International Journal of Prenatal & Life Sciences
in search of meaning
ISSN: 2945-011X
DOI: 10.24946/IJPLS
WOMBING PEACE

Publication Date: 12 May 2023
DOI: 10.24946/IJPLS/202312205
International Journal of Prenatal & Life Sciences, ISSN: 2945-011X, DOI: 10.24946/IJPLS

Change In Middle Cerebral Artery Pulsatility Index Over Time Due To Fetal Response To Defined Sound Stimulation:

Human fetal responses to airborne sound stimulation

Authors: Ljiljana Jeličić[1,2], Svetlana Janković[3,4], Mirjana Sovilj[2], Miško Subotić[1]

[1]Cognitive Neuroscience Department, Research and Development Institute "Life Activities Advancement Institute", Belgrade 11000, Serbia; lj.jelicic@add-for-life.com (Lj.J.); m.subotic@add-for-life.com (M.S.)
[2]Department of Speech, Language and Hearing Sciences, Institute for Experimental Phonetics and Speech Pathology, Belgrade 11000, Serbia; m.sovilj@iefpg.org.rs
[3]Department of Acute Perinatal Pathology, Belgrade University Medical School, Belgrade 11000, Serbia; svetlanajankovic.r@gmail.com
[4]Clinic for Gynecology and Obstetrics Narodni front Belgrade, Belgrade 11000, Serbia
Correspondence: Ljiljana Jeličić, email: lilijen@ymail.com

Abstract

The estimation of fetal reactions to different stimuli indicates the cortical structure's development and maturity. Recent studies pointed out that Pulsatility index (PI) changes could be associated with auditory stimulation.

Each reaction to a particular stimulus has time dynamics which include: the period before the stimulus, the period during and immediately after the stimulus, the period of response and reaction to the stimulus, and the period of returning to the state of rest. Bearing in mind this principle, the preliminary results of the analysis of PI changes measured in the middle cerebral artery (MCA) as a fetal reaction to a defined sound stimulus are given in the paper. The study was conducted at the Clinic for Gynecology and Obstetrics "Narodni front" in Belgrade, Serbia. The research sample included 5 women with no-risk pregnancies. The PI measuring in fetal MCA was conducted in the period between the 31th and the 32nd week of gestation.

The results indicate the time dynamics of PI change exist and point to the necessity of a different approach to PI measurement in the conditions of defined sound stimulation, concerning the procedures described so far in the literature.

Key words: Pulsatility index, time dynamics, sound stimulus, fetal reaction**,** fetal middle cerebral artery

Introduction

The development of auditory and other perceptions and reactions to higher nervous activity is conditioned by factors of maturation and experience. Auditory perception is the process by which an organism detects, distinguishes, interprets, and responds to sound stimuli (Kristal, 1996).

The hearing mechanism consists of the auditory mechanism, the auditory nervous system, and the auditory areas in the cortex of the brain. The hearing mechanism, as one of the most sensitive sensory organs of man at the same time, transforms the acoustic signal into neural impulses, and from that point, an acoustic signal is not acting under the laws of acoustics but under the laws of neurophysiology (Jovičić, 1999).

It can be assumed that an early prenatal perception of sensory stimuli is carried out by the auditory together with the somatosensory and vestibular systems (Blum, 1991). During the period of prenatal development, it is characteristic that the fetus lives in a stimulating environment of sounds, vibrations, and movements, despite a series of concentric barriers that protect it from the outside world: amniotic fluid, embryonic membranes, the uterus, and the mother's stomach. Many studies have confirmed that the voice is passed through the womb before they are defeated by background noise produced by the mother and the placenta. Intonation patterns of height, accent, and rhythm like music reach the fetus without significant distortion. The mother's voice is especially powerful because it is transferred to the uterus through her body, reaching the fetus in a stronger form than outside sounds (Lecanuet, Granier-Deferre, Jacquet, Capponi & Ledru, 1993). Besides the mother's voice, there are other internal noises produced by the rich and varied tonal and rhythmic sounds of the environment (Abrams, 1995). Internal noise includes the mother's breathing, cardiovascular and intestinal activity, physical movements, fetal cardiovascular pulsation, and vibration of very low frequencies (below 50 Hz). However, it was nevertheless found that the uterus is a relatively quiet place (Deliege & Sloboda, 1996), and comparable with what we have experienced in our surroundings, between 50 and 60 dB. Also, it is important to note that the uterus may weaken the sound up to 70 dB, although recent research suggests that most of the sounds from the immediate maternal environment come to the fetus at a reduced intensity of about 30-35 dB (Logan, 1995). In fact, the sounds of lower frequencies that pass through the mother's abdomen and uterine wall, come to the fetus without significant loss in intensity. Sounds of high frequencies around 4000 Hz suffer a loss of intensity up to 10 dB (Richards, Frentzen, Gerhardt, McCann & Abrams, 1992), while for the sounds of the high-frequency domain (10 kHz), this loss increases to 35 dB (Lecanuet, 1996).

Alfred Tomatis develops the thesis that the fetus hears in the fourth month of prenatal life (Tomatis, 1981). This is a period when the prenatal child begins to perceive the acoustic environment in the uterus through intense listening, not only by the developed auditory system but also by the somatosensory and vestibular systems (Blum, 1991). Research in the field of fetal auditory perception indicates that it develops in the period between 16 and 24 weeks of gestation (Bindman, Lippold, 1981; Pujol, Lavigne-Revilard & Uziel, 1990; Lecanuet, 1996; Bronson, 1982; Lecaneut and Schaal, 1996). The hearing threshold from 27 to 29 weeks of gestation is about 40 dB and decreases to almost 13.5 dB at 42 weeks of gestation, indicating continuing maturation of auditory pathways (Lary, Briassoulis, De Vries, Dubowitz &, Dubowitz, 1985).

The cochlea plays a key role in the sense of hearing and participates in the process of auditory transduction. Cochlear ear structures begin to function until the 20th week of gestation, and mature synapses are observed between the 24th and 28th weeks of gestation. More precisely, although the cochlea is not fully mature functionally in the 20th week of gestation, the fetal hearing is fully functional in the last trimester of pregnancy. The auditory system, which begins to develop around the 20th gestational week, continues to specialize during the postnatal period, until 2 years of age, with the acquisition of abilities such as sound detection, discrimination, and localization (Moore, Ponton, Eggermont, Wu, and Huang, 1996).

These findings indicate the complexity of hearing, giving support to the idea that receptive hearing begins with skin and skeletal development, and that the skin becomes a multi-receptive organ integrating input from vibration, thermal receptors, and pain receptors. The original hearing system is then amplified with the vestibular and cochlear information as it becomes available. Hearing is obviously the main information channel, which functions around 24 weeks before birth.

Examining the maturity of the fetal auditory system may be crucial as it may indicate the auditory potential necessary for speech and language development (Jeličić et al., 2020). The method of prenatal hearing screening (PHS) was developed and applied by Sovilj and Ljubic in 1992 (Sovilj, Ljubi, and Milenković, 1992) with the aim of estimating fetal auditory perception. The PHS method is based on measuring the Pulsatility Index (PI) before and after defined auditory stimulation (Jeličić Dobrijević et al., 2009). The application of the PHS gave reliable findings with regard to fetal auditory reactions (Jeličić Dobrijević et al., 2009; Plesinac et al., 2013; Jankovic-Raznatovic et al., 2014; Jeličić et al., 2020), revealing a potential for a reliable prenatal hearing screening test.

On the other hand, each reaction to a particular stimulus has time dynamics, which include the following: the period before the stimulus, the period during and immediately after the stimulus, the period of response and reaction to the stimulus, and the period of returning to the state of rest. Bearing in mind this principle, the research aim was to analyse the PI changes over time measured in the middle cerebral artery (MCA) due to fetal response to defined sound stimulation.

Methods

The study was conducted at the Clinic for Gynecology and Obstetrics "Narodni front" in Belgrade, Serbia. This study was part of a larger experimental study conducted under the supervision of the Ministry of education and health of the Republic of Serbia during the period from 2011 until 2019. The research sample included 5 women with no-risk pregnancies. The PI measuring in fetal MCA was conducted in the period between the 31^{th} and the 32^{nd} week of gestation.

Procedure of Prenatal Hearing Screening comprises:

- Creation of documentation and taking heteroanamnestic data.
- Procedure of standard ultrasound examination.
- Placing antiphones on pregnant woman's ears in order to exclude the influence of sound stimulus via the mother's auditory system.
- Determining the position of the fetus' head.
- Determining the auricle of a fetus, turned towards the mother's abdomen.
- Placing loudspeakers according to the vertical axis, 5 cm from the pregnant abdomen, in the direction of the fetus' ear.
- Positioning of fetal middle cerebral artery (MCA).
- Reading basic values of Pulsatility index (PI).
- Generating of digitalized defined sound stimulus.
- Reading peak values of Pulsatility index (PI).
- Measuring time needed for Pulsatility index (PI) to return to basic value.

The PHS is applied during the period from 27 to 31 gestation weeks. A defined sound stimulus is a digitally generated sound with an intensity of 90 dB, a frequency range of 1500–4500 Hz, and a duration of 0.2 seconds (click). It is applied by MIMS-GENERATOR SOUND STIMULANT (production by Inkomark, Belgrade, Serbia; Patent No. P 2010/0519) developed at the Institute for Experimental Phonetics and Speech Pathology in Belgrade.

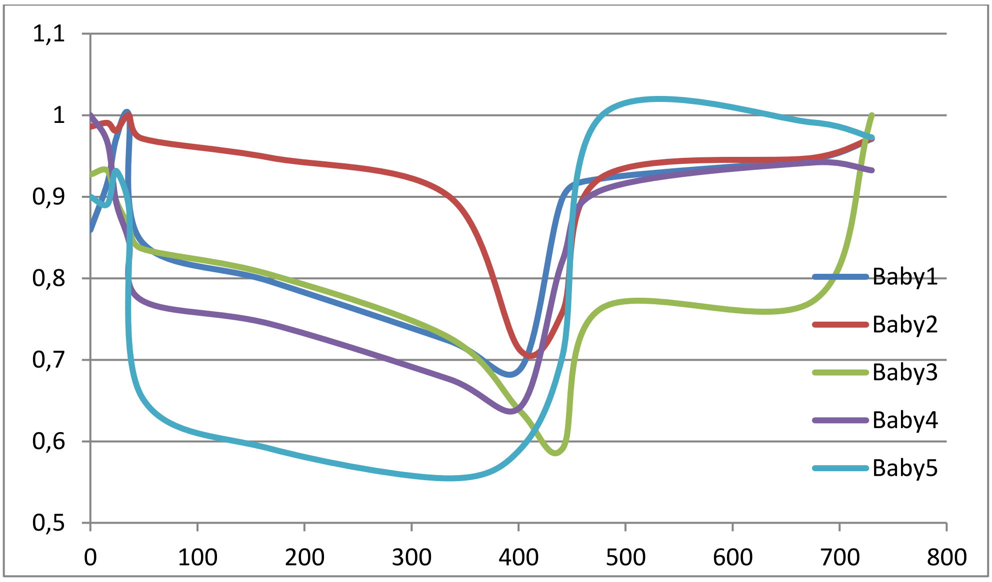
PHS examines circulation changes that are registered in the middle cerebral artery (MCA). Measuring the changes in cerebral blood flow is performed on a Doppler ultrasound apparatus with a convex and sector probe at a frequency of 3.5MHz. The Doppler wave analysis in the observed arteries is performed by registering the values of the Pulsatility index – Pi = (S-D)/M (Gosling, 1975). A decrease or increase of PI in the ACM, which indicates peripheral vascular resistance (Evans, 1980), points to an increase or decrease in blood flow in the observed blood vessel. PI values were measured at the state of rest-PI basic (PIB) and following auditory stimulation-PI reactions (PIR).

The complete study protocol had been approved by the Ethics Committee of the Clinic for Gynecology and Obstetrics "Narodni Front" (Date: 9 February 2012, No 1/12), in Belgrade which operates in accordance with the Ethical Principles in medical research involving human subjects, established by Declaration of Helsinki 2013. Written informed consent was obtained from all participants.

Results

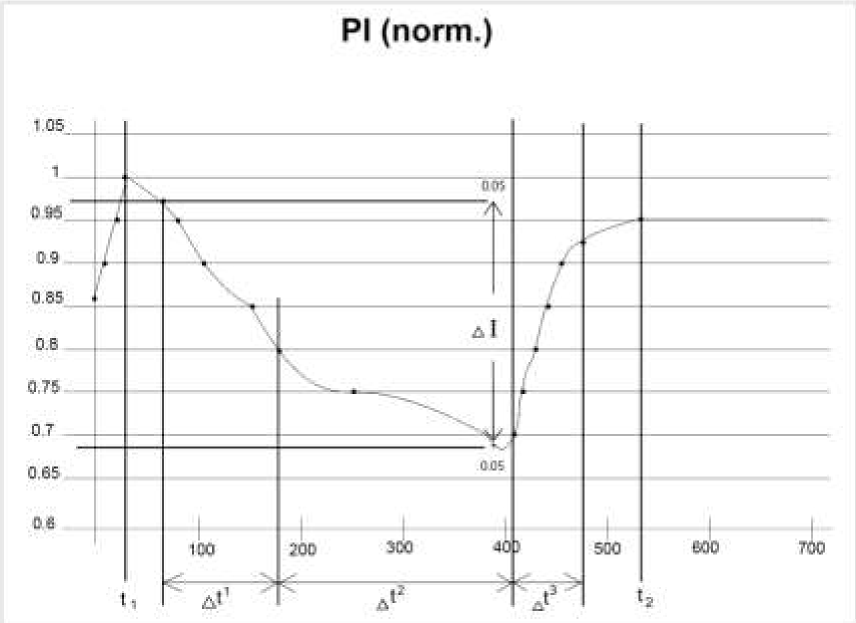
The obtained results of PI measurements on a sample of 5 babies, immediately before, during, and after the application of a defined sound stimulus are shown in Figure 1.

Figure 1. Change the PI on time for each baby individually.



The following significant time moments to pay attention to (Figure 2) are observed: the time before stimulation; time from stimulation to fetal response; time from the onset of Pulsatility index change (10% change) to the moment of PI change stabilization (90%); time of stable PI level; time of PI change from 90% to 10%.

Figure 2. The change in the normalized mean PI value over time.



Information that may be relevant is the relative change in PI calculated between the initial baseline PI and the maximum change in PI (90%) as well as the difference in baseline PIs before stimulation and after return to equilibrium.

Discussion

The importance of estimating fetal reactions to various stimuli can be defined by the fact that the obtained results indicate the cortical structure's development and maturity, and also the maturity of cortical sensory pathways. The estimation of PI changes in MCA due to auditory stimulation gave some reliable findings regarding fetal auditory reactions. Accordingly, these studies pointed out that Pulsatility index (PI) changes could be associated with auditory stimulation (Jeličić Dobrijević et al., 2009; Plesinac et al., 2013; Jankovic-Raznatovic et al., 2014; Jeličić et al., 2020).

Each reaction to a particular stimulus has a time dynamics in which it can be recognized: the period before the stimulus, the period during and immediately after the stimulus, the period of response and reaction to the stimulus, and the period of returning to rest. In that sense, the research aim was to analyse the PI changes over time measured in the middle cerebral artery (MCA) due to fetal response to defined sound stimulation. Our preliminary research results in this pilot study confirm the fact about the time dynamics of the reaction to a particular stimulus. Measurements conducted in this way would give a much clearer picture of the temporal dynamics of the fetal response to the auditory stimulus.

Figure 1 shows an example. It is clear that each baby has its own unique reaction dynamics, reflecting the physiological and cognitive characteristics of the baby.

Standardization of different temporal and intensity parameters (Figure 2) would enable the definition of the limits of a typical reaction in relation to the gestational week as well as the limits beyond which the reaction would be considered atypical and indicate deviations in the auditory perception of the fetus. Further research will show which of the proposed parameters has the highest discriminant value and potential quality for use for diagnostic purposes.

Conclusions

Changes in PI values due to defined auditory stimulation may be observed as complex values that allow examination of fetal auditory perception. Time dynamics of PI change exist and point to the necessity of a different approach to PI measurement in the conditions of defined sound stimulation, concerning the procedures described so far in the literature.

Author's note: LJ and MSo are working members and management committee members of COST Action CA18211: DEVoTION: Perinatal Mental Health and Birth-Related Trauma: Maximizing best practice and optimal outcomes. This paper contributes to the EU COST Action 18211: DEVoTION.

Funding: This work was partially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia within the project "Influence of psychophysiological, sociological, and cultural factors on speech and language in the child population". This project is realized in cooperation with the Faculty of Medical Sciences, University of Kragujevac, Serbia.

References

1. Kristal, D., & Terić, G. (1996). Kembrička enciklopedija jezika. Nolit. (In Serbian).
2. Jovičić, S. (1999). Speech communication: physiology, psychoacoustic and perception. Nauka izdavačko preduzeće, Beograd. (In Serbian).
3. Lecanuet, J.P., Granier-Deferre, C., Jacquet, A.Z., Capponi, I., Ledru, L. (1993). Prenatal discrimation of male and female voice uttering the same sentence. Early Devel Parenting; 2; 217-228.
4. Abrams, R.M. (1995). Perception and cognition of music. In: Deliege I & Sloboda JA (Eds), Philadelphia, PA: Psychology Press;. p. 83-101.
5. Deliege, I., Sloboda J. (1996). (Eds.) Musical beginnings, Oxford University Press.
6. Logan, B. (1995). Fetal Sonic Stimulation. In The Royal College of General Practitioners, Official Reference Book- London.
7. Richards, D.S., Frentzen, B., Gerhardt, K.J., McCann, M.E., Abrams, R.M. (1992). Sound levels in the human uterus. Obstetrics and Gynecology; 80; 186-190.
8. Lecanuet, J.P. (1996). Prenatal auditory experience. In: Deliege I, Sloboda JA, (Eds), Musical Beginnings. Oxford University Press.
9. Tomatis, A. (1981). La Nuit Uterine. Editions Stock, Paris.
10. Blum, T. (1991). Early Prenatal Perception and Adequate Auditive Stimulation, Int. J. Prenatal and Perinatal Studies; 283-296.
11. Bindman, L., Lippold, O. (1981). The Neurophysiology of the Cerebral Cortex. New York: Raven Press.
12. Pujol, R., Lavigne-Revillard, M., Uziel, A. (1990). Physiological correlates of development of the human cochlear. Seminars in Perinatology; 14; 275-280.
13. Lecanuet, J.P. (1996). Prenatal auditory experience. In: Deliege I, Sloboda JA, (Eds), Musical Beginnings. Oxford University Press.
14. Bronson, G.W. (1982). Psychobiology of the Human Newborn. In: Stratton P (Eds), John Wiley and Sons, Ltd.
15. Lecanuet, J.P., Schaal, B. (1996). Fetal sensory competencies. European Journal of Obstetrics & Gynecology and Reproductive Biology; 68; p.1 – 23.
16. Lary, S., Briassoulis, G., De Vries, L., Dubowitz, L.M., Dubowitz, V. (1985). Hearing Threshold in Preterm and Term Infants by Auditory Brainstem Response. Journal of Pediatry; 107; 593-599.

17. Moore JK, Ponton CW, Eggermont JJ, Wu BJ, Huang JQ. Perinatal maturation of the auditory brain stem response: changes in path length and conduction velocity. Ear Hear. 1996;17(5):411-8.
18. Jeličić, L., Janković, S., Sovilj, M., Adamović, T., Bogavac, I., Gavrilović, A., & Subotić, M. (2020). Fetal Middle Cerebral Artery Pulsatility Index in No-Risk Pregnancies: Effects of Auditory Stimulation and Pregnancy Order. International Journal of Molecular Sciences, 21(11), 3855.
19. Sovilj, M.; Ljubic, A.;, Milenkovic, V.; Djokovic, S. Possibilities of prenatal examination of reactions on acoustical stimulation of fetuses with congenital infections. Proceedings of the 10th Symposium of Perinatal Medicine of Serbian Medical Society, Belgrade, Serbia, **1992**, 17-18.
20. J Dobrijević, Lj.; Ljubić, A.; Sovilj, M.; Ribarić-Jankes, K.; Miković, Ž.; Cerović, N. Changes in Doppler blood flow velocity in middle cerebral artery in response to airborne sound in low- and high-risk human fetuses. Int J Pediatr Otorhinolaryngol 2009, 73, 1381–1384.
21. Plesinac, S.; Jankovic, S.; Plecas, D.; Antonovic, O.; Adamovic, T.; Sovilj, M. Change of Pulsatility Index of the fetal middle cerebral artery after auditory stimulation in no risk pregnancies and in pregnancies with gestational hypertension. Clin Exp Hypertens 2013, 35, 628-631.
22. Jankovic-Raznatovic, S.; Dragojevic-Dikic, S.; Rakic, S.; Nikolic, B.; Plesinac, S.; Tasic, L.; Perisic, Z.; Sovilj, M.; Adamovic, T.; Koruga, Dj. Fetus sound stimulation: cilia memristor effect of signal transduction. BioMed Res Internat 2014, Article ID 273932, DOI:10.1155/2014/273932.
23. Gosling, R. G., & King, D. H. (1975). Ultrasound angiology. Arteries and veins, 1, 61-71.
24. Evans, D. H., Barrie, W. W., Asher, M. J., Bently, S., Bell, P. R. F. (1980). The relationship between ultrasonic pulsatility index and proximal arterial stenosis in a canine model. Cir res, 46, 470-5.