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Evaluation of Hemodynamics at Various Stages of Off-Pump Coronary Artery Bypass Surgery

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Abstract. At the National Amosov Institute of Cardiovascular Surgery in 2018, we used impedance cardiography in 78 off-pump coronary artery bypass grafting (CABG) procedures. We used impedance cardiography for the cardiac index (CI), stroke volume index (SVI), oxygen delivery index and systemic vascular resistance index (SVRI) monitoring. We implemented the “beating heart” surgery technique using compression-type stabilizer. This technique requires extensive monitoring of the patient’s hemodynamics at all stages of the intervention. CI decrease was found at the stage of anastomosis placement (from 3.22±0.11 to 2.83±0.32, p=0.251) accompanied by the SVI decrease (from 42.86±5.64 to 37.62±3.26) and SVRI increase (from 2619.5±154.2 to 2876.2±185, p=0.288). CI decrease was found at the stage of induction of anesthesia from 3.97±0.38 to 2.46±0.32 (p=0.003). SVI changes from 42.86±5.64 to 37.62±3.26 (p=0.422) at the stage of distal anastomosis placement and from 47.28±4.35 to 34.50±3.45 (p=0.023) at the stage of induction of anesthesia were directly proportional to that of CI. During the CI decrease, we found that SVRI increased at the same stages of the surgical intervention.

Conclusion. Impedance cardiography is a good opportunity to study hemodynamics, to manage volemic load and trends and to detect hemodynamic changes during off-pump CABG; it helps to avoid complications and urgent switch to cardiopulmonary bypass. Impedance cardiography is useful for prediction of low cardiac output syndrome. Cardiac output monitoring helps to maintain hemodynamic stability in patients during dislocation of the heart for grafting of the distal ends of the coronary anastomoses in off-pump CABG surgery. Our study shows usefulness of routine use of cardiac output monitoring in all cases of off-pump CABG.

Keywords: *off-pump coronary artery bypass grafting, impedance cardiography, cardiac index.*

Postoperative complications in isolated off-pump coronary artery bypass grafting procedures are most often associated with intraoperative factors – unstable hemodynamics, cardiac rhythm disturbances, and myocardial ischemia. These factors cause an urgent switch to cardiopulmonary bypass (CPB) [1]. Literature data indicate that an urgent switch worsens the results of surgical interventions [2].

The optimal way to prevent complications is to improve the intraoperative hemodynamic study by monitoring cardiac index (CI). Intraoperative CI monitoring allows detection of impaired myocardial contractibility, timely stabilization of the patient's hemodynamics during the operation, and prevention of an urgent switch to CPB [3]. According to the literature, 30-60% of patients after coronary artery bypass grafting tend to have a decreased CI during the operation and during the early postoperative period [6, 7], which may be the cause of early postoperative complications [4]. The most severe postoperative complication in this group of patients is the development of low cardiac output syndrome (LCOS), with which the postoperative mortality can reach 20% [5].

The purpose of the work is to evaluate CI and other hemodynamic parameters at all stages of off-pump coronary artery bypass surgery.

Materials and methods

Cardiac index was determined in 78 patients operated in the department of surgical treatment of coronary heart disease of National Amosov Institute of Cardiovascular Surgery during 2018. Hemodynamic parameters were determined using impedance cardiography during off-pump coronary artery bypass grafting.

Characteristics of patients. The average age of the subjects was 67 ± 6 years; among them, men were 63 (81%), women – 15 (19%). The average left ventricular ejection fraction (LVEF) before surgery was 56 ± 9.4%, systolic output (SO) was 65 ± 8.5 cm^3, end-systolic volume (ESV) was 76 ± 8.5 cm^3, end-diastolic volume (EDV) was 152 ± 37 cm^3. According to EuroSCORE2 scale, the average value of preoperative risk was 5.4 ± 2.9. The average number of anastomoses was 3.4 ± 0.8. All anastomoses were applied to the beating heart using a compression-type stabilizer.

Results and discussion

On the day before the surgery, patients underwent preoperative preparation and received premedication. Patients received benzodiazepines (Sibazon at a dose of 10-30 mg) intramuscularly. In the operating room before the surgery, standard VI-lead ECG monitoring with ST segment analysis, saturation control was performed in each patient; if necessary, oxygen inhalation was used, after which CI was monitored with the help of impedance cardiography (ICG) using the UTAS UM300 monitor with the ICG module adapted to it.

A peripheral venous line, a catheter in the radial artery were used in patients for invasive blood pressure (BP) monitoring. The central venous catheterization was performed for infusion and control of central venous pressure (CVP).

At the beginning of the operation, fluid deficiency was restored after placing intravenous catheters by infusion of balanced saline solutions, and, if necessary, gelatine or starch solutions. The liquid infusion rate was regulated under the CVP control.

An off-pump coronary artery bypass grafting procedure was divided into several stages. Stage 1 – the baseline, during which the patient was prepared for surgery: the patient's monitoring was set up and peripheral vein and artery were catheterized for monitoring invasive arterial pressure. Stage 2 – induction of anesthesia: patients received intravenous propofol at a dose of 2-4 mg/kg and fentanyl at a dose of 10-15 μg/kg/h. Stage 3 – Intubation: Relaxation for tracheal intubation was maintained with rocuronium bromide (Esmeron) at a dose of 0.6-1 mg/kg. Mechanical ventilation was carried out with a semi-closed circuit in a normoventilation mode with 30-60% oxygen concentration (FiO_2), with normocapnia support. The respiratory volume was 6-8 ml/kg, the respiratory rate was 8-12 breaths per 1 min. Ventilation parameters were controlled by determining the gas composition of arterial and venous blood. Stage 4: anesthesia support was carried out with propofol and fentanyl, the adequacy of anaesthetic management was evaluated by the BIS-monitor parameters. Stage 5 – placement of distal anastomoses. Stage 6 – end of the operation.

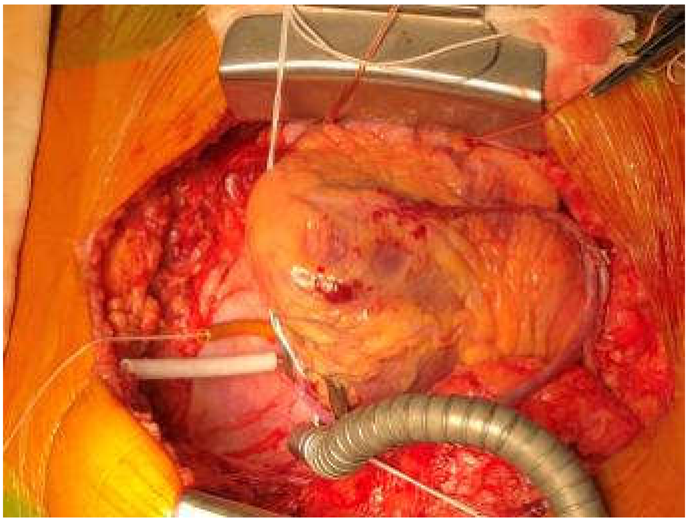

Fig. 1. Placement of distal anastomosis using a compression-type stabilizer

The hemodynamic assessment of patients was based on the determination of the following parameters: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), central venous pressure, cardiac index, systolic output index (SVI), total systemic vascular resistance index (SVRI), oxygen challenge index (OCI).

During the induction of anesthesia, a statistically significant decrease in hemodynamic parameters was observed compared with baseline data: SBP – 142.25 ± 12.4 to 92.45 ± 6.7 mmHg ($p = 0.001$), DBP – 68.3 ± 3.17 to 60.15 ± 2.3 mmHg ($p = 0.039$), CI – 3.97 ± 0.38 to 2.46 ± 0.32 l/min/m^2 ($p = 0.003$), SVI –

47.28 ± 4.35 to 34.50 ± 3.45 ml/m² (p = 0.023); at this stage of the operation SVRI had negative changes – decreased from 2467.3 ± 89.5 to 2150.5 ± 97.8 dyne × sec × cm^{-5} × m² (p = 0.018).

Table 1

Parameters of the hemodynamic system and functional heart condition at various stages of coronary artery bypass grafting (n = 78)

Parameter	Baseline data	Induction	Intubation	Anesthesia support	Distal anastomoses	End of the operation
HR (bpm)	69.5±7.6	82.25±2.39	97.69±3.42*	78.34±2.39	84.25±5.45	76.52±6.51
SBP (mmHg)	142.25±12.4	92.45±6.7*	113.14±8.17	129.17±2.17	98.64±6.35*	113.14±7.10*
DBP (mmHg)	68.3±3.17	60.15±2.3*	74.3±5.34	70.1±3.25	57.15±3.4*	73.3±5.16
CVP (mmWG)	45.3±6.7	52.3±9.8	61.3±7.4	58.3±6.3	70.1±5.4*	65.3±7.8
CI (l/min/m²)	3.97±0.38	2.46±0.32*	3.48±0.94	3.22±0.11	2.83±0.32*	3.14±0.97
SVI (ml/m²)	47.28±4.35	34.50±3.45*	45.05±4.34	42.86±5.64	37.62±3.26	41.25±4.26
SVRI (dyne × sec × cm^{-5} × m²)	2467.3±89.5	2150.5±97.8*	2385.4±163.5	2619.5±154.2	2876.2±185*	2265.3±148.5
OCI ml/min/m²	620	570	600	640	530	700

Note.*statistically significant changes in the parameter compared with the baseline level, p <0.05 (evaluation by Wilcoxon criterion).

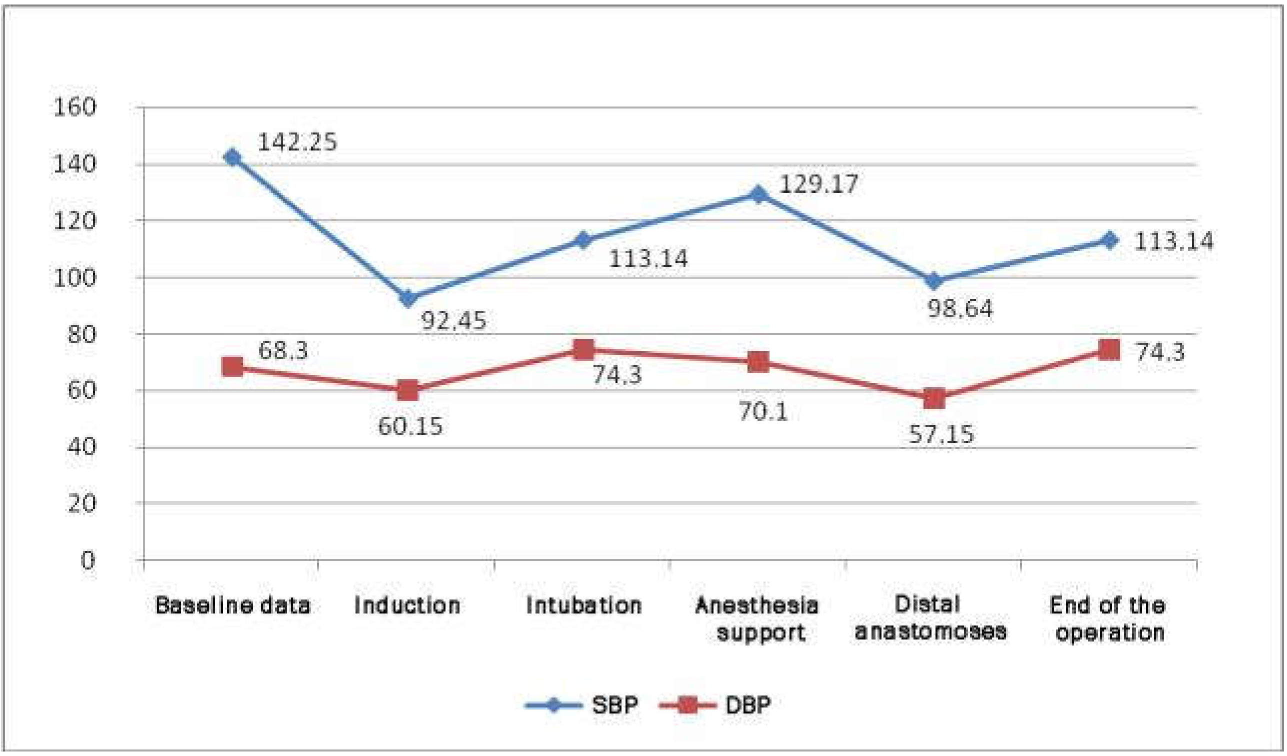

Fig. 2. Changes in SBP (mmHg) and DBP (mmHg) at the stages of the operation

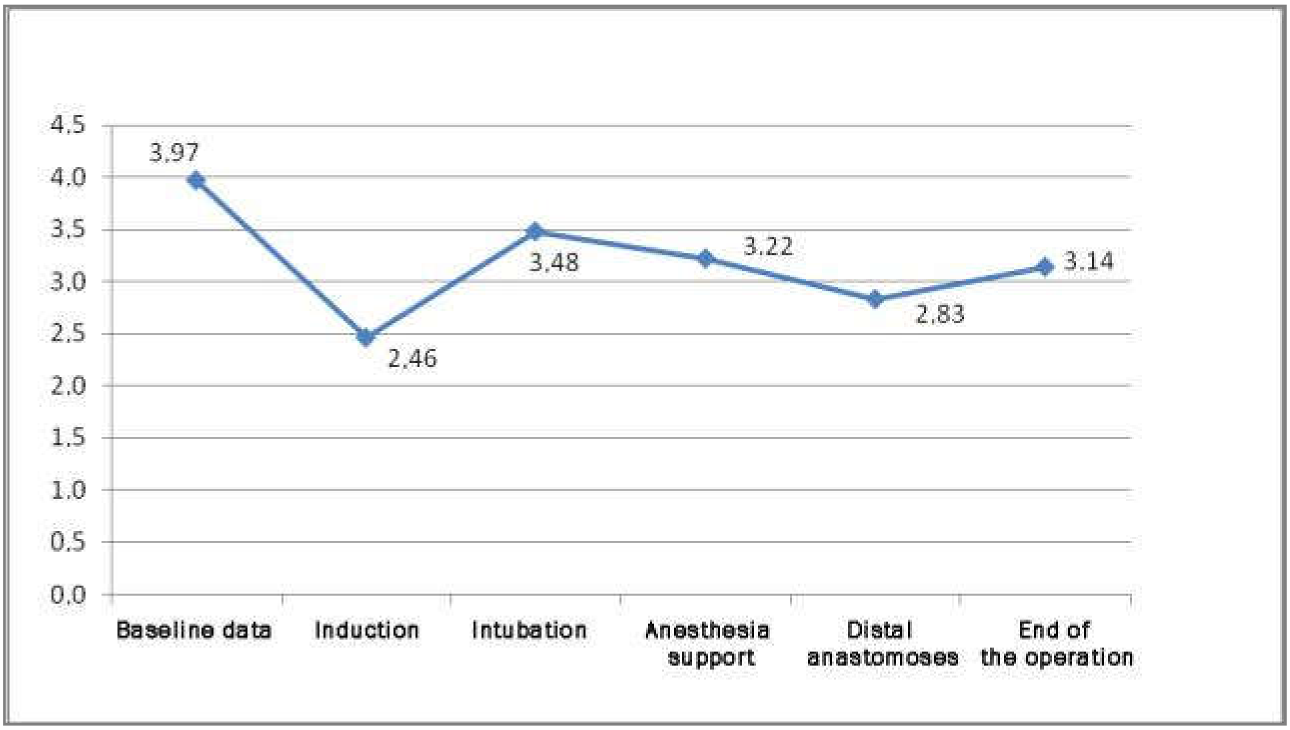

Fig. 3. CI changes (l/min/m^2) at the stages of the operation

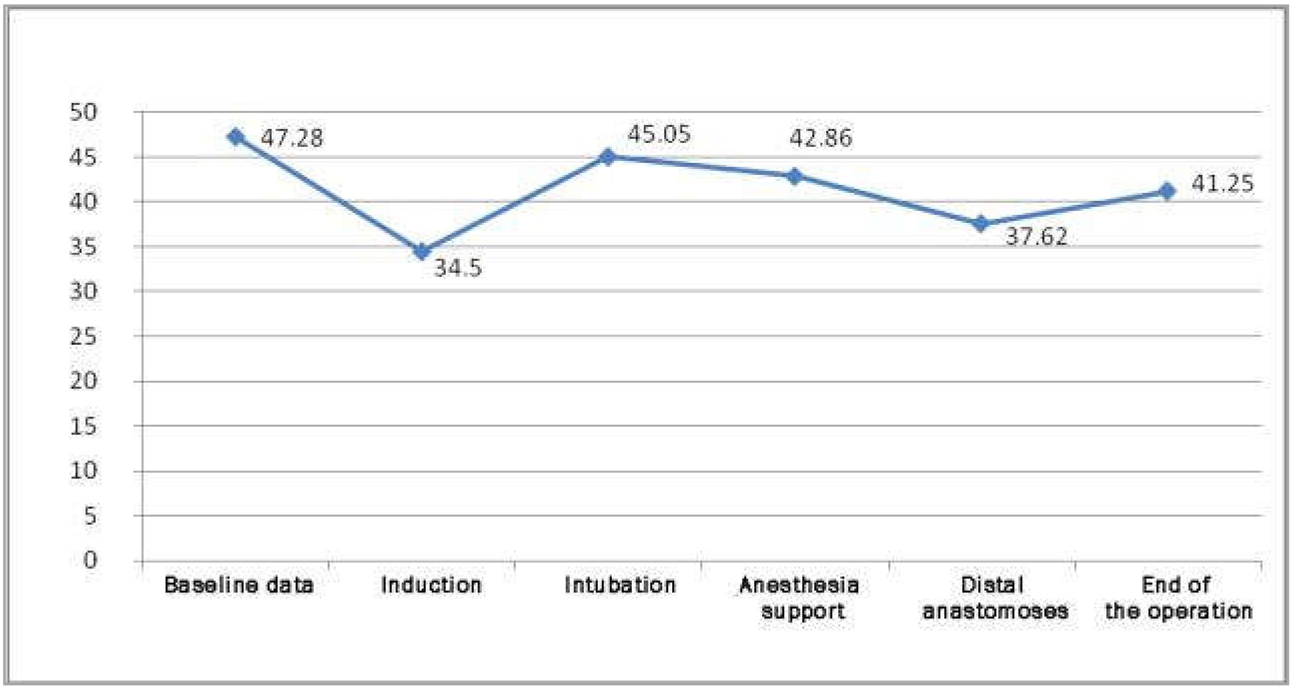

Fig. 4. SVI (ml/m^2) during the operation

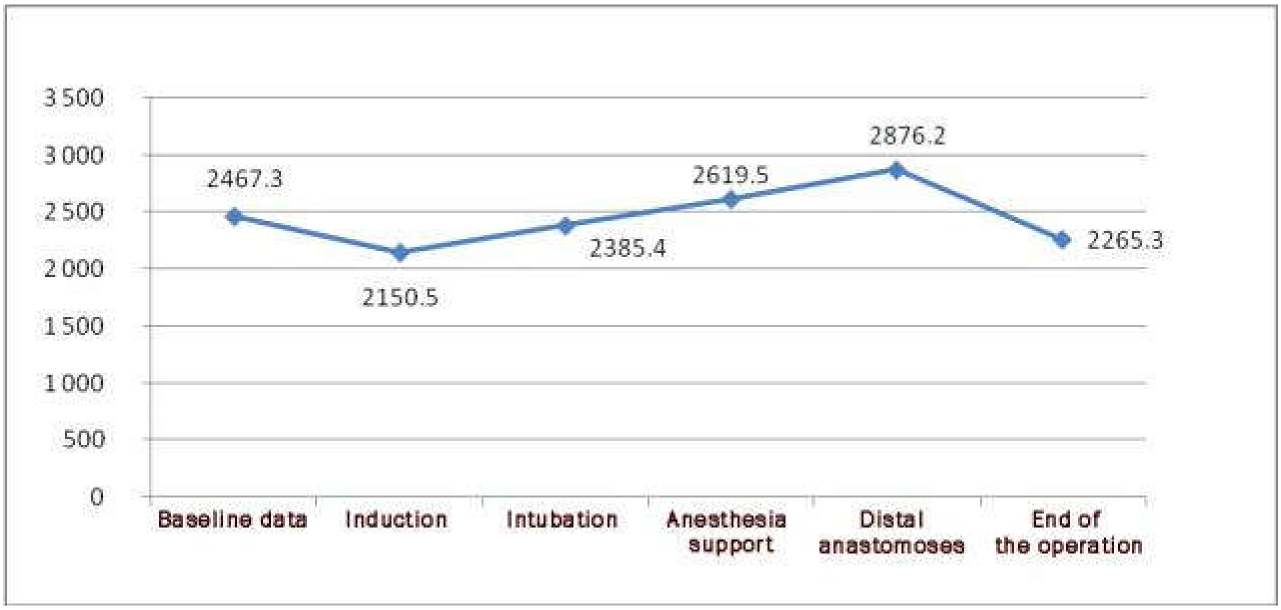

Fig. 5. SVRI (dyne × sec × cm^{-5} × m^2) during the operation

A significant decrease in hemodynamic parameters at the stage of placing distal anastomoses was detected in comparison with the baseline data: SBP – 142.25 ± 12.4 to 98.64 + 6.35 mmHg ($p = 0.002$), DBP – 68.3 ± 3.17 to 57.15 ± 3.4 mmHg ($p = 0.018$), CI – 3.97 ± 0.38 to 2.83 ± 0.32 l/min/m^2 ($p = 0.023$). Unlike the previous data, at this stage of the operation SVRI had positive changes – increased from 2467.3 ± 89.5 to 2876.2 ± 185 dyne × sec × cm^{-5} × m^2 ($p = 0.048$). At this stage of the operation, the above hemodynamic changes indicate impaired myocardial contractility.

The most significant changes in hemodynamics requiring therapeutic measures were reported at the induction stage and at the stage of placing distal anastomoses. During the stage of placing distal anastomoses, the patient was in a head-down tilt position providing optimal preload; in case of unsatisfactory hemodynamics, the volume status was corrected with crystalloid solutions, and with further decrease of CI and SVI, vasopressors and sympathomimetics were used. Dynamics of CI changes at different stages of the operation is shown in Fig. 3.

It should be noted that a statistically significant decrease in CI was observed during induction of anesthesia – 3.97 ± 0.38 to 2.46 ± 0.32 ($p < 0.05$); after intubation, the growth of the cardiac index from 2.46 ± 0.32 to 3.48 ± 0.94 was reported. Significant decrease in CI was also observed during the stage of placing distal anastomoses – up to 2.83 ± 0.32 ($p < 0.05$). In general, negative changes were observed, which were preserved when comparing the baseline CI value (3.97 ± 0.38) with the CI level (3.14 ± 0.97) ($p > 0.05$) at the end of the operation: the CI value at the end of the operation was 21% less than before it began.

CI reduction at the stage of placing distal anastomoses was accompanied with a decrease in SVI and an increase in SVRI (Figures 3 and 4), indicating a decrease in the myocardial contractility at this stage of the operation.

SVRI level was inversely proportional to CI and SVI, as shown in Fig. 5.

Conclusions

1. There is a significant decrease in CI at the induction stage of anesthesia and at the stage of placing distal anastomoses.

2. Comparative analysis of the CI changes at the beginning and at the end of the operation had a negative dynamics, CI decreased by 21%.

3. CI reduction at the stage of placing distal anastomoses was accompanied with a decrease in SVI and an increase in SVRI, indicating an impaired myocardial contractility.

4. CI determination and assessment of its changes during off-pump coronary bypass grafting provides an opportunity to provide adequate pre-loading, anticipate and timely prevent Low cardiac output syndrome and avoid an urgent switch to cardiopulmonary bypass.

5. Our research proves the expediency of the routine use of CI measurement for off-pump coronary artery bypass grafting.

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