS patients who had Tmax of 15.87±7.72 seconds[10]. Considering our previously published study done on healthy individuals and the comparison of their Tmax with the Tmax observed in our AIS patients we were expecting to see an increase of reaction time to music with the progression of stroke severity. However, we found no statistically significant difference in reaction time and percentage of change in amplitude between patients with strokes of different severity. Although we did observe a trend of longer Tmax with every 2 NIHSS score increase. A larger sample size would quite possibly prove a significant Tmax increase between AIS patients with milder and those with more severe forms of stroke. Our division of patients into only two groups (mild and severe stroke) was apparently inappropriate due to the fact that more severe stroke correlates with greater brain tissue damage and probably a greater dysfunction of vasoreaction to musical stimuli, thus a more gradual gradation would prove to be more efficient. In our cur-

rent study such a division did not seem suitable since that would leave us with groups consisting of too few individuals for an appropriate statistical analysis. Further studies on larger groups are needed to investigate music response. There was no difference in percentage of change in amplitude between stroke patients and healthy individuals[10]. Other published studies deal with music as an auditory stimulus in healthy individuals, some studies suggesting right hemisphere dominance for nonmusicians and possible left hemispheric dominance for musicians while the others observed a bilateral increase of MBFV in both hemispheres[11,17,18]. Some studies analyzed the influence of musical features of different musical tasks[19].

We did show that nearly 80% of stroke patients, regardless of their NIHSS score, had a significant response to music in terms of MBFV increase which proves that their vasoreactivity was not so impaired that it could not be activated by an appropriate stimulus. This goes to prove that listening to music could be a helpful tool in neurorehabilitation of patients with AIS.

Our study has shown that reaction to auditory stimuli can be measured non-invasively by means of TCD as MCA MBFV increase. Since AIS patients have the same reaction curve as healthy individuals, in terms of activation and acceleration of MBFV as a response to auditory stimuli, using TCD to measure cerebral circulation has many advantages. Compared to conventional methods such as fMRI or single photon emission CT, the advantages of TCD include real time non-invasiveness and bed-side monitoring. TCD monitoring, thus, enables follow-up of the recovery process of stroke, and can be helpful in prediction of patients' outcome.

In conclusion, music is an auditory stimulus in acute stroke patients. It improves cerebral haemodynamic, which can be monitored non-invasively by means of TCD. Furthermore our results lead us to believe that music stimulation can be an effective tool in neurorehabilitation of stroke patients.

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MUZIKA KAO SLUŠNI PODRAŽAJ U BOLESNIKA S MOŽDANIM UDAROM

SAŽETAK

Slušna stimulacija povećava srednje vrijednosti strujanja krvi (SBSK) u arteriji cerebri mediji (ACM) kod zdravih pojedinaca. Naš je cilj bio praćenje tih promjena u zahvaćenoj ACM kod pacijenata s akutnim ishemijskim moždanim udarom (AIS). U našu su studiju bila uključena 66 netrombolizirana pacijenta s AIS koji su potom bili podijeljeni u dvije skupine s obzirom na njihov National Institutes of Health Stroke Scale (NIHSS) rezultat. U zahvaćenoj ACM pratili smo SBSK transkranijskim kolor Dopplerom (TCD). Skupina I sastojala se od bolesnika s NIHSS rezultatom ≤10 a skupina II imala je NIHSS rezultat ≥11. Mjerili smo SBSK u ACM za vrijeme slušanja muzike u trajanju od 30 minuta. Mjerili smo vrijeme (Tmax) i postotak promjene amplitude (Amax) prvog maksimalnog odgovora SBSK u ACM. Za

statističku analizu koristili smo Pearson Chi-Square test. U 78.85% bolesnika primijetili smo značajan porast u SBSK u usporedbi sa osnovnim vrijednostima. Nismo našli statistički značajnu razliku ni u Tmax ni u Amax između te dvije skupine. Ipak, primijetili smo trend produljenja Tmax za svaka dva boda na NIHSS ljestvici. Muzika djeluje kao slušna stimulacija u bolesnika s moždanim udarom što je moguće mjeriti TCDom kao porast SBSK u ACM. Iako naša studija nije pokazala statistički značajnu promjenu vremena reakcije sa težinom simptoma moždanog udara, primijetili smo trend produljenja vremena reakcije na muziku s porastom NIHSS rezultata.