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DETECTION OF NON-RADIOCONTRAST FRAGMENTS IN MILITARY FIELD SURGERY BY THE NOISE EMITION METHOD

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ABSTRACT

A special tool for inspecting wound canals has been developed, consisting of a flexible probe for individual use and a handle-holder with a microphone capsule, the membrane of which is directly connected to the probe and reacts to mechanical contact with an obstacle, and the capsule itself is directly connected to the oscilloscope through a signal amplifier, which has spectral signal processing chains.

Functional conditioning of the controlled signals from the shape and type of the foreign object in the wound channel was revealed. The expediency of using the frequency-amplitude characteristic of noise emission as a controlled parameter has been proven. Thus, the existence of a functional conditioning of the width of the spectrum of the noise emission signal at the time of mechanical contact with a foreign object in the wound, its shape and type is shown; it was determined that the use of an oscilloscope with a spectral analysis channel allows fairly accurate identification of a non-radiocontrast foreign object in a wound.

1. INTRODUCTION

The main method used in modern medicine to find fragments is diagnostics, which does not involve direct contact with the fragment itself. Detection methods are aimed at interaction through human tissues, using the properties of fragments such as: ferromagnetism, X-ray contrast, etc. Thus, fragments that do not have the appropriate properties are difficult to detect. It can be glass, plastic, composites, etc.

The biggest danger is small fragments, regardless of their size, they prevent the healing of the wound, besides, they are difficult to detect and remove [1, 2]. Fragments can remain not only at the end of the wound channel, but also on its walls, which further complicates their detection.

When the fragment enters the soft tissues of a person, it leaves behind a cone-shaped entrance hole that can be used for laparoscopic examinations.

The laparoscopic approach can also be used to remove ferromagnetic fragments using magnetic means, in particular [3-5]. The difference is that the holder with a magnet is inserted not into the wound itself, but into an incision on the human body after the surgeon's manipulations. This method can remove even the smallest fragments. To diagnose fragments, you can use the wound channel formed by the fragment itself [6].

2. EXPOSITION

Given the peculiarities of the wound channel, the device that is introduced into the human body should be flexible enough to be inserted into the wound with minimal damage. In addition, the device must be made disposable to minimize the likelihood of infection, contamination, and other people's blood entering the wound. Also, the device should be able to scan the side walls of the channel.

However, it is worth remembering that for a better recovery of human tissues after a shrapnel injury, it is necessary to perform surgical intervention to remove tissues with primary necrosis. This can be done using a laparoscope probe with a scissor clamp.

The effect of noise emission was used to detect fragments. There are always damages and defects on the surface, so when something is passed over it, a noise occurs. If you take and run something over soft tissues and a solid object (shard), there will be significant differences on the oscillogram. Due to such a difference in noise, it is possible to tactilely diagnose the location of the fragment.

Thus, our device should consist of 2 parts: 1) a replaceable part that is inserted into the wound; 2) a reusable device with a microphone for capturing noise and the appropriate software (software) for its processing.

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A developed laparoscopic tool for inspecting wound channels, consisting of a flexible probe for individual use and a handle-holder with a microphone capsule, the membrane of which is directly connected to the probe and reacts to mechanical contact with an obstacle, and the capsule itself is directly connected to the oscilloscope through a signal amplifier, which has spectral signal processing chains.

The device consists of 2 parts (Fig. 1). The first part consists of elements 7, 6, 5, 4 and 8. This part is reusable. The second of elements 1, 2, 3 and 8. Let's consider each of the parts in detail.

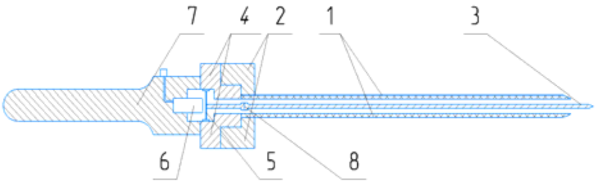


Fig. 1. Drawing of the device for detecting fragments in the body (assembled)

Consider the static model of the device. Let's start with the variable part (Fig. 2). The flexible tube 1, connected to the fastening element 2, enters the wound channel. Buge 3 is slightly longer than the tube and looks out of it. During the passage of the wound channel, it touches it and creates noises, and accordingly oscillations, which are transmitted through probe 3 to the reusable part. Fastening element 2 is attached to element 4 using a threaded connection. Let's consider the dynamic model of the device. Before the start of use, part 1 and part 2 are fastened together with fastening elements 2 and 4, and with an element 8. Holding the device by element 7, tube 1 with an element 3 is inserted into the wound. When in contact with the surface, noise occurs, which is transmitted in the form of vibrations, transmitted by the bushing 3 through the connection 8 to the noise-generating membrane 5, the microphone 6 picks up this noise and transmits it in the form of electrical signals to the device with the appropriate software for further processing of the signal.

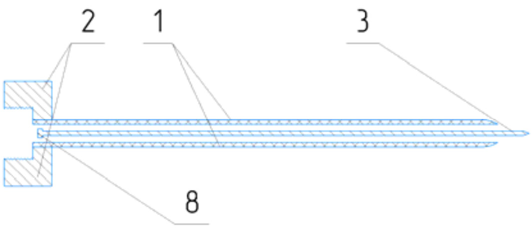
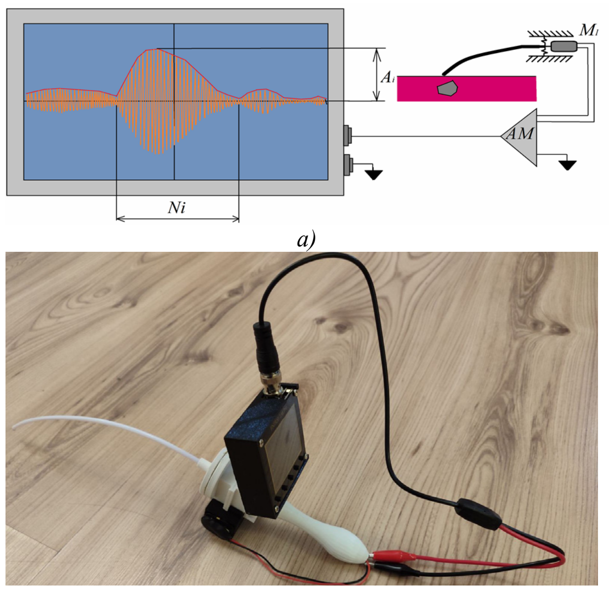


Fig. 2. Replaceable part of the device

The reusable part is attached to the replaceable part by the fastening element 2, which is securely attached to the housing-handle 7, in which the microphone 6 is mounted. The plug 3, thanks to a small magnet 8, is connected to its extension in the reusable part. The extension of the boom 3 is attached to the membrane 5, which, accordingly, creates vibrations that are picked up by the microphone 6. Then the signal is transmitted to a computer or other device with the necessary software.

Before the start of use, part 1 and part 2 are fastened together with fastening elements 2 and 4, and with an element 8. Holding the device by element 7, tube 1 with an element 3 is inserted into the wound. When in contact with the surface, noise occurs, which is transmitted in the form of vibrations, transmitted by the bushing 3 through the connection 8 to the noise-generating membrane 5, the microphone 6 picks up this noise and transmits it in the form of electrical signals to the device with the appropriate software for further processing of the signal.

The scheme of the experiment is presented in fig. 3. Using the probe connected to the capsules of the microphone M, connected to the low-frequency AM amplifier built on KT315B transistors, the output stage of which is connected to the REGOL oscilloscope, we are able to form a broadband noise emission in non-stationary contact with shrapnel in the wound channel. The controlled values will be the amplitude Ai obtained after spectral analysis and the width of the band Ni, which can be recorded on the oscilloscope screen. The averaged values of Ai as well as the width of the band Ni in the memory cells of the oscilloscope, which simplifies the transfer of data for further statistical processing.



a)

b)

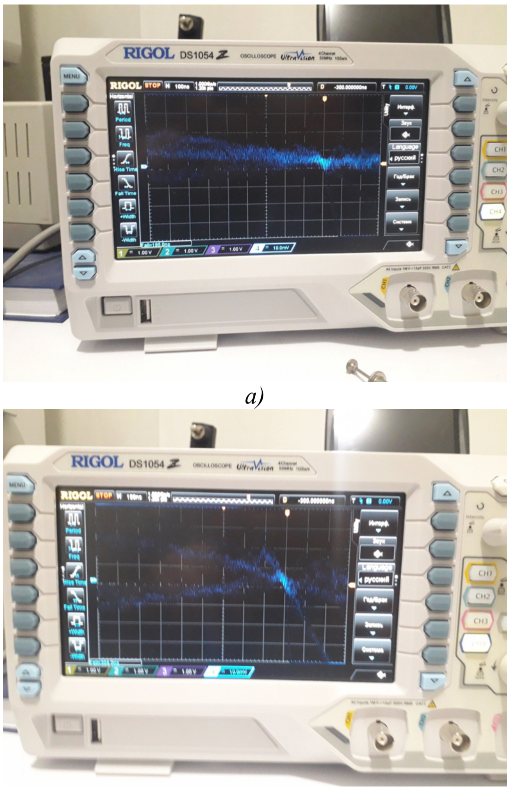
Fig. 3. Conducting an experiment (a) and photo of device (b)

The following were used for the experiment: 3D scanner "Revopoint Pop I", software for the scanner, oscilloscope "RIGOL DS-1054", optical microscope "Digital microscope ADSM301" with 40x magnification, microphone, amplifier of low-frequency signals, plastic fragment, surgical demonstrator, scalpel, lancet, tweezers.

When determining the location of the fragment in the surgical demonstrator, its location was fixed both with the help of a 3-D scanner and by inserting the probe of the proposed device. At the same time, the level, amplitude and spectrum of the noise emission signal were monitored on the oscilloscope screen, Fig. 4.

In the future, the signal was processed using the statistical processing program Statgraphik+. 3 types of fragments were considered: plastic fragment, glass fragment and stone fragment (mineral). These parameters are qualitative. Thus, this parameter is the level of variation of foreign body factors in the wound channel. The output (controlled) values are the amplitude Ai and the width of the channel.

Statistical processing of the array of data showed that the A_i scattering fields of each sample are compared with each other and compared with the general scattering field, there is no functional conditioning. So with a probability of 95%, we can assume that the controlled amplitude does not depend on which fragment is in the wound, but appears randomly.



a)

b)

Fig. 4. Picture on the oscilloscope screen in the absence of a fragment and when it is detected

Unlike the amplitude, which does not depend on the type and size of the inclusions, the width of the frequency band is quite clearly determined by the type and size of the rolling pin.

Thus, control of the frequency emission band can be a reliable indicator that determines not only the presence of a fragment in the patient's body, but also its type and relative size.

The functional conditioning of the width of the spectrum of the noise emission signal at the time of mechanical contact with a foreign object in the wound, its shape and type has been proven; it was determined that the use of an oscilloscope with a spectral analysis channel allows fairly accurate identification of a non-radiocontrast foreign object in a wound.

It is proved that the noise emission bandwidth parameter is effective, while the signal amplitude parameter did not reveal such a property. To improve the informativeness of the signal, it is processed according to a certain procedure

1. The received noise signal is sent filtered, where the largest noise effects are cut off.

2. Next, the signal passes through a Hanna window for high-resolution spectra and for frequency refinement, and through a flat-top (rectangular) window for a low-resolution spectrum (for amplitude level refinement).

When passing through the window, according to the signal, the hardware is multiplied with the function of the window $w(n)$: $w(n)=1$ – for a flat-top (rectangular) window; $w(n)=0.5-0.5*cos\left(\frac{2\pi n}{n-1}\right)$ – for the Hanna window. Here is the function of the window that depends on the value of the signal n, N is the value of the sample.

3. Next, the signal passes through the Fourier transform unit and the amplitude spectrum is obtained. The signal is transformed using fast Fourier transforms.

Fast Fourier transforms are a method of calculating the discrete Fourier transform for computers (the discrete transform formula has the form

$$X(f)=\sum_{n=-\infty}^{+\infty}x(n)exp(-j2\pi fnT), \qquad -1/(2T)\leq f\leq 1/(2T)$$

where is the result of transformation, frequency function (amplitude-frequency spectrum); f – reference (sampling) frequency, Hz; T – reference interval in time (sampling), s; x(n) is a discrete signal of n time intervals with an interval T. Discretization allows you to divide the spectrum into time intervals, using an infinite number of which the original amplitude-frequency spectrum can be restored.

The result of signal processing is displayed on the oscilloscope window and allows the surgeon. Determine the size and position of the fragment.

Further research can be directed to the creation of data analysis tools based on fuzzy logic and further study of the influence of the characteristics of the fragments and their location in the patient's body on the width of the noise emission band.

So, we proved that the noise emission that occurs during the non-static contact of a flexible, elastic probe with a foreign body in the wound channel, and which is characterized by the amplitude and width of the spectrum at certain resonant frequencies, can serve as a reliable signal for determining the presence of a foreign object in the wound. The width of the noise emission frequency spectrum reliably determines the type of foreign object (glass, plastic, etc.).

An innovative tool for inspecting wound canals is offered, consisting of a flexible probe for individual use and a holder handle with a microphone capsule, the membrane of which is directly connected to the probe and reacts to mechanical contact with an obstacle, and the capsule itself is directly connected to an oscilloscope through a signal amplifier, which has chains of spectral signal processing.

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