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Enhancing the Safety of Medical Personel Through the Use of Modern Technology

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ABSTRACT

Security of a society is related to the level of its health which largely depends on the level of professional education of medical staff whose task is to help a person in life-threatening situations. Life-threatening situations include among others acute cardiac failure or renal failure. One of the methods to improve health condition of patients with these medical problems is intravenous treatment with dopamine administered by an infusion pump. Medical staff is responsible for proper programming of a pump so that it gives a patient the appropriate dose. Introduction of modern technology to training programme can facilitate the process of learning how to programme an automatic infusion pump. The article describes an example of a simple computer programme created on the basis of free software which is GeoGebra and shared as HTML pages. The prepared learning resource does not require from its receivers any programming skills or special software.

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A proper vocational preparation and continuous intellectual development of certain social groups is a foundation of security culture. According to the definition, security culture is basically all the legacy earned by a man, both material and non-material, which serves his widely understood defence, both military as well as non-military[1].

In order to develop this culture, an appropriate environment is needed – the so-called security environment. It is defined as a system which is dependent on dynamic interactions of many factors[2]. Our environment will be safer if we surround ourselves with people who know the best the activities they perform on a daily basis.

Throughout ages a human has been learning to spot and distinguish various threats. He has become aware of the need to cope with these threats and learned that there are opportunities to avoid threats and effectively prevent them[3]. The man observed that the better physical and mental state he is in, the more effectively he is able to care for his security as well as for the security of his relatives. So it is a truism to claim that the security of society is related to the individual's health status[4].

Only a healthy man will be able to properly care for the environment's security. According to the World Health Organisation, health is a physical and mental welfare. To maintain the state of health at the highest possible level, the whole population needs to be educated on health, both in terms of pro-health behaviour and appropriate education and professional preparation of medical personnel whose job is to help people in health prophylaxis as well as in the emergency of life threatening situations.

One of the elements of such education, obviously apart from familiarising the future medical professionals with pathomechanism of particular diseases, is the education on how to proceed in life threatening circumstances.

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1 J. Piwowarski, Kultura bezpieczeństwa i jej trzy wymiary, „Kultura Bezpieczeństwa. Nauka-Praktyka-Refleksje", Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego „Apeiron" w Krakowie, Kraków 2012, vol. 12, p. 7 – 10.

2 J. Piwowarski, *Fenomen bezpieczeństwa. Pomiędzy zagrożeniem a kulturą bezpieczeństwa*, Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego „Apeiron" w Krakowie, Kraków 2014, p. 6 – 7.

3 *Ibidem*, p. 10 – 11.

4 D. Szczeblowska, I. Grys, *Zdrowy tryb życia jako element kultury bezpieczeństwa*, „Kultura Bezpieczeństwa. Nauka-Praktyka-Refleksje", Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego „Apeiron" w Krakowie, Kraków 2014, vol. 16, p. 475.

Life threatening situations are such situations in which if the life-sustaining actions are not undertaken immediately, the person's general condition worsens and ultimately it may lead to his death[5]. Among many procedures to be undertaken when saving somebody's life and health, one should include the selection of appropriate medications and their safe administration. Therefore, it is essential to prepare the medical staff in this respect. It requires from the teaching personnel adequate adjusting of the didactic process, prepare the training programme and didactic materials. To acquire such skills, one needs to learn the basic mathematical principles.

These principles are used to determine the dosage of medications which are administered in life-threatening situations, and such situations are numerous. Their pathophysiology is different, hence the treatment also differs, which requires the application of various pharmacological means. Such conditions include, among others, renal failure, heart failure, hyperglycaemic coma, conditions involving severe pain plus many others. One of the means to improve health in such situations is intravenous administration of various pharmacological drugs in meticulously selected dosages. Such drugs include, among others, dopamine, dobutamine, norepinephrine, insulin, morphine or fentanyl. The most precise method of intravenous drug administration is their application through infusion pumps. The use of computer programmes to simulate the selection of dosages will be presented on the example of dopamine which is used in the treatment of acute kidney and heart failure or in the exacerbation of chronic kidney and heart failure.

Acute kidney failure or exacerbation of chronic kidney failure is a sudden impairment of their function, primarily glomerular filtration which takes hours and days, and involves the reduction of urine excretion, reducing also the excretion of toxic compounds produced in life processes. These compounds which are not excreted with urine, poison our body. The cause of this clinical problem, apart from damaging the kidney structure itself (failure of kidney origin) and blocking the outflow of urine through the urinary tract (post-renal failure), may be a reduction of the circulated blood volume, the so-called hypovolaemia. Hypovolaemia may be related with a haemorrhage or with low cardiac output resulting from its impairment[6].

[5] M. Buchfelder, A. Buchfelder, *Podręcznik pierwszej pomocy*, Wydawnictwo Lekarskie PZWL, Warszawa 2014, p. 17 – 19.

[6] I. Mikulska, *Interna Szczeklika*, Medycyna Praktyczna, Kraków 2015, p. 1489 – 1497.

Heart failure in turn, is a condition which involves the reduction of cardiac output (the volume of blood reaching the peripheral vessels decreases, the heart stops functioning as a pump), or a proper cardiac output is maintained thanks to the increased pressure of filling the heart cavities. The increased pressure of filling the heart cavities causes damage of this organ. The consequence of heart failure is the occurrence of clinical symptoms which include, among others, limitation of exercise tolerance, dyspnoea, peripheral oedema. In elderly people, the most frequent cause of acute heart failure or the exacerbation of chronic heart failure is the ischaemic heart disease. In younger people, the most frequent cause is dilated cardiomyopathy (a condition of various aetiology related to the dilation of heart cavities), arrhythmia, congenital and acquired heart defects, myocarditis[7].

In the treatment of acute renal failure and acute cardiac conditions, the popularly used drug is the synthetic derivative of dopamine, a neurotransmitter which is important for proper functioning of the body. It belongs to the so-called pressor amines and is used primarily in patients in whom, despite proper hydration, the low blood pressure persists[8]. Since dopamine has a short half-life (about 2 minutes), it has to be administered by continuous intravenous infusion through the infusion pump. The procedure involves ECG-guiding and monitoring blood pressure.

To prepare the solution for infusion, a 5% of glucose and 0.9% of NaCl can be used, or a mixture of these two solutions. There are dopamine formulas in 5 ml ampoules containing 50 mg of active ingredient and 10 ml ampoules containing 200 mg of active ingredient.

The administration of dopamine at a dose of 0.5–3 μg/kg of BW/min causes increased renal flow, glomerular filtration and sodium excretion. In such doses, dopamine does not affect the heart.

In dosage of 5–10 μg/kg of BW/min it increases the strength of heart contraction at the same time having no influence on peripheral vessels. In doses above 10 μg/kg BW/min, dopamine causes generalised contraction of blood vessels, which increases the systolic and diastolic blood pressure[9].

In view of the above, it is especially important to use dopamine in a specific and carefully controlled doses. A big advantage is the proposed intro-

[7] *Ibidem*, p. 403 – 405.

[8] *Ibidem*, p. 406 – 409, 1493 – 1494.

[9] J.K. Podlewski, A. Chwalibogowska-Podlewska, *Leki Współczesnej Terapii*, Medical Tribune Polska Sp. z o.o., Warszawa 2010, p. 238 – 239.

duction of a technique of automatic infusion pump computer programming. It increases the effectiveness of treatment and safety of patients' health as well as the professional safety of medical personnel involved in the treatment. The risk of making medical error is significantly reduced when calculating the appropriate dose of the drug.

Dopamine is widely administered by infusion pumps which ensure a constant rate of the flow. Such pumps allow for administration of the content of one or more syringes (containing 25, 50 or 100 ml) by means of a piston drive. The pump enables dosing the medicine at a rate of 0.1 to 100 ml/h[10]. Many clinics have older models of the pumps on the stock which allow for the adjustment of the dose from 0.5 ml/h with the accuracy of up to 0.5ml/h. We will carry out further deliberations taking those differences into account.

Fig. 1. Syringe infusion pump

The mathematical knowledge necessary to make calculations does not exceed the basic scope from a matriculation exam. If, however, apart from (sometimes completely) ungrounded unwillingness to mathematics the stress factors appears, multiplied by the feeling of responsibility for other man's life, even simple calculations may prove to be a big problem and may increase mental stress. This ever growing spiral of fear may contribute to medical errors. Let's trace the calculations necessary for proper drug application.

A doctor orders the administration of a drug specifying its dose in micrograms per kilogram of the *patient's* body weight per minute [e.g. 0.5 μg/kg BW/min.]. The infusion pump administers the drug at a previously set

[10] K. Zahradniczek, *Pielęgniarstwo*, Wydawnictwo Lekarskie PZWL, Warszawa 2004, p. 465 – 467.

rate in millimetres per hour [e.g. 20 ml/h]. The concentration of the solution prepared for the pump should be specified and the pump's flow rate should be appropriately programmed.

In the first place, we should specify the amount of the drug which a given patient will hypothetically take within one hour. The calculations are not complicated and in most cases are based on the proportion. To better illustrate the core calculations, we set the exemplary values: we assume that our patient weighs 72 kg and the doctor recommended the dosing of the drug at 2.5 μg/kg BW/min. Then the dose adjusted to this individual patient is:

2.5 μg – 1 kg of body weight

X1 μg – 72 kg body weight

that is X1 = 2.5 x 72 = 180 [μg]

So, the patient should receive 180 μg/min. And how to calculate how much is it per hour? Let's use the proportion again:

180 μg – 1 min

X2 μg – 60 min

that is X2 = 180 x 60 = 10,800 [μg]

So, our patient should receive 10,800 μg/h. And how is this related to the concentration of the solution and the infusion pump's settings?

Let's assume for a moment that we want to prepare 50 ml of the solution. For this purpose, we will use two ampoules of dopamine of 5 ml each (50 mg). So, these 2 ampoules of the drug should be dissolved in 40 ml of the infusion fluid. Why is that? We need 50 ml of fluid in total. 2 ampoules of drug will give us 2 x 5 ml = 10 ml, so 50 – 10 = 40 [ml] – this is the amount of the infusion fluid which should be used.

What is the concentration of the solution created in this way? And more precisely, how many μg of drug contains 50 ml of this solution? The answer is simple: the same as in all the used ampoules, that is 2 x 50 mg = 100 mg = 100,000 μg of the drug.

One thing left is to think about how many millilitres of this fluid should our patient take per hour to cover the demand of 10,800 μg of drug? Let's use the proportion again:

100,000 μg – 50 ml – the amount of drug units which our solution contains

10,800 μg – X3 ml – the amount of units which the patient must take in one hour that is X3 = (50 x 10,800): 100,000 = 5.4 [ml]

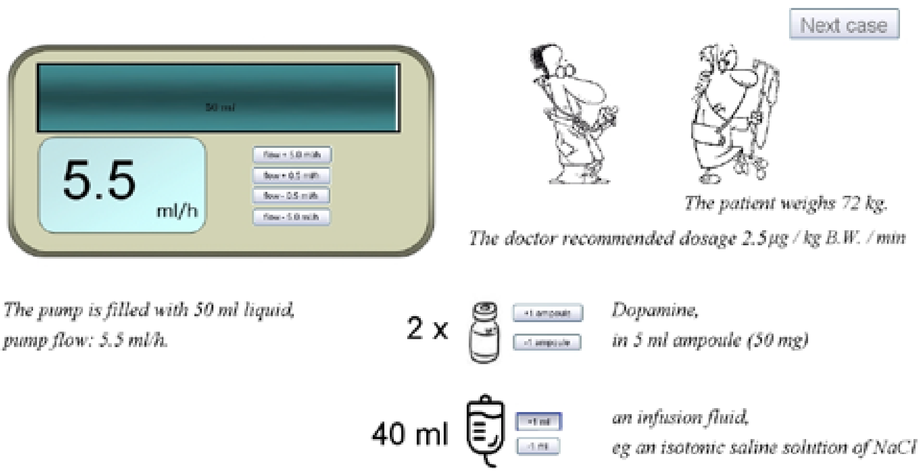
So, the pump's flow should be set at 5.4 ml/h.

In newer pump models the making this setting does not require any additional actions. In older models there may be certain difficulty due to technical limitations of the equipment.

As previously indicated, the older types of infusion pumps may dose the solution with the accuracy of 0.5 ml/h. So practically, the prepared solution may be applied to the device with the setting of5.5 ml/h (Fig. 2). With time however, it leads to the increased error in dosing the drug.

Clinically it is not significant because the dosage is modified depending on the patient's condition. The patient requiring the administration of pressor amines in infusion is a patient in a generally serious condition and needs to be continuously monitored. So, we should monitor his blood pressure, ECG record, diuresis and clinical symptoms. If there is no improvement of his general health, the flow rate of the pump should be increased in accordance with the dosage scheme recommended by the manufacturer. If there are side effects, the flow is reduced at a given time and following the decision of the doctor supervising the treatment.

Fig. 2. Proper setting of the pump with data taken from the discussed example



However, in this particular situation, it is worth putting every effort in order for the dose to be as close as possible to the recommended dose. Let's investigate in detail, how big is the error?

As calculated above, the theoretical dose is 10,800 μg of drug per hour. We can calculate the dosing error using the proportion:

10,800 μg – 5.4 ml/h – theoretical dosing

X4 μg – 5.5 ml/h – practical dosing

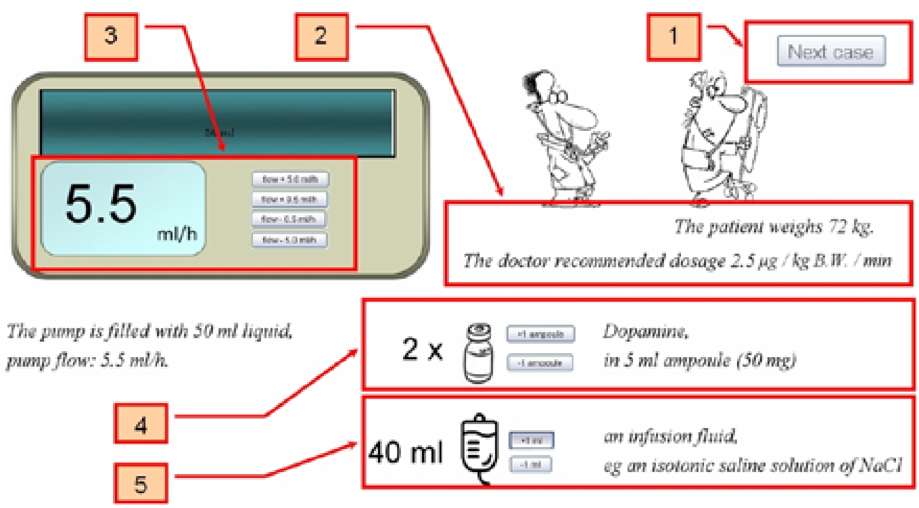
that is X4 = (5.5 x 10,800): 5.4 = 11,000 [μg]

The difference is 11,000 – 10,800 = 200 [μg]

It means that after one hour of the infusion, the difference in the dose of the drug would be 200 [μg]. Taking into account the previous remarks regarding the constant monitoring of the patient, it can be assumed that such deviation in dosing is admissible.

The prepared sheets are based on the GeoGebra scripts and are made available in the form of HTML websites. From the technical point of view, GeoGebra (www.geogebra.org) is a multiplatform, free of charge, DGS (Dynamic Geometry System) programme with CAs elements (Computer Algebra System), dedicated rather to exact sciences. It is widely applied in many branches of mathematics. A big advantage of the programme is its intuitiveness and simplicity of operation. Simple in use, it gives huge modification possibilities. It does not require a deep knowledge of programming to achieve the objectives. It allows to combine the graphics, text and calculations in a friendly manner. Thanks to these features the GeoGebra gained huge popularity among many circles of scientists and teachers.

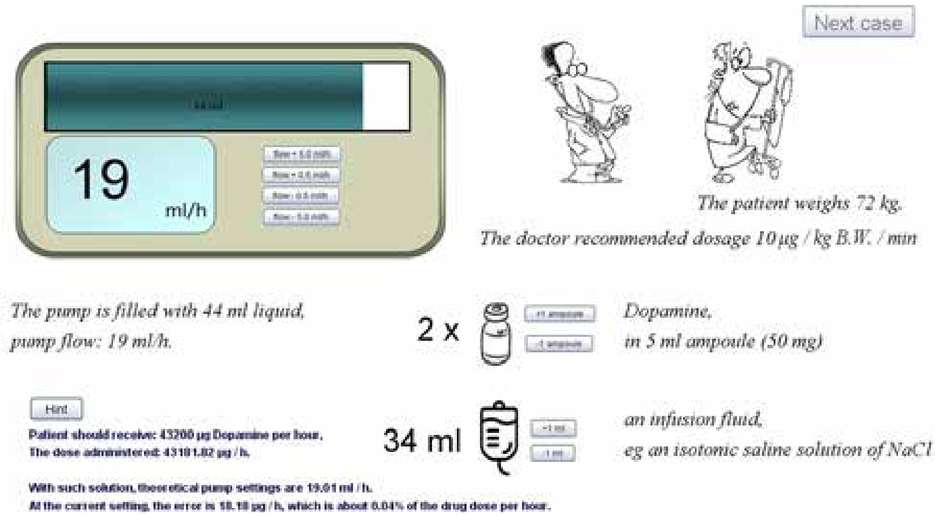
Fig. 3. Description of didactic sheet



Materials prepared in GeoGebra do not require the recipients to have the programming skills or to have this programme installed. Because all one needs to do is to export the prepared sheets to the so-called dynamic worksheet. The programme will then create the necessary files which we can put on the server or CD. To use them, only the internet browser is needed which operates Java Script. The didactic materials described in this paper have been prepared and made available in this form.

The sheets have been prepared in two variants: simulation and evaluation variant. Both of them have five common, basic areas (compare with Figure 2).

Fig. 4. Presentation of the simulation sheet

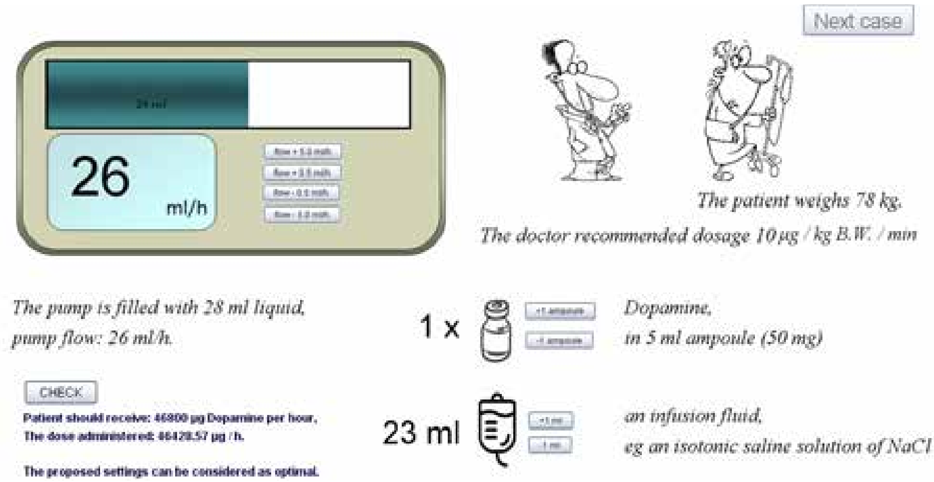


Area 1 is the button generating a new example. After pressing this button, the sheet makes calculations and presents new data. Area 2 is the section where the core of the problem is presented – medical case study. Here all patient's data and doctor's recommendations are presented. Area 3 is the section responsible for the settings of the infusion pump. The buttons allow for changing the flow values. All the sheet's values (i.e. the setting of the flow and the volume of the fluid in the syringe) are inserted automatically and presented in this section of the screen in a graphic form thus simulating the pump's image. Areas 4 and 5 are the sections responsible for the setting of the amounts of selected ampoules of the drug (area 4) and the amount of the infusion fluid (area 5) used to prepare the solution.

The above elements allow for the calculation of various cases and analysis of different situations, drugs proportions and the pump's settings.

Additionally, the sheet in the simulation form (Fig.4) has the option of giving hints of the proper settings after entering the initial data. It allows for learning several solutions of the same case, and consequently helping in gaining the experience which is so necessary. In practice, this method allows for tracking down any actual cases and comparing the results of various settings of the pump and drug's concentrations.

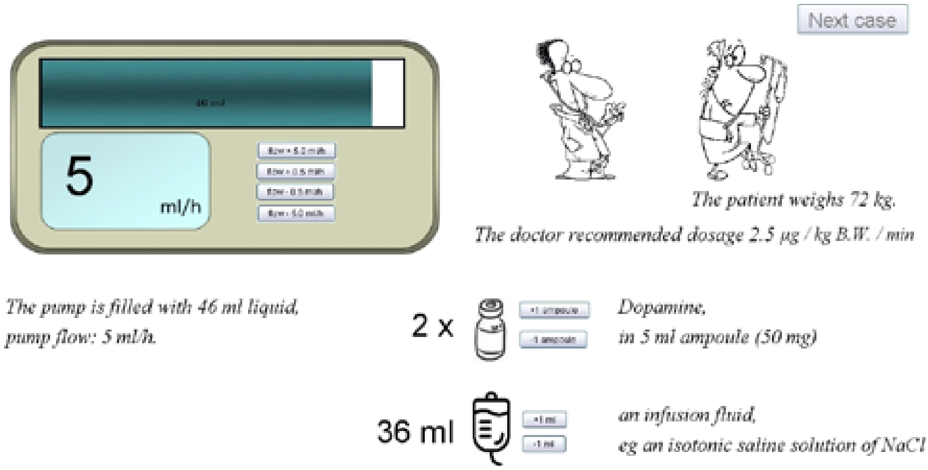
Fig. 5. Presentation of the evaluation sheet



The evaluation sheet (Fig. 5) allows for checking the acquired knowledge and skills. The sheet generates the example – medical case study – to which proper optimal parameters of drug dosing should be chosen. The student's answer is immediately verified. After the settings are done, you can press the "Check" button and the sheet will assess if you have done the task correctly. If the proposed answer is different than the theoretical answer by less than 1%, the sheet suggests an ideal solution to the problem. If the error is less than 3%, the answer is evaluated as very good and if the deviation does not exceed 5%, the answer is deemed correct. In the case when the error is more than 5%, the sheet suggests that the task has been performed incorrectly.

Coming back to the previously discussed example and the possibilities of application of didactic tool to simulate the medical case study – a slight change of parameters of the solution and the pump's settings may cause that the selected configuration will prove to be more optimal (Fig. 6).

Fig. 6. A more optimal setting of the pump for data taken from the example discussed at the beginning of this article



In the new case, the hourly dose of the drug is 10,869.57 μg (which is closer to the recommended 10,800 μg). Thanks to this, the student may freely modify all parameters of simulation without increasing the treatment costs and, more importantly, without the risk of threatening the patients' life and health, which is of crucial importance to the widely understood safety culture. The simulation sheet allows for analysing the same situation in several variants, and the experience gained while solving the hypothetical situations translate into effective actions in treating patients or even saving their lives.

As a result, the optimisation of the infusion settings translates into:

– effective and quicker improvement of the patient's health and often saving his life;
– reduction of stress of the personnel involved in saving the patient's health and life, thus decreasing the danger of making mistakes;
– reduces material costs related to the saving life activities.

The prepared sheets have been provided to a group of students of nursing faculty and to young prospective professionals.

We think that the remarks and comments are very valuable as the experienced nurses, while verifying such help, compare it with their own experience and doubts.

Below there are some examples of their statements:

> Only by having the opportunity to »play« with this programme made me realise that the same case may be solved in several ways. Sometimes there can be better solution than the one offered at the first time. It is great that you can try again while saving the drugs.

> I have always had problem with such calculating, I was not good at maths at school, but when I can practice, it proves to be not so difficult.

Health and lives of the individuals are the pillars of the societies' security. Proper vocational preparation of medical personnel is an investment in our safety. The availability of modern didactic technologies allow for better and quicker preparation of the staff to perform hard and responsible work. It also reduces the stress which accompanies their job while making them more effective. So, the implementation of new technologies seems to be the necessity nowadays. And teaching the medical staff modern technologies requires proper preparation of the teaching staff. It needs to cope with familiarising the paramedics with using the basic mathematical principles and teaching them how to use new technologies in everyday work. It is a requirement of our times, based on the knowledge acquired over the ages and related to implementing new technologies.

References

1. Buchfelder M., Buchfelder A., *Podręcznik pierwszej pomocy*, Wydawnictwo Lekarskie PZWL, Warszawa 2014.
2. Mikulska I., *Interna Szczeklika*, Medycyna Praktyczna, Kraków 2015.
3. Piwowarski J., *Fenomen bezpieczeństwa. Pomiędzy zagrożeniem a kulturą bezpieczeństwa*, Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego „Apeiron" w Krakowie, Kraków 2014.
4. Piwowarski J., *Kultura bezpieczeństwa i jej trzy wymiary*, „Kultura Bezpieczeństwa. Nauka-Praktyka-Refleksje", Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego „Apeiron" w Krakowie, Kraków 2012, vol. 12.
5. Podlewski J. K., Chwalibogowska-Podlewska A., *Leki Współczesnej Terapii*, Medical Tribune Polska Sp. z o.o., Warszawa 2010.

6. Szczeblowska D., Grys I., *Zdrowy tryb życia jako element kultury bezpieczeństwa*, „Kultura Bezpieczeństwa. Nauka-Praktyka-Refleksje". Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego „Apeiron" w Krakowie, Kraków 2014, vol. 16.
7. Zahradniczek K., *Pielęgniarstwo*, Wydawnictwo Lekarskie PZWL, Warszawa 2004.

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