Can impedance cardiography be routinely applied in patients with sepsis and severe sepsis?

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Abstract

Introduction: In the European Union only, about 146 000 patients die due to sepsis per year. Impedance cardiography (ICG) is a totally non-invasive and thus devoid of the risk of the above complications method of monitoring numerous hemodynamic parameters. The method recommended for routine application in patients with sepsis and severe sepsis should be precise, repeatable and possible to use in every case. The objective of this study was to determine the quality of the obtained impedance cardiography (ICG) signal and the value of thoracic fluid content (TFC) in patients with sepsis and severe sepsis.
Material and methods: It was a prospective study. The study was performed in the Department of Anaesthesiology and Intensive Care Unit, Medical University Hospital, in the group of 20 patients with sepsis and severe sepsis. In total 128 ICG measurements (NICCOMO) were performed in all patients. Each time the level of ICG signal (in %) was determined and several hemodynamic parameters were measured including TFC.
Results: The quality of ICG was ≥70% in 53.91% of the measurements, ≥30% in 88.28% of the measurements. In 11.72% of the measurements the signal quality was <30%. Thoracic fluid content was >65kΩ^{-1} in six measurements (4.69%). The mortality in the studied group was 30%.
Conclusions: In conclusion the level of the obtained ICG signal and the measured TFC values in patients with sepsis and severe sepsis allow to apply ICG routinely in this group of patients.

Key words: Impedance cardiography, sepsis, severe sepsis.

Introduction

In the USA about 750 000 cases of severe sepsis are registered per year [1]. On a world scale, a similar number of septic cases end in death [2]. In the European Union only, about 146 000 patients die due to sepsis per year [3]. The mentioned septic states particularly severe sepsis and septic shock are associated with serious prognostication and increased mortality [1]. Popularisation of invasive therapeutic and diagnostic methods, increasing resistance to antibiotics and aging of the population are the causes of a consistently increasing incidence of sepsis [2].

Septic patients often require long-term hemodynamic monitoring. In the majority of cases this monitoring is based on invasive methods associated with the risk of the occurrence of dysrhythmia, pulmonary embolism or the damage of cardiac valves and endocardium. In the USA, the frequency of such complications is estimated to be about 7.2% [3, 4].

Impedance cardiography is a totally non-invasive and thus devoid of the risk of the above complications method of monitoring numerous hemodynamic parameters. However, ICG is not applied routinely in hemodynamic monitoring of patients with sepsis and severe sepsis.

The method recommended for routine application in patients with sepsis and severe sepsis should be precise, repeatable and possible to use in every case.

Impedance cardiography is based on a theoretical model of blood flow in the thorax. Some limitations result from that. In the case when the patient's physiological or clinical conditions do not correspond with the model assumptions, there may appear parametric inaccuracy, markedly differing from the real state. Precise impedance monitoring is impossible in the following cases: septic shock, aortic regurgitation, atrial septal defect, ventricular septal defect, severe aortic atherosclerosis, aortic prosthesis, severe hypertension, intra-aortic counterpulsation, marked tachycardia, excessively tall or short stature or extreme overweight or underweight. Precise impedance monitoring is also possible in the cases of extreme volume of extravascular lung water [5], causing the increase of TFC. The available impedance units are designed generally for the measurement of hemodynamic parameters in the recumbent position, at rest and the measured parameters are useful only when the registered curves were obtained from good quality signals and when artifacts were not observed during registration. The applied in impedance cardiographs mathematical rules for stroke volume calculation also affect the precision and repeatability of the measurements performed with the ICG method [5]. In the majority of modern equipment Sramek's or Sramek-Bernstein's algorithm is used.

ICG was developed for the NASA in the 60s [6]. In the meantime a lot of validation studies have been published [5, 7-20]. A very different estimation of the reliability and usefulness of the impedance cardiography catches the attention. Fuller's meta – analysis is of importance. He determined the correlation between ICG and thermodilution method (r=0.82), Fick's method (r=0.80) and the method of isotopic angiography (r=0.65) [14].

A smaller number of publications concerns ICG validation in patients with sepsis and severe sepsis [5, 8, 16, 17]. The research and experiments carried out so far allow to regard impedance cardiography as a method in which the obtained results are comparable with those obtained through the method of thermodilution, on condition that when the ICG method is applied, its limitations are taken into account and the method is not used in patients with some heart diseases in the course of or directly after cardiosurgical procedures and that the obtained ICG signal is good [20].

Obtaining a good enough level of the ICG signal in the course of the measurement is another requirement to be met to apply the ICG method routinely in patients with sepsis and severe sepsis. Furthermore, TFC value should not exceed the values determined by the producer if the applied rule is dependent on extravascular lung water (Sramek-Bernstein's rule). An excessive volume of extravascular lung water may cause an inaccuracy of the measurement of stroke volume and of other hemodynamic parameters associated with it.

In our own research a NICCOMO impedance cardiograph was used (Medis. Medizinische Messtechnik GmbH, Germany) (correlation between ICG and reference method: r=0.857) [21]. The quality of the ICG signal was determined objectively with NICCOMO software in % from 0 to 100%. The TFC value >65 $k\Omega^{-1}$ may cause an inaccuracy of stroke volume measurement. NICCOMO software recognizes and eliminates automatically the effect of some artifacts.

We assumed that the level of the obtained ICG signal and the measured TFC values in patients with sepsis and severe sepsis allow, taking into account a good correlation of ICG and reference method, to apply routinely ICG in this group of patients.

The aim of the study was to obtain data concerning the values of hemodynamic parameters measured by the ICG method in patients with sepsis and severe sepsis.

Material and methods

Having obtained an approval of the Bioethics Committee of the Medical University of Lodz, Poland (RNN/26/03/KB), 20 patients were qualified for the study: 15 men, aged 21 to 69 years (mean 49 years) and 5 women, aged 27 to 90 years (mean 61 years). The basic data about the investigated group are demonstrated in Table I.

The criteria of sepsis according to the definition accepted at the ACCP/SCCM conference were the base for being enrolled into the study [22, 23].

The patients with aortic regurgitation, atrial septal defect, ventricular septal defect, severe hypertension (mean arterial pressure, MAP >130 mmHg), tachycardia over 250/min, and extreme cases of overweight or underweight and height were excluded from the study.

The investigations were carried out in each patient until they stopped meeting the criteria of sepsis according to the definition accepted at the ACCP/SCCM conference or when the patient died.

Table I. Basic data on the studied group

Patient's number	Base of inclusion into the study	Infection site	No of scores in APACHE II on the study initiation	Number of scores in SOFA on the study initiation	Number of measurements	The highest number of organ failure	Death in the course of the study	Cause of death
1	Sepsis	Abdominal cavity	7	1	5	0	No	–
2	Sepsis	Abdominal cavity	14	5	13	3	No	–
3	Severe sepsis	Abdominal cavity	17	5	6	1	No	–
4	Sepsis	Abdominal cavity	9	2	9	5	Yes	MODS, DIC
5	Severe sepsis	Abdominal cavity	10	2	6	2	No	–
6	Severe sepsis	Lungs/Abdominal cavity	19	8	14	4	No	–
7	Sepsis	Abdominal cavity	3	1	5	1	No	–
8	Sepsis	Lungs	12	6	6	1	No	–
9	Severe sepsis	Lungs	14	9	4	1	No	–
10	Severe sepsis	Abdominal cavity	17	5	11	4	Yes	MODS
11	Severe sepsis	CNS	11	6	4	2	No	–
12	Severe sepsis	Abdominal cavity	8	4	4	1	No	–
13	Severe sepsis	Abdominal cavity	12	7	2	3	Yes	Respiratory – circulatory failure
14	Severe sepsis	Abdominal cavity	10	3	4	1	No	–
15	Severe sepsis	Abdominal cavity	13	8	6	3	Yes	Respiratory – circulatory failure
16	Severe sepsis	Lungs	24	13	3	4	Yes	Respiratory – circulatory failure
17	Severe sepsis	Abdominal cavity	7	5	5	2	No	–
18	Severe sepsis	Abdominal cavity	4	3	9	2	No	–
19	Severe sepsis	Abdominal cavity	11	6	8	2	No	–
20	Severe sepsis	Lungs	17	12	4	4	Yes	Respiratory – circulatory failure

All patients were given verbal and written information about the potential risks and benefits of participation in the study. They gave their consent in writing prior to the study.

Subjects were recruited consecutively from patients attending the ICU from 1st July 2003 to 31st July 2004. All patients were treated by the same team of physicians. The standard treatment included administration of adequate antibiotics, control of the source of infection and supportive therapy (intravenous fluids, medication aiding the circulatory system, vasopressors, aiding the failing organs). The applied protocol ordered, among others, maintaining SpO_2 >90%, mean arterial pressure at the level at least 70 mmHg, central venous pressure within the limit 8-12 mmHg. If application of mechanical ventilation was necessary, $paCO_2$ had to be maintained within the limit of 35-45 mmHg.

The following hemodynamic parameters were tested with the impedance cardiograph: heart rate (HR) in beats/min, stroke volume (SV) in ml, cardiac output (CO) in l/min, stroke index (SI) in ml/m^2, cardiac index (CI) in l/min/m^2, pre-ejection period (PEP) in ms, left ventricular ejection time (LVET) in ms, acceleration index (ACI) in l/s^2, systolic time ratio (STR) in %, thoracic fluid content in kΩ^{-1}, systemic vascular resistance index (SVRI) in dyne.s/cm^{-5}/m^2, left cardiac work index (LCWI) in kg.m/m^2, mean arterial pressure in mmHg, systolic blood pressure (BPs) in mmHg and diastolic blood pressure (BPd) in mmHg. Furthermore, procalcitonin (PCT) and N-terminal brain natriuretic propeptide (NT-proBNP) concentrations were determined in arterial blood and the patient's clinical state was assessed according to the Sepsis-related Organ Failure Assessment (SOFA) score [24-28] and Acute Physiology and Chronic Health Evaluation System II (APACHE II) [29].

The first ICG recording with blood sample collection was performed within 12 h after the patient's inclusion into the study, the second 12 h after the first, the third 24 h after the first, the fourth 48 h after the first, the fifth and the next 48 h after the previous one.

ICG curve record was performed with the impedance cardiograph NICCOMO (Medis. Medizinische Messtechnik GmbH, Germany) working on the basis of Sramek-Bernstein rule.

The quantitative measurement of procalcitonin concentration (in ng/ml) was performed with immunoluminometric method with the use of two monoclonal antigen-specific antibodies binding PCT. The luminescence was read in BERLUX 250 luminator with LUMI test PCT reagent (Brahms Diagnostica GmbH).

The quantitative determination of NT-proBNP (in pg/ml) was based on the immumoenzymatic method: the test based on competitive EIA method (precision of this method is on the average about CV 4.7%). The reading was performed on ETI Max 3000 analyzer (Dia Sorin) using Biomedica reagents.

A statistical analysis was performed with Statistica 5.1 PL (StatSoft, Poland) and Office 97 programs (Microsoft, Poland). Basic statistics were calculated: mean, standard deviations, minimum, maximum, median for all the tested parameters.

Results

The quality of the ICG signal and TFC were determined in all 128 measurements.

The quality of ICG was ≥70% in 53.91% of the measurements, ≥30% in 88.28% of the measurements. In 11.72% of the measurements the signal quality was <30%. Thoracic fluid content was >65 kΩ^{-1} in six measurements (4.69%). The obtained results are presented in Tables II and III.

The obtained values of hemodynamic parameters, the values of procalcitonin and NT-proBNP concentrations and SOFA and APACHE II scores in patients with sepsis and severe sepsis are presented in Table IV.

The mortality in the studied group was 30%

Discussion

The possibility of routine application of impedance cardiography in patients with sepsis and severe sepsis depends on several factors. Appropriate validation of the method is a sufficient factor. In the case of ICG, the quality of the signal and sometimes TFC value (Sramek-Bernstein's rule) are of significant importance.

The evaluation of ICG signal quality is subjective in the case of a majority of impedance cardiographs. There are no objective data allowing to determine precisely when the quality of the signal is good enough and when it is not. In some types of impedance cardiographs, including NICCOMO, the quality of the ICG signal is determined in per cent. It makes easier the evaluation of the ICG signal but still, the question whether the obtained per cent of the ICG signal is sufficient to be regarded as reliable is left to the subjective assessment of the researcher. The authors established quite rigorous criteria of evaluation. In the opinion of the authors, the quality of the ICG signal was very good in the presented study (≥70%) in 53.91% of the measurements and satisfactory (≥30%) in 88.28% of the measurements. Only in 11.72% of the measurements, the quality of the signal was low (<30%).

Thoracic fluid content >65kΩ^{-1} may cause, but not necessarily, an inaccuracy of the measurement of stroke volume and other hemodynamic parameters associated with it. Such a value was found only in 6 out of 128 of the performed measurements (4.69%). This allows to conclude that excessive hydration of pulmonary tissue, frequently accompanying sepsis

Table II. Impedance cardiography (ICG) quality of signal expressed in %

Patient's number	Measurement 1 (%)	Measurement 2 (%)	Measurement 3 (%)	Measurement 4 (%)	Measurement 5 (%)	Measurement 6 (%)	Measurement 7 (%)	Measurement 8 (%)	Measurement 9 (%)	Measurement 10 (%)	Measurement 11 (%)	Measurement 12 (%)	Measurement 13 (%)	Measurement 14 (%)
1	57	54	67	79	91									
2	57	99	100	86	92	97	97	94	100	57	54	72	64	
3	13	15	36	38	31	17								
4	68	68	20	40	71	99	89	100	100					
5	91	81	89	91	94	94								
6	88	95	100	96	71	77	62	86	94	27	87	40	84	71
7	99	95	95	93	61									
8	94	100	100	100	63	79								
9	31	20	13	55										
10	45	85	76	83	56	11	87	79	1	3	91			
11	51	31	46	4										
12	16	74	38	26										
13	35	20												
14	80	38	71	81										
15	94	44	55	51	66	98								
16	94	41	91											
17	100	89	86	73	65									
18	90	87	68	74	48	56	16	60	61					
19	34	79	89	52	78	89	50	76						
20	60	35	73	41										

Table III. Thoracic fluid content (TFC) expressed in $k\Omega^{-1}$

Patient's number	Measurement 1 (%)	Measurement 2 (%)	Measurement 3 (%)	Measurement 4 (%)	Measurement 5 (%)	Measurement 6 (%)	Measurement 7 (%)	Measurement 8 (%)	Measurement 9 (%)	Measurement 10 (%)	Measurement 11 (%)	Measurement 12 (%)	Measurement 13 (%)	Measurement 14 (%)
1	33.8	26.2	39.0	41.1	27.0									
2	42.2	30.1	43.1	43.6	42.9	29.7	36.4	41.4	36.7	33.5	27.6	28.7	26.3	
3	30.5	27.8	30.1	31.3	30.3	35.5								
4	45.2	41.2	35.8	43.0	27.5	26.0	21.8	26.2	46.4					
5	36.7	32.2	33.0	31.6	35.5	34.0								
6	46.7	45.6	46.1	41.4	46.1	40.3	42.6	46	48.4	57.8	41.5	57.8	56.1	47.0
7	39.3	36.8	37.0	36.7	22.3									
8	35.1	46	41.5	34.3	35.0	37.2								
9	39.6	36.5	37.3	43.2										
10	46.7	59.3	60.5	64.2	62.4	42.8	48.3	51.3	54.7	56.6	47.6			
11	80.8	65.4	69.1	87.0										
12	52.5	63.7	51.9	43.5										
13	36.4	55.7												
14	63.6	63.7	60.2	49.8										
15	42.2	43.9	40.8	44.9	46.5	57.3								
16	118.5	132.2	58.0											
17	53.4	50.5	50.4	63.0	51.1									
18	59.6	58.5	62.8	59.2	54.9	58.1	50.5	48.5	50.7					
19	26.8	42.8	41.9	49.0	52.5	52.0	50.5	40.8						
20	36.4	37.2	49.9	49.9										

Table IV. The obtained values of hemodynamic parameters with the ICG method in patients with sepsis and severe sepsis. Minimum, maximum, median, mean, standard deviation

Parameter	Minimum	Maximum	Median	Mean	Standard deviation
Heart rate (beat/min)	62	152	106	106.32	±19.18
Stroke volume (ml)	31.80	157.80	71.95	74.34	±25.24
Cardiac output (1/min)	0.21	17.41	7.56	7.63	±2.53
Stroke index (ml/m^2)	18.60	81.90	38.20	39.28	±12.54
Cardiac index (l/min/m^2)	1.82	9.04	4.00	4.08	±1.19
Pre-ejection period (ms)	7.00	168.00	43.00	49.20	±26.17
Left ventricular ejection time (ms)	112.00	384.00	210.50	213.38	±44.87
Acceleration index (1/s^2)	0	9.40	3.10	3.21	±1.66
Systolic time ratio (%)	3.00	118.00	21.00	24.74	±14.77
Thoracic fluid content (kΩ^{-1})	21.80	132.20	43.35	45.91	±15.57
Systemic vascular resistance index (dyne.s/cm^{-5}/m^2)	584	4092	1582.5	1748.95	±711.05
Left cardial work index (kg x m/m^2)	1.60	9.30	4.20	4.45	±1.44
Mean arterial pressure (mmHg)	49.00	139.00	81.00	84.26	±17.53
Blood pressure systolic (mmHg)	70.00	178.00	121.00	121.63	±22.61
Blood pressure diastolic (mmHg)	40.00	101.00	64.00	66.45	±12.98
Procalcitonin (ng/ml)	0	666.69	1.25	22.32	±97.41
NT-proBNP (pg/ml)	19.70	399.00	115.35	140.80	±84.65
SOFA (pts)	0	17	6	6.31	±3.75
APACHE II (pts)	3	24	12	12.29	±4.97

and severe sepsis, in practice does not affect significantly the value of the obtained results of SV and CO. The patients with sepsis or severe sepsis are within the theoretical model being the base of impedance cardiography.

Owing to the lack of adequate data in literature, the authors could not refer to the results obtained by other authors.

The obtained values of hemodynamic parameters measured with the ICG method in patients with sepsis and severe sepsis (128 measurements) may be the point of reference in further studies to be conducted in this group of patients.

Conclusions

The level of the obtained ICG signal and the measured values of TFC in patients with sepsis and severe sepsis with NICCOMO cardiograph allow to apply ICG routinely in this group of patients.

The authors recommend application of ICG in patients with sepsis and severe sepsis as a reliable and repeatable method on condition that using it, its limitations are taken into account and this method should not be applied in patients with some heart diseases, in the course or directly after cardiosurgical procedures, and the obtained level of the ICG signal (in %) is ≥30%, whereas the thoracic fluid content is not >65kΩ^{-1}.

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References

1. Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR. Epidemiology of severe sepsis in the United States: analysis of incidence, outcome and associated costs of care. Crit Care Med 2001; 29: 1303-10.
2. Piechota M, Irzmanski R, Banach M, Piechota-Urbanska M, Kowalski J, Rysz J, et al. NT-proBNP levels correlate with organ failure in septic patients. Heart Lung 2006; 35 (3), in press.
3. Machala W, Rysz J, Gaszynski T, Gaszynski W. Analgetic and sedative agents administered to the patients in life-threatening conditions. Arch Med Sci 2005; 1: 138-43.
4. Matthay MA, Chatterjee K. Bedside catheterization of the pulmonary artery: Risk compared with benefits. Ann Intern Med 1988; 109: 826-34.
5. Raaijmakers E, Faes TJ, Kunst PW, Bakker J, Rommes JH, Goovaerts HG, et al. The influence of extravascular lung water on cardiac output measurements using thoracic impedance cardiography. Physiol Meas 1998; 19: 491-9.
6. Kubicek WG, Karnegis JN, Patterson RP, Witsoe DA, Mattson RH. Development and evaluation of an impedance cardiac output system. Aerosp Med 1966; 37: 1208-12.

7. Gotshall RW, Wood VC, Miles DS. Comparison of two impedance cardiographic techniques for measuring cardiac output in critically ill patients. Crit Care Med 1989; 17: 806-11.
8. Wong DH, Tremper KK, Stemmer EA, O'Connor D, Wilbur S, Zaccari J, et al. Noninvasive cardiac output: simultaneous comparison of two different methods with thermodilution. Anesthesiology 1990; 72: 784-92.
9. Zacek P, Kunes P, Kobzova E, Dominik J. Thoracic electrical bioimpedance versus thermodilution in patients post open-heart surgery. Acta Medica (Hradec Kralove) 1999; 42: 19-23.
10. Critchley LA, Calcroft RM, Tan PY, Kew J, Critchley JA. The effect of lung injury and excessive lung fluid, on impedance cardiac output measurements, in the critically ill. Intensive Care Med 2000; 26: 679-85.
11. Van De Water JM, Miller TW, Vogel RL, Mount BE, Dalton ML. Impedance cardiography: the next vital sign technology? Chest 2003; 123: 2028-33.
12. Koobi T, Kaukinen S, Turjanmaa VM. Cardiac output can be reliably measured noninvasively after coronary artery bypass grafting operation. Crit Care Med 1999; 27: 2206-11.
13. Ng HW, Coleman N, Walley TJ, Mostafa SM, Breckenridge AM. Reproducibility and comparison of cardiac output measurement by transthoracic bioimpedance and thermodilution methods in critically ill patients. Clin Intensive Care 1993; 4: 217-21.
14. Banach M, Okonski P. AMS congress report. Heart Failure and Europace 2005. Arch Med Sci 2005; 1: 126-8.
15. Jensen L, Yakimets J, Teo KK. A review of impedance cardiography. Heart Lung 1995; 24: 183-93.
16. Young JD, McQuillan P. Comparison of thoracic electrical bioimpedance and thermodilution for the measurement of cardiac index in patients with severe sepsis. Br J Anaesth 1993; 70: 58-62.
17. Shoemaker WC, Wo CC, Yu S, Farjam F, Thangathurai D. Invasive and noninvasive haemodynamic monitoring of acutely ill sepsis and septic shock patients in the emergency department. Eur J Emerg Med 2000; 7: 169-75.
18. Rosenberg P, Yancy CW. Noninvasive assessment of hemodynamics: an emphasis on bioimpedance cardiography. Curr Opin Cardiol 2000; 15: 151-5.
19. Moshkovitz Y, Kaluski E, Milo O, Vered Z, Cotter G. Recent developements in cardiac output determination by bioimpedance: comparison with invasive cardiac output and potential cardiovascular applications. Curr Opin Cardiol 2004; 19: 229-37.
20. NICCOMO: Validation of the Cardiac Output Calculation. Available online at: http://www.niccomo.com/en/validation.html. Accessed June 2, 2005.
21. Stark HJ, Schultz K, Krieger E, Korn V, Petro W. Nichtinvasive Ermittlung des Herzzeitvolumens mit der Impedanzkardiographie. Hohe Korrelation mit der invasiven Fickschen Methode. Atemw Lungenkrkh 1996; 22: 73-5.
22. Bone RC, Balk RA, Cerra FB, Dellinger RP, Fein AM, Knaus WA, et al. Definitions for sepsis and organ failure and guidelines for the use of innovative therapies for sepsis. The ACCP/SCCM Concensus Conference Committee. American College of Chest Physicians/Society of Critical Care Medicine. Chest 1992; 101: 1644- 55.
23. Members of the American College of Chest Physicians/Society of Crit Care Med Consensus Conference Committee. American College of Chest Physicians/Society of Crit Care Med Consensus Conference: Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. Crit Care Med 1992; 20: 864-74.
24. Antonelli M, Moreno R, Vincent JL, Sprung CL, Mendoca A, Passariello M, et al. Application of SOFA score to trauma patients. Sequential Organ Assessment. Intensive Care Med 1999; 25: 389-94.
25. Janssens U, Graf C, Graf J, Radke PW, Konigs B, Koch KC, et al. Evaluation of the SOFA score: a single-center experience of medical intensive care unit in 303 consecutive patients with predominantly cardiovascular disorders. Sequential Organ Failure Assessment. Intensive Care Med 2000; 26: 1037-45.
26. Moreno R, Vincent JL, Matos R, Mendonca A, Cantraine F, Thijs L, et al. The use of maximum SOFA score to qualify organ dysfunction/failure in intensive care. Results of prospective, multicenter study. Working Group on Sepsis Related Problems of the ESICM. Intensive Care Med 1999; 25: 686-96.
27. Oda S, Hirasawa H, Sugai T, Shiga H, Nakanishi K, Kitamura N, et al. Comparison of Sepsis-related Organ Failure Assessment (SOFA) score and CIS (cellular injury score) for scoring of severity for patients with multiple organ dysfunction syndrome (MODS). Intensive Care Med 2000; 26: 1786-93.
28. Vincent JL, de Mendonca A, Cantraine F, Moreno R, Takala J, Suter PM, et al. Use of SOFA score to assess the incidence of organ dysfunction/failure in intensive care units: result of a multicenter, prospective study. Working group on „sepsis related problems" of the European Society of Intensive Care Medicine. Crit Care Med 1998; 26: 1793-800.
29. Morgenthaler NG, Struck J, Christ-Crain M, Bergmann A, Muller B. Pro-atrial natriuretic peptide is a prognostic marker in sepsis, similar to the APACHE II score: an observational study. Crit Care 2005; 9: 37-45.