Acoustic and Biomedical Engineering

The Distribution of Biological Particles Suspended in Normal Cerebrospinal Fluid (CSF)

W. Staroń[a*] and L. Herbowski[b]

[a]Institute of Physics, University of Szczecin, Wielkopolska 15, 70-451 Szczecin, Poland

[b]Public Provincial Hospital Complex in Szczecin, Poland

Cerebrospinal fluid's functions are protecting, expelling and transporting which are influenced by properties of the fluid. Disorder of one of the functions may bring a disease. Cerebrospinal fluid mainly consists of water (99%), cells and proteins suspended in it. Due to the suspension it can be considered as dispersion medium. Every dispersion medium is characterized by the parameters of particles suspended in it. Parameters of dispersion medium may be classified as single or cumulative parameters. Hence, there is possible to determine additional parameters which characterize CSF in order to give full description of the fluid. The authors present results of research on suspension in normal cerebrospinal fluid worked out on the basis of 2500 microscoping pictures and they also give a statistical analysis of particle diameters. The paper is a part of research project on "Physico-chemical processes in cerebrospinal fluid obtained by puncture from patients diagnosed with the disorders of cerebrospinal fluid (CSF) circulation" realized by Institute of Physics, University of Szczecin in co-operation with Neurosurgery Ward of Public Provincial Hospital Complex in Szczecin.

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1. Introduction

Cerebrospinal fluid is produced continuously in the brain by choroids plexuses in cerebral cavity. Cerebrospinal fluid is transported through three ventricles and surrounds the spinal cord and the brain. Protecting, expelling and transporting are the function of cerebrospinal fluid in a human body. Daily production of cerebrospinal fluid is about 500 ml whereas the capacity of fluid space is estimated to be about 100 to 150 ml [1]. Overproduction of cerebrospinal fluid is absorbed by bloodstream in the upper part of a head — the subarachnoid space. Disorder in circulation may result in disorder in absorption and this may be a reason, for example hydrocephalus.

2. Cerebrospinal fluid as a dispersion medium

Normal cerebrospinal fluid consists of water and suspended objects, which have different sizes and shapes. There are cells and proteins among them [2, 3].

From the physical point of view, cerebrospinal fluid is a dispersion medium influenced by objects suspended in it. Therefore it is important to clearly describe the objects. In biophysics to describe objects one uses single parameters as well as cumulative ones [4]. Single parameters characterize single particles, for example total object specific area or object boundary specific perimiter. Cumulative parameters characterize all suspended objects, for example count or numerical density [5].

Circulation and absorption of cerebrospinal fluid occur respectively in dependence on parameters of a dispersion medium. Objects suspended in a dispersion medium go through different physical processes such as aggregation or coagulation [6].

For this reason it is important to describe objects suspended in a dispersion medium in such many parameters which allow one to know better the mechanism of circulation and absorption. In this way the parameters may become additional parameters in diagnosis of diseases.

The authors analyzed the count and diameter of each particle suspended in normal cerebrospinal fluid.

3. Material and methodology

Cerebrospinal fluid was sampled from the patients hospitalized in the Neurosurgery Ward of of Public Provincial Hospital Complex in Szczecin. The cerebrospinal fluid was sampled during routine diagnostic procedures and treatment. The cerebrospinal fluid was physiological both macroscopically (clear and transparent), biochemically (normal protein level) and cytologically (normal cell content). It was tested with a microscopic method under the Eclipse 600 microscope with magnification of 1200x compatible with a computer through a digital camera. Obtained pictures of cerebrospinal fluid were analyzed by computer. There were 2500 pictures analyzed in order to find count and total object specific area.

4. Results

Due to different shapes of suspended objects, it must be calculated an equivalent diameter dz of each object, later called diameter.

* corresponding author; e-mail: staron@wmf.univ.szczecin.pl

The equivalent diameter is calculated with the use of circle area formula by comparing the total object specific area to a circle of the same area.

Then the counted diameters of objects were classified according to their sizes every 0.5 μm. Results were ordered in an increasing sequence and the diameters were analyzed.

The smallest diameter was 1 μm and the biggest one was 21.5 μm. The range was 20.5 μm. The average diameter of an object was $Sdz = 4.85$ μm.

On the basis of standard deviation [7, 8] the spread was determined around the average. The standard deviation SD was 3.03 μm. It included 68% of observed objects. Then standard deviation of average σ was calculated and it is 0.11 μm.

For more detailed description of variability of a sample there was determined coefficient of variability CV. According to:

$$CV = (SD/Sdz) \times 100\%, \tag{1}$$

where CV — coefficient of variability, SD — standard deviation, Sdz — average equivalent diameter of an object, $CV = 62.4\%$.

During the analysis there were observed only a few "large" objects that means the objects whose equivalent diameter was bigger than 10 μm. The analysis showed that objects with diameters larger than 10.5 μm are fewer than 2% of all. Large objects overestimate the value of an average diameter. According to Chauvenet's criterion [7] the results may be rejected and not be taken into consideration in further analysis as they are insignificant. However, in the point of biophysics view the results cannot be rejected because such big objects are present in cerebrospinal fluid and they are put on observation, for example sizes of macrophages are from 15 to 45 μm. In order to more detailed analysis median of a sequence which was 3.75 μm and mode were determined. Objects of a diameter 2 μm were the most often observed and there were recorded 114 of them.

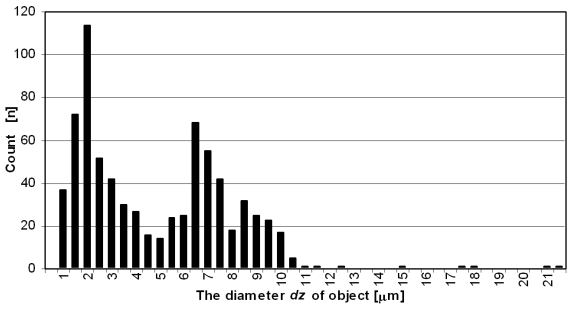

Fig. 1. Count n of objects of given equivalent diameter in normal cerebrospinal fluid.

Quartiles also were determined $Q1 = 2.09$ μm, $Q2 = 4.24$ μm and $Q3 = 7.11$ μm. It means that 25% of the objects have diameters smaller than 2.09 μm. The second quartile shows that 50% of the objects have diameters smaller than 4.24 μm. The third quartile shows that 75% of the objects have diameters smaller than 7.11 μm.

On the basis of the measuring results a diagram of dependence of count on the equivalent diameter was drawn (Fig. 1).

The diagram shows that the distribution of the variable is not symmetrical. In order to determine the deviation from the symmetry skeweness which is 0.859 was determined. Curtosis which describes whether the distribution is leptokurtic or platykurtic was also was determined. It was 1.651.

5. Conclusions

Objects present in normal cerebrospinal fluid differ according to their sizes. Suspended particles of diameters smaller than 10 μm are in substantial majority. It is confirmed by the facts that probability of observation of the most often occurring object (diameter of 2 μm) is 0.15 as well as by the result of the third quartile: 7.11 μm, which means that 75% of the observed objects have diameters smaller than 7.11 μm.

The shape of distribution of diameters shows that the distribution is not symmetrical. Here it is right-skew because coefficient of the skewness is positive and it is 0.859. Positive value of curtosis shows that the distribution is leptokurtic.

The distribution of diameters is bimodal that confirms results of the previous research worked out on the smaller sample. In statistical analysis such type of a distribution is premise to classify the data.

The method of description of distribution of objects suspended in cerebrospinal fluid may find the use in assessment of pathologic changes in the cerebrospinal fluid in diseases of nervous system and it demands further clinical research.

References

[1] M. Uszyński, (editor.), *Fluids in body cavities*, PZWL, Warsaw 1998, (in Polish).

[2] T. Yamada, I. Mukaiyama, N. Miyake, J. Igari, *Rinsho Byori* **50**, 6 2002.

[3] P. Lewczuk, H. Reiber, H. Ehrenreich, *Neurochem. Res* **23**, (1998).

[4] W. Staroń, L. Herbowski, H. Gurgul, *Proc. of SPIE* **6609**, (2007).

[5] K.W. Zieliński, M. Strzelecki, *Computer analysis of biomedical picture*, PWN, Warsaw-Łódź 2002, (in Polish).

[6] H. Sonntag, *Colloids*, PWN, Warsaw 1982, (in Polish).

[7] J.R. Taylor, *An Introduction to Error Analysis*, PWN, Warsaw 1995, p. 300, (in Polish).

[8] C. Watała, *Biostatystics*, α-medica press, Bielsko-Biała 2002, (in Polish).