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Long-stay predictors in the intensive care unit after Bentall procedure: retrospective research

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SOUHRN

Cíl: Analyzovat frekvenci časných pooperačních komplikací a identifikovat prediktory dlouhodobého pobytu na jednotce intenzivní péče (JIP) po Bentallově operaci.
Materiály a metody: V této retrospektivní studii byly použity údaje ze zdravotní dokumentace dospělých pacientů (ve věku 18–75), kteří v letech 2012 až 2021 prodělali Bentallovu operaci pro aneurysma na vzestupné aortě. Podle délky pobytu na JIP byli pacienti rozděleni do dvou skupin: délka pobytu na JIP do 3 dnů (1. skupina) a délka pobytu na JIP nad 3 dny (2. skupina). K určení prognostických rizikových faktorů byla provedena univariační i multivariační analýza (logistická regrese).
Výsledky: Mezi hlavní charakteristiky pacientů ve 2. skupině patřily jednoznačně vyšší věk (p = 0,005), z komorbidit častější přítomnost arteriální hypertenze (p = 0,044) a statisticky významně nižší vstupní glomerulární filtrace (GF) (p = 0,045). V případě 2. skupiny pacientů byl kvůli vyšší incidenci krvácení ve srovnání s 1. skupinou sběrný zásobník (cell saver) použit 3,6krát častěji (p = 0,0005) při téměř 6násobně (p = 0,0037) vyšší potřebě retorakotomie v důsledku krvácení, při 4,3krát (p = 0,0002) vyšší incidenci akutní renálního selhání a 3,3krát (p = 0,0004) častějším akutním respiračním selhání. Multivariační logistická regrese identifikovala dva nezávislé prediktory dlouhodobého pobytu na JIP: délku mechanické ventilace (OR 1,204 [CI 1,053–1,377], p = 0,007) a rozvoj akutního renálního selhání (OR 4,069 [CI 1,040–15,923], p = 0,044).
Závěry: Aby se předešlo peroperačním a pooperačním komplikacím, je sice nutno léčit všechny pacienty stejně, ale pacientům s faktory zvyšujícími riziko dlouhodobého pobytu na JIP je nutno věnovat obzvláštní pozornost.

Keywords:
Ascending aortic aneurysm
Bentall's procedure
Length of ICU stay
Risk factors

ABSTRACT

Aim: To analyze the frequency of early postoperative complications and predictors of long-stay patients in the intensive care unit (ICU) after the Bentall procedure.
Materials and methods: This retrospective study is based on the obtained medical records of adult patients (aged 18–75), who underwent Bentall procedure for an ascending aortic aneurysm between 2012 and 2021. Depending on the length of ICU stay, all patients were divided into two groups: length of ICU stay up to 3 days (group 1) and length of ICU stay longer than 3 days (group 2). Univariate and multivariate analysis (logistic regression) was used to determine prognostic risk factors.
Results: Patients of the second group were characterized by reliably older age (p = 0.005), more frequent presence of arterial hypertension (p = 0.044) among concomitant diseases (p = 0.044) and significantly lower baseline glomerular filtration rate (GFR) (p = 0.045). In case of the second group of patients in comparison with the first one, cell saver was used 3.6 times (p = 0.0005) more often and almost 6 times (p = 0.0037) more often, as well as the need for rethoracotomy due to bleeding, 4.3 times (p = 0.0002) more often acute renal failure and 3.3 times (p = 0.0004) more often acute respiratory failure. Multivariate logistic analysis revealed two independent predictors of long-stay ICU: duration of mechanical ventilation (OR 1.204 [CI 1.053–1.377], p = 0.007) and development of acute renal failure (OR 4,069 [CI 1,040–15,923], p = 0.044).
Conclusions: All the patients must be treated in the same way to avoid per- and postoperative complications, but patients with risk factors for long-stay ICU should be under special attention.

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Introduction

Reconstructive surgery of ascending aortic aneurysms (AAA) is one of the most challenging issues in modern cardiac surgery. As early as 1968, Bentall and De Bono proposed an operation using a composite valve-containing conduit or a self-assembled aortic valve conduit for the surgical treatment of AAA.[1]

Today, the Bentall procedure has been widely implemented in various pathological conditions, including aortic regurgitation, Marfan syndrome, aortic dissection, and aortic aneurysm.[2] At the same time, due to a significant number of complications associated with bleeding from the proximal anastomosis and the site of coronary artery implantation, the original technique has undergone a number of modifications, which allowed this procedure to be performed with a relatively lower incidence of hemorrhagic postoperative complications.[3–5]

However, despite the modification of the Bentall procedure, a number of postoperative complications still persist, such as hemodynamic instability, acute kidney injury, respiratory failure with prolonged mechanical ventilation, which can affect the length of intensive care unit (ICU) stay.[6,7]

Prolonged ICU stay leads to significant healthcare costs and excessive consumption of medical resources, as well as to an increase in perioperative mortality and complications.

Aim

To analyze the frequency of early postoperative complications and predictors of long-stay patients in ICU after the Bentall procedure.

Materials and methods

Patient characteristics

In this retrospective study, medical records of adult patients (18 to 75 years of age) who underwent the Bentall procedure for AAA at the State Institution "Heart Institute Ministry of Health of Ukraine" between 2012 and 2021 were obtained. The exclusion criteria were: concomitant cardiac surgery; patients aged younger than 18 years or older than 75 years.

The study was approved by the Ethics Committee of the Shupyk National Healthcare University of Ukraine, protocol No 11 of 16. 11. 2021.

Anesthesia and cardiopulmonary bypass

Intraoperative monitoring included electrocardiogram, invasive blood pressure, central venous pressure, arterial blood oxygen saturation, cerebral oximetry, ultimate respiratory concentration of sevoflune, nasopharyngeal and bladder temperature, and urine output.

General anesthesia was maintained by titrating sevoflurane at a dose of 1.5 vol% to 2.5 vol% to maintain BIS values from 40 to 60. Sevoflurane was supplied into the oxygenator circuit during cardiopulmonary bypass (CPB) through a calibrated vaporizer.

Mechanical ventilation (MV) was performed using anesthesia machines with FiO_2 of 50% of air-oxygen mixture in the normoventilation mode under the control of arterial blood gases (arterial blood pCO_2 values were maintained at 35–40 mmHg).

All patients were operated on through a midline approach. The Bentall procedure was performed using a heart-lung machine (HLM) with disposable membrane oxygenators. A dose of heparin of 300 IU/kg body weight was administered intravenously before CPB start to achieve an activated clotting time (ACT) above 480 seconds. ACT was measured every 30 minutes during CPB. Protamine sulfate was used to counteract the anticoagulant effect of heparin after CPB termination. The priming volume consisted of 500 ml of colloid solutions, 100 ml of 4.2% sodium bicarbonate solution, 300 ml of 0.9% sodium chloride solution, and 100 ml of 15% mannitol solution. If necessary, deep hypothermic circulatory arrest (DHCA) was performed when the body temperature reached 22 °C. Cerebral oximetry was monitored in all patients using a regional oximeter.

Data collection

Preoperative, intraoperative, and postoperative data were collected. At the preoperative stage, such indicators as demographic characteristics (age, gender, body weight), echocardiographic parameters (left ventricular ejection fraction [LVEF] and ascending aortic diameter) and comorbidities were recorded.

Intraoperative data included surgery duration, aortic cross-clamping duration, and DHCA duration.

Data collected during the postoperative period included duration of MV, use of sell saver, the frequency of postoperative complications (myocardial infarction, acute respiratory failure, acute renal failure, acute hepatic failure, gastrointestinal bleeding, rethoracotomy), length of ICU stay and length of hospitalization.

In our routine ICU practice the usual length of ICU stay after Bentall procedure is 3 days, so the patients who needed more time in ICU were referenced to long-stay group.

The decision about extubation was made regarding the following clinical criteria: full recovery from muscle relaxation and anesthesia; patients are easy to rouse, neurologically intact, lift head and stick out tongue; stable hemodynamics (heart rate and blood pressure are within ordered parameters, bleeding is controlled); spontaneous muscle movement with stable respiratory rate and adequate oxygenation, which was confirmed by arterial blood gases (SaO_2 >92%, on FiO_2 <50%). Postoperative arrhythmias included clinically significant atrial fibrillation (ECG recordings on one or more ECG leads), which demonstrated the presence of atrial fibrillation characteristics ECG features lasting at least 30 s in the (intra- and) postoperative setting which requires treatment with rate or rhythm control agents or requires anticoagulation, and/or extends the duration of hospitalization; ventricular tachycardia, ventricular fibrillation and atrioventricular block. Patients were on continuous ECG monitoring during two days after surgeries. Acute renal failure was defined as absolute increase in sCr, at least 0.3 mg/dL (26.5

μmol/L) within 48 hours or by a 50% increase in sCr from baseline within 7 days, or a urine volume of less than 0.5 mL/kg/h for at least 6 hours. Acute heart failure was defined as a need of using high doses of at least two inotropes intraoperatively and during the first two postoperative days. Indication for using cell saver was anticipated blood loss more than 20% blood volume after protamine administration.

Statistical analysis

The results of the study were presented as the arithmetic mean (M) ± standard deviation (SD). In the case of abnormal distribution of results, the data were presented as median (Me) and the 1st (Q25) and 3rd (Q75) quartiles – Me (Q25; Q75). In the case of a normal distribution of data, the Student's t-test is used to determine the reliability of statistical indicators, and at the same time, in the absence of a normal distribution, the nonparametric Mann–Whitney U-test is used. For the analysis of categorical variables, such as the incidence of postoperative complications in both groups, the Pearson's χ^2 test or Fisher's exact test was used (when appropriate). For logistic multivariate analysis, factors with a significance of p <0.05 in univariate analysis were included. Differences at p <0.05 (95.5%) were considered significant. To analyze the data obtained, the program of statistical data processing "SPSS Statistics ver. 27" was implemented.

Results

In total, during 2012–2021, 197 Bentall procedures for ascending aortic aneurysm were performed at the State Institution "Heart Institute Ministry of Health of Ukraine". Sixty-seven patients who underwent concomitant cardiac surgery in addition to the Bentall procedure were excluded from the study. One patient died intraoperatively and was excluded from the study. In addition, 5 patients were excluded due to missing data in their medical records. Thus, this study included 124 patients, aged 18 to 70 years. Marfan syndrome was observed in 9 (7.26%) patients and bicuspid aortic valve was detected in 75 (60.5%) patients. In 2 (1.16%) cases, the operation was an emergency.

The most frequent postoperative complications included arrhythmias – 65 (52.4%) cases, acute respiratory failure – 24 (19.4%), acute renal failure– 23 (18.5%), and acute heart failure – 21 (16.9%).

Depending on the length of ICU stay, all patients were divided into two groups: the first group – length of ICU stay up to 3 days – 99 patients; the second group – length of ICU stay longer than 3 days – 25 patients.

Baseline characteristics of patients depending on the length of stay in the ICU are shown in Table 1.

As can be seen from Table 1, patients who stayed in the ICU for more than 3 days were characterized by significantly older age (p = 0.005), more frequent presence of arterial hypertension among comorbidities (p = 0.044) and significantly lower baseline GFR (p = 0.045).

No significant differences are observed between the study groups in intraoperative parameters such as duration of surgery (p = 0.712), duration of CPB (p = 0.626), and duration of hypothermic circulatory arrest (p = 0.638) (Table 2).

Table 1 – Initial characteristics of patients depending on length of ICU stay (m±SD)

Parameters		Group 1 (N = 99)	Group 2 (N = 25)	p
Age, years		48.1±13.1	56.4±12.2	**0.005**
Male gender, n (%)		91 (91.9%)	20 (80.0%)	0.135
BMI, kg/cm^2		28.2±7.47	26.4±3.93	0.266
Marfan syndrome, n (%)		9 (9.09%)	0 (0.00%)	0.202
Bicuspid aortic valve, n (%)		56 (56.6%)	19 (76.0%)	0.075
Concomitant diseases, n (%)	AH	78 (78.8%)	24 (96.0%)	**0.044**
	DM	6 (6.0%)	1 (4.00%)	1.0
	AF	5 (5.05%)	1 (4.00%)	1.0
	COPD	1 (1.01%)	0 (0.00%)	1.0
	CVA	2 (2.02%)	0 (0.00%)	1.0
LVEF, %		57.4±9.64	55.2±13.8	0.348
Ascending aorta diameter, cm		5.41±1.04	5.18±0.70	0.295
GFR, ml/min/1.73 m^2		100.6±26.1	88.9±23.5	**0.045**
Emergency surgery, n (%)		2 (2.02%)	0 (0.00%)	1.0
Cardiac surgery reoperation, n (%)		3 (3.03%)	2 (8.00%)	0.264

AF – atrial fibrillation; AH – arterial hypertension; BMI – body mass index; COPD – chronic obstructive pulmonary disease; CVA – cerebrovascular accident; DM – diabetes mellitus; GFR – glomerular filtration rate; LVEF – left ventricular ejection fraction.

At the same time, patients who stayed in the ICU for more than 3 days, had a significantly longer stay on MV (p = 0.0001) compared with patients who stayed in the ICU for up to 3 days (Table 2).

In addition, due to significantly higher bleeding in patients of the second group compared to the first (p = 0.0005), patients of the second group used cell saver 3.6 times more often (p = 0.0005) and had a significantly almost 6 times (p = 0.0037) higher need for rethoracotomy due to bleeding (Table 2).

Patients in the second group had 4.3 times (p = 0.0002) more frequent acute renal failure and 3.3 times (p = 0.0004) more frequent acute respiratory failure compared with the first group (Table 2).

Logistic regression analysis identified the following two independent predictors of prolonged ICU stay: the duration of MV and acute renal failure in the early postoperative period (Table 3).

Discussion

The results of our retrospective study have shown that older age, arterial hypertension, and lower GFR, as well as a longer MV, acute renal failure, acute respiratory failure, higher blood loss, and reoperation in the postoperative

Table 2 – Characteristics of the intraoperative and early postoperative period depending on length of ICU stay (m±SD)

Parameters		Group 1 (N = 99)	Group 2 (N = 25)	*p*
Surgery duration, min		4.16±1.08	4.25±1.02	0.712
CPB duration, min		128.8±39.8	133.2±42.9	0.626
Hypothermic circulatory arrest - n (%) - average duration, min		 31 (31.3%) 10.2±2.45	 11 (44.0%) 10.6±3.72	 0.145 0.638
MV duration, hour		10 (9; 12.5)	12 (12; 25.0)	**0.0001**
Blood loss in ICU, ml (Me [Q_1; Q_3])		700 (550; 900)	1 050 (500; 1 200)	**0.0005**
Cell saver, n (%)		11 (11.1%)	10 (40.0%)	**0.0005**
Length of hospitalization, days		14 (13.0; 19.0)	19 (14; 23)	**0.001**
Complications, n (%)	Focal lesions	2 (2.02%)	1 (4.00%)	0.494
	AHF	15 (15.2%)	6 (24.0%)	0.369
	MI	5 (5.05%)	2 (8.00%)	0.627
	Arrhythmia	48 (48.5%)	17 (68.0%)	0.081
	Acute respiratory failure	13 (13.3%)	11 (44.0%)	**0.0004**
	Acute kidney injury	11 (11.1%)	12 (48.0%)	**0.0002**
	Acute liver failure	2 (2.02%)	2 (8.00%)	0.180
	Gastrointestinal bleeding	8 (8.08%)	4 (8.00%)	0.258
	Rethoracotomy	2 (2.02%)	5 (12.0%)	**0.0037**

AHF – acute heart failure; CPB – cardiopulmonary bypass; ICU – intensive care unit; MI – myocardial infarction; MV – mechanical ventilation.

Table 3 – Multivariate logistic regression analysis

Parameters	OR	CI	*p*
Age, year	1.032	0.960–1.110	0.396
AH, n (%)	9.144	0.418–12.393	0.160
GFR, ml/min	0.991	0.962–1.021	0.552
MV duration, hours	1.204	1.053–1.377	**0.007**
Blood loss in ICU, ml	0.982	0.962–1.003	0.095
Rethoracotomy, n (%)	1.812	0.180–18.198	0.614
Arrhythmia, n (%)	1.965	0.590–6.544	0.271
Acute respiratory failure, n (%)	1.187	0.225–5.525	0.827
Acute kidney injury, n (%)	4.069	1.040–15.923	**0.044**

AH – arterial hypertension; GFR – glomerular filtration rate; ICU – intensive care unit; MV – mechanical ventilation.

period were significantly more common in patients who required ICU stay for more than 3 days.

Due to the technical complexity of the Bentall procedure, aortic reconstruction can pose a significant risk of postoperative complications and, accordingly, a long-stay ICU.[8,9] Thus, according to Dunne et al. (2013), among postoperative complications after surgery for AAA, the prevalence of arrhythmias was 33.7%, acute renal failure – 14.6%, bleeding/tamponade – 14.6%, while hospital mortality was recorded at 15.6%.[10] In our opinion, such a high mortality rate, in contrast to our work, is due to the high frequency of emergency operations (43%) and the presence of concomitant cardiac surgery. At the same time, the prevalence of acute renal failure and arrhythmias in the postoperative period was relatively similar to our study – 52.4% and 18.4%, respectively.

Indeed, a subsequent study by Benke et al. (2016) showed that NYHA class III and IV (OR 9.2, 95% CI 0.972–87.240, p = 0.050), aortic dissection (OR 6.817, 95% CI 1.392–33.393, p = 0.018), concomitant coronary artery bypass grafting (OR 15.722, 95% CI, 3.087-80.064, p = 0.001) and concomitant mitral valve surgery (OR 5.207, 95% CI 0.987–27.480, p = 0.049) were independent risk factors for early complications.[11]

It is worth noting that the development of postoperative complications can affect the duration of ICU stay. In turn, a prolonged stay in the ICU is associated with an increase in the cost of treatment and additional use of medical resources, and also leads to a shortage of ICU beds, which can lead to the cancellation of operations.[12] In addition, as reported by Giakoumidakis et al. (2011), patients who stay in ICU for a long time are usually characterized by lower quality of life and higher mortality after discharge.[13]

According to Sheng et al. (2019), independent predictors of prolonged ICU stay in patients undergoing surgery for acute aortic dissection type A were the duration of MV, postoperative stroke, acute renal failure, and acute respiratory failure.[14]

Despite a number of significant factors in univariate analysis, multivariate logistic analysis in our study revealed only two independent predictors of prolonged ICU stay: duration of MV (OR 1.204 [CI 1.053–1.377], p = 0.007) and development of acute renal failure (OR 4.069 [CI 1.040–15.923], p = 0.044).

Our study has several limitations. First, the study is retrospective, which may limit our conclusions. Also, the number of patients involved in the study is relatively small, which may call into question the external validity of our study. The research represents the experience of only one center, and Bentall procedures were performed by different cardiac surgical teams, which may also affect the study results. The medical records do not reflect long-term patient outcomes.

To summarize, our results show that older age, arterial hypertension, lower GFR, longer MV, higher blood loss, reoperation rate, acute renal failure, and acute respiratory failure in the postoperative period were significantly more common in patients who required ICU stay for more than 3 days. Longer MV and the development of acute renal failure were independent predictors of prolonged ICU stay. Further studies with larger sample sizes are needed to fully analyze all the factors of prolonged ICU stay in patients undergoing Bentall procedure.

Conflict of interest

The authors stated that there is no potential conflict of interest in research, authorship and/or publication of this article.

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Ethical statement

The study was approved by the Ethics Committee of the Shupyk National Healthcare University of Ukraine, protocol No 11 of 16. 11. 2021.

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