END-TO-END CONVOLUTIONAL NEURAL NETWORK FOR AUTOMATIC ENCODING FACIAL DESCRIPTOR (N-CNN) IN THE DIAGNOSIS OF INTRAUTERINE DISTRESS

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ABSTRACT

Background. *Existing methods for studying intrauterine distress, despite their prevalence, still have their limitations, so studying and assessment of fetal movements during ultrasound diagnostics can become a convenient and affordable additional tool for diagnosing this pathological condition.*

The aim of the study. *To assess the prevalence and diagnostic significance of a known set of fetal facial movements for the timely determination of intrauterine distress.*

Methods. *This prospective single-center study included 225 fetuses of a gestational age from 32 to 40 weeks. The FIGO chart was used as fitting criteria of intrauterine distress. The assessment of facial movements in all fetuses was carried out using the BabyFACS technique, where the action unit (AU) used for the assessment; its coding is carried out in strict accordance with the chart of motor descriptors (MD). Statistical data processing was carried out using SPSS Statistics 20 (IBM Corp., USA). The Mann – Whitney test was used as the main statistical parameter, where a threshold level of 0.05 was chosen to interpret the p-tests value.*

Results. *Despite the occurrence of AU1, AU2, AU3, AU4 in both groups, these MDs were recorded in the group with confirmed distress (p = 0.00001). Facial units such as AU9 and AU20 were found only in children with intrauterine distress, which, in the total amount of the MD assessment, can be considered one of the main search signs that specialists should first of all pay attention to. All motor descriptors showed high positive predictive value and diagnostic sensitivity, with the highest results registered for AU9 and AU20.*

Conclusion. *Assessment of facial units during ultrasound diagnostics can be a convenient tool as an additional diagnosis of the development of intrauterine distress and requires further study.*

Key words: *ultrasound diagnostics, neonatology, motor descriptors, facial movements, intrauterine distress, fetuses*

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СКВОЗНАЯ СВЁРТОЧНАЯ НЕЙРОНАЛЬНАЯ СЕТЬ ДЛЯ АВТОМАТИЧЕСКОГО КОДИРОВАНИЯ ЛИЦЕВЫХ ДЕСКРИПТОВ (N-CNN) В ДИАГНОСТИКЕ ВНУТРИУТРОБНОГО ДИСТРЕССА

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РЕЗЮМЕ

Обоснование. *Существующие методы исследования внутриутробного дистресса, несмотря на свою распространённость, всё ещё имеют недостатки, поэтому изучение и оценка движений плода во время проведения ультразвуковой диагностики могут стать удобным и доступным дополнительным инструментом для диагностики данного патологического состояния.*

Цель исследования. *Оценка распространённости и диагностической значимости известной совокупности лицевых движений плода для своевременного определения внутриутробного дистресса.*

Методы. *В настоящее проспективное одноцентровое исследование были включены 225 плодов с гестационным возрастом от 32 до 40 недель. В качестве критериев соответствия внутриутробного дистресса использовалась таблица FIGO. Оценка лицевых движений у всех плодов проводилась с помощью методики BabyFACS, где для оценки использовалась двигательная единица (AU, action unit), кодировка которой проводится в строгом соответствии с таблицей двигательных дескрипторов (ДД). Статистическая обработка данных проводилась с использованием SPSS Statistics 20 (IBM Corp., США). В качестве основного статистического параметра был использован критерий Манна – Уитни, где для интерпретации значения p-тестов выбран пороговый уровень 0,05.*

Результаты. *Несмотря на встречаемость AU1, AU2, AU3, AU4 в обеих группах, данные ДД регистрировались в группе с подтверждённым дистрессом (p = 0,00001). Такие лицевые единицы, как AU9 и AU20, встречались только у детей с внутриутробным дистрессом, что в общей сумме оценки ДД можно считать одними из главных поисковых знаков, на которые в первую очередь следует обратить внимание специалистам. Все двигательные дескрипторы показали высокую прогностическую ценность положительного результата и диагностическую чувствительность, где самые высокие результаты зарегистрированы для AU9 и AU20.*

Заключение. *Оценка лицевых единиц при проведении ультразвуковой диагностики может быть удобным инструментом в качестве дополнительной диагностики развития внутриутробного дистресса и требует дальнейшего изучения.*

Ключевые слова: *ультразвуковая диагностика, неонатология, двигательные дескрипторы, лицевые движения, внутриутробный дистресс, плоды*

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OBJECTIVES

To date, in numerous studies, we can see the growing interest of the scientific community in understanding individual behavioral reactions based on the assessment of facial expressions, body and head movements, or sound signals [1–4].

Facial expression can give an idea of a person's emotional state, and automatic facial expression analysis is the subject of extensive research [5], however, this method cannot be fully used in both neonatology and perinatology for several good reasons. Firstly, facial expressions of infants and fetuses include additional important units that are not present in the standard coding system [6]. Secondly, such various individual parameters as gestational age significantly affect facial features in connection with the development of the central nervous system [6]. Thirdly, the processing stage in the case of newborns or fetuses is more complex and requires the use of existing experience, since these two groups do not allow establishing communicative contact.

Having some personal experience [7, 8] in evaluating facial movements in both infants and fetuses with different gestational ages, we decided to consider the prospects for evaluating facial movements during ultrasound examination as a possible predictor of fetal distress before cardiotocography (CTG).

Fetal distress is a syndrome of respiratory and circulatory insufficiency caused by fetal intrauterine hypoxia and is closely related to changes in fetal heart rate signals [9]. Early detection and possible diagnosis of the risk of developing this condition can help prevent damage to vital organs; that is why it is so important to strengthen monitoring of the fetal condition during pregnancy in order to ensure the safety of both the fetus and the pregnant woman.

The most common method of monitoring the condition of the fetus in clinical practice is CTG monitoring [10], where the received signal consists of a curve of heart rate (HR) and a curve of uterine contraction. CTG monitoring undoubtedly helps doctors diagnose this pathological condition in time to take effective therapeutic measures to protect the health of a fetus; in addition, this examination method is absolutely safe and painless. At the moment, CTG of a fetus in the absence of any disorders in a woman is carried out starting from the 32nd week about 2 times a month, while between these examinations women often undergo ultrasound research, and then modern technologies allow real-time monitoring of facial expressions and facial movements that the fetus demonstrates [11, 12].

Thus, the study of fetal facial movements and their sequence at the time of planned ultrasound diagnostics can in the future become a convenient and affordable additional tool that helps identify predictors of fetal distress even before CTG is performed.

THE AIM OF THE STUDY

To assess the prevalence and diagnostic significance of a known set of fetal facial movements for the timely determination of intrauterine distress.

METHODS

This prospective single-center study included 225 fetuses of a gestational age from 32 to 40 weeks, whose mothers underwent examinations and inpatient treatment at the Perinatal Center of the Voronezh Regional Clinical Hospital No. 1 from 2017 till 2021. All the patients were divided into two groups: group I (n = 125) – fetuses with a CTG–confirmed diagnosis of «intrauterine distress»; group II (n = 100) – fetuses without a CTG-confirmed diagnosis of «intrauterine distress» (control group). Study entry criteria: consent of legal representatives to participate in the study; regular obstetric examinations during pregnancy; conducting the presented complex of instrumental studies on the basis of the Perinatal Center; completeness and accuracy of records of clinical observation and results of instrumental studies; absence of severe fetal dentofacial anomalies that prevent visual assessment of facial movements. The FIGO chart was used as fitting criteria of intrauterine distress, which is included in the clinical recommendations of the Russian Society of Obstetricians and Gynecologists (ROAG) 2022, where at least one criterion of the following is required for confirmation: basal heart rate less than 100 or more than 170 bpm; variability less than 5 bpm in 40 minutes or sinusoidal rhythm; lack of acceleration; variable or late deceleration. Confirmation of fetal distress was also necessarily carried out after birth, when the following diagnostic criteria were considered: Apgar score < 7 points 5 minutes after birth; assessment of the acid-base state of umbilical cord blood (pH < 7.00 and base deficiency ≥ 12 mmol/l). The assessment of facial movements in all fetuses was carried out using the BabyFACS technique, where the action unit (AU) was used for the assessment; its coding is carried out in strict accordance with the chart of motor descriptors (MD): AU1 – inner corners of eyebrows are lifted; AU2 – outer corners of eyebrows are lifted; AU3 – inner corners of eyebrows are drawn together; AU4 – eyebrows are lowered; AU9 – wrinkled nose; AU12 – lip corners are pulled up; AU14 – dimples on cheeks; AU18 – wrinkled lips; AU20 – lips are stretched; AU25 – lips are parted; AU28 – lips are sucked in. Visualization of action units was carried out using an expert-class ultrasound diagnostic device by a medical specialist with mandatory fixation of photo and video materials for subsequent evaluation and creation of a database. The assessment of action units was carried out by a certified specialist who has been trained and has a FACS (Facial Action Coding System) certificate confirming it. Statistical data processing was carried out using SPSS Statistics 20 (IMB Corp., USA), the sample size for this study

was not pre-calculated. The main outcome of the study was the determination of the prevalence of facial units and their diagnostic significance in confirmed intrauterine distress, additional research outcomes – the compilation of summary tables for each of the variables of facial units in order to determine sensitivity, specificity and prognostic value. The Mann – Whitney test was used as the main statistical parameter; the threshold level of 0.05 was chosen to interpret the *p*-tests value. This study was conducted with the written permission of the administration of the medical organization and with the approval of the local ethics committee of Voronezh State Medical University named after N.N. Burdenko of the Ministry of Health of the Russian Federation (Protocol No. 1 dated March 28, 2019).

RESULTS

When assessing the prevalence of criteria for compliance with intrauterine distress according to the FIGO chart, it can be noted that according to CTG data the prevailing criteria are monotony of rhythm and variable deceleration, which were recorded in 100 % of cases; the prevalence of other criteria for compliance with the study group is presented in Table 1.

TABLE 1

PREVALENCE OF INTRAUTERINE DISTRESS CRITERIA ACCORDING TO THE FIGO CHART IN STUDY GROUP I

Analyzed criteria	The percentage of occurrence of the criterion, %
BHR = 110–170 bpm	1.6
BHR > 170 bpm	31.2
BHR < 110 bpm	67.2
Variable monotonous rhythm	100
Early decelerations > 50	36.0
Late decelerations > 30	64.0
Variable decelerations > 50	100

Note: BHR – Basal Heart Rate.

When assessing the frequency of facial movements in each of the study groups, it was revealed which of the MDs were statistically significantly more common in the group

TABLE 2

FREQUENCY OF OCCURRENCE OF MOTOR DESCRIPTORS IN EACH OF THE STUDY GROUPS

Motor descriptors	Frequency of occurrence of MDs in group I (*n* = 125), %	Frequency of occurrence of MDs in group II (*n* = 100), %	*p*
AU1	92	5	*p* = 0.00001
AU2	95.2	13	*p* = 0.00001
AU3	94.4	13	*p* = 0.00001
AU4	91.1	8	*p* = 0.00001
AU9	92.8	0	*p* = 0.00001
AU12	4.8	75	*p* = 0.00001
AU14	4	68	*p* = 0.00001
AU18	4	49	*p* = 0.00001
AU20	92	0	*p* = 0.00001
AU25	4	49	*p* = 0.00001
AU28	4	65	*p* = 0.00001

TABLE 3

DIAGNOSTIC SIGNIFICANCE OF MOTOR DESCRIPTORS AT BASAL HEART RATE < 100 BPM OR > 170 BPM ACCORDING TO CARDIOTOCOGRAPHY

Indicators	AU1	AU2	AU3	AU4	AU9	AU20
Diagnostic sensitivity	94.16 %	89.39 %	88.54 %	91.73 %	98.27 %	100 %
Diagnostic specificity	90.47 %	94.62 %	92.55 %	89.32 %	91.74 %	92.72 %
Positive predictive value	91.86 %	95.93 %	94.30 %	90.98 %	92.68 %	93.49 %
Diagnostic effectiveness of the test	92.44 %	91.55 %	90.22 %	90.62 %	95.11 %	96.44 %

TABLE 4

DIAGNOSTIC SIGNIFICANCE OF MOTOR DESCRIPTORS IN EARLY DECELERATIONS > 50 ACCORDING TO CARDIOTOCOGRAPHY

Indicators	AU1	AU2	AU3	AU4	AU9	AU20
Diagnostic sensitivity	36.66 %	32.57 %	30.53 %	31.40 %	62.93 %	36.52 %
Diagnostic specificity	99.04 %	97.84 %	94.68 %	94.17 %	98.16 %	97.27 %
Positive predictive value	97.77 %	95.55 %	88.88 %	86.36 %	97.33 %	93.33 %
Diagnostic effectiveness of the test	65.77 %	59.55 %	57.33 %	60.26 %	80 %	66.22 %

TABLE 5

DIAGNOSTIC SIGNIFICANCE OF MOTOR DESCRIPTORS IN LATE DECELERATIONS > 30 ACCORDING TO CARDIOTOCOGRAPHY

Indicators	AU1	AU2	AU3	AU4	AU9	AU20
Diagnostic sensitivity	62.5 %	60.60 %	62.59 %	64.46 %	66.37 %	66.95 %
Diagnostic specificity	91.42 %	95.69 %	97.87 %	94.17 %	93.57 %	93.63 %
Positive predictive value	89.28 %	95.23 %	97.61 %	92.85 %	91.66 %	91.66 %
Diagnostic effectiveness of the test	76 %	75.11 %	77.33 %	78.12 %	79.55 %	80 %

TABLE 6

DIAGNOSTIC SIGNIFICANCE OF MOTOR DESCRIPTORS FOR VARIABLE DECELERATIONS > 50 ACCORDING TO CARDIOTOCOGRAPHY

Indicators	AU1	AU2	AU3	AU4	AU9	AU20
Diagnostic sensitivity	95.83 %	90.15 %	90.07 %	93.38 %	100 %	100 %
Diagnostic specificity	90.47 %	93.54 %	92.55 %	89.32 %	91.74 %	90.90 %
Positive predictive value	92 %	95.19 %	94.39 %	91.12 %	92.80 %	92 %
Diagnostic effectiveness of the test	93.33 %	91.55 %	91.11 %	91.51 %	96 %	95.55 %

TABLE 7

ASSESSMENT OF THE COMBINED EFFECT OF ALL STUDIED PARAMETERS ON THE SEVERITY OF THE CONDITION

Groups	Means	95% CI		Standard deviation (%)	Min	Max	Q25	Median	Q75
Group I	0.38	0.36	0.40	0.10	0.07	0.47	0.33	0.33	0.47
Group II	0.20	0.19	0.20	0.02	0.00	0.20	0.20	0.20	0.20

Note. 95% CI – 95% confidence interval; Q25 – 25th percentile; Q75 – 75th percentile.

AU1 **AU2** **AU3** **AU4**

FIG. 1.

An example of ultrasound imaging of motor descriptors, which are significantly more common in fetal distress

with diagnosed intrauterine distress compared with the control group (Table 2).

Considering that the diagnosis of intrauterine distress requires confirmation by CTG, we evaluated the diagnostic sensitivity and specificity, the positive predictive value and the diagnostic effectiveness of MDs, which were statistically significantly more often recorded in the group with intrauterine distress, for each of the criteria of this pathological condition according to the FIGO chart (Tables 3–6). According to the analysis, AU9, AU20 and AU1 demonstrated the highest diagnostic sensitivity of all possible MDs.

To assess the combined effect of all the studied parameters, a total indicator of the severity of the condition was compiled, obtained by summing a proportionally weighted crossing of the threshold value: the average value in the control group is 0.2 ± 0.02, in group I – 0.38 ± 0.10 (Table 7).

DISCUSSION

Although advances in prenatal medicine allow treatment as early as the intrauterine period, the question of whether we can identify facial expression in general and, in particular, the expression of «distress» in the fetus is becoming increasingly important. Despite the fact that the experience of pain and distress is subjective and entails a psychological component, anatomical and functional development is necessarily associated with the perception of an irritant [9, 10].

Mimic «anxious» movements are important components of the development of the severity of distress in fetuses. In one of the studies, the neonatal facial coding system was used to describe in detail facial activity of premature infants from 24 to 36 weeks of pregnancy during painful procedures [11].

In our previous study, facial movements and their combinations, which we assessed as fundamental combinations of actions on the fetal face during confirmed distress, were diagnosed [12]. The basis of this study was to prove, using mathematical statistical models, that the listed facial movements are statistically significantly more common in fetuses with confirmed distress, thereby being early predictors of this condition.

When assessing the frequency of occurrence of motor descriptors, it was found that, despite the occurrence of AU1, AU2, AU3, AU4 (Fig. 1) in both groups, statistically significantly more often MD data were recorded in the group with confirmed distress ($p = 0.00001$). Facial units such as AU9 and AU20 were found only in children with intrauterine distress, which, in the total amount of the MD assessment, can be considered one of the main search signs that specialists should first of all pay attention to. All motor descriptors showed a high positive predictive value and diagnostic sensitivity, with the highest results registered for AU9 and AU20 (Fig. 2).

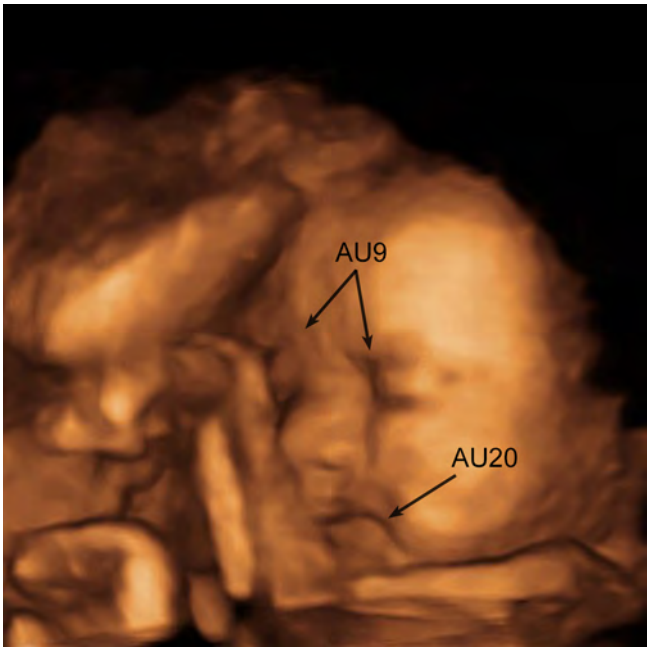

FIG. 2.
An example of ultrasound imaging of motor descriptors AU9 and AU20, which showed the highest prognostic value and diagnostic sensitivity

CONCLUSION

Assessment of facial units during ultrasound diagnostics can be a convenient tool as an additional diagnosis of the development of intrauterine distress and requires further study.

Conflict of interest

The authors of this article declare the absence of a conflict of interest.

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