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# FREQUENCY CHARACTERISTICS OF ACOUSTIC FEATURES OF SOUND SIGNALS IN THE LUNGS OF CHILDREN WITH PNEUMONIA USING A NEW ACOUSTIC DIAGNOSTIC DEVICE "TREMBITA-CORONA"

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***Summary***

***Relevance.*** *Community-acquired pneumonia (CAP) is an urgent problem in practical medicine and the main cause of morbidity and mortality in the world. Diagnosing pneumonia is complex and requires a comprehensive study, taking into account many factors. The development of passive diagnostic methods, such as acoustic ones, is especially promising for children, as this approach reduces significantly the level of radiation exposure to an unformed child's body.*

***The aim.*** *To determine the peculiarities of the frequency characteristics of acoustic signals in the lungs of children with pneumonia using the new acoustic diagnostic device «Trembita-Corona».*

***Materials and methods.*** *We studied 120 children aged 1 month to 18 years, who were treated in the pediatric departments of the Children's Clinical Hospital №. 5 and Children's Clinical Hospital № 7. The children were divided into two groups: Group I – 60 patients with community-acquired pneumonia, Group II – 60 healthy children. Children from I group underwent a comprehensive examination. All children underwent research using the "Trembita-Corona" acoustic monitoring device for the diagnosis of respiratory noise and localization of lung lesions. The computerized analysis of breathing sounds was carried out using mathematical methods without involving human factors.*

*The study was conducted in accordance with the international principles of conducting clinical studies GCP, GLP, the protocol was approved at the meeting of the Commission on Bioethical Expertise at the National Medical University named after O.O. Bogomolets (protocol No. 138 of November 10, 2020). Informed consent of parents/guardians was obtained for conducting the study, which was approved at the same meeting of the Commission on Bioethical Expertise at Bogomolets National Medical University (protocol № 138 of November 10, 2020).*

*Statistical processing of the obtained results was carried out using the licensed programs "MedStat", "Matlab" and with the original calculation programs included in the "Trembita-Corona" system. This work is a part of the complex research work (CRW) of the Department of Pediatrics of Postgraduate Education of Bogomolets National Medical University "Characteristics of the state of health of children who have suffered from COVID-19 and the justification of medical and rehabilitation measures" (2022-2024). State registration number 0122U000486. The authors are performers of the CRW fragment.*

***Results.*** *In children, the clinical picture of CAP consisted of pulmonary (respiratory) complaints, symptoms of intoxication, RF, and local physical changes. Respiratory lung sounds in the frequency range from 0.1 Hz to 30 kHz were studied in all patients using the "Trembita-Corona" device and the corresponding original software. The most promising is the selection of the pathological process of lung damage in pneumonia in the ranges of 0, 1, 2, 3, 4, 5, 6 octaves based on the differences between the average signal power ($p<0.05$) in children with CAP and healthy children.*

***Conclusion.*** *We, in cooperation with leading specialists of the National Aviation University, have developed an experimental sample of the "Trembita-Corona" acoustic monitoring device for the diagnosis of respiratory lung sounds. The "Trembita-Corona" acoustic monitoring device is a new and promising acoustic method for determining the location of a pathological process in the lungs. It was found that the most promising is the selection of the pathological process of lung damage in pneumonia in the ranges of 0, 1, 2, 3, 4, 5, 6 octaves based on the differences between the average signal power ($p<0.05$) in children with CAP and healthy children.*

***Key words:*** *«Trembita-Corona» Acoustic Monitoring Device; Community-Acquired Pneumonia; Diagnosis; Children.*

## Introduction

Community-acquired pneumonia (CAP) is currently an urgent problem of practical medicine and the main cause of morbidity and mortality in the world. In recent years, international recommendations for improving the treatment and diagnosis of CAP have been updated. Quick diagnosis of CAP has great practical importance for timely diagnosis and treatment [1,2,3,4,5].

Diagnosis of CAP requires a comprehensive study taking into account the clinical picture and the results of paraclinical research methods [6,7,8,9]. Diagnosis and treatment of CAP is carried out in accordance with the new order № 1380 of the Ministry of Health of Ukraine (Standards of medical care "Community-acquired pneumonia in children") dated August 2, 2022, according to which the diagnosis of community-acquired pneumonia is established on the basis of anamnesis, clinical manifestations, as well as the use of the results of instrumental and laboratory research methods [10,11]. According to this order, X-ray examination of community-acquired pneumonia is not mandatory and is carried out only in direct projection. According to the clinical guideline 2022 year "Pneumonia in children", the diagnosis of community-acquired pneumonia is made clinically, since the use of radiological examination in children also has negative consequences. One of the reasons for this is the high biological sensitivity of children to X-ray radiation. Also, according to this instruction and the guidelines of the British Thoracic Society, the results of an X-ray examination do not allow to verify the etiology of the disease, therefore, in patients with a mild form of community-acquired pneumonia, an x-ray examination of the lungs is not usually used. However, in patients with persistent symptoms of community-acquired pneumonia, X-ray signs of infiltrative lung damage make it possible to establish a final diagnosis of community-acquired pneumonia. X-ray examination of the chest organs is a widespread and affordable diagnostic method for visualization of pathological

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processes in the lungs. According to the literature, the sensitivity of the radiological method for detecting pneumococcal pneumonia is 93% (CI 80-98%), and the negative predictive value is 92% (CI 77-98%) [4]. In patients with severe community-acquired pneumonia, X-ray examination is used to identify or rule out complications. Therefore, according to the instructions of the Ministry of Health of Ukraine and the guidelines of European countries, X-ray examination should not be performed routinely in patients with community-acquired pneumonia, but only according to individual indications [12,13,14].

Currently, the world is experiencing a pandemic of COVID-19. In connection with the COVID-19 pandemic, the order of the Ministry of Health of Ukraine dated March 28, 2020 №. 722 "Organization of medical care for patients with coronavirus disease (COVID-19)" entered into force in 2020. According to this order, all patients with increased body temperature and in the presence of catarrhal syndrome, suspicion of lung inflammation are required to be tested for the detection of SARS-CoV-2 antigens or for the detection of SARS-CoV-2 RNA. That is why timely diagnosis of CAP acquires great practical importance for the appointment of adequate therapy. A safer method of diagnosis in the initial stages of the disease and for monitoring changes in the lungs in dynamics is respiratory acoustics [4,12,13,14,15].

Currently, respiratory acoustics is a promising scientific direction, the main tasks of which are the development of the theory of propagation and generation of sound in the lungs and the creation of objective acoustic methods that can improve the diagnosis of diseases [12,13].

In children's pulmonology, the method of pulmonography is used [13,14]. When using this method, respiratory sounds are registered at certain points above the lungs using electret microphones. The received signals are filtered and digitized with further mathematical data analysis. However, with the help of this method, it is possible to analyze only one type of noise, and this method also does not allow to precisely localize the location of the noise source in the lungs.

In pulmonology, the method of computer phonospirography is used, thanks to which it is possible to visualize additional noises over the lungs. The method is based on the analysis of two-dimensional phonospirograms and determination of the time of a complete respiratory cycle. Electronic auscultation is performed using only 4 fixed sensors, which reduces topical diagnostics. During this study, the patient must stand or sit, which makes it impossible to use the device for lying patients. Deciphering and interpretation of the results is carried out by the doctor, which subjectively affects the result [4].

The creation of a fully automated system for control and evaluation of respiratory noises is an urgent task [15,16,17,18]. Currently, the problem of early diagnosis of inflammatory changes in the lungs, which can be determined using the acoustic method, has become acute [19,20,21]. This is important for the diagnosis of CAP in the early stages of the disease, when the disease is asymptomatic, or when the affected area of the lung is behind the rib [22,23,24,25,26,27].

The purpose of the study is to determine the features of the frequency characteristics of acoustic signals in the lungs of children with pneumonia using the new acoustic diagnostic device "Trembita-Corona".

## Materials and methods

We examined 120 children (56 boys, 64 girls) aged from 1 month to 18 years who were treated in the pediatric departments Children's hospital №5 and Children's hospital № 7 in Kyiv.

The children were divided into two groups: Group I – 60 patients with community-acquired pneumonia; Group II - 60 healthy children. The distribution by age and gender is presented in table 1.

**Table 1**

**Distribution of patients according to age and sex**

| Indicator | I group, community-acquired pneumonia, n=60 | II group, healthy children, |
|---|---|---|
| n= 60 | 9,6±0,3 | 12,1±0,5 |
| Age, years | 9,6±0,3 | 12,1±0,5 |
| The number of boys | 35 (58,33%) | 21(35%) |
| Number of girls | 25(41,67%) | 39 (65%) |

The criteria for including patients in the 1st group were:
- children aged from 1 month to 18 years;
- community-acquired pneumonia, confirmed by anamnestic, clinical laboratory and radiological data;
- informed consent of the child's parents or guardians.

The criteria for excluding patients from group I were:
- congenital pneumonia,
- endocrine diseases (hypothyroidism, hypocorticism, pseudohypoparathyroidism, growth hormone deficiency),
- genetic syndromes (Prader-Willi, Kogan, Carpenter, etc.),
- congenital heart defects,
- organic diseases of the brain.

The children from the 1st group underwent complex studies that required community-acquired pneumonia, namely:
- objective examination (percussion, palpation, auscultation),
- X-ray of the lungs,
- laboratory tests (general blood test, biochemical blood test).

Also, all children were examined using the "Trembita-Corona" acoustic monitoring device for the diagnosis of breathing sounds and localization of lung lesions [12,13,15]. The analysis of respiratory sounds is carried out using mathematical methods without the involvement of the human factor, the general view of which is shown in Fig. 1.

**Fig. 1. General view of "Trembita-Corona" acoustic monitoring device and data acquisition and analysis system**

The essence of the proposed control method is to record and analyze acoustic vibrations with the help of two receivers at each of the investigated points of acoustic analysis. After mathematical processing of acoustic signals, it becomes possible to analyze the nature and characteristic features of these acoustic vibrations, as well as to calculate the direction and position of the source of these vibrations using acoustic triangulation of the signal, which makes it possible to accurately determine the location of the lesion in the lungs. Thus, it becomes possible to make a general characteristic of the state of the lungs in a real time scale with the possibility of localization of zones of lesions, including in the extracostal zones.

The device has an automated system of control and evaluation of respiratory noises with the complete exclusion of the human factor and with the possibility of mathematical data processing.

The study was conducted in accordance with the international principles of conducting clinical studies GCP, GLP, the protocol was approved at the meeting of the Commission on Bioethical Expertise at the National Medical University named after O.O. Bogomolets (protocol No. 138 of November 10, 2020). Informed consent of parents/guardians was obtained for conducting the study, which was approved at the same meeting of the Commission on Bioethical Expertise at Bogomolets National Medical University (protocol No. 138 of November 10, 2020).

Statistical processing of the obtained results was carried out using the licensed programs "MedStat", "Matlab" and with the original calculation programs included in the "Trembita-Corona" system. This work is a part of the complex research work (CRW) of the Department of Pediatrics of Postgraduate Education of Bogomolets National Medical University "Characteristics of the state of health of children who have suffered from COVID-19 and the justification of medical and rehabilitation measures" (2022-2024). State registration number 0122U000486. The authors are performers of the CRW fragment.

The patient examination procedure is as follows: each patient and parent or guardian is told about the upcoming procedure, how it will be performed, and informed consent is provided for the child's parent or guardian. Next, the patient is offered to free the chest cell from clothing, and the lungs are examined in a certain methodical sequence. First, the examination is carried out with an ordinary phonendoscope, and then with the "Trembita-Corona" acoustic monitoring device, the lungs are listened to: first, the front, then the back surface, then the side surfaces of the chest.

The doctor stands in front and to the right of the patient. Start listening to lung sounds from the front surface of the lungs. The "Trembita-Corona" acoustic monitoring device is placed in such a way that the earpieces of the device's sound receiver are tightly pressed to the surface of the patient's body, and the axis connecting the centers of the shell ring (sound receiver lips) of the double sound receiver is parallel to the line connecting the patient's clavicles, as shown in Fig. . 2.

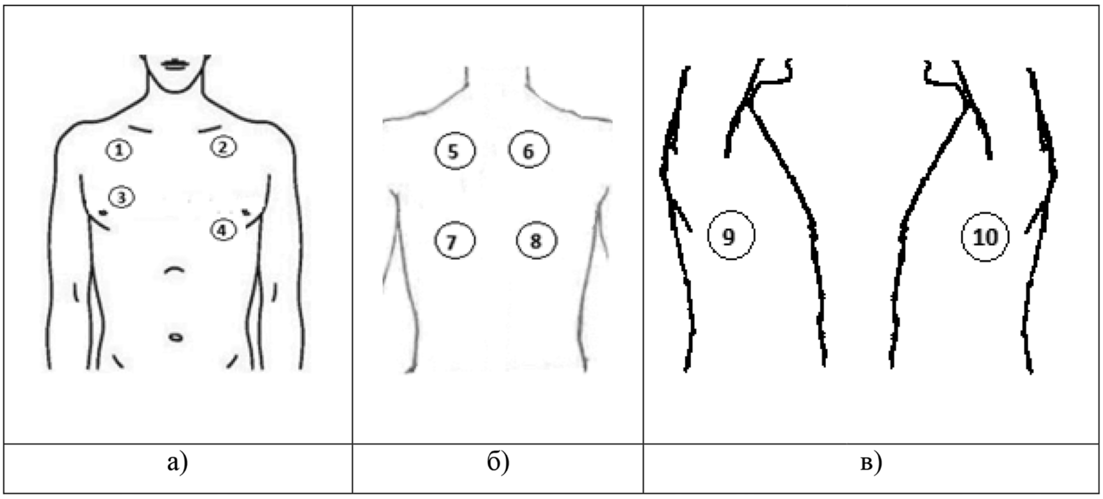


**Fig.2. The main points for listening to the lungs with the "Trembita-Corona" device (a - front surface, b - back surface, c - side surfaces)**

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Then the sound receiver of the acoustic monitoring device "Trembita-Corona" is successively placed on symmetrical areas of the front wall of the chest at the level of the II intercostal space, and the mid-clavicular line should pass between the two sides of the device, then the device is rearranged on the right in the III intercostal space, and on the left - in the 5th intercostal space (points 1, 2, 3, 4).

When listening to lung sounds from behind, the "Trembita-Corona" device is placed symmetrically in the middle interscapular space and symmetrically under the shoulder blades (points 5, 6, 7, 8).

When listening to lung sounds from the side, the "Trembita-Corona" device is placed along the midaxillary line in the 6th intercostal space (points 9, 10).

In addition, the same measurements were performed for patients in the supine position, and during acoustic monitoring of points on the back, the patient turned over and lay on his stomach. These studies were conducted to assess the possibility of acoustic diagnosis of patients who, due to the severity of the condition, cannot stand or sit.

Using the "Trembita-Corona" acoustic monitoring device, sounds are analyzed at different octaves, and an octave was considered to be an interval in which the frequency ratio between sounds is one to two, that is, the frequency of a high sound is twice as high [3,4,5,12, 13]. Subjectively by ear, the octave is perceived as a stable, basic acoustic interval. Successive octaves make up sounds that are similar to each other, although they differ in pitch. A frequency of 1000 Hz was taken as the base frequency.

Table 2 shows the average fm and band edge frequencies ($f_1$ та $f_2$) in Hz of the first 11 octaves, and in the calculations, it was assumed that the lowest and highest octaves include frequencies from 0.1 Hz to 30 kHz, respectively.

**Table 2**

**Band limit frequencies (f1 and f2) in Hz of the first 11 octaves**

| Octave | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| f m | 5,610092272 | 15,84893192 | 31,6227766 | 63,09573445 | 125,8925412 | 251,1886432 |
| $f_1$ | 0,1 | 11,22018 | 22,38721 | 44,66836 | 89,12509 | 177,8279 |
| $f_2$ | 11,22018 | 22,38721 | 44,66836 | 89,12509 | 177,8279 | 354,8134 |
| Octave | 6 | 7 | 8 | 9 | 10 | 11 |
| f m | 501,1872336 | 1000 | 1995,262315 | 3981,071706 | 7943,282347 | 15848,93192 |
| $f_1$ | 354,8134 | 707,9458 | 1412,538 | 2818,383 | 5623,413 | 11220,18 |
| $f_2$ | 707,9458 | 1412,538 | 2818,383 | 5623,413 | 11220,18 | 30000 |

When performing calculations and analysis in octave and third-octave ranges, it was assumed that the limit frequencies of the band are such frequencies of the lower and upper limit of the band that the exact center frequency is the geometric mean value of the lower and upper limit frequencies $f_1$ and $f_2$, respectively.

We calculated the limiting frequencies of the bandwidth according to the formulas:

$$f_1 = (G^{-1/(2b)})(fm)$$
$$f_2 = (G^{+1/(2b)})(fm)$$

where: G – octave ratio of frequencies, calculated according to the formula (G10=10 3/10=1,99526) in the system with a decimal base;

fm – the exact center frequency of the passband, calculated by the formula (fm=(G x/b)(fr).

The generally accepted objective unit of relative pitch is the octave. An octave characterizes a two-fold ratio of frequencies. The octave is divided into half octaves, third octaves (thirds), semitones and cents. For example, a third is 21/3 = 1.26; semitone–21/12 = 1.06; cent — 21/1200 = 1.0006.

The signal power is defined as the integral of the square of the amplitude over time or frequency, that is, as the sum of the squared amplitudes recorded at different points in time. In this case, the integral means that the signal is not simply divided into two or three parts and the averaged amplitudes of each part are taken. Using the "Trembita-Corona" acoustic monitoring device and computer data processing, we split the signal into a series of short-term sections, and carry out precise analysis of the amplitude value at each sampling point. We have taken s(t) as a periodic signal with a repetition period of To. This type of signal depends on the class of power signals and for it the average power is equal to:

$$Po = \frac{1}{To}\int_{to}^{to+To} \lfloor s(t) \rfloor^2 dt$$

where, s(t) a periodic signal with a repetition period To, to – arbitrary point in time

### Results and discussion

All children were examined on the "Trembita-Corona" acoustic monitoring device for the diagnosis of breathing sounds. A computerized lung monitoring acoustic signal database was created, which included more than 1200 recordings, each of which was digitized and processed according to the above acoustic signal processing techniques.

Statistical processing of the acoustic monitoring materials of both groups of children, which were included into the above-mentioned created database of acoustic signals, allowed, at the first stage, to confirm with a probability of more than 97.5% the possibility of diagnosing pneumonia using the proposed computerized acoustic method according to the proposed algorithms of analysis using the device "Trembita-Corona".

All patients were tested for average signal power in 12 octaves using the "Trembita-Corona" device.

It was found that in children with CAP in the 0th octave, the average values of the signal power vary from 500,000 Conventional Units (C.U.) up to 3,000,000 C.U. In healthy children in 0 octave, the average values of the signal power are from 100,000 C.U. - 450,000 C.U. (Fig. 3)

When comparing the central tendencies for two independent samples, namely children with CAP and healthy children, the central tendencies differ at the significance level of $p<0.001$.

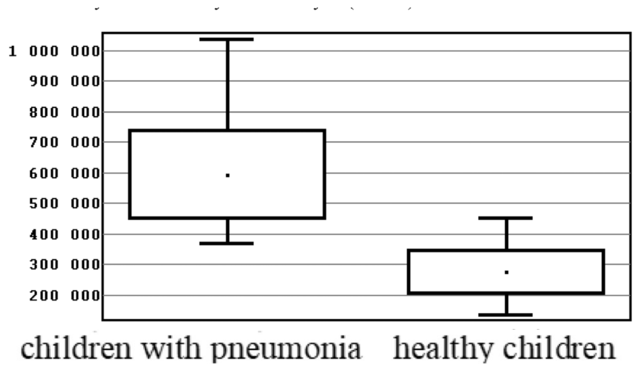


**Fig. 3. Confidence interval when comparing central tendencies for two independent samples, namely children with pneumonia and healthy children in 0 octave (p<0.001)**

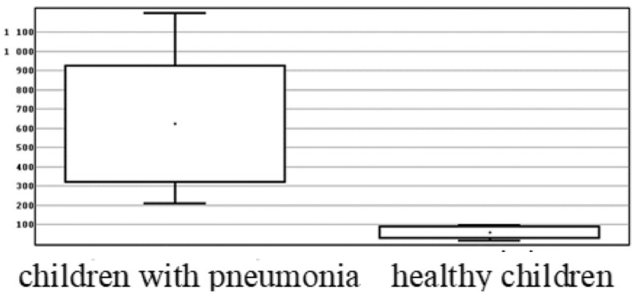


**Fig. 4. Graph comparing the average of two independent samples in the 5th octave according to the Student's criterion. Two-sided critical area (p<0.001).**

When studying the average values of the signal power in 1 octave in children with CAP, it was found that the average values of the signal power vary from 0 to 3500000 C.U.

3 main groups were distinguished, namely from 0-800000 C.U. - 1 group, from 800,000 C.U. – 1,300,000 C.U. - 2nd group, from 1,300,000 C.U. - 3500000 C.U. - 3rd group. In healthy children, the average values of the signal power in 1 octave range from 800,000 C.U. – 1,300,000 C.U. When comparing the average values of the signal power in children of group 1 with healthy children, the averages differed at the significance level of $p<0.001$. If we compare the average values of signal power in children of group 3 with healthy ones, the central tendencies differ at the significance level of $p<0.001$. When comparing the average values of the signal power in children of 2 groups with healthy ones, no statistical differences were found.

On the basis of the found out peculiarities of the signals, which were described above, it was concluded that if the differences in the average values of the signal power are in the range of less than 800,000 C.U. or more than 1,300,000 C.U., then you can think about pneumonia, but if the data is between 800,000 C.U. and 1300000 C.U., then it is necessary to check the power in other octaves and then draw a conclusion.

When studying the average values of the signal power in 2 octaves in children with CAP, it was found that the average values of the signal power vary from 200,000 C.U. up to 1,600,000 C.U. 2 groups were allocated, namely from 200,000 C.U. up to 800,000 C.U. - 1 group, from 1,000,000 C.U. – 1,600,000 C.U. - 2nd group. In healthy children in 2 octaves, the average values of the signal power range from 500,000 C.U. up to 1,500,000 C.U. When comparing the average values of the signal power in children from group 1 with healthy ones, the averages differ at the significance level of $p=0.008$. When comparing the average values of the signal power in children from the 2nd group with healthy ones, it was found that the averages differ at the significance level of $p=0.027$. Based on the findings described above, it was concluded that with a confidence level of 97,3%, we can distinguish the acoustic picture in children with CAP compared to healthy children using the average values of the signal strength. Therefore, if we separate part of the patients into a separate group, in which the frequency in the 2nd octave is less than 800,000 C.U., and make a comparison with healthy ones, then we can conclude that at significance level of 0,008 can state that if the integral noise index is in the 2nd octave is less than 800,000 C.U., then this patient has pneumonia. For a more detailed analysis, it is necessary to analyze acoustic signals in other octaves or third octaves of this octave.

When studying the average values of the signal power in 3 octaves in children with CAP, it was found that the average values of the signal power vary from 0 to 300,000 C.U. In healthy children, the average values of the signal power in the 3rd octave range from 40,000 C.U. up to 90,000 C.U. When comparing the average values of the signal strength in children with CAP with healthy ones, the averages differ at the significance level of $p<0.001$.

For a more accurate analysis, the average values of the signal power of children with CAP were separated into 2 groups, namely from 0 to 100,000 C.U. - 1 group, from 100,000 C.U. - 300,000 C.U. - 2nd group. If we compare the average values of the signal power in children of group 1 with healthy ones, the difference in the averages is not statistically significant, $p=0.406$. If we compare the average values of the signal strength in children from group 2 with healthy ones, the averages differ at the significance level of $p<0.001$. Therefore, it can be concluded that with average values of signal power from 100,000 C.U. up to 300,000 C.U. the probability of detecting pneumonia increases, the means differ at the significance level of $p<0.001$.

When studying the average values of the signal power in 4 octaves in children with CAP, it was found that the average values of the signal power vary from 0 to 6000 C.U. In healthy children, the average values of the signal power in the 4th octave range from 0 to 700 C.U. When comparing the average values of the signal strength in children with CAP with healthy central tendencies, they differ at the significance level of $p<0.001$.

For a more accurate analysis, 2 groups were allocated, namely from 0 to 700 C.U. - 1 group, from 700 C.U. - 6000 C.U. - 2nd group. When comparing the average values of the signal power in children of group 1 with healthy ones, a difference in the averages was found, which was not statistically significant, $p=0.472$. If we compare the average values of signal power in children of group 2 with healthy ones, the central tendencies differ at the level of significance $p<0.001$. Therefore, we can conclude that with average values of signal power from 700 C.U. up to 6000 C.U. the probability of detecting pneumonia increases. Central tendencies differ at the significance level of $p<0.001$.

When studying the average values of the signal power in 5 octaves in children with CAP, it was found that the average values of the signal power vary from

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200 C.U. up to 1500 C.U. In healthy children, the average values of the signal power in the 5th octave range from 0 to 100 C.U. When comparing the average values of the signal strength in children with CAP with healthy ones, the averages differ at the significance level of p<0.001, which is presented in Fig. 4.

For a more accurate analysis, 2 groups were selected, namely from 200 C.U. up to 650 C.U. - 1 group, from 650 C.U. - 1500 C.U. - 2nd group. If we compare the average values of the signal power in children from group 1 with healthy ones, the averages differ at the significance level of p<0.001. If we compare the average values of the signal strength in children from group 2 with healthy ones, the averages differ at the significance level of p<0.001.

When studying the average values of the signal power in 6 octaves in children with CAP, it was found that the average values of the signal power vary from 0.5 C.U. up to 10 C.U. In healthy children, the average values of the signal power in the 6th octave range from 0 to 0.5 C.U. When comparing the average values of the signal power in children with CAP with healthy central tendencies differ at the significance level of p<0.001, which is presented in Fig. 5.


**Fig. 5. Graph of comparison of central tendencies for two independent samples in the 6th octave for patients with pneumonia and healthy people according to Wilcoxon's W-criterion (p<0.001)**

When studying the average values of the signal strength in the 7th octave in children with CAP and healthy children, no statistically significant differences were found (p=0.287), which is presented in Fig. 6.

No statistically significant differences were found when examining the average values of the signal power in the 8th and 9th octave in children with CAP and healthy children (p=0.691 and p=0.513, respectively). Also, in octaves 10, 11, 12, no differences were found between the average values of the signal strength in healthy children and children with CAP.

Based on this, it can be concluded that the most promising is the determination of the pathological process of lung damage in pneumonia in the ranges of 0, 1, 2, 3, 4, 5, 6 octaves by the differences between the average signal power (p<0.05) in children with CAP and healthy children.

A detailed analysis of the acoustic signals of the lungs, which was carried out by the "Trembita-Corona" acoustic monitoring device, showed the possibility of detecting the pathological process at the maximum of the signal power precisely in places where it is better to auscultate, with the help of a phonendoscope, pneumonia. However, with the help of the "Trembita-Corona" acoustic monitoring device, in other listening points, not above the inflammatory focus of pneumonia, it is also possible to listen to a special acoustic signal that corresponds to lung damage. These specific acoustic signals were found for the first time thanks to the use of highly sensitive acoustic receivers and mathematical processing of the recorded signal. Thanks to this, the use of the Trembita-Corona acoustic monitoring device and computer processing together make it possible to hear specific acoustic signals over the entire plane of the lungs, and not only at the location of the pathological process.

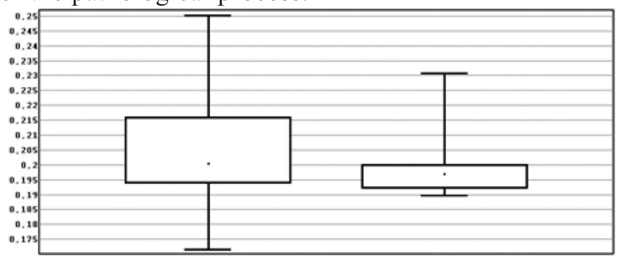


**Fig. 6. Graph of comparison of central tendencies for two independent samples in children with pneumonia and healthy children according to Wilcoxon's W-test (p=0.287).**

The "Trembita-Corona" acoustic monitoring device during the COVID-19 pandemic will improve and speed up the diagnosis of the disease, thanks to the precise localization of the lung damage zone and the ability to use the method remotely. The "Trembita-Corona" acoustic monitoring device is a new and promising acoustic method for determining the location of the pathological process in the lungs with CAP.

## Conclusions

1. Developed and patented "Trembita-Corona" acoustic monitoring device for more effective diagnosis of breathing noises and their localization in the lungs.
2. It was established that for determining the inflammatory process in the lungs during pneumonia, the most promising are the studies of respiratory sounds in the ranges of 0, 1, 2, 3, 4, 5, 6 octaves.

Prospects for further research.

1. The "Trembita-Corona" acoustic monitoring device is a new and promising acoustic method for determining the location of the pathological process in the lungs with CAP.
2. The "Trembita-Corona" acoustic monitoring device during the COVID-19 pandemic will improve and speed up the diagnosis of the disease, thanks to the precise localization of the lung damage zone and the possibility of using the method remotely.

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# ЧАСТОТНА ХАРАКТЕРИСТИКА АКУСТИЧНИХ СИГНАЛІВ У ЛЕГЕНЯХ ДІТЕЙ З ПНЕВМОНІЄЮ ЗА ДОПОМОГОЮ НОВОГО ПРИЛАДУ АКУСТИЧНОЇ ДІАГНОСТИКИ «TREMBITA-CORONA»

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## Резюме

**Актуальність.** Позалікарняна пневмонія (ПП) наразі є актуальною проблемою практичної медицини та основною причиною захворюваності і смертності у світі. Діагностика пневмонії складна і потребує комплексного дослідження з урахуванням багатьох факторів. Особливо перспективним для дітей є розвиток пасивних методів діагностики типу акустичних, що суттєво знижує рівень опромінення на несформований дитячий організм.

**Мета дослідження.** Визначити особливості частотних характеристик акустичних сигналів у легенях дітей з пневмонією за допомогою нового приладу акустичної діагностики «Trembita-Corona».

**Матеріали і методи.** Було досліджено 120 дітей віком від 1 місяця до 18 років, що проходили лікування в педіатричних відділеннях ДКЛ №5 та ДКЛ№ 7. Дітей було розділено на дві групи: I група – 60 пацієнтів з ПП, II група – 60 здорових дітей. У дітей з I групи були проведені комплексні дослідження, що потребувала ПП. Також всім дітям було проведено дослідження на пристрої акустичного моніторингу «Trembita-Corona» для діагностики дихальних шумів та локалізації зон ураження легень.

Дослідження було проведено відповідно до міжнародних принципів проведення клінічних досліджень GCP, GLP, протокол затверджено на засіданні Комісії з питань біоетичної експертизи при НМУ імені О.О. Богомольця ( протокол № 138 від 10 листопада 2020 року). На проведення дослідження було отримано інформовану згоду батьків/опікунів, що була затверджена на тому ж засіданні Комісії з питань біоетичної експертизи при НМУ імені О.О. Богомольця ( протокол № 138 від 10 листопада 2020 року).

Статистичну обробку отриманих результатів проводили з використанням ліцензійних програм «MedStat», "Matlab" та за допомогою оригінальних розрахункових програм, які входять в систему «Trembita-Corona».

Дана робота є частиною комплексної науково–дослідної роботи кафедри педіатрії післядипломної освіти НМУ імені О.О. Богомольця "Характеристика стану здоров'я дітей, що перенесли COVID-19, та обгрунтування лікувально-реабілітаційних заходів" (2022-2024 роки). Номер держреєстрації 0122U000486. Автори – виконавці фрагмента НДР.

Результати та їх обговорення. У дітей клінічна картина ПП складалася з легеневих (респіраторних) скарг, симптомів інтоксикації, ДН, локальних фізикальних змін. Нами у співробітництві з провідними спеціалістами Національного Авіаційного Університету був розроблений експериментальний зразок пристрою акустичного моніторингу «Trembita-Corona» для діагностики дихальних шумів легень. Всім пацієнтам за допомогою пристрою «Trembita-Corona» і відповідного оригінального програмного забезпечення були досліджені дихальні шуми легень в діапазоні частот від 0.1 Гц до 30 кГц. Найбільш перспективним є виділення патологічного процесу ураження легень при пневмонії в діапазонах 0, 1, 2, 3, 4, 5, 6 октав по відмінностях між середньою потужністю сигналу ($p<0,05$) у дітей з ПП та здорових дітей.

**Висновок.** Пристрій акустичного моніторингу «Trembita-Corona» є новим і перспективним акустичним методом для визначення місця розташування патологічного процесу в легенях. Виявлено, що найбільш перспективним є виділення патологічного процесу ураження легень при пневмонії в діапазонах 0, 1, 2, 3, 4, 5, 6 октав по відмінностям між середньою потужністю сигналу ($p<0,05$) у дітей з ПП та здорових дітей.

**Ключові слова:** діти; позалікарняна пневмонія; діагностика; пристрій акустичного моніторингу «Trembita-Corona».

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