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NON-INVASIVE ASSESSMENT OF HAEMODYNAMIC PARAMETERS IN AN EMERGENCY DEPARTMENT

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Abstract

INTRODUCTION: Hospital Emergency Departments are places where fractions of a second decide about human life and every possibility of quickly and reliably obtaining additional information about the patient's condition is extremely important. Therefore, an attempt was made to determine the usefulness of non-invasive assessment of haemodynamic parameters in patients in Emergency Departments.

MATERIAL AND METHODS: The research was conducted in June and July 2019 in the Emergency Room of the Bielański Hospital, Jerzy Popiełuszko in Warsaw. Non-invasive measurement of haemodynamic parameters was performed with the ICON (Osypka Medical, GmbH) Heart Rate Monitor. The study was conducted among patients of the green part of the Emergency Department. $P < 0.05$ was adopted as the significance level.

RESULTS: One-way non-parametric ANOVA confirmed the existence of statistically significant differences (all p for trend < 0.05) between BMI ($p < 0.001$), HR ($p = 0.040$), ICON ($p = 0.048$), and CO ($p = 0.006$) and for the four groups according to the reason for reporting to the Emergency Department (orthopaedic injuries, surgical intervention, internal medicine, other medical fields). One-way non parametric ANOVA confirmed the lack of statistically significant differences (all p for trend > 0.05) between age ($p = 0.418$), SV ($p = 0.161$), TFC ($p = 0.142$), and STR ($p = 0.094$) and for the four groups according to the reason for reporting to the Emergency Department.
In simple linear regression analysis (Spearman), BMI was negatively correlated with CO, ICON, SV, and TFC (all p for trend < 0.05). Age was negatively correlated with CO, ICON, and SV.

CONCLUSIONS: Due to the diversity of patients and their conditions, non-invasive assessment of haemodynamic parameters can become an invaluable help during the diagnosis and subsequent treatment of Emergency Department patients.

KEY WORDS: Emergency Department, cardiac output, thoracic fluid content, non-invasive monitoring

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INTRODUCTION

Haemodynamics of the heart is one of the basic functions of the circulatory system that allows the proper functioning of the body, and hence it is extremely important to have a continuous and reliable reading of the parameters that prove the efficiency of the heart, especially in a state of danger to life and health. Therefore, an attempt was made to determine the characteristics of haemodynamic parameters among patients of the Hospital Emergency Department.

For many years, doctors around the world have been able to determine haemodynamic parameters by invasive methods, but these are time-consuming, expensive, risky methods requiring extensive

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knowledge and high skills of the personnel obtaining them, and they are burdened with a high risk of complications and require appropriate sterile conditions. Non-invasive methods have proven to be a real breakthrough in medicine, allowing not only minimisation of costs, but also rapid, if not instant, results and significant simplification of the entire procedure leading to their receipt. They can be carried out in almost any conditions, the results are given in real time, and obtaining them, including connecting the patient to the equipment, does not take more than five minutes.

Assessment of haemodynamic parameters could be an important element of diagnostics in departments such as Hospital Accident and Emergency Department, Operating Theatres, Intensive Care Units (ICUs), and Cardiology Departments and their quick and non-invasive acquisition with the gold standard, because traditional measurement of blood pressure, pulse, or saturation provides too little information. The comprehensive picture of haemodynamic parameters allows for better quality patient care, earlier response in life-threatening situations, and thus in many situations the avoidance of complications.

The aim of the study was to make a non-invasive measurement of haemodynamic parameters in patients of a Hospital Accident and Emergency Department and to determine the degree of utility of this type of care in Emergency Departments.

MATERIAL AND METHODS

The measurements of haemodynamic parameters were carried out in June and July 2019 in the Emergency Room located at the Bielański Hospital, Fr. Jerzy Popiełuszko in Warsaw, while complying with the principles of the Declaration of Helsinki and after obtaining permission to conduct the study from the Head of the Hospital Emergency Department.

The research was conducted on the green part, where patients report to the Emergency Room by themselves and their health condition allows them to wait for a medical doctor for 60 to 360 minutes, which is determined by a paramedic or a properly trained nurse, based on a preliminary interview and physical examination. Patients imported by the Medical Emergency Teams and remaining on the red side due to their critical health were excluded from the study.

The inclusion criteria of the research sample were the possibility of expressing in writing fully informed consent to participate in the conducted research and the age of participants being above 18 years. Patients who met these requirements were verbally instructed on the purpose of the tests and on the method and course of measuring haemodynamic parameters. The study did not include patients under 18 years of age, who could not give written, informed consent, including people under the influence of alcohol or other psychoactive substances.

A total of 132 patients were asked to participate in the study, of whom 42 patients gave written, informed consent to take measurements. The youngest participant was 25 years old and the oldest was 88 years old. The research group consisted of 20 women aged 28 to 88 and 22 men aged 25 to 88 years.

The sample was divided into four groups according to their reason for reporting to the Emergency Department. The first group consisted of patients after orthopaedic injuries — eight persons, among whom torsional limb injuries predominated. The second group included patients requiring surgical intervention — four persons, mainly with upper limb wounds qualified for sewing. The third patient group was admitted by a specialist in internal medicine — 24 persons — the most diverse group, comprising people after drug intoxication, cardiac incidents, fainting, and with chest pain. The fourth patient group comprosed those requiring consultation by specialists from other medical fields, mainly neurologists and laryngologists — six persons.

Non-invasive measurement of haemodynamic parameters was performed with the index of contractility (ICON) Osypka Madical, GmbH Heart Rate Monitor (Fig. 1). The tests were conducted during the patients' stay in the Hospital Emergency Department by placing four electrodes on the left side of the patient's body — two on the neck and two on the side of the chest (Fig. 2, 3). The device emits a low-amplitude, high-frequency current, and based on resistance measurements haemodynamic parameters are measured. The study was performed on patients remaining lying down during its duration, as well as previously collecting data such as age, height, and weight.

The following parameters were analysed: HR, (ICON), stroke volume (SV), cardiac output (CO), thoracic fluid content (TFC), and systolic time ratio (STR).

Statistical analysis

Results concerning quantitative variables were presented as average values ± standard deviation. Qualitative variables (age, sex) were presented as quan-

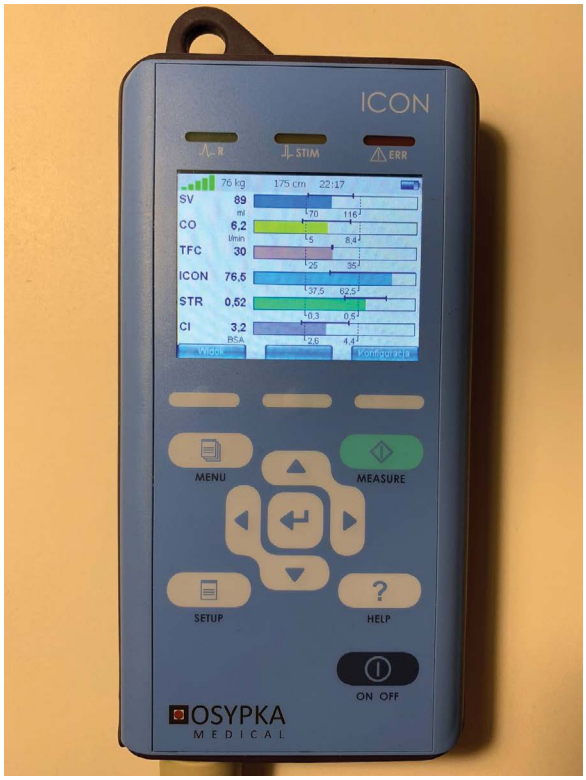

FIGURE 1. ICON Osypka Madical, GmbH Heart Rate Monitor; ICON — index of contractility

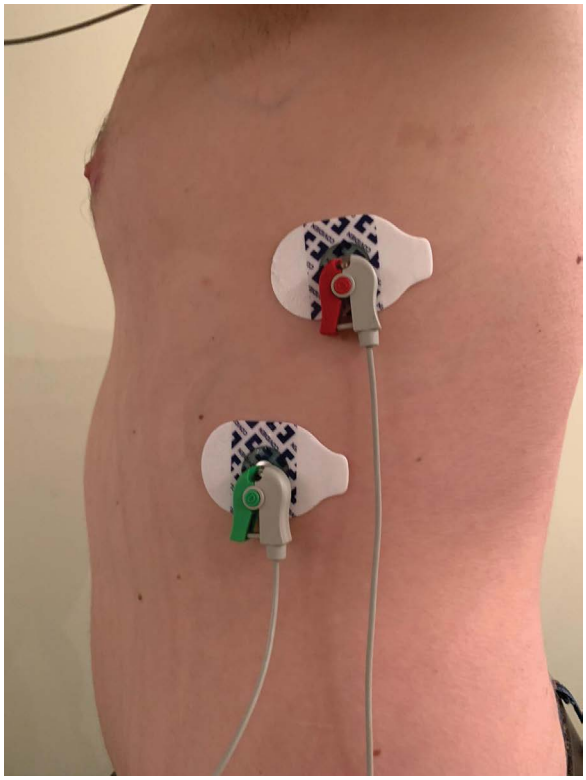

FIGURE 2. Localisation of 2 electrodes on the neck

tity (n) and percentage values of the whole group (%). The one-way ANOVA on ranks was applied to compare the different times and to determine the statistical difference for each group (post-hoc). In the comparative analysis of BMI, age, and haemodynamic parameters simple linear regression analysis (Spearman) was applied to detect and describe the strength and direction of correlations of clinical data. Statistica 13.3 software (Tibco Inc., Tulsa, USA) was used in the statistical analysis. $P < 0.05$ was adopted as the significance level.

RESULTS

Among the examined Emergency Department patients, the average results of haemodynamic parameter measurements were within the generally accepted standards — only TFCs were recorded outside the lower limit, on average it was 23.08 1/kΩ. However, if one considers the sex of the respondents, there is a significant discrepancy in results. The surveyed women have a lower average TFC score of 20.80 1/kΩ compared to the norm — Table 1.

In the group of patients after orthopaedic injuries, a decrease in CO to 4.23 l/min on average and TFC to 22.50 1/kΩ on average dominated.

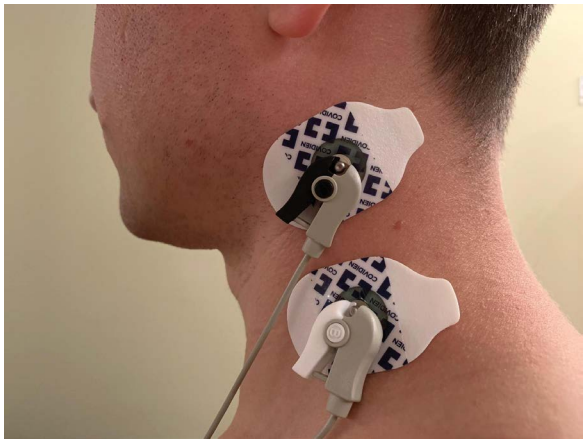

FIGURE 3. Localisation of 2 electrodes on the side of the chest

Women presented a decrease in parameters such as ICON average to 29.70, SV to 53.00 ml, CO to 3.35 l/min and TFC to 16.50 1/kΩ. The characteristics of the haemodynamic parameters of the group of patients after orthopaedic injuries are presented in Table 2.

In the group of patients requiring the intervention of a surgeon, the results of haemodynamic parameters were not collected from any women, so the group analysis was carried out only among men. They were characterised by increased pulse — on

Table 1. General characteristics of the study group

		Woman (n = 20)		Man (n = 22)		Altogether (n = 42)	
		Average	SD	Average	SD	Average	SD
Age (years)		55	21	57	24	56	23
BMI (kg/m^2)		26.20	4.76	26.27	2.9	26.24	3.85
Haemodynamic parameters	HR (bpm)	71	8	82	18	77	15
	ICON	55.94	45.89	45.41	20.46	50.42	35.78
	SV (ml)	64.30	24.65	74.91	11.54	69.86	19.93
	CO (l/min)	5.46	3.94	6.17	2.28	5.83	3.23
	TFC (1/kOhm)	20.80	8.59	25.36	5.52	23.19	7.58
	STR	0.42	0.14	0.45	0.07	0.43	0.11

CO — cardiac output; HR — heart rate; ICON — index of contractility; n — number of people surveyed; TFC — thoracic fluid content; SD — standard deviation; STR — systolic time ratio; SV — stroke volume

Table 2. Clinical characteristics of the group of patients after orthopaedic injuries

		Woman (n = 4)		Man (n = 4)		Altogether (n = 8)	
		Average	SD	Average	SD	Average	SD
Age (years)		65	9	27	2	46	20
BMI (kg/m^2)		30.28	5.24	24.80	2.07	27.54	4.78
Haemodynamic parameters	HR (bpm)	73	3	69	4	71	4
	ICON	29.70	2.20	51.60	0.40	40.65	11.11
	SV (ml)	53.00	7.00	76.50	3.50	64.75	12.99
	CO (l/min)	3.35	0.05	5.50	0.20	4.46	1.12
	TFC (1/kOhm)	16.50	1.50	28.50	4.50	22.50	6.84
	STR	0.31	0.04	0.38	0.07	0.34	0.07

CO — cardiac output; HR — heart rate; ICON — index of contractility; n — number of people surveyed; TFC — thoracic fluid content; SD — standard deviation; STR — systolic time ratio; SV — stroke volume

average up to 95 bpm, reduced ICON parameter — on average to 31.60, and slightly reduced TFC — on average to 24.00 1/kΩ. Table 3. presents the characteristics of the haemodynamic parameters of the group of patients requiring surgical intervention.

Among the patients admitted by the internist, the most common changes were ICON — the mean of this parameter was 61.34 and the TFC average was 24.67 1/kΩ. An increase in HR to 86 bpm was characteristic for men, while the rest of the haemodynamic parameters were mostly normal. In women, an increase in ICON to 73.08 on average and a decrease in TFC to 23.83 1/kΩ on average dominated. The characteristics of the haemodynamic parameters of the group of patients admitted by the internist are presented in Table 4.

Patients consulted by other specialists constituted a very diverse group, in which changes of such parameters as ICON (to 33.13 on average), CO (to 3.78 l/min on average), and TFC (to 18.50 1/kΩ) on average were noticeable. In addition, in this group,

Table 3. Clinical characteristics of the group of patients requiring surgical intervention

		Man (n = 4)	
		Average	SD
Age (years)		51	19
BMI (kg/m^2)		30.13	0.99
Haemodynamic parameters	HR (bpm)	95	5
	ICON	31.63	2.33
	SV (ml)	70.50	6.03
	CO (l/min)	6.45	0.21
	TFC (1/kOhm)	24.00	0.71
	STR	0.47	0.03

CO — cardiac output; HR — heart rate; ICON — index of contractility; n — number of people surveyed; TFC — thoracic fluid content; SD — standard deviation; STR — systolic time ratio; SV — stroke volume

Table 4. Clinical characteristics of the group of patients admitted by the internist

		Woman (n = 12)		Man (n = 12)		Altogether (n = 24)	
		Average	SD	Average	SD	Average	SD
Age (years)		51	25	68	23	59	25
BMI (kg/m^2)		23.48	2.37	25.23	2.50	24.36	2.59
Haemodynamic parameters	HR (bpm)	70	10	86	19	78	17
	ICON	73.08	52.39	49.60	25.59	61.34	42.87
	SV (ml)	72.50	28.62	76.33	14.81	74.42	22.86
	CO (l/min)	6.83	4.60	6.65	2.89	6.74	3.84
	TFC (1/kOhm)	23.83	9.94	25.50	6.45	24.67	8.42
	STR	0.43	0.16	0.46	0.07	0.45	0.12

CO — cardiac output; HR — heart rate; ICON — index of contractility; n — number of people surveyed; TFC — thoracic fluid content; SD — standard deviation; STR — systolic time ratio; SV — stroke volume

Table 5. Clinical characteristics of the group of patients consulted by other specialists

		Woman (n = 4)		Man (n = 2)		Altogether (n = 6)	
		Average	SD	Average	SD	Average	SD
Age (years)		61	6	66	0	62	5
BMI (kg/m^2)		30.46	2.84	27.77	0.01	29.12	2.60
Haemodynamic parameters	HR (bpm)	73	3	65	5	69	6
	ICON	30.75	9.25	35.75	0.25	33.25	7.01
	SV (ml)	51.00	5.00	72.00	1.00	61.50	11.10
	CO (l/min)	3.45	0.15	4.10	0.10	3.78	0.35
	TFC (1/kOhm)	16.00	1.00	21.00	1.00	18.50	2.69
	STR	0.51	0.09	0.42	0.00	0.47	0.08

CO — cardiac output; HR — heart rate; ICON — index of contractility; n — number of people surveyed; TFC — thoracic fluid content; SD — standard deviation; STR — systolic time ratio; SV — stroke volume

SV women had an average reduction of 51.00 ml. Table 5. presents the characteristics of the haemodynamic parameters of the group of patients consulted by other specialists.

The one-way non-parametric ANOVA confirmed the existence of statistically significant differences (all p for trends < 0.05) between BMI ($p < 0.001$), HR ($p = 0.040$), ICON ($p = 0.048$), CO ($p = 0.006$) and the four groups according to the reason for reporting to the Emergency Department (orthopaedic injuries, surgical intervention, internal medicine, other medical fields). The one-way non parametric ANOVA confirmed the lack of statistically significant differences (all p for trends > 0.05) between age ($p = 0.418$), SV ($p = 0.161$), TFC ($p = 0.142$), STR ($p = 0.094$) and thefour4 groups according to the reason for reporting to the Emergency Department.

Table 6. Results of simple regression analyses between BMI, age, and haemodynamic parameters

	BMI		Age	
	R	P	R	P
CO	-0.426	0.005	-0.419	0.006
HR	-0.075	0.638	-0.053	0.736
ICON	-0.738	< 0.001	-0.408	0.007
SV	-0.552	< 0.001	-0.568	< 0.001
TFC	-0.474	0.002	-0.032	0.839
STR	0.058	0.713	0.031	0.847

CO — cardiac output; HR — heart rate; ICON — index of contractility; TFC — thoracic fluid content; STR — systolic time ratio; SV — stroke volume

In simple linear regression analysis (Spearman), BMI was negatively correlated with CO, ICON, SV, and TFC (all p for trends < 0.05). Age was negatively correlated with CO, ICON, and SV (Tab. 6) (Fig. 4, 5).

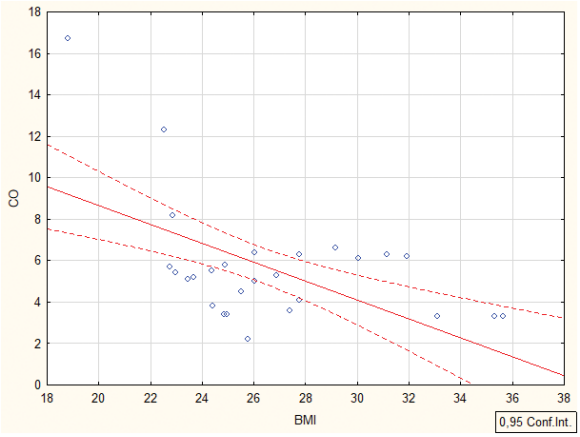

FIGURE 4. Simple linear regression analysis (Spearman) of CO and BMI; CO — cardiac output

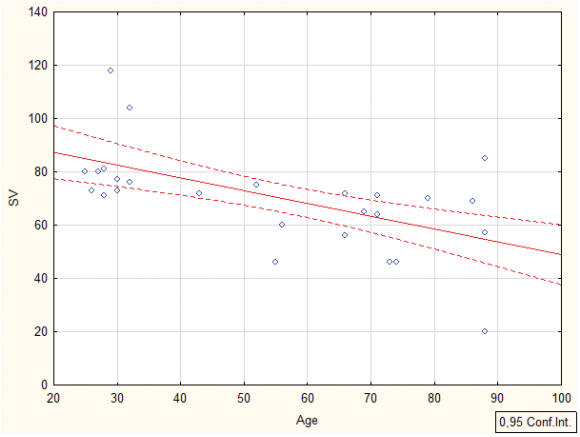

FIGURE 5. Simple linear regression analysis (Spearman) of SV and age; SV — stroke volume

DISCUSSION

Currently, many valuable clinical studies are being prepared regarding non-invasive measurement of haemodynamic parameters. They show that in many respects this type of measurement is characterised by versatile usefulness in many fields of medicine, ranging from determining the appropriate antihypertensive treatment, through monitoring during dialysis, to high mountain climbing.

P. Krzesiński et al. [1] showed the usefulness of non-invasive monitoring of haemodynamic parameters among participants of high-altitude climbing and the possibility of using this method even in extreme conditions. The study involved 13 participants of two spring expeditions in the Himalayas. A comprehensive examination of the expedition members was carried out before departure and again at an altitude between 4300 and 5700 m a.s.l. considering the symptoms of acute mountain sickness. Studies have shown that despite very individual responses to altitude, non-invasive measurement of haemodynamic parameters can be a useful tool for monitoring at high altitudes, especially when it comes to breathing disorders.

The study of Trzeciak et al. [2] showed that with the help of non-invasive measurement of haemodynamic parameters it can be easily determined whether hypertension is well controlled in patients. The study involved 199 patients treated for hypertension by primary care physicians. The patients were divided into two groups: the first consisted of those whose blood pressure was well controlled (< 140/90 mmHg), and the second consisted of patients with poorly controlled hypertension. The study showed that haemodynamic parameters differentiate these two groups of patients. In the group with poorly controlled arterial pressure, such parameters as HR, TFC, or stroke volume index (SI) increase, while in the group with well-controlled hypertension these values are within normal limits.

In an article published in the Family Medicine Forum, Siebert et al. [3] mention impedance cardiography as one of the possible methods for extending stroke monitoring. They point to numerous cardiovascular complications occurring in connection with damage to important brain structures, as well as the frequent occurrence of hypertension, which is a risk factor for re-stroke. With the help of non-invasive measurement of haemodynamic parameters, it is possible to monitor the patient's condition in real time without requiring intervention that predisposes to further complications, while providing accurate and reliable data that allows for adequate correction of the treatment process.

Further evidence confirming the comprehensive possibilities of impedance cardiography is the study of the impact of obesity on the haemodynamic profile of men with coronary artery disease conducted by Krzesiński et al. [4]. Fifty-two men who were in the second stage of rehabilitation in 87% after acute coronary syndrome participated in the study. During measurements, obese men had significantly lower cardiac impedance indices of cardiac function as a pump relative to non-obese participants. In addition, impedance cardiography enabled early detection of the presence of left ventricular systolic dysfunction, and thus the implementation of actions aimed at improving the quality of patients' functioning and eliminating further complications.

In an article on the importance of research on haemodynamic changes in patients with chronic

kidney disease by Siebert et al. [5] the topic of monitoring haemodynamic parameters of dialysed patients was discussed. The incidence of dialysis complications such as hypotension, which affects up to half of patients on dialysis, muscle cramps, cardiovascular incidents, headaches, and itching of the skin, as well as nausea and vomiting, are underlined. Attention was drawn to a variety of complications, including stroke, acute ischaemia, sudden cardiac arrest, or sepsis, and to the rare occurrence of prodromal symptoms, which greatly hinder early and adequate medical response to the patient's condition. High efficiency of continuous haemodynamic parameters has been shown to reduce adverse events in dialysis patients. It allows early detection of changes that herald dialysis complications and implementation of appropriate medical procedures aimed at stabilising the patient's condition.

A large research group can boast of non-invasive monitoring of patients with suspected heart failure, sepsis, and stroke conducted by Nowak et al. [6], in which 510 patients were examined — 185 with suspected heart failure, 194 with sepsis, and 131 with stroke. Each patient was subjected to a non-invasive study of haemodynamic parameters of the beat-to-beat type, which allowed the authors to state that all these groups were characterised by different deviations of haemodynamic parameter measurements. Consequently, the study led to the conclusion that an early non-invasive examination of haemodynamic parameters could in the future allow for initial diagnosis of patients, individual adjustment of therapy based on the readings obtained, and estimation of mortality within 30 days. At the same time, scientists warn against hasty enthusiasm and recommend further scientific research aimed at expanding the study group and specifying more precisely the standards of conduct.

Another study emphasising the utility of measuring haemodynamic parameters is the study by Karpiarz et al. [7] in which 31 patients requiring intervention of an Emergency Medical Team participated. As the authors emphasised, measurements made by impedance cardiography showed significant discrepancies in the parameters between trauma/poisoning patients, patients with suspected cardiovascular disease, and patients with other suspected disease entities. Based on the results obtained, the authors concluded that impedance cardiography can be a useful tool especially for use in patients with haemorrhagic shock or circulatory failure, where the possibility of additional measurements can determine the fate of the patient.

In the article published in the pages of Anestezjologia i Ratownictwo T. Trafidło, T. Gaszyński, and W. Gaszyński [8] familiarise the reader with the laws that allow the reading of haemodynamic parameters, present principles that can help in the selection of methods for monitoring haemodynamic parameters, and indicate the main differences between the various measurement methods. They emphasise the usefulness of such monitoring and draw attention to how rapidly all methods of monitoring cardiac output are developing.

Noteworthy is the work of B. Żuchowski and P. Guzik [9], which transparently explains the principles of non-invasive measurement of haemodynamic parameters and compares non-invasive measurement of haemodynamic parameters to more traditional methods of assessing the cardiovascular system. Electric bioimpedance of the chest, despite its many advantages such as accuracy and speed of measurement, non-invasiveness, and wide application possibilities, also has some limitations, which the authors of the article mention. For the results of this method to be reliable, the patient must remain still. Conditions such as atrial fibrillation, severe arrhythmia, and frequent extrasystoles interfere with interpretation of the record. In addition, non-standard dimensions of the patient's body also affect the reliability of the bioimpedance curve recording.

This study has some limitations. Firstly, compared to the other studies, our sample was quite small. Secondly, the fate of the patients was evaluated only in the Emergency Department.

CONCLUSIONS

1. Non-invasive measurement of haemodynamic parameters should be the gold standard for Emergency Departments due to the complexity of the problems that patients report and the relatively short time required to service the patient. Haemodynamic parameters allow for an accurate assessment of the condition and, acquired quickly and non-invasively with the help of the Heart Rate Monitor, can be a valuable source of information enabling the introduction of adequate treatment, consequently preventing many complications. It should be empha-

sised that the method is cheap and allows for significant reduction of costs in the future, even in terms of treatment of complications that can be avoided.

2. Research on non-invasive measurement of haemodynamic parameters of Emergency Department patients should be conducted again by expanding the green group of patients, and similar studies should be initiated among Emergency Department patients admitted on the red side.

Acknowledgments

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Conflict of interest

The authors declare that they have no conflicts of interest. None of the authors involved in this study have any financial relationship.

Source of support

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