**UDC 616.24-002-053.2**
**DOI: 10.15587/2519-4798.2023.283687**

# EVALUATION OF ACOUSTIC SIGNAL FEATURES IN CHILDREN WITH COMMUNITY-ACQUIRED PNEUMONIA AND PNEUMONIA CAUSED BY THE SARS-COV-2 VIRUS USING THE NEW ACOUSTIC MONITORING DEVICE "TREMBITA-CORONA"

**Olha Khomych, Yurii Marushko**

*Early diagnosing pneumonia caused by the SARS-CoV-2 virus is an urgent problem today. The diagnosis of pneumonia caused by the SARS-CoV-2 virus is difficult, which is why it is promising to use acoustic monitoring to speed up the diagnosis and start of therapy.*

***Aim:** to determine the features of acoustic diagnostics of children with pneumonia caused by the SARS-CoV-2 virus using the "Trembita-Corona" acoustic monitoring device to correct and supplement traditional diagnostic methods. That is why respiratory acoustics is currently a promising scientific direction. We, pediatric specialists from Ukraine and leading specialists of the National Aviation University (Ukraine), have developed an experimental sample of the "Trembita-Corona" acoustic monitoring device. This device is used to diagnose breathing sounds. A patent protects the main constructive technical solutions of this device.*

***Methods.** We studied 230 patients aged 1 month to 18 years. The children were divided into 3 groups: 1 group – 100 patients with CAP (the PCR test for the determination of the SARS-CoV-2 virus is negative), 2 group– 100 healthy children (the PCR test for the determination of the SARS-CoV-2 virus is negative), 3 group - 30 children with pneumonia caused by the SARS-CoV-2 virus the PCR test for the determination of the SARS-CoV-2 virus is positive).*

*The study complied with the international principles of GCP, GLP for clinical research. The protocol was approved at the meeting of the Commission on Bioethical Expertise at the National Medical University, named after O. O. Bogomolets. Mathematical processing was performed on specialized software developed in the Python language in the Google Codelabs environment. Further statistical processing of the obtained results was performed in specialized programs Medstart, EZR (R-Statistics) and "Matlab".*

***Results.** We use the "Trembita-Corona" acoustic monitoring device to analyze sounds at different octaves. In each of the 11 octaves using the "Trembita-Corona" acoustic monitoring device, we investigated the following indicators: the average signal power, frequency of the acoustic signal and amplitude.*

*Using the acoustic monitoring device "Trembita-Corona", were found differences between children with CAP and healthy ones in average signal power in 0,1,2,3,4,5,6 octaves, in the frequency of the acoustic signal in 0 and 5 octaves, and in the amplitude of the acoustic signal in 0,2,3,4,5,6 octaves. Differences between children with CAP and children with pneumonia caused by the SARS-CoV-2 virus in terms of average signal power in 0,1,2,3,4,5,6,7,9 octaves, frequency of the acoustic signal in 0 and 5 octaves, and amplitude of the acoustic signal in 0,1,4,5,6 octaves were also analyzed.*

*Differences in average signal power and amplitude of the acoustic signal between pneumonia caused by the SARS-CoV-2 virus and healthy children were determined in the $2^{nd}$ octave (**$p<0.01$**). Also, differences between these groups were found in the amplitude of the acoustic signal in the $8^{th}$ octave.*

***Conclusion.** The "Trembita-Corona" acoustic monitoring device is a new and promising acoustic method for determining the location of a pathological process in the lungs. Characteristic differences were found in the average signal power and amplitude of the acoustic signal between pneumonia caused by the SARS-CoV-2 virus and healthy children ($p<0.01$) in the 2nd octave and in the amplitude of the acoustic signal in the 8th octave*

***Keywords:** acoustic monitoring, diagnostics, "Trembita-Corona" device, community-acquired pneumonia, COVID-19, SARS-CoV-2*

**How to cite:**
Khomych, O., Marushko, Y. (2023). Evaluation of acoustic signal features in children with community-acquired pneumonia and pneumonia caused by the SARS-CoV-2 virus using the new acoustic monitoring device "Trembita-Corona". ScienceRise: Medical Science, 2 (53), 31–37. doi: http://doi.org/10.15587/2519-4798.2023.283687

## 1. Introduction

Community-acquired pneumonia (CAP) is currently an urgent problem of practical medicine and the main cause of morbidity and mortality in the world [1]. Currently, the world and Ukraine are updating international recommendations on diagnosing CAP [2]. Diagnosis of CAP requires a comprehensive study considering the clinical picture and the results of paraclinical research methods. That is why a new guideline has been issued in Ukraine, which is an adapted German guideline S2k-Leitlinie "Management der ambulant erwerbenen Pneumonie bei Kindern und Jugendlichen (pädiatrische ambulant erwerbene Pneumonie, pCAP)", 2017, which was selected by the working group of the Ministry of Health of Ukraine, as an example of the best practice of providing medical care to children with CAP and is based on evidence-based medicine data regarding the effectiveness and safety of medical interventions, pharmacotherapy and organizational principles of its provision [3].

The COVID-19 pandemic has just ended in the world, so a timely diagnosis of pneumonia is of great practical importance for the appointment of adequate therapy [4]. A safer method of diagnosis in the initial stages of the disease and for monitoring changes in the lungs in dynamics is respiratory acoustics [5].

The classic method of measuring lung sounds is a stethoscope. The mechanism of operation of the stethoscope consists of the isolation of sounds from the vibrating chest wall and the mechanical filtering of frequencies that the human ear can hear. The stethoscope was developed in 1816 by the distinguished scientist René-Théophile-Hyacinthe Laennec [6]. Therefore, the stethoscope has been used for almost two centuries to help doctors in diagnosing the condition of the lungs. Doctors widely use the method of auscultation of the lungs and has a number of advantages, among which the main ones are the speed of application and the low cost of the equipment. However, this method also has disadvantages, the main of which is the subjective assessment of the obtained sound phenomena and the possibility of different recognition of specific lung signals by doctors [7, 8].

That is why respiratory acoustics is currently a promising scientific direction. The tasks of this direction are the development of the theory of sound propagation in the lungs and the creation of objective acoustic methods, which in turn improve the diagnosis of lung diseases [9, 10].

We, pediatric specialists from Ukraine and leading specialists of the National Aviation University (Ukraine), have developed an experimental sample of the "Trembita-Corona" acoustic monitoring device [9–11]. This device is used to diagnose breathing sounds. The main constructive technical solutions of this device are protected by a patent [11].

**The aim** of the research was to evaluate the acoustic signal features in children with community-acquired pneumonia and pneumonia caused by the SARS-CoV-2 virus using the new acoustic monitoring device "Trembita-Corona".

## 2. Materials and Methods

**Target Population**. The article was performed on the basis of an examination of 230 patients aged 1 month to 18 years (8,4±2,3 years), 100 patients with community-acquired pneumonia (the PCR test for the determination of the SARS-CoV-2 virus is negative), 30 patients with pneumonia caused by the SARS-CoV-2 virus (the PCR test for the determination of the SARS-CoV-2 virus is positive) and 100 healthy children (the PCR test for the determination of the SARS-CoV-2 virus is negative).

**Study design**. An observational case-control study was conducted at two Kyiv hospitals: KNP "Children's Clinical Hospital No. 5 of Sviatoshyn district of Kyiv" and KNP "Children's Clinical Hospital No. 7" (Pechersk district of Kyiv).

**Study Duration**. Three years from September 2020 to May 2023.

**Sample size**. The sample size was calculated for three comparison groups (α=0.017, taking into account the Bonferroni correction), with a power of 80 % and a sample size ratio of 2:1. The clinical value of the effect is 10 %, s=10 %. The minimum sample size is 1 group – 100 patients with community-acquired pneumonia (the PCR test for the determination of the SARS-CoV-2 virus is negative), 2 group - 100 healthy children (the PCR test for the determination of the SARS-CoV-2 virus is negative) and 3 group - 30 patients with pneumonia caused by the SARS-CoV-2 virus (the PCR test for the determination of the SARS-CoV-2 virus is positive).

**Sampling Method.** The examination included all children whose parents/guardians signed consent for the study and were admitted for inpatient treatment in a Kyiv hospital during this period.

**Inclusion Criteria.** 3 groups of children (1 month–18 years) were included in the examination. Group 1: children from 1 month to 18 years with community-acquired pneumonia, which is confirmed by clinical, paraclinical and laboratory data. Group 2: healthy children from 1 month to 18 years. Group 3: children from 1 month to 18 years with pneumonia caused by the SARS-CoV-2 virus, confirmed by a laboratory method.

**Exclusion Criteria**. Exclusion criteria were: congenital pneumonia, endocrine diseases (hypothyroidism, hypocorticism, pseudohypoparathyroidism, growth hormone deficiency), genetic syndromes (Prader-Willi, Kogan, Carpenter, etc.), congenital heart defects, kidney diseases, organic brain diseases.

**Data collection procedure**. We developed the "Trembita-Corona" acoustic monitoring device for the diagnosis of respiratory sounds. The main constructive technical solutions are protected by a patent [11]. The essence of the proposed diagnostic method consists of the recording and analysing acoustic vibrations using two receivers at each of the investigated points. In the future, mathematical processing of acoustic signals and analysis of these sound vibrations' nature and characteristic features will be carried out. Also, with the help of mathematical processing, the direction and position of the source of these vibrations are calculated using the method of acoustic signal triangulation. This method makes it possible to accurately determine the location of the lesion in the lungs. That is why we can make a general description of the state of the lungs in real-time with the possibility of localizing the zones of lesions, even if they are located in the extracostal zones.

The patient is told about the upcoming procedure and how it will be carried out, and informed consent is provided for the child's parents or guardians. 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. 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 [11].

**Statistical analysis**. Mathematical processing was performed on specialized software developed in the Python language in the Google Codelabs environment. Further statistical processing of the obtained results was performed in specialized programs Medstart, EZR (R-Statistics) and "Matlab". The sample size was calculated for three comparison groups (α=0.017, taking into account the Bonferroni correction), with a power of 80 % and a sample size ratio of 2:1. The clinical value of the effect is 10 %, s=10 %. The minimum sample size is 30 patients in the group of patients with pneumonia caused by the SARS-CoV-2 virus, 100 patients in the group of healthy children and 100 patients with community-acquired pneumonia.

**Ethical considerations**. The study was conducted in compliance with the international principles of GCP, GLP for clinical research. The protocol was approved at the meeting of the Commission on Bioethical Expertise at the National Medical University, named after O. O. Bogomolets (138 protocol of November 10, 2020). Informed consent of parents/guardians was also obtained, which was approved at the meeting of the Commission on Bioethical Expertise at the National Medical University, named after O.O. Bogomolets (138 protocol of November 10, 2020).

### 3. Results

We use the "Trembita-Corona" acoustic monitoring device to analyze sounds at different octaves. An octave was considered an interval in which the ratio of frequencies between sounds is one to two; that is, the frequency of a high sound is twice as high (Marushko Y. V., Khomych O.V., 2023). 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. During the calculations, it was considered that the lowest and highest octaves include frequencies from 0.1 Hz to 30 kHz, respectively.

In each of the 11 octaves using the "Trembita-Corona" acoustic monitoring device, we investigated the following indicators: the average signal power, frequency of the acoustic signal and amplitude. Table 1 presents the main characteristics of the acoustic signal in the first 11 octaves using the "Trembita-Corona" acoustic monitoring device.

Table 1

The main characteristics of the acoustic signal in the first 11 octaves

| Indexes/ Octave | The average signal power | Frequency of the acoustic signal | Amplitude of the acoustic signal |
|---|---|---|---|
| 0<br>(0,1-11,22 Hz) | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* |
| 1<br>(11,22-22,38 Hz) | 1 group/2 group**<br>1 group/3 group p<0.01* | – | 1 group/3 group p<0.01* |
| 2<br>(22,38-44,66 Hz) | 1 group/2 group**<br>1 group/3 group p<0.01*<br>2 group/3 group p<0.01* | – | 1 group/2 group p=0.01*<br>2 group/3 group p<0.01* |
| 3<br>(44,66-89,12 Hz) | 1 group/2 group p=0,03*<br>1 group/3 group p<0.01* | – | 1 group/2 group p<0.01* |
| 4<br>(89,12-177,82 Hz) | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* | – | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* |
| 5<br>(177,82-354,81 Hz) | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* | 1 group/2 group p=0.05*<br>1 group/3 group p=0.04* | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* |
| 6<br>(354,81-707,94 Hz) | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* | – | 1 group/2 group p<0.01*<br>1 group/3 group p<0.01* |
| 7<br>(707,94-1412,53 Hz) | 1 group/2 group**<br>1 group/3 group p=0.03* | – | – |
| 8<br>(1412,53-2818,38 Hz) | - | – | 2 group/3 group p=0.03* |
| 9<br>(2818,38-5623,41 Hz) | 1 group/3 group p<0.01* | – | – |

*Note: * – the difference between the both groups is statistically significant. ** differences are statistically confirmed in the case of group division into subgroups*

As can be seen from the table, in 0 octave, the average signal power, frequency and amplitude of the acoustic signal differ significantly (p<0.01) in children from group 1 and group 3. Also, significant differences (p<0.01) were found in the average signal power, frequency and amplitude of the acoustic signal between the 1st group and the 3rd group. No significant differences in 0 octave were found between group 2 and group 3. Interval estimation of the average signal power in 0 octaves between 3 groups is shown in Fig. 1.

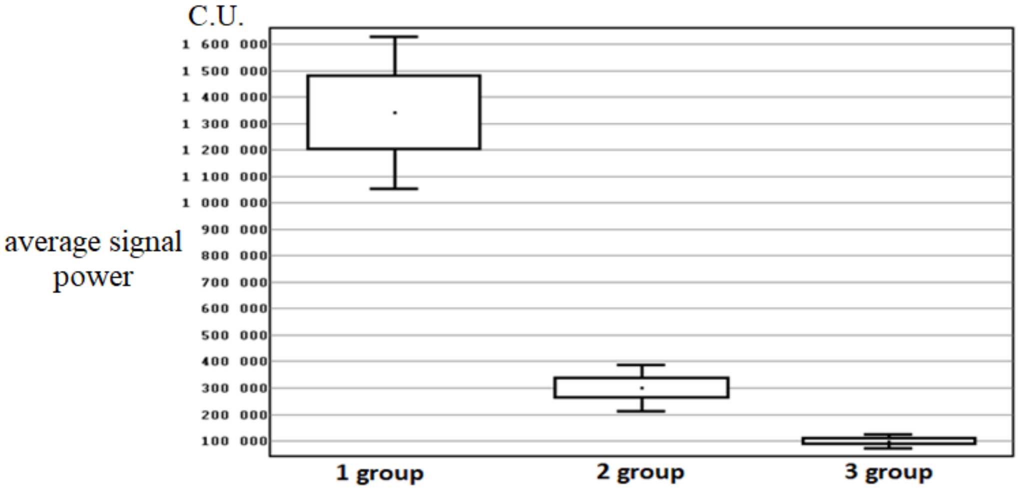


Fig. 1. Interval estimation of the average signal power in 0 octave between 3 groups (the median, standard error and 95 % CI of the median estimate are indicated)

In 1 octave, differences were found between group 1 and group 3 in the average signal power and in the amplitude of the acoustic signal. As can be seen from the table, there were no significant differences in levels of average signal power between children of groups 1 and 2. However, in our previous works (Marushko Y.V., Khomych O.V., 2022), we made clearer comparisons between children with pneumonia and healthy children and found reliable differences. Children with pneumonia were divided into subgroups depending on the mean values of average signal power. Based on the above, it was concluded that if the differences in average signal power 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 make a conclusion.

In the 2nd octave, significant differences were found in the average signal power between the 1st and 3rd groups and between the 2nd group and the 3rd group. Differences were also found between group 1 and group 2 and between group 2 and group 3 in the amplitude of the acoustic signal. As can be seen from the table, there were no significant differences in average signal power between children of groups 1 and 2. However, in our previous works (Marushko Y.V., Khomych O.V., 2022). we conducted more accurate comparisons of children with pneumonia and healthy children and found reliable differences. Children with pneumonia were divided into subgroups depending on the mean values of the average signal power. When conducting multiple comparisons, the Sheffe method revealed a statistical difference in the mean values of the average signal power in children with pneumonia of subgroup 1 (200,000 C.U. to 800,000 C.U.) and subgroup 2 (1,000,000 C.U. – 1,600,000 C.U.) ($p<0.01$), in children with pneumonia of subgroup 1 (200,000 C.U. to 800,000 C.U.) and healthy children (500,000 C.U. to 1,500,000 C.U.) ($p<0.01$), children with pneumonia of subgroup 2 (1,000,000 C.U. – 1,600,000 C.U.) and healthy children ($p<0.01$).

Only in the 2nd octave were significant differences found between the 2nd and 3rd groups in the average signal power and in the amplitude of the acoustic signal.

In the 3rd octave, significant differences in the average signal power were found between groups 1 and 2, and between groups 1 and 3, presented in Fig. 2. Also, differences in the amplitude of the acoustic signal were found between groups 1 and 2.

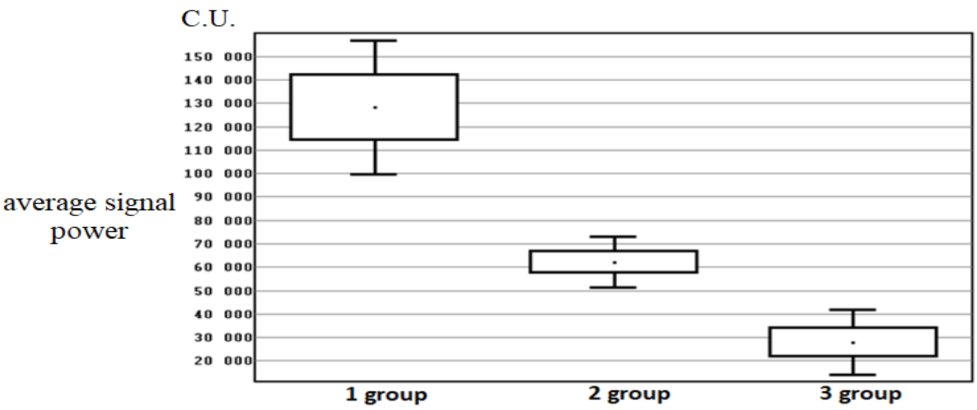


Fig. 2. Interval estimation of the average signal power in 0 octave between the three studied groups (the median, standard error and 95 % CI of the median estimate are indicated)

In the 4th octave, significant differences in the average signal power and amplitude of the acoustic signal were found between the 1st and 2nd groups and between the 1st and 3rd groups.

In the 5th octave, differences were found in the average signal power, frequency and amplitude of the acoustic signal between the 1st and 2nd groups and between the 1st and 3rd groups. There were no differences in these parameters between group 2 and group 3.

In 6 octaves, significant differences in the average signal power and amplitude of the acoustic signal were found between the 1st and 2nd groups and between the 1st and 3rd groups.

In the 7th and 9th octaves, differences in the average signal power were found between the children of the 1st and 3rd groups. In the 8th octave, statistically significant differences in the average signal power and acoustic signal frequency were not found. However, differences in the amplitude of the acoustic signal between the 2nd and 3rd groups were found.

Thus, the study of the acoustic signal in 11 octaves in children from the three studied groups using the new acoustic monitoring device "Trembita-Corona" gives us a more accurate and clear description of the acoustic signals in the lungs.

**4. Discussion**

Respiratory acoustics today is a promising scientific field [1, 5, 6]. The main task in this field is the development of theories of proliferation and generation of acoustic sound in the lungs and creating objective acoustic methods that can improve the diagnosis of diseases.

We, the specialists from the Bohomolets Medical University and the leading specialists of the National Aviation University, developed the new acoustic monitoring device "Trembita-Corona" to diagnose respiratory sounds above the lungs [9]. This device makes acoustic monitoring of the lungs, which in turn speeds up the diagnosis and helps to localize the zones of lung damage [11]. In previous works, we discovered that for determining the inflammatory process in the lungs during pneumonia, the most promising are the studies of acoustic sounds in the ranges of 0, 1, 2, 3, 4, 5, 6 octaves [10].

In children's pulmonology, many devices are used to diagnose acoustic changes in the lungs. These devices have their own positive and negative aspects.

One of these methods is the method of children's pulmonography [7, 8]. During pulmonography, respiratory sounds are recorded at certain points above the lungs using electret microphones.

Signals obtained using this method undergo a filtering process and are digitized with subsequent mathematical data analysis. However, this method has a number of peculiarities. One of them is that with the help of this method, it is possible to analyze only one type of sound, and the second is that this method does not provide an opportunity to accurately localize the location and positioning of the source of the pathological process in the lungs. Therefore, the use of such diagnostic methods has not become widespread in medical practice. Currently, computer analysis of respiratory sounds has proven to be a promising tool for diagnosing pathological processes in the lungs [5].

In contradistinction to this device, our acoustic monitoring device, "Trembita-Corona", records and analyzes acoustic vibrations with the help of two receivers in each of the examined points of sound diagnostics. Then mathematical processing of acoustic signals and analysis of the nature and characteristic features of these sound vibrations is carried out. After that, the direction and position of the source of these vibrations are calculated using the method of acoustic signal triangulation. Using this method, we can precisely determine the location of the lesion in the lungs. That is why it is possible to make a general description of the state of the lungs in real-time with the possibility of localization of the zones of lesions.

In pulmonology, the method of computer phonospirography is also used [5]. This method makes it possible to visualize additional noises over the lungs. The method is based on the analysis of two-dimensional phonospirograms and determining the time of a complete respiratory cycle. Electronic auscultation uses only 4 fixed sensors, reducing topical diagnostics. The device is used only in a sitting or standing position. This makes it impossible to use the device for lying patients. The interpretation of the results is carried out by a doctor, which can affect the result. The device has permanent sensors, making it impossible to use in children with pneumonia caused by the SARS-CoV-2 virus.

Also, the device has large dimensions, so the mobility of the method is impossible. When using our acoustic monitoring device, "Trembita-Corona", the acoustic signal is automatically processed without the involvement of the human factor.

The creation of a fully automated system of control and assessment of respiratory noises is an urgent task [5]. The problem of early diagnosis of inflammatory changes in the lungs, which can be determined using the acoustic method, has become acute. And our acoustic monitoring device, "Trembita-Corona", is just like that.

The use of a fully automated system for the control and assessment of respiratory sounds will improve and speed up the diagnosis of CAP in the early stages of the disease, during the asymptomatic course of the disease, or when the affected area of the lungs is behind the rib [5].

On May 5, 2023, WHO Director-General Tedros Adhanom Ghebreyesus stated during a briefing that the Covid-19 pandemic is officially over, and the spread of a new type of coronavirus infection is no longer considered an emergency of international concern. However, this does not mean that Covid-19 has stopped being a global threat to public health. Therefore, 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 [12].

Therefore, in our work, children were divided into 3 groups and multiple comparisons were made between groups. Differences were found between children with CAP (group 1) and healthy ones (group 2) in average signal power in 0,1,2,3,4,5,6 octaves, in the frequency of the acoustic signal in 0 and 5 octaves, and in the amplitude of the acoustic signal in 0,2,3,4,5,6 octaves. Differences between children with CAP (group 1) and children with pneumonia caused by the SARS-CoV-2 virus (group 3) in terms of average signal power in 0,1,2,3,4,5,6,7,9 octaves, frequency of the acoustic signal in 0 and 5 octaves, and amplitude of the acoustic signal in 0,1,4,5,6 octaves were also analyzed.

It was found that the characteristic features of acoustic signals in pneumonia caused by the SARS-CoV-2 virus are at marginal levels below CAP and are almost similar to healthy people.

That is why differences in average signal power and amplitude of the acoustic signal were found between pneumonia caused by the SARS-CoV-2 virus (group 3) and healthy children (group 2) in the 2nd octave ($p<0.01$). We proposed a theory of why exactly, in the 2nd octave, we can see changes in the power and amplitude of the sound signal. For this, it is necessary to delve into the pathogenesis of pneumonia caused by the SARS-CoV-2 virus.

According to the authors [12], a significant role in the pathogenesis of pneumonia caused by the SARS-CoV-2 virus is played by changes of a coagulopathic nature, and inflammation of the vascular endothelium. For direct penetration into the cell, SARS-CoV-2 uses the receptor of angiotensin-converting enzyme-2, which is present in the cells of the lung alveoli. It is this process that causes lung damage. It is also known that with interstitial pneumonia, such as pneumonia caused by the SARS-CoV-2 virus and interstitial pulmonary oedema, pathological auscultatory phenomena, which are necessary for establishing a diagnosis of pneumonia, cannot be heard by auscultation (Rao A et al.,2022). We do not hear fine-bubble moist and often dry rales due to the lack of liquid content in the alveoli.

Using the acoustic monitoring device "Trembita-Corona", we found differences between children with pneumonia caused by the SARS-CoV-2 virus (group 3) and healthy children (group 2) precisely in the 2nd octave. 2nd octave is in the range of 22.38721 – 44.66836 Hz, and the minimum sound wave threshold that our ear can perceive starts at 16 Hz. That is why the sound signal processing made it possible to detect special differences with the help of the acoustic monitoring device "Trembita-Corona".

As you know, the amplitude is the largest deviation of a value that periodically changes from the zero value. It is in the 8th octave that there are differences in the amplitude of the sound signal between healthy children and children with pneumonia caused by SARS-CoV-2. This acoustic characteristic is insensitive to the human ear due to the subjectivity of the doctor's assessment; these changes can be perceived as residual or minor deviations. However, it is they who have a probable difference and are significant for making a diagnosis, so the use of an automated measurement system is relevant.

That is why using the acoustic monitoring device "Trembita-Corona" makes it possible to improve and speed up the diagnosis of CAP and pneumonia caused by the SARS-CoV-2 virus and identify their characteristic features.

**Limitations of the study.** Noisy surroundings in the room where auscultation is carried out can potentially affect oscillations when recording acoustic phenomena. But these typical limitations of acoustic studies, which usually affect data in similar investigations, were overcome by the proposed and elaborated methods used in this research. According to this procedure, the acoustic signal was analyzed at specially selected frequencies. It made external noises captured simultaneously irrelevant to the carried-out analysis, as experimental validation of the proposed methods for tested patients with confirmed diagnoses proves.

**Prospects for further studies.** Evaluation of acoustic signal features in children with community-acquired pneumonia and pneumonia caused by the SARS-CoV-2 virus in third octaves using the new acoustic monitoring device "Trembita-Corona".

## 5. Conclusions

1. The acoustic monitoring device "Trembita-Corona" makes it possible to improve diagnostics and identify characteristic features of pneumonia and pneumonia caused by the SARS-CoV-2 virus based on the analysis of average signal power, frequency and amplitude of the acoustic signal in 11 octaves.

2. Using the acoustic monitoring device "Trembita-Corona", were found differences between children with CAP (group 1) and healthy ones (group 2) in average signal power in 0,1,2,3,4,5,6 octaves, in the frequency of the acoustic signal in 0 and 5 octaves, and in the amplitude of the acoustic signal in 0,2,3,4,5,6 octaves. Differences between children with CAP (group 1) and children with pneumonia caused by the SARS-CoV-2 virus (group 3) in terms of average signal power in 0,1,2,3,4,5,6,7,9 octaves, frequency of the acoustic signal in 0 and 5 octaves, and amplitude of the acoustic signal in 0,1,4,5,6 octaves were also analyzed.

3. Using the acoustic monitoring device "Trembita-Corona", were found differences in average signal power and amplitude of the acoustic signal between pneumonia caused by the SARS-CoV-2 virus (group 3) and healthy children (group 2) in the 2nd octave ($p<0.01$). Also, differences between these groups were found in the amplitude of the acoustic signal in the 8th octave.

**Conflict of interest**

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this article.

**Funding**

The study was conducted without financial support.

**Data availability**

Data will be made available on reasonable request.

**References**

1. de Benedictis, F. M., Kerem, E., Chang, A. B., Colin, A. A., Zar, H. J., Bush, A. (2020). Complicated pneumonia in children. The Lancet, 396 (10253), 786–798. doi: https://doi.org/10.1016/s0140-6736(20)31550-6

2. Klinichna nastanova, zasnovana na dokazakh «Pnevmonii u ditei» (2022). Nastanova No. KN 2022-1380. 02.08.2022. Available at: https://www.dec.gov.ua/?ZG93bmxvYWQ=d3AtY29udGVudC91cGxvYWRzLzIwMjIvMDgvMjAyMl8xMzgwX2tuX3BuZXZtb25peWlfdV9kaXRlai5wZGY=

3. Standarty medychnoi dopomohy «Pozalikarniani pnevmonii u ditei» (2022). Nakaz MOZ Ukrainy No. 1380. 02.08.2022. Available at: https://ліки.укр/admin/upload/file/NPA%20and%20projects/38989-dn_1380_02_08_2022.pdf

4. Yun, K. W., Wallihan, R., Juergensen, A., Mejias, A., Ramilo, O. (2019). Community-Acquired Pneumonia in Children: Myths and Facts. American Journal of Perinatology, 36 (S 02), S54–S57. doi: https://doi.org/10.1055/s-0039-1691801

5. Marushko, Y. V., Khomych, O. V., Hyshchak, T. V., Tarynska, O. L., Shchegel, G. O. (2021). State of the art usage of radiological and acoustic methods for the diagnosis of pneumonia, including those caused by SARS-CoV-2 virus, in children. Review. Medical Science of Ukraine (MSU), 17 (2), 114–124. doi: https://doi.org/10.32345/2664-4738.2.2021.16

6. le Roux, D. M., Zar, H. J. (2017). Community-acquired pneumonia in children – a changing spectrum of disease. Pediatric Radiology, 47 (11), 1392–1398. doi: https://doi.org/10.1007/s00247-017-3827-8

7. Marushko, Y., Khomych, O. (2023). Frequency characteristics of acoustic features of sound signals in the lungs of children with pneumonia using a new acoustic diagnostic device "Trembita-Corona." Neonatology, Surgery and Perinatal Medicine, 12 (4 (46)), 59–66. doi: https://doi.org/10.24061/2413-4260.xii.4.46.2022.9

8. Marushko, Yu., Khomych, O. (2023). Characterization of the average power, frequency and amplitude of acoustic signal peaks over the lungs in children with community-acquired pneumonia using the new device "Trembita-Corona." Medical Science of Ukraine (MSU), 19 (1), 53–69. doi: https://doi.org/10.32345/2664-4738.1.2023.08

9. Isaienko, V., Kharchenko, V., Astanin, V., Shchegel, G., Olefir, V., Olefir, O. et al. (2020). System for acoustic diagnostics and symptomatic assistance to covid-19 patients for use in extremal conditions "Trembita-Corona NAU". Proceedings of the National Aviation University, 82 (1), 58–63. doi: https://doi.org/10.18372/2306-1472.82.14612

10. Marushko, Yu. V., Khomych, O. V. (2023). Assessment of acoustic signal characteristics in children with community-acquired pneumonia according to the prevalence and nature of lung tissue damage using the new device «Trembita-Corona». Modern Pediatrics. Ukraine, 2 (130), 79–88.

11. Pavlenko, P. M., Marushko, Yu. V., Olefir, O. I., Khomych, O. V., Shchehel, H. O., Khomych, V. M., Olefir, A. O. (2021). Pat. No. 148836 UA. Prystrii akustychnoho sposterezhennia iz osovoiu diahramoiu napravlenosti. MKP G10K 11/08 (2006.01), G10K 11/28 (2006.01), G01V 1/46 (2006.01), G01S 11/14 (2006.01). No. u202102140. declareted: 23.04.2021; published: 22.09.2021, Bul. No. 38.

12. Rao, A., Huynh, E., Royston, T. J., Kornblith, A., Roy, S. (2019). Acoustic Methods for Pulmonary Diagnosis. IEEE Reviews in Biomedical Engineering, 12, 221–239. doi: https://doi.org/10.1109/rbme.2018.2874353

*Received date 21.02.2023*
*Accepted date 23.03.2023*
*Published date 31.03.2023*

**Yuriy Marushko**, Doctor of Medical Sciences, Professor, Department of Pediatrics Postgraduate Education, Bogomolets National Medical University, T. Shevchenko blvd., 13, Kyiv, Ukraine, 01601

**Olha Khomych***, Assistant, Department of Pediatrics Postgraduate Education, Bogomolets National Medical University, T. Shevchenko blvd., 13, Kyiv, Ukraine, 01601

***Corresponding author:** *Olha Khomych, e-mail: khomychov@gmail.com*