Utilizing Infant Cry Acoustics to Determine Gestational Age

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Summary: Objectives/Hypothesis. The date of last menstruation period and ultrasonography are the most commonly used methods to determine gestational age (GA). However, if these data are not clear, some scoring systems performed after birth can be used. New Ballard Score (NBS) is a commonly used method in estimation of GA. Cry sound may reflect the developmental integrity of the infant. The aim of this study was to evaluate the connection between the infants' GA and some acoustic parameters of the infant cry.

Study Design. A prospective single-blind study was carried out.

Methods. In this prospective study, medically stable infants without any congenital craniofacial anomalies were evaluated. During routine blood sampling, cry sounds were recorded and acoustic analysis was performed. Step-by-step multiple linear regression analysis was performed.

Results. The data of 116 infants (57 female, 59 male) with the known GA (34.6 ± 3.8 weeks) were evaluated and with Apgar score of higher than 5. The real GA was significantly and well correlated with the estimated GA according to the NBS, F0, Int, Jitt, and latency parameters. The obtained stepwise linear regression analysis model was formulized as $GA = (31.169) - (0.020 \times F0) + (0.286 \times GA\ according\ to\ NBS) - (0.003 \times Latency) + (0.108 \times Int) - (0.367 \times Jitt)$. The real GA could be determined with a ratio of 91.7% using this model.

Conclusions. We have determined that after addition of F0, Int, Jitt, and latency to NBS, the power of GA estimation would be increased. This simple formula can be used to determine GA in clinical practice but validity of such prediction formulas needs to be further tested.

Key Words: Infant cry–Acoustic analysis–Cry analysis–Gestational age–New Ballard Score.

INTRODUCTION

Crying is the primary method of communication for infants to express their physical status. Infant cry is not just a simple reflex sound. It contains complex acoustic signals produced by combined proper interactions between central and peripheral nervous systems, respiratory system, larynx, acoustic tract, and motor activities of many muscles.[1] Studies of cry analysis in infants have had a fast and growing evolution. In particular, there has been a greater appreciation for the complexities of crying. Studies investigating the association of acoustic features of infant cry with the biological condition of infant have been performed since 1940s.[2,3] Easily recorded cry sound can be analyzed by widespreading voice analysis programs which will be achieved without difficulty in the future. In the studies of LaGasse et al (pain-induced cry) and Wermke et al (spontaneous cry) performed with this aim, it was reported that the acoustic cry characteristics of preterm infants or infants with neurological problems may be different from that of healthy term infants; so it has been stated that cry may reflect neuromuscular integrity and maturation of the infants.[4,5] Michelsson et al (pain-induced cry) determined that shorter gestational age (GA) was significantly associated with higher fundamental frequency and shorter total cry duration.[1]

The determination of GA at birth is of vital importance in terms of appropriate clinical and therapeutic approach, assessment of morbidity and mortality risks, and the accuracy of institutional and social infancy statistics.[6] In determination of GA, the most commonly benefited data are the date of last menstrual period (LMP) and the first trimester ultrasonography (USG) (obstetric estimation of gestation) findings. Many women can state the first day of their LMP but the reliability of this approach depends on a number of factors including the woman's accurate recall of the LMP, regularity of menstrual cycles, use of contraceptives or breastfeeding that could influence the timing of ovulation, and her sociocultural status. Because of such potential errors, estimation of GA based on LMP is considered to be not reliable enough.[7] Although, estimating GA by prenatal USG is considered to be more reliable than LMP, USG dating may not always take into consideration biological variations of fetal growth and length of pregnancy. Some factors such as maternal malnutrition and intrauterine growth restriction reduce the reliability of USG. It was stated that USG examination provides a younger estimate of GA than that of estimated by the LMP.[8] Especially, low socioeconomic status may result in: not to know the date of LMP, inadequate prenatal follow-up, and late enrollment for antenatal care.[9] Absence of prenatal follow-up and uncertainty of LMP are two negative common grim realities in developing countries (like us) where prenatal care is usually inadequate which makes infant management more difficult. If appropriate prenatal USG is absent or LMP is not known, after delivery in estimation of GA, some subjective scoring systems such as Dubowitz, Farr, New Ballard Score (NBS), and Eregie depending on the data obtained by the physical and neurological examinations of infants may be beneficial.[6,7,9] NBS is a commonly used technique of GA assessment. NBS uses seven physical

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and six neurological criteria obtained by the physical examination of infants; sum of all criteria (total score) is then extrapolated to the GA by use of a maturity rating sheet. NBS relies on the intrauterine changes and maturation that the fetus undergoes during the pregnancy period. The neurological criteria depend mainly upon muscle tone and the physical criteria mainly rely on anatomical changes.[9,10] The NBS was reported as a valid and accurate gestational assessment tool for all infants. The strong correlation between NBS and USG/LMP was also reported.[10] Despite all, there is still no general consensus on USG examination criteria or a clinical formula employed to determine GA. Thus, possible systematic errors within studies will cause variations and mistakes.[7]

The current gold standards (USG and LMP) used to measure GA are not available always and they are sometimes inadequate; it's that acoustic parameters may be another "tool" in the "toolbox" as a means to provide a more accurate estimate of GA. The reports of LaGasse et al and Wermke et al provided us an insight as acoustic features of infant cry could supply additional measures while determining GA of infants as a noninvasive tool.[1,4,5]

Another rationale for the study is that when GA cannot be readily calculated via anthropometric measurements and physical examination, some other current methods (such as biochemical parameters in amniotic fluid, lens capsule vascularity) were studied to obtain "real" GA. However, these methods are invasive, compared to acoustic parameters.[11]

The aim of this study was to investigate the usability of acoustic cry analysis parameters together with NBS, that is one of the most commonly performed methods in this topic, in the estimation of GA of infants and to develop a method for clinical practice.

METHODS

Study design

This is a multidisciplinary, prospective study performed by the collaboration of ear-nose-throat diseases and newborn diseases clinics. The study was approved by the Clinical Investigations Ethics Committee (Decision No.: 13/2014; Decision date: 18 February 2014).

Patients

Mother and/or father of all patients included in the study were informed about the study in detail by the specialists of the subject, and the parents signed the informed consent forms comprehending the data about the procedures that will be performed during the study. After delivery in newborn unit, in the first 72 hours while they were with their mothers, a complete routine newborn physical examination and flexible fiberoptic laryngeal examination were performed to the patients having the required inclusion criteria. Prenatal and maternal histories of infants, known GA (KGA), gender, and birth weight were recorded. The inclusion criteria were as follows: regular follow-up during pregnancy and to know the exact GA, absence of congenital craniofacial anomalies, absence of any abnormal physical or neurological findings regarding infant's GA in first examination after delivery, to have an Apgar score of higher than 5 in the fifth minute after delivery, not to be intubated, and absence of any form of respiratory failure and laryngeal anomaly. Patients who were not stable medically, and who had severe hypoglycemia or hyperbilirubinemia requiring phototherapy in follow-up were not included in the study.

Estimation of GA by NBS

Three different experienced neonatologists in NBS assessment, who were blind for the clinical features of cases, independently examined the infants according to the NBS system and estimated GA was recorded. A universally declared ready score sheet was used to estimate GA using total NBS. This was stated as estimated GA in this study. The comment of criteria in the NBS system may vary depending on the evaluator. The compatibility between NBS evaluators was analyzed using Fleiss' kappa and intraclass correlation tests prior to the study and was determined as statistically significant (87%, $P = 0.01$).

Cry analysis

The cry sounds were recorded during routine blood sampling procedures to avoid causing additional discomfort. To diminish the environmental noise as much as possible, recordings were obtained during evening hours in separate, quiet examination rooms free of any background noise that could potentially confound acoustic variables.

Cry sounds were recorded by high-quality and 24-byte sound cards (Creative Audigy; Creative Labs Inc., Milpitas, California) and circular all-direction microphone (Shure SM48; Shure Inc.). The sounds were recorded by the same otolaryngologist who was experienced on this topic and blind to the patients. During sound recording, babies were lying on an open cradle on flat, supine position. During the records, the distance between the microphone and the mouth was approximately 15 cm. The sampling frequency of records was selected as 44,100 Hz and the resolution was set as 16 bytes. The recorded cry sounds were analyzed via Computerized Speech Lab (CSL; KayPENTAX CSL model 4500, Montvale, New Jersey) operating system. The cry sounds containing at least three crying signals and lasting for at least 10 seconds were included. After the latency time was measured, the analyses were performed after elimination of first seconds of parts at the beginning and at the end of the records to prevent the disorders on sounds. The five acoustic parameters analyzed in this study were as follows: mean fundamental frequency (Fo), jitter % (Jitt), shimmer % (Shim), noise-to-harmonic ratio (NHR), and Intensity (Int). As the temporal patterns of crying, latency in milliseconds (time period passed between the painful stimuli and the first signal of crying), total cry time (TCT) in seconds, and mean utterance duration time (MUDT) in milliseconds (the mean of standstill periods between crying signals) were determined manually.

Statistical analysis

The statistical analyses were performed with *Statistical Package for the Social Sciences (SPSS)*, Version 22.0 (IBM Corp, New York). To determine the power of sound analysis parameters together with NBS in estimation of GA, stepwise linear regression

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