Original paper

Early postoperative complications in heart transplant patients hospitalised in the intensive care unit

Natalia K. Padula, Karolina Ryś, Iwona Bodys-Cupak

Department of Nursing Fundamentals, Institute of Nursing and Midwifery, Faculty of Health Sciences, Jagiellonian University Medical College, Krakow, Poland

Medical Studies
DOI: https://doi.org/10.5114/ms.2026.159732

Key words: heart failure, transplantation, nursing care, intensive care, complications.

Abstract

Introduction: Heart transplantation remains the most effective therapy for end-stage heart failure. Despite medical and surgical progress, early complications remain a challenge.
Aim of research: To identify early postoperative complications and the factors that distinguish them.
Material and methods: The study employed the method of documentoscopy, utilising quantitative and descriptive analysis techniques. Data were collected using the author's questionnaire, which was based on the analysis of patients' medical records – completed by nurses and doctors – and direct observation of patients treated in the Department of Anaesthesiology and Intensive Care. The data collection covered the years 2019 to 2023. Analysed variables included demographic data, details of the surgical procedure, postoperative parameters, assessment methods, haemodynamic support, volume of transfused blood products and their components, pharmacotherapy and immunosuppressive treatment, length of hospitalisation, and complications.
Results: In the early postoperative period after heart transplantation (HTX), the most common complications were respiratory failure and cardiac arrhythmias. Patients with cardiac arrhythmias, infection, acute kidney injury (AKI), and respiratory failure were hospitalised for longer periods. Blood product transfusions are affected by haemoglobin values and the amount of drainage. Age over 50 years is associated with an increased risk of infection after surgery. The need for mechanical support of circulation before HTX reduces the risk of cardiac arrhythmias after surgery.
Conclusions: drainage volume, diuresis volume, central venous pressure, surgery time, cardiopulmonary bypass time, and clamping time of the recipient's aorta significantly affected postoperative complications.

Introduction

Heart failure is a condition in which the heart is unable to pump enough blood to the organs of the body, often caused by dilated cardiomyopathy or ischemic heart disease [1, 2]. It affects around 23 million people worldwide and 3.2% of the Polish population [3, 4]. Heart failure (HF) should be considered for heart transplantation if optimal medical therapy, as recommended by the ACC/AHA (American College of Cardiology/American Heart Association) guidelines, and cardiac resynchronisation therapy has failed to improve symptoms or halt progression of the underlying pathology. Transplantation significantly improves survival and quality of life in patients with advanced heart failure [3, 5, 6].

In Poland, 178 heart transplants were performed in 2023, with a total of 1286 since 2015. Advances in surgical techniques, immunosuppression, and patient selection have increased survival rates, although complications remain a key challenge, especially in the early postoperative period [7, 8]. The importance of continuous education and training for intensive care unit (ICU) nurses is highlighted to maintain their competence in handling the unique challenges associated with heart transplant patients [9].

There are relatively few studies on heart transplant complications in patients after transplantation.

Aim of the research

The aim of this study was to present the complications that occurred in patients in the early postoperative period after heart transplantation and the factors that distinguish them.

Material and methods

Study design and sample

The retrospective study used the documentoscopy method, analysing medical records of adult heart transplant patients hospitalised in the ICU from 2019 to 2023. Records of patients undergoing other cardiac surgeries were excluded. Of 73 cases reviewed, 2 were excluded due to incomplete data, resulting in a final sample of 71 patients, including 62 men and 9 women.

Data collection

Data were collected using a questionnaire developed by the author from November 2023 to February 2024 at the medical archive of one of the six heart transplantation centres in Poland. Reviewed medical records included patient history, intensive care cards, surgical protocols, pain management, and immunosuppressive treatment documentation, as well as results from the New York Heart Association (NYHA), Numerical Rating Scale (NRS), and Behavioural Pain Scale (BPS).

The questionnaire covered demographic data, cause of transplantation, comorbidities, surgical details, and postoperative information such as vital signs, pharmacotherapy, haematotherapy, and complications. The tool was created based on a literature review.

Statistical analysis

The collected research material was subjected to quantitative and descriptive analysis. Descriptive statistics were applied to measurable variables, while categorical variables were presented as counts (*n*) and percentages (%). Normality was tested using the Shapiro-Wilk test. For non-normal distributions, the Wilcoxon rank-sum test was used. The Friedman test compared repeated measures, Pearson's correlation assessed linear relationships, and the χ^2 test examined associations between dichotomous categorical variables. The Kruskal-Wallis and Mann-Whitney tests compared independent groups. Analyses were conducted using IBM SPSS Statistics 22, with significance set at $p < 0.05$.

Results

In this study, women accounted for 12.7% of the study group, whereas men accounted for 87.3%. The patients studied were between 22 and 65 years of age. The mean age of the patients was 49.21 ±12 years, with a median age of 53 years. The main cause of heart transplantation is heart failure, which is unspecified (40.8%, *N* = 29), congestive heart failure (23.9%, *N* = 17) or dilated cardiomyopathy (18.3%, *N* = 13). Smoking occurred in 22.5% (*N* = 16) of patients. The NYHA score before surgery was equal to 3 or 4 points. All patients received positive inotropic drugs prior to surgery. Preoperative mechanical cardiovascular support was implemented in 15.5% (*N* = 11) of patients. The average right atrial pressure was 6.87±5.03 and was measured for 12 people.

The average duration of operation was 318.55 ±74.21 minutes. The mean duration of cardiopulmonary bypass was 154.30 ±31.19 minutes. The mean aortic clamping time was 82.68 ±21.16 minutes.

Clinical status of patients after heart transplantation

Table 1 shows vital signs during the first 7 days after heart transplant. The decreasing number of patients reflects ICU discharges due to clinical improvement or death.

Selected health factors of patients after heart transplantation and the occurrence of complications after heart transplantation

The most common complications in heart transplant patients were respiratory failure (47.9% *N* = 34), arrhythmias (43.7% *N* = 31), transplant rejection and AKI (both 33.8% *N* = 24), infections (31% *N* = 22), and cardiac tamponade (26.8% *N* = 19). Bleeding occurred in 12.7% and neurological issues in 4.2% of patients. ICU mortality affected 19 people, and 15 people were readmitted. Average length of ICU stay was 16.87 ±14.8 days.

Infections were more frequent in patients over 50 years of age. Arrhythmias were significantly more common without pre-transplant mechanical circulatory support. Post-op hyperglycaemia on day 0 was seen in 74.1% of patients.

Postoperative bleeding was more common in patients with a heart rate > 120 bpm (beats per minute) on day 3 ($p = 0.05$) and active drainage > 100 ml/h on day "0" ($p < 0$), with a haemoglobin value in the range of 6–8 g/dl on day "0" ($p = 0.03$). AKI occurred more frequently in patients whose day-3 systolic blood pressure was between 80 and 100 mm Hg ($p = 0.02$), those on day 3 ($p < 0$) and day 7 ($p = 0$), diuresis less than 50 ml/h, a day-7 CVP greater than 10 ($p = 0$), and day-7 BPS or NRS values less than 5 ($p = 0.03$).

Respiratory failure or other respiratory complications occurred more frequently in patients whose day-3 systolic blood pressure was 80–100 mm Hg or 101–120 mm Hg and whose day 3 diuresis was less than 50 ml/h ($p < 0$), or day 7 diuresis of less than 50 ml/h ($p = 0$), day 7 had glycaemia of more than 10 mmol/l ($p = 0.04$), day 7 had a CVP of more than 10 ($p = 0.01$), and a day-7 BPS or NRS score of less than 5 ($p = 0$). Eight percent (*N* = 3) of patients with postoperative respiratory failure or other pulmonary complications were smokers. HFNO and BIPAP were each used in 55.9% (*N* = 19) of patients, and 30.1% (*N* = 22) of patients experienced respiratory failure.

Arrhythmias were linked to longer surgery, bypass, and aortic clamping times ($p = 0$). ICU stays were prolonged due to arrhythmia, infection, AKI, and respiratory failure ($p < 0$). All patients received cardiac monitoring; 59.2% had external pacemakers. Blood transfusions correlated with high drainage and low haemoglobin on day 0. In patients whose active drainage at day 0 exceeded 100 ml/h, PRBCs (packed red blood cells) were transfused significantly more often ($p = 0.03$).

The selected factors and variables related to the duration of medical procedures affecting the occurrence of postoperative complications are shown in Tables 2 and 3.

Table 1. Vital signs during the first 7 days after heart transplant surgery

Parameter	Day					
	Day "0"		Day "3"		Day "7"	
	N	%	*N*	%	*N*	%
Systolic blood pressure						
< 80 mm Hg	2	2.8	0	0.0	1	1.8
80–100 mm Hg	24	33.8	9	13.0	8	14.5
101–120 mm Hg	38	53.5	48	69.6	37	67.3
< 120 mm Hg	7	9.9	12	17.4	9	16.4
Heart rate						
< 60	1	1.4	0	0.0	0	0.0
60–80	36	50.7	31	44.9	20	36.4
81–100	22	31.0	24	34.8	22	40.0
101–120	11	15.5	12	17.4	8	14.5
> 120	1	1.4	2	2.9	5	9.1
Diuresis						
< 50 ml/h	5	7.0	15	21.7	18	32.1
50–100 ml/h	24	33.8	19	27.5	9	16.1
> 100 ml/h	42	59.2	35	50.7	29	51.8
Drainage						
> 100 ml/h	8	11.3	0	0.0	0	0.0
< 100 ml/h	63	88.7	69	100.0	44	100.0
Haemoglobin						
< 6.0 g/dl	0	0.0%	0	0.0	0	0.0
6.0–8.0 g/dl	2	2.8	0	0.0	0	0.0
8.1–10.0 g/dl	28	39.4	30	43.5	12	21.4
> 10 g/dl	41	57.7	39	56.5	44	78.6
Glycaemia						
< 3.9 mmol/l	0	0.0	0	0.0	0	0.0
3.9–5.5 mmol/l	0	0.0	1	1.4	0	0.0
5.6–10 mmol/l	17	23.9	64	92.8	50	89.3
> 10 mmol/l	54	76.1	4	5.8	6	10.7
CVP						
< 2	0	0.0	0	0.0	0	0.0
2–10	34	47.9	15	21.7	32	57.1
> 10	37	52.1	54	78.3	24	42.9
Pain						
0	0	0.0	2	2.8	15	21.2
< 5 BPS or < 5 NRS	71	100.0	69	97.2	56	78.9
5–7 BPS or 5-7 NRS	0	0.0	0	0.0	0	0.0
> 7 BPS or > 7 NRS	0	0.0	0	0.0	0	0.0

CVP – central venous pressure, BPS – Behavioural Pain Scale, NRS – Numerical Rating Scale.

Table 2: Selected factors vs. complications after heart transplant surgery

Factors		Heart rate [BPM]					Drainage [ml/h]		Haemoglobin [g/dl]				Blood pressure [mm hg]				Diuresis [ml/h]			Diuresis [ml/h]			CVP [mm Hg]			NRS or BPS [points]				Glycaemia [mmol/l]				Age		MCS before HTX	
Day of observation		3					0		0				3				3			7			7			7				7							
Complications		< 60	60–80	81–100	101–120	> 120	> 100	< 100	< 6.0	6.0–8.0	8.1–10.0	> 10	< 80	80–100	101–120	> 120	< 50	50–100	> 100	< 50	50–100	> 100	< 2	2–10	> 2	0	< 5	5–7	> 7	< 3.9	3.9–5.5	5.6–10.0	> 10	< 50	> 50	No	Yes
Bleeding [amount of patients]	No	0	30	19	11	1	0	62	0	1	22	39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Yes	0	1	5	1	1	8	1	0	1	6	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P			*F* = 6.919; *p*(*F*) = 0.05			*p*(*F*) = 0				*F* = 6.834; *p*(*F*) = 0.033			–				–			–			–			–				–				–		–	
AKI [amount of patients]	No	–	–	–	–	–	–	–	–	–	–	–	0	3	31	11	3	12	30	2	6	25	0	25	8	14	33	0	0	–	–	–	–	–	–	–	–
	Yes	–	–	–	–	–	–	–	–	–	–	–	0	6	17	1	12	7	5	16	3	4	0	7	16	1	23	0	0	–	–	–	–	–	–	–	–
	P			–				–			–			*F* = 7.551; *p*(*F*) = 0.02			*F* = 19.605; *p*(*F*) = 0			*F* = 27.042; *p*(*F*) = 0			χ^2 = 11.36 8; *p*(χ^2) = 0			χ^2(Y) = 4.815; *p*(Y) = 0.028								–		–	
Respiratory complications [amount of patients]	No	–	–	–	–	–	–	–	–	–	–	–	0	2	24	10	1	8	27	1	6	16	–	–	–	14	23	0	0	0	0	23	0	–	–	–	–
	Yes	–	–	–	–	–	–	–	–	–	–	–	0	7	24	2	14	11	8	17	3	13	–	–	–	1	33	0	0	0	0	27	6	–	–	–	–
	P			–				–			–			*F* = 7.859; *p*(*F*) = 0.017			*F* = 23.13; *p*(*F*) = 0			*F* = 15.407; *p*(*F*) = 0				–			χ^2(Y) = 10.939; *p*(Y) = 0.001				*p*(*F*) = 0.037				–		–	
Arrhythmia [amount of patients]	No	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	31	9
	Yes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	29	2
	P			–				–			–			–				–			–			–			–				–				–		OR = 0.097; *p* = 0.036	
Infection [amount of patients]	No	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	28	21	–	–
	Yes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	17	–	–
	P			–				–			–			–				–			–			–			–				–			OR = 3.570; *p* = 0.049			–	

BPM – beats per minute, AKI – acute kidney injury, CVP – central venous pressure, MCS – mechanical circulatory support, HTX – heart transplantation, BPS – Behavioural Pain Scale, NRS – Numerical Rating Scale, OR – odds ratio.

Table 3. Selected variables of duration of medical procedures vs. complications after heart transplant surgery

Factors		Length of hospitalisation			Duration of procedure			Extracorporeal circulation time			Aortic cross-clamping time		
Complications		*M*	*SD*	*P*	*M*	*SD*	*P*	*M*	*SD*	*P*	*M*	*SD*	*P*
Cardiac tamponade	No	14.96	13.96	Z = –1.926; *p* = 0.054	314.15	77.08	Z = –1.260; *p* = 0.208	154.42	30.92	Z = –0.059; *p* = 0.953	81.42	22.54	Z = –1.124; *p* = 0.261
	Yes	22.11	16.15		330.58	66.12		153.95	32.77		86.11	16.90	
Bleeding	No	16.61	14.22	Z = –0.113; *p* = 0.91	313.77	73.07	Z = –1.538; *p* = 0.124	154.92	31.95	Z = –0.346; *p* = 0.729	82.34	20.74	Z = –0.017; *p* = 0.986
	Yes	18.67	19.27		351.44	77.98		150.00	26.58		85.00	25.15	
Arrhythmia	No	11.45	9.90	Z = –4.425; *p* < 0	299.25	63.60	Z = –2.533; *p* = 0.011	144.45	27.91	Z = –2.966; *p* = 0.003	76.55	21.19	Z = –3.166; *p* = 0.002
	Yes	23.87	17.15		343.45	80.33		167.00	31.00		90.58	18.63	
Transplant rejection	No	18.19	16.09	Z = –0.463; *p* = 0.644	326.68	80.85	Z = –1.276; *p* = 0.202	156.66	32.32	Z = –0.87; *p* = 0.384	82.79	22.56	Z < 0.001; *p* = 1
	Yes	14.29	11.78		302.63	57.33		149.67	28.94		82.46	18.59	
Infection	No	11.00	5.18	Z = –4.671; *p* < 0	311.43	76.66	Z = –1.567; *p* = 0.117	152.35	30.25	Z = –0.703; *p* = 0.482	81.55	19.03	Z = –0.883; *p* = 0.377
	Yes	29.95	20.23		334.41	67.39		158.64	33.49		85.18	25.61	
Aki	No	12.57	10.76	Z = –4.469; *p* < 0	311.21	65.29	Z = –0.979; *p* = 0.328	154.62	29.74	Z = –0.17; *p* = 0.865	79.49	20.89	Z = –1.763; *p* = 0.078
	Yes	25.29	17.99		332.92	88.93		153.67	34.51		88.92	20.71	
Respiratory complications	No	10.32	6.49	Z = –5.096; *p* < 0	305.35	61.33	Z = –1.22; p *p* = 0.222	151.68	29.54	Z = –0.657; *p* = 0.511	79.43	21.91	Z = –1.319; *p* = 0.187
	Yes	24.00	17.84		332.91	84.67		157.15	33.10		86.21	20.04	
Neurological complications	No	16.29	13.40	Z = 0.989; *p* = 0.989	316.13	73.98	Z = 0.13; p *p* = 0.141	154.12	31.05	Z = 0.852; *p* = 0.861	82.59	18.93	Z = 0.898; *p* = 0.904
	Yes	30.00	37.27		373.33	68.37		158.33	41.63		84.67	60.50	

AKI – acute kidney injury, M – mean, SD – standard deviation, p – significance level, Z-test.

Discussion

The obtained results allow us to understand the importance the therapeutic team plays in the care of patients after heart transplantation. A nurse in the ICU should recognise worrying symptoms in heart transplant patients at an early stage and report them. This allows for the proper identification of postoperative complications and the implementation of appropriate treatment [10, 11].

According to studies by Neethling *et al.* in heart transplant patients, the main complications are AKI (72%), respiratory complications (34.7%), arrhythmias (41.8%), and postoperative bleeding (8.4%). Their studies revealed respiratory failure or other respiratory complications (47.9%), arrhythmias (43.7%), cardiac rejection (33.8%), and AKI (33.8%). Postoperative bleeding occurred in 12.7% of patients [12].

Pulmonary complications are common after heart transplantation and may result from heart failure duration, extracorporeal circulation, immunosuppressants, or comorbidities [13, 14]. According to Fischer MO, for example, pulmonary complications such as dyspnoea, pneumonia, pleural effusion, and respiratory failure occur in 1 in 2 patients after cardiac surgery. This leads to an increase in the length of hospitalisation in the intensive care unit and in the hospital [13]. In our own studies, 47.9% of patients who underwent heart transplantation developed respiratory failure or other respiratory complications, which significantly increased the duration of hospitalisation in the ICU.

Non-invasive ventilation (NIV) is effective in managing respiratory failure post HTX. Bozbaş *et al.* applied NIV in 3 of 9 patients with respiratory failure at one-week post-transplant [14]. In our cohort, 47.1% of patients with respiratory failure received NIV. Although 8.8% of smokers developed respiratory failure, the association was not statistically significant.

According to Kourek *et al.*, postoperative hyperglycaemia, i.e. a glycaemic value > 10 mmol/l, affects 30% of patients after cardiac surgery and increases the risk of AKI [15]. In in-house studies, 76.1% of patients had postoperative hyperglycaemia on day 0. Glycaemia values > 10 mmol/l on day 0 have not been shown to significantly increase the incidence of AKI in patients.

The literature indicates that prolonged cardiopulmonary bypass increases the risk of AKI, which extends the ICU stay. Elevated CVP is also associated with postoperative AKI [8, 16]. Our study confirmed that AKI prolongs ICU hospitalisation, but cardiopulmonary bypass time had no significant effect on AKI incidence. Those requiring continuous renal replacement therapy (CRRT) stayed in the intensive care unit for an average of 25 ±19 days, compared with 12 ±10 days for those without AKI [17]. Our data also showed a statistically significant association between AKI and elevated CVP.

Postoperative haemorrhage treatment after heart transplantation is rarely addressed in the literature; however, the use of four-factor prothrombin complex concentrates, platelet concentrates, and irradiated leukocyte-poor packed red blood cells is recommended [8, 15]. In our study, most transfusions of PRBCs occurred in patients with drainage > 100 ml/h on day 0 and were more frequent in those with lower haemoglobin levels.

Infections most often occur within the first month posttransplant. Therefore, after HTX, the patient is placed under protective isolation. Standard infection control measures include protective isolation, hand hygiene, equipment disinfection, and daily linen changes [7]. In our cohort, infections affected 31% of patients. According to Carrillo-Gómez *et al.*, bacterial infections are predominant in the first month posttransplant, accounting for 21.05% of cases [18]. Another study identified diabetes and recent antibiotic use as key infection risk factors within the first year post transplant, underscoring the importance of stringent infection control measures immediately after transplantation [19]. A review of early postoperative management strategies after heart transplantation included the prevention of infections due to immunosuppression [20].

Studies have shown that older age increases the risk of infection after heart transplantation. Sponga *et al.* reported more frequent infections in patients over 40 years of age [21], while Pons *et al.* found a significant association between age over 60 years and early bacterial or fungal infections [22]. Our data confirmed that infections occurred significantly more often in patients over 50 years of age. Other studies also linked age > 60 years with higher rates of graft dysfunction, infections, and complications [23, 24].

Our study showed a link between the occurrence of cardiac arrhythmias and the duration of surgery, cardiopulmonary bypass, and aortic cross-clamping – the longer these times, the higher the arrhythmia risk. While similar findings are scarce in the literature, one study did report a significant association between prolonged cross-clamp time and arrhythmias within 48 h after surgery [25]. Other recent studies have confirmed these durations as key risk factors [26]. The literature indicates that pre-transplant mechanical circulatory support (MCS) does not significantly affect postoperative mortality [23, 27], which is consistent with our findings. However, in our study, arrhythmias were more common in patients without prior MCS. This finding is supported by studies indicating that pre-transplant MCS may reduce the risk of severe arrhythmias and improve clinical outcomes [28–30], whereas its absence is linked to higher rates of complications and mortality [31, 32].

No comparison of mortality rates with data from other countries was made due to the lack of access to sufficiently accurate and comparable data, which prevented a reliable international analysis.

Conclusions

In the early postoperative period after heart transplantation, respiratory failure and arrhythmias were the most common complications. Incidence of complications was influenced by drainage volume, diuresis, CVP, surgery duration, extracorporeal circulation time, and aortic implantation time. Older patients had more infections, and arrhythmias were more frequent in those without prior mechanical circulatory support.

Funding

No external funding.

Ethical approval

The study was approved by the director of the hospital, the head of the department, the Dean of the Faculty of Health Sciences at the Jagiellonian University Medical College.

Conflict of interest

The authors declare no conflict of interest.

References

1. Jemielity M, Urbanowicz T. Transplantacja serca. In: Transplantologia i pielęgniarstwo transplantacyjne. Rolka H, Kowalewska B, Jankowiak B, Krajewska-Kułak E, ed. PZWL, Warszawa 2017; 209-18.
2. Schultheiss H, Fairweather D, Caforio ALP, Escher F, Hershberger RE, Lipshultz SE, Liu PP, Matsumori A, Mazzanti A, McMurray J, Priori SG. Dilated cardiomyopathy. Nat Rev Dis Primers. 2019; 5: 32.
3. Alraies MC, Eckman P. Adult heart transplant: indications and outcomes. J Thorac Dis. 2014; 6(8): 1120-1128.
4. Kałużny-Oleksy M (ed.). Niewydolność serca w Polsce – realia, koszty, sugestie poprawy sytuacji. 2020 [cited 2023 Oct 13]. Available from: https://ptkardio.pl/resources/data/sections/245/niewydolnosc_podsumowanie_net.pdf
5. Squires RW. Cardiac transplant and exercise cardiac rehabilitation. Heart Fail Rev. 2023; 28: 1267-1275.
6. Tackmann E, Dettmer S. Health-related quality of life in adult heart-transplant recipients – a systematic review. Herz. 2020; 45: 475-482.
7. Statystyka przeszczepiania narządów. [cited 2024 Jul 26]; Available from: www.poltransplant.org.pl
8. Litwiński P, Zieliński T, Sobieszczańska-Małek M, Parulski A, Juśmierczyk M. Transplantacja serca: przeszłość i teraźniejszość. Kardiol Dypl. 2019; 1: 7-22.
9. Hoogen M, Seghers L, Manintveld OC, Roest S, Bekkers JA, den Hoed CM, Minnee RC, de Geus HRH, van Thiel RJ, Hesselink DA. Care for the organ transplant recipient on the intensive care unit. J Crit Care. 2021; 64: 37-44.
10. Hoy S, Frisbee J. Common postoperative heart transplant complications. Crit Care Nurs Q. 2018; 41(4): 383-388.

11. Nesseler N, Mansour A, Cholley B, Coutance G, Bougle A. Perioperative management of heart transplantation: a clinical review. Anesthesiology. 2023; 139(4): 493-510.
12. Neethling E, Garijo JM, Mangalam TK, Badiwala MV, Billia P, Wasowicz M, Van Rensburg A, Slinger P. Intraoperative and early postoperative management of heart transplantation: anesthetic implications. J Cardiothorac Vasc Anesth. 2020; 34(8): 2189-2206.
13. Fischer MO, Brotons F, Briant AR, Suehiro K, Gozdzik W, Sponholz C, Kirkeby-Garstad I, Joosten A, Neto CN, Kunstyr J, Parienti JJ, Abou-Arab O, Ouattara A; VENICE study group. Postoperative pulmonary complications after cardiac surgery: the VENICE International Cohort Study. J Cardiothorac Vasc Anesth. 2022; 26(8 Pt A): 2344-2351.
14. Bozbaş ŞS, Ulubay G, Eyüboğlu FÖ, Sezgin A, Haberal M. Prevalence, cause, and treatment of respiratory insufficiency after orthotopic heart transplant. Exp Clin Transplant. 2015; 13 Suppl 3: 140-143.
15. Kourek C, Georgopoulou M, Kolovou K, Rouvali N, Panoutsopoulou M, Kinti C, Soulele T, Doubou D, Karanikas S, Elaiopoulos D, Karabinis A, Dimopoulos S. Intensive care unit hyperglycemia after cardiac surgery: risk factors and clinical outcomes. J Cardiothorac Vasc Anesth. 2024; 38(1): 162-169.
16. Jocher BM, Schilling JD, Fischer I, Nakajima T, Wan F, Tanaka Y, Ewald GA, Kutkar K, Masood M, Itoh A. Acute kidney injury postheart transplant: an analysis of perioperative risk factors. Clin Transplant. 2021; 35(6): e14296.
17. Nadziakiewicz P, Grochla M, Krauchuk A, Szyguła-Jurkiewicz B, Cymerys M, Zembala MO, Przybyłowski P. Prognostic value of creatinine concentration and glomerular filtration rate in acute kidney injury development in the early postoperative period after heart transplantation. Transplant Proc. 2020; 52(7): 2091-2093.
18. Carrillo-Gómez DC, Rojas-Perdomo CC, Orozco-Echeverri N, Montes MC, Flórez-Elvira L, López-Pónce de León JD, Olaya-Rojas P, Flórez-Alarcón N, Gómez-Mesa JE. Infections in the first year after heart trans-plantation in a Latin American country. Transpl Infect Dis. 2024; 26 (1): e14166.
19. Zhou Y, Cai J, Wang X, Du S, Zhang J. Distribution and resistance of pathogens in infected patients within 1 year after heart transplantation. Int J Infect Dis. 2021; 103: 132-137.
20. Hwang NC, Sivathasan C. Review of postoperative care for heart transplant recipients. J Cardiothorac Vasc Anesth. 2023; 37(1): 112-126.
21. Sponga S, Deroma L, Sappa R, Piani D, Lechiancole A, Spagna E, Tursi V, Nalli C, Livi U. Recipient age impact on outcome after cardiac transplantation: should it still be considered in organ allocation? Interact Cardiovasc Thorac Surg. 2016; 23(4): 573-579.
22. Pons S, Sonneville R, Bouadma L, Styfalova L, Ruckly S, Neuville M, Radjou A, Lebut J, Dilly MP, Mourvillier B, Dorent R, Nataf P, Wolff M, Timsit JF. Infectious complications following heart transplantation in the era of high-priority allocation and extracorporeal membrane oxygenation. Ann Intensive Care. 2019; 9(1): 17.
23. Immohr M, Aubin H, Westenfeld R, Bruno R, Dalyanoglu H, Erbel-Khurtsidze S, Tudorache I, Akhyari P, Lichtenberg A, Boeken U. Show less. Heart transplantation in an aging society: impact of recipient age on postoperative outcome. Thoracic Cardiovasc Surg. 2021; 69: S1-S85.
24. Ortiz-Gonzalez Y, Yip D, Patel PC, Leoni-Moreno JC, Goswami RM. Evaluation of infection risk based on induction immunotherapy within the first year after heart transplantation. J Heart Lung Transplant 2020; 39 4S: S481.
25. Khassawneh M, Maayah S, Abu Taleb MA, Alrihani MA, Alhourani WK. Correlation between prolonged aortic cross clamp and new onset cardiac arrhythmia after cardiac surgery. SAS J Surg. 2023; 9(6): 586-596.
26. Alotaibi R, Saleem A, Alsharef FF, Alnemer ZA, Saber YM, Abdelmohsen GA, Bahaidarah SA. Risk factors for early postoperative cardiac arrhythmia after pediatric cardiac surgery. Saudi Med J. 2022; 43: 1111-1119.
27. Danilevych T, Rasputina L, Mostovoy YM, Belinskyi AV. Predictors of rhythm disorders following cardiac surgery. Eur J Prev Cardiol. 2021; 28 Supp. 1: zwab061.462.
28. Ouyang D, Gulati G, Ha R, Banerjee D. Incidence of temporary mechanical circulatory support before heart transplantation and impact on posttransplant outcomes. J Heart Lung Transplant. 2018; 37(9): 1060-1066.
29. Carter KT, O'Brien R, Larson SB, Creswell LL, Kutcher M, Baran DA, Copeland JG, Copeland H. Venoarterial extracorporeal membrane oxygenation is a viable option as a bridge to heart transplant. J Thorac Cardiovasc Surg. 2022; 163(1): 140-147.
30. Pruna-Guillen R, Martínez E, Alcocer J, Quintana E. A heart transplant under temporary paracorporeal biven-tricular circulatory support. Multimed Man Cardiothorac Surg. 2023; Mar 21; 2023. doi: 10.1510/mmcts.2023.008.
31. Gopinathannair R, Cornwell W, Dukes JW, Ellis CR, Hickey KT, Joglar JA, Pagani FD, Roukoz H, Slaughter MS, Patton KK. Device therapy and arrhythmia management in left ventricular assist device recipients: a scientific statement from the American Heart Association. Circulation. 2019; 139: e967-e989.
32. Tavazzi G, Dammassa V, Colombo CNJ, Arbustini E, Castelein T, Balik M, Vandenbriele C. Mechanical circulatory support in ventricular arrhythmias. Front Cardiovasc Med. 2022; 9: 987008.

Address for correspondence

Natalia K. Padula
Department of Nursing
Fundamentals
Institute of Nursing
and Midwifery
Faculty of Health Sciences
Jagiellonian University
Medical College
31-501 Krakow, Poland
E-mail: natalia.padula@uj.edu.pl

Received: 13.06.2025
Accepted: 2.08.2025
Online publication: 25.02.2026