Correlations Between the Cerebrospinal Fluid Surface Tension Value and 1. Concentration of Total Proteins 2. Number of Cell Elements

A. Kratochvíl and E. Hrnčíř

Clinic of Occupational Diseases, Third Faculty of Medicine, Charles University, Prague, Czech Republic

Abstract. The contribution gives a survey about the problematics of surface tension in biomedical sciences. The paper presents results of a study devoted to the cerebrospinal fluid. The distribution of the surface tension values of this liquid in healthy individuals is presented ($n = 33$), and further, statistically significant correlations between the cerebrospinal fluid surface tension value and 1. concentration of total proteins expressed by Spearman's coefficient $\rho_s = (-0.995)$ and 2. number of cell elements expressed through Spearman's coefficient $\rho_s = (-0.965)$ in cerebrospinal fluid are described.

Key words: Cell elements — Cerebrospinal fluid — Correlation — Proteins — Surface tension

Introduction

In biomedicine, the term "surface tension" is used above all in connection with surface tension of the lung surfactant and evaluation of the lung maturity, and exploring the role of the lung surfactant in such pathological states as adult respiratory distress syndrome, respiratory distress syndrome, bronchopulmonary dysplasia, syndrome of meconium aspiration, bronchial asthma, and bacterial and virus pneumonia (Wiswell et al. 1994; Friedrich et al. 1996; Gunther et al. 1996). For example, the following connection has been proved: Diverse characteristics of surfactants obtained from lungs of different degree of maturity that relate to the surface tension of samples in different surface age, explain the high resistance of immature lungs to the first inspiration (Friedrich et al. 1996).

In addition to pneumology, there are studies evaluating the surface tension of urine where a statistically significant correlation between decrease of the surface tension of this liquid and the value of a 24 hour proteinuria has been proved (Diskin et al. 2000).

Correspondence to: MUDr. Antonín Kratochvíl, Clinic of Occupational Diseases, Third Faculty of Medicine, Charles University, Šrobárova 50, 100 34 Prague 10, Czech Republic. E-mail: ant.kratochvil@centrum.cz

From our point of view the works of Brydon et al. (1995) are very contributive. They studied surface tension of the cerebrospinal fluid samples in patients with a cerebrospinal fluid infection, hemorrhage, congenital and tumour hydrocephalus, and CNS malformations also with use of the shunt valve opening facility (Brydon et al. 1995).

The objectives of this study, using the drop weight method for determination of surface tension, were to map the surface tension values of the cerebrospinal fluid (CSF) in both groups of samples that showed abnormal values in parameters we have followed and some other samples without these abnormalities. Further we wanted to use the possibility of correlation of this physical quality with measured parameters most often chosen in practise. We hypothesised, that the surface tension of the cerebrospinal fluid might correlate with other parameters owing to the physical-chemical character of proteins and their total content in the cerebrospinal fluid. Furthermore, dependence between the cerebrospinal fluid surface tension and the presence of cell elements was predicted, owing to the amphiphility of phospholipids of cell membranes and their ability to decrease surface tension.

In addition to our determination of surface tension we also refer further to numerous works of Siniachenko et al. (1998a) who are engaged above all in changes in the surface tension of body liquids from the standpoint of its correlation directly to the development of single pathological states. Their contributions show the changes and further development of surface tension of biological liquids at a different surface age during the progress of such pathological states as nervous system tumours, malignant tumours of reproductive organs, rheumatoid arthritis, kidney diseases, etc. (Kazakov et al. 1998; Siniachenko et al. 1998a,b).

Existing results of studies concerning experimental influence of changes in the surface tension refer, above all, to examinations of the course of air embolism in context with the research of the decompression sickness (Jensen et al. 1993; Hrnčíř 1996).

Materials and Methods

In our study the drop weight method was chosen to measure the surface tension of the cerebrospinal fluid. This method, also called stalagmometry, is a course enabling so called "relative measuring" of the surface tension. At the drop weight method the mass of drops of both the examined and the standard liquid are measured. As the standard liquid we used redistilled water with surface tension $\sigma = 72.45$ mN/m at 22℃ (22℃ was the temperature of the samples and the surroundings during measurements). Drops were torn off from the capillary under static conditions. The value of the sample surface tension of the cerebrospinal fluid was determined based on the dependence between its value and the weight of the drop – to tear off the drop from the capillary, the weight of the drop had to overcome the force of the surface tension at the narrows (Kellö and Tkáč 1977). The total number of drops weighted within the framework of one measurement had to correspond with the capacity and readability of used balances. We used balances with capacity

of 10 g and readability of 0.002 g for our measurements (Ohaus corp. 1998). The accuracy of measurements obtained, given by a weighting mistake (0.002 g) and by other influences (air stream, vibration or evaporation), was fully comparable to the measuring accuracy of other methods used for determination of the surface tension value (Cole-Parmer 1999). The convenience for the specific use of this method was verified by comparison of measurement results of several liquids of known surface tension (redistilled water, glycerol, ethanol, mercury, toluene, etc.) with respective surface tensions.

To reach our objectives, we examined 111 samples of cerebrospinal fluid (44 men and 67 women aged 22 to 79 years). The average age was 49.5 years for the men and 53.9 years for the women. The cerebrospinal fluid was native and it was taken by a usual procedure for diagnostic purposes. Along with execution of the above mentioned measurements we also performed the following: concentration of total proteins and glucose in the fluid; number of erythrocytes, monocytes and polymorphonuclear leukocytes in the cerebrospinal fluid; determination of haemoglobin derivatives. The following values were treated as normal: Total proteins up to 0.5 g/l, glucose 2.4–4.0 mmol/l, cytology 1–15 cells, and absence of haemoglobin derivatives.

Further, the relations among the values of surface tension of the CSF, total concentration of proteins in the fluid and the amount of the cell elements contained were examined. For this purpose, only the samples with abnormality in the parameter under study were used. The data were statistically processed through the method of Spearman's coefficient of serial correlation and the coefficient of determination. The level of statistical significance $\alpha < 0.001$ was used (Kubánková and Hendl 1986). Spearman's coefficient of serial correlation was chosen as a non-parametric variation of correlation coefficients at the assumption of non-linear dependence.

Results

The parameters described above enabled us to determine a group of 33 patients with normal examination results (9 men and 24 women). The other samples showed abnormal values in one or more of the following parameters: increase in the number of total proteins in 57 cases, low level of glucose in 3 cases, high level of glucose in 6 cases and cell element increase in 52 cases.

Arithmetical average of the CSF surface tensions obtained at 22 ℃ by means of data processing of all observed samples ($n = 111$) was $\chi = 61.55$ mN/m; standard deviation $s = 5.13$ mN/m, and thus dispersion $s^2 = 26.32$ μN^2/m^2 and variation coefficient $V = 8.34\,\%$ (not shown).

Arithmetical average of the cerebrospinal fluid surface tensions of samples with no laboratory abnormalities detected ($n = 33$) was $\chi = 63.36$ mN/m at 22 ℃; standard deviation $s = 1.86$ mN/m, dispersion $s^2 = 3.44$ μN^2/m^2 and variation coefficient $V = 2.93\,\%$.

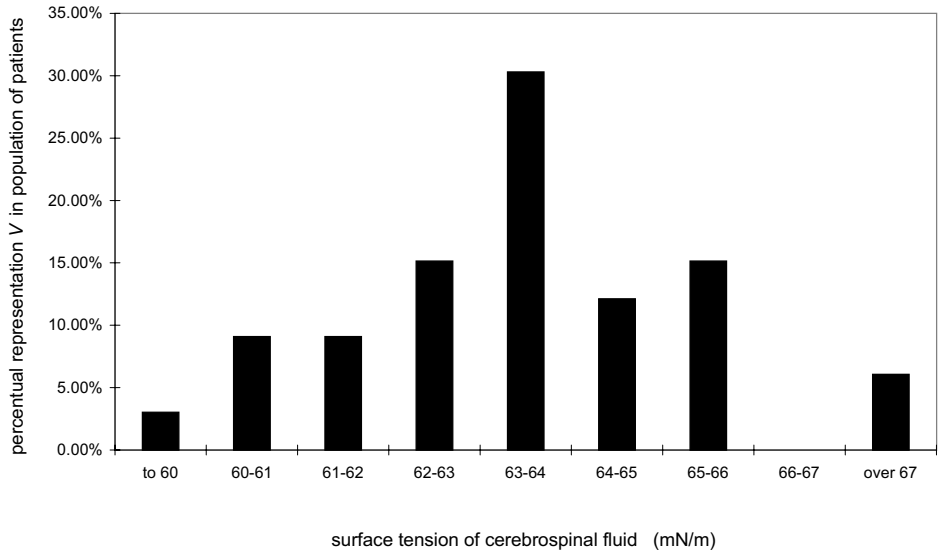

Figure 1. Distribution of surface tension of the cerebrospinal fluid at 22 °C in "healthy" population (samples taken from patients with no laboratory abnormality in the studied parameters detected, $n = 33$).

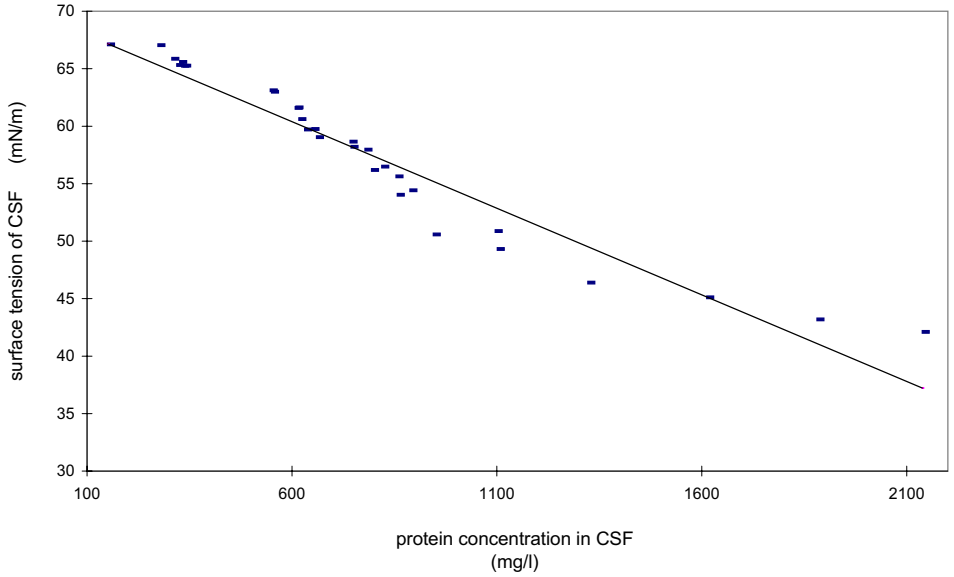

Figure 2. Dependence of surface tension (y_i) of the cerebrospinal fluid (CSF) on the concentration of total proteins (x_i) at 22 °C. Regress line $y_i = a \cdot (x_i) + b$; $a = -0.01507$ $\mathrm{mN \cdot l \cdot mg^{-1} \cdot m^{-1}}$; $b = 69.44$ $\mathrm{mN \cdot m^{-1}}$.

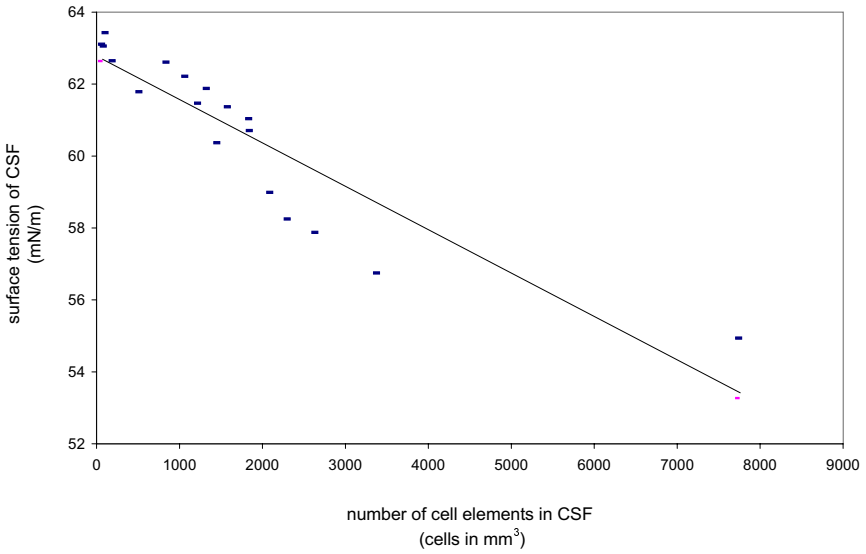

Figure 3. Dependence of surface tension of the cerebrospinal fluid (y_i) on the number of cell elements (x_i) at 22 °C ($n = 18$). Regress line $y_i = a \cdot (x_i) + b$; $a = -0.00122$ mN·mm^3·m^{-1}; $b = 60.7$ mN·m^{-1}.

Further, we followed the dependence of surface tension of the cerebrospinal fluid upon concentration of total proteins (Fig. 2) and upon the content of cell elements in the CSF (Fig. 3). For this purpose, only the samples with abnormality in correlated parameters have been selected. This condition was fulfilled for total proteins in 23 samples and for cell elements in 18 samples. In correlation of surface tension of the cerebrospinal fluid with concentration of total proteins in the CSF (Fig. 2), we used also the samples with concentration of proteins below 0.5 g/l for a better approach.

In Figs. 2 and 3, an evident (negative) dependence is seen between surface tension of the cerebrospinal fluid and both the concentration of total proteins (Fig. 2) and content of cell elements in fluid (Fig. 3) expressed through Spearman's coefficient $\rho_s = (-0.995)$ and $\rho_s = (-0.965)$, respectively. These values exceed the critical value for the given coefficient on the level of significance $\alpha = 0.001$. The determination coefficient was 99 % for protein concentration and 93 % for content of cell elements (Kubánková and Hendl 1986).

Both relationships studied show inverse character of dependence.

Discussion

Our discovery of the correlation between the cerebrospinal fluid surface tension and the total protein concentration in a sample examined is in agreement with the

nature of proteins as the main surfactant in the cerebrospinal fluid. The indicated exponential character of the course (Fig. 2, visible comparing short lines with the regression line) can be caused by smaller changes of liquid surface at the higher protein concentrations. The dependence of the cerebrospinal fluid surface tension upon the contents of proteins described by Brydon et al. (1995) is in agreement with our results. In their contribution the authors do not mention whether the correlated samples of the cerebrospinal fluid show also other abnormalities besides the increased contents of proteins – with regards to characteristics of the basic group (for example an increased number of cell elements, abnormal concentration of glucose).

The correlation between the CSF surface tension and the occurrence of cell elements in the examined sample is, in accordance with our opinion, more likely conditioned by positive adsorption of relevant components of cell membranes in the surface layer of the sample than by participation of other factors (for example changes of the composition of the cytokine level) because the elevation in the cell component concentration was caused above all by the heightened erythrocyte number caused by the artificial bleeding.

The drop weight method is, in our opinion, suitable for determination of the surface tension of the cerebrospinal fluid considering quickness and accuracy of the determination when processing a smaller number of samples.

Acknowledgements. We thank to the Clinic of Neurology of the University Hospital Královské Vinohrady for their kind providing us with examined material and relevant laboratory results.

References

Brydon H. L., Hayward R., Harkness W., Bayston R. (1995): Physical properties of cerebrospinal fluid of relevance to shunt function. 2. The effect of protein upon CSF surface tension and contact angle. Br. J. Neurosurg. **9**, 645—651

Cole-Parmer instrument company (1999): Tensiometers. In: General Catalogue, pp. 508—511, Vernon Hills

Diskin C. J., Stokes T. J., Carter L. M., Radclif F. L. (2000): Surface tension, proteinuria and the urine bubbles of Hippocrates. Lancet **335**, 901—902

Friedrich W., Schmalisch G., Haufe M. (1996): Surface tension measurements on pharyngeal and tracheal aspirate samples from newborns without and with RDS. Biol. Neonate **70**, 75—83

Gunther A., Siebert C., Schmidt R., Ziegler S., Grimminger F., Yabut M., Temmesfeld B., Walmrath D., Morr H., Seeger W. (1996): Surfactant alterations in severe pneumonia, acute adult respiratory distress syndrome and cardiogenic lung edema. Am. J. Respir. Crit. Care Med. **153**, 176—184

Hrnčíř E. (1996): Importance of surface tension in therapeutic Compression in decompression sickness. Physiol. Res. (Prague) **45**, 476—470

Jensen B. M., Vik A., Brubakk, A. O. (1993): Effects of treatment with Pluronic F-68 during continuous venous air embolism in swine. Undersea Hyperbaric Med. **20**, 17—26

Kazakov V. N., Siniachenko O. V., Trukhin D. V., Pison U. (1998): Dynamic interfacial tensiometry of biologic liquids. Colloids Surf., A **143**, 441—459

Kellö V., Tkáč, A. (1977): Surface tension. In: Physical Chemistry (Ed. V. Kellö), pp. 233—627, Alfa, Bratislava

Kubánková V., Hendl J. (1986): Statistics for health personnel. Zdrav. Aktual. **208**, 273—278 (in Czech)

Ohaus Corporation (1998): Portable Advanced Electronic Balances CT Series Instruction Manual. Hannover

Siniachenko O. V., Kazakov V. N., Fainerman V. B., Miller R., Antonova L. N., Nazarenko V. G., Trukhin D. V. (1998a): Dynamic interphase tensiometry of the cerebrospinal fluid and blood serum in nervous system tumours. Zh. Vopr. Neirokhir. Im. N. N. Burdenko **2**, 23—25 (in Russian)

Siniachenko O. V., Kazakov V. N., Muller H., Fainerman V. B., Miller R., Joss P., Ermolaeva M. V. (1998b): Dynamic surface tension of blood and synovial fluid in rheumatoid arthritis. Ter. Arkh. **70**, 46—49 (in Russian)

Wiswell T. E., Peabody S. S., Davis J. M. (1994): Surfactant therapy and high frequency jet ventilation in the management of a piglet model of the meconium aspiration syndrome. Pediatr. Res. **36**, 494—500

Final version accepted: October 30, 2001