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Retrospective hemolysis comparison between patients with centrifugal biventricular assist and left ventricular assist devices

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Ретроспективная оценка уровня гемолиза у пациентов после имплантации левожелудочковой и бивентрикулярной систем механической поддержки кровообращения центрифугального типа

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Немногое известно об уровне гемолиза в случае применения двух имплантируемых систем механической поддержки кровообращения центрифугального типа для лечения бивентрикулярной терминальной сердечной недостаточности. В данном исследовании проведен анализ уровня гемолиза среди пациентов, которым применена имплантируемая система механической поддержки кровообращения центрифугального типа «HeartWare HVAD» для левожелудочкового и бивентрикулярного обходов. Проведен ретроспективный анализ параметров гемолиза и анемии у 20 пациентов, которым была имплантирована система «HeartWare HVAD» для бивентрикулярного (n=10) и левожелудочкового обходов (n=10) в нашей клинике в период с сентября 2009 по сентябрь 2010 года. Данные собраны в течение второй или пятой недели, 3 и 6 месяцев механической поддержки кровообращения. Дооперационный уровень гемоглобина, лактат дегидрогеназы и общего билирубина были сходны в обеих группах. Также не было найдено различия уровней свободного гемоглобина плазмы, лактат дегидрогеназы и общего билирубина в течение всего периода наблюдения. Только уровень гаптоглобина плазмы крови был значительно ниже у пациентов с бивентрикулярным обходами вплоть до 3 месяцев после имплантации: вторая неделя (63.5 (ранг 8-237) мг/дл vs. 151 (ранг 11-263) мг/дл, p=0.05); 5-я неделя (67 (ранг 8-196) мг/дл vs. 215 (ранг 56-292) мг/дл, p=0.046); после 3 месяцев (42 (ранг 8-205) мг/дл vs. 220 (ранг 157-256) мг/дл, p=0.048). Ретроспективный анализ пациентов с левожелудочковым и бивентрикулярным обходом с помощью системы «HeartWare HVAD» показал отсутствие клинически значимого гемолиза в случае применения двух имплантируемых центрифугальных насоса для лечения бивентрикулярной сердечной недостаточности.
Ключевые слова: бивентрикулярный обход, центрифугальный насос, гемолиз, система механической поддержки кровообращения

Little is known about the hemolysis rate in the case of concomitant implantation of two continuous flow pumps for the treatment of biventricular heart failure. We present a retrospective study comparing the hemolysis parameters in patients supported with one implantable centrifugal pump of the type HeartWare HVAD employed as a left ventricular assist device (LVAD) and with two pumps as a biventricular assist device (BiVAD). A total of 20 consecutive patients who received HeartWare BiVAD (n=10) and LVAD (n=10) support at our institution between September 2009 and September 2010 were examined. Hemolysis- and anemia-related parameters were analyzed after 2 weeks, 5 weeks, 3 months and 6 months of support. Preoperative levels of hemoglobin, LDH and total bilirubin were similar in both groups. There were no differences in LDH, fHB or total bilirubin levels postoperatively for up to 6 months. Only the haptoglobin level was lower in BiVAD recipients up to 3 months after surgery: second week (63.5 (range 8-237) mg/dl vs. 151 (range 11-263) mg/dl, p=0.05), 5th week (67 (range 8-196) mg/dl vs. 215 (range 56-292) mg/dl, p=0.046), after 3rd month (42 (range 8-205) mg/dl vs. 220 (range 157-256) mg/dl, p=0.048). Our retrospective analysis of BiVAD HeartWare and LVAD HeartWare recipients showed a lack of a clinically important degree of hemolysis when two centrifugal HeartWare pumps are used for biventricular support.
Key words: biventricular support, centrifugal pump, VAD related hemolysis

Hemolysis is one of the complications observed following implantation of mechanical circulatory support devices. On the one hand, pump design (high rotor speed operation in continuous flow pumps, artificial surface properties, mechanical bearings, high shear stress, use of mechanical valves in pulsatile devices etc.) and on the other hand postoperative complications (hypercoagulable patient status, onset of HIT, malposition of apical cannula,

kinking of outflow grafts, pump thrombosis) may cause postoperative hemolysis [1-3].

In our experience, about 20 to 30% of patients with end stage heart failure require biventricular support [4]. Extracorporeal devices for the treatment of biventricular heart failure such as the Thoratec PVAD (Thoratec Corporation, Pleasanton, CA) showed significantly higher rates of blood cell damage due to several factors: pneumatically operated pulsatile systems, pulsatile flow in combination with long blood connecting cannulas result in high peak flow velocities and high pressure gradient during device valve closure (water-hammer effect). Moreover, they contain four mechanical valves with well-known potential for hemolysis [1, 5, 6].

With the use of two small implantable centrifugal pumps for the support of both failing ventricles a new therapy option for the treatment of biventricular heart failure is now available in the clinical setting [7].

The impeller in the HeartWare HVAD (HeartWare International Inc., Framingham, MA) implantable centrifugal pump of the third generation of implantable LVADs has eliminated mechanical wear and friction; these devices suspend the impeller without mechanical contact by magnetic or hydrodynamic bearings, leading to very low hemolysis rates compared to those of other VADs. Hence, Heilmann et al. presented a lower hemolysis rate in centrifugal LVAD VentrAssist, which is similar to the HeartWare HVAD, compared to axial flow HeartMate II recipients [1].

However, little is known about the hemolysis rate in the case of concomitant implantation of two continuous flow pumps, running at different numbers of revolutions per minute (rpm). Additionally, the biological impact of the adaptation necessary to operate the HeartWare HVAD in assisting pulmonary circulation (RVAD outflow graft banding) and operating venous blood is uncertain [7].

We present a retrospective study comparing the parameters of hemolysis between HeartWare HVAD left ventricular assist device (LVAD) and biventricular assist device (BiVAD) recipients.

Methods

Twenty consecutive patients who underwent LVAD or BiVAD implantation using the HeartWare HVAD between September 2009 and September 2010 at our center were retrospectively evaluated. Ten of them were supported with an LVAD (LVAD group) and the other ten with a BiVAD (BiVAD group) employing two HeartWare HVAD pumps after some modifications, as described previously (7). We analyzed the hemolysis-related parameters such as haptoglobin, free hemoglobin in plasma, LDH, total bilirubin, anticoagulation level of patients (aPTT and INR levels) and the anemia-related values total hemoglobin, hematocrit and number of reticulocytes. To diminish variation of data, the medians of all documented parameters within the second week, the 5th week, at 3 months (± 2 weeks) and at 6 months (± 2 weeks) after VAD implantation were analyzed retrospectively.

Plasma level variation of LDH and free hemoglobin, total bilirubin within two-fold range of parameters registered at the second week together with lowering of the haptoglobin plasma level without signs of severe anemia (hemoglobin level higher than 8 g/dl) were considered to be clinically irrelevant.

Clinically relevant hemolysis was defined as an increase of more than two-fold of LDH and free hemoglobin in plasma compared to the values in the second week after surgery together with hyperbilirubinemia, severe anemia (hemoglobin below 8 g/dl) and need for red-blood cell (RBC) transfusion in absence of bleeding. Free plasma hemoglobin over 40 mg/dl together with a three-fold and more increase of LDH plasma level, macrohematuria, hyperbilirubinemia, need for RBC transfusions associated with increased device energy consumption together with recurrence of heart failure symptoms were the definition for pump thrombotic dysfunction with severe VAD-related hemolysis.

Under German law the retrospective data analysis did not require approval by the ethics committee (in accordance with the Helsinki Declaration of Human Rights).

Device and surgical procedures

The HeartWare HVAD is a small implantable centrifugal pump. The only moving part is a wide-bladed impeller suspended by a combination of magnetic and hydrodynamic bearings. A minimum speed of 1800 rpm is necessary for safe operation of the hydrodynamic bearings. Typical operating speed is 2500–3500 rpm according to the manufacturer.

The HeartWare LVAD was implanted through a routine median sternotomy. The inflow graft was inserted into the left ventricular apex and the outflow graft was anastomosed to the ascending aorta as described elsewhere. [8]

BiVAD implantation technique has been described by our group (7). Briefly, following median sternotomy during cardiopulmonary bypass (CPB), one HeartWare pump was implanted into the apex of the LV, and the outflow graft connected to the ascending aorta. The optimal position for the second HeartWare pump (as an RVAD) on the free wall of the right ventricle (at point of maximal distance from the ventricular septum) was determined by transesophageal echocardiography (TEE). The inflow cannula was placed in the RV cavity and secured as described for the LVAD with two additional silicone rings (total 5 mm thickness) placed under the fixation ring to shorten the part of the inflow cannula protruding into the RV. The outflow graft, narrowed before surgery from 10mm to 5-6mm diameter, was sutured to the pulmonary artery. Both pumps were placed in the pericardium and the chest was primarily closed. The pumps' speed was adjusted to achieve flow of approximately 5 l/min (left pump) and 3-4 l/min (right pump).

Anticoagulation

After cessation of postoperative bleeding (drainage loss less than 50 ml/h within 4 consecutive hours in absence of tamponade or unclear drop in haemoglobin level) anticoagulation for all patients was started with heparin or argatroban (if serologically (positive ELISA test) or clinically heparin-induced thrombocytopenia was suspected) in the period of 8 to 24 hours postoperatively with a target partial thromboplastin time (PTT) of 50-60 s in LVAD recipients and 60–80 s in BiVAD recipients. It was changed to warfarin after removal of the chest drains and sufficient oral ingestion. Target INR was 2.2–2.7 for the LVAD recipients and 2.5–3.0 for the BiVAD recipients.

Platelet aggregation was inhibited by acetylsalicylic acid (ASA) 50 mg day−1 plus dipyridamol 400 mg-1 and adjusted according to the results of aggregometry with stimulation by collagen, arachidonic acid, adenosine 5′-diphosphate (ADP) and epinephrine. Starting after POD 7 with 25 mg per os (only if platelet count and function in aggregometry studies recovered, no clinical signs for bleeding or tamponade) aspirin dosis was gradually adjusted to maximal 100 mg together with dipiridamol 200-400 mg daily.

Laboratory analysis

Free hemoglobin in plasma was calculated by direct photometry at 380, 415 and 450 nm (Harboe method) on a spectral photometer (LS 500, Lange, Berlin, Germany). Total hemoglobin was assessed photometrically (SE-9000, Sysmex, Norderstedt, Germany) and hematocrit by measuring impedance (XE-2100, Sysmex). LDH activity was measured enzymatically according to the IFCC method (Roche). Haptoglobin was measured using antibody-based turbidimetric tests (antibodies: Roche, Mannheim, Germany; Dade Behring, Marburg, Germany, reader: Modular).

Statistics

The statistical analysis was performed with SPSS 10.0.0 for Windows (SPSS Inc., Chicago, IL, US). Data are presented as median and ranges. Comparisons to assess differences between the two groups (LVAD vs. BiVAD) were performed using the Mann-Whitney U-test. A p -value< 0.05 was considered significant.

RESULTS

A total of 20 VAD patients (median age 60, range 29-70 years, three female – one of them in the BVAD group) were included in the analysis. Reasons for terminal heart failure were dilatative cardiomyopathy in 10 patients and ischemic cardiomyopathy in the other ten. Two BiVAD recipients had had prior cardiac surgery (s.p. mechanical mitral vale replacement and CABG in 1998 in one and s.p. CABG in 1996 in another), as did one of the LVAD recipients (s.p. CABG in 1990). At 6 months of support all patients from the LVAD group, compared to 7 BiVAD recipients, were ongoing. Two patients from the BiVAD group died after 23 and 121 days of support due to sepsis and multiorgan failure. One other BiVAD recipient suffered lethal intracerebral bleeding after hospital discharge on the 46th day of support. A 29 yearold male biVAD recipient had been successfully transplanted after 261 days of support and is still alive over 6 months after heart transplantation. Overall, at 1 year all ten LVAD patients were ongoing compared to 6 patients of the BiVAD group.

Six patients suffered after surgery from heparin-induced thrombocytopenia and were treated with argatroban i.v. (3 BiVAD and 3 LVAD patients).

Preoperatively there were no differences in hemoglobin, bilirubin, LDH levels in plasma, hematocrit, aPTT, INR or reticulocytes.

Data obtained on postoperative days 7-14 showed no differences in free plasma hemoglobin, LDH, total bilirubin or reticulocyte level and the same anticoagulation profile in both groups. Median rpm in the BVAD group were as follows: LVAD median rpm 3200 (range 2700-3240 rpm); RVAD median rpm 2450 (range 1800-3600 rpm). LVAD-group median rpm was 2900 (range 2500-3000 rpm). Haptoglobin level only was lower in the BiVAD group.

Data gained in the 5th week of support presented similar differences in haptoglobin level (lowered). There were no differences in free plasma, hemoglobin, total bilirubin, LDH or reticulocyte levels. Median rpm in BVAD group were as follows: LVAD median rpm 3000 (range 2700-3240 rpm); RVAD median rpm 2500 (range 1800-3800 rpm). LVAD-group median rpm was 2800 (range 2500-3000 rpm).

After 3 months of support a similar difference in the lowered haptoglobin level in BiVAD and LVAD patients was observed. Free hemoglobin level, LDH and reticulocyte level were similar. Median rpm in BVAD group were as follows: LVAD median rpm 3000 (range 2800-3200 rpm); RVAD median rpm 2450 (range 1800-3400 rpm). LVAD-group median rpm was 2800 (range 2700-3000 rpm).

After 6 months of support, again the BiVAD group had a lower level of haptoglobin but at this time it did not reach statistical significance. The free hemoglobin level of BiVAD recipients was slightly lower than in the LVAD group but without statistical significance. LDH level was similar in both groups. Median rpm in BVAD group were as follows: LVAD median rpm 3000 (range 2800-3200 rpm); RVAD median rpm 2450 (range 1800-3400 rpm). LVAD-group median rpm was 2750 (range 2700-3000 rpm). /table 1/.

During the whole postoperative course (within second week, within 5th week, 3 months and 6 month after VAD implantation) BiVAD recipients had lower median hemoglobin and hematocrit levels, but these differences reached statistical significance only at 6 months of support. Three BiVAD recipients experienced a bleeding episode requiring red blood cell transfusion after hospital discharge (gastrointestinal bleeding on 112 day of support in female patient, severe epistaxis in two male patients on 161 and 30 day of support, respectively).

Table 1

Laboratory data

Parameters	**Group**	**n**	**Hb, g/dl**	**Hematocrit**	**INR**	**aPTT, s**	**Bilirubin total, mg/dl**	**LDH, U/l**	**Haptoglobin, mg/dl**	**fHb, mg/dl**	**Reticulocytes, % of RBC**
Normal range			12-14	42-50	1.15-0.85	22-35	0-1	W:<214, M:<225	30-200	- 2.0	W: 0.63-2.2 M: 0.9-2.71
Pre-OP Data	BiVAD	10	11 (10-15.2)	33 (29-46)	1.2 (1-1.7)	46 (29-64)	1 (0.5-4.4)	182 (95-325)	n.a	n.a	2.2 (1.4-5.3)
	LVAD	10	12 (9.4-16)	35 (28-47)	1.3 (1-3.2)	45 (38-69)	0.8 (0.6-4.5)	280 (143-497)	n.a	n.a	2.6 (1.8-2.8)
	p-value		ns	ns	ns	ns	ns	ns	-	-	ns
Data at 2nd week	BiVAD	10	10 (7.9-11)	29 (24-33)	1.2 (1.1-2.1)	56 (51-67)	1.2 (0.5-8.3)	380 (273-809)	63 (8-237)	5.5 (4.6-6.9)	3.7 (1.8-7.5)
	LVAD	10	10.4 (8.4-12)	32 (23-33)	1.3 (1.1-1.85)	58 (44-72)	0.7 (0.4-4.0)	298 (230-480)	151 (11-263)	6.9 (4.6-17)	3.6 (1.3-5.6)
	p-value		ns	ns	ns	ns	ns	ns	0.052	ns	ns
Data at 5th week	BiVAD	9	10.4 (9-12)	30 (27-36)	1.4 (1.1-2.1)	64 (58-73)	0.7 (0.4-1.6)	278 (190-617)	67 (8-196)	6.5 (5.1-9.6)	3.1 (2.2-6.6)
	LVAD	10	11 (10-15)	32 (28-44)	1.3 (1.1-2.3)	55 (39-59)	0.6 (0.3-1.7)	234 (181-530)	215 (56-292)	6.6 (5.2-8.9)	3.7 (1.6-4.8)
	p-value		ns	ns	ns	0.001	ns	ns	0.046	ns	ns
Data at 3 Month	BiVAD	8	9.6 (8.3-12)	29 (24-35)	2.2 (1.3-2.8)	56 (45-74)	0.5 (0.4-1.2)	253 (163-532)	42 (8-205)	7.1 (6.8-13)	4.1 (2.9-13)
	LVAD	10	12 (9-13)	35 (26-39)	2.3 (1.7-2.7)	51 (38-72)	0.8 (0.3-1.6)	217 (149-288)	220 (157-256)	8.8 (3.9-11)	3.5 (2.9-4.0)
	p-value		ns	0.054	ns	ns	ns	ns	0.048	ns	ns
Data at 6 Month	BiVAD	7	11 (8.3-13)	31 (25-39)	2.5 (1.4-3.5)	56 (46-67)	0.37 (0.36-1.3)	235 (97-648)	57 (8-234)	8.1 (4.9-13)	5 (3.6-9.8)
	LVAD	10	13 (10-16)	38 (29-45)	2.1 (1.2-2.9)	44 (38-54)	0.9 (0.5-1.6)	205 (176-243)	192 (20-272)	13.2 (5.5-35)	3.5 (3.4-3.6)
	p-value		0.03	0.042	ns	0.01	ns	ns	ns	ns	ns

Note: aPTT – activated partial thromboplastin time, fHb – plasma free hemoglobin, Hb – hemoglobin, INR –international normalized ratio, LDH – lactate dehydrogenase, M: - male, RBC – red blood cells, W:- women.

None of the patients required pump exchange nor suffered clinically relevant or severe device-related hemolysis during the observation time period.

DISCUSSION

Our data indicate absence of clinically relevant hemolysis in patients with biventricular support with the HeartWare HVAD for up to 6 months of support.

Lower INR requirements for this BiVAD configuration (2.5-3.0 in our cohort) together with increased mobility and quality of life (absence of bulky, noisy driver units of available extracorporeal biventricular systems or TAH) are giving clinicians a new option for the treatment of biventricular end-stage heart failure.

However, the data showed lower haptoglobin level in BiVAD recipients in the first month of support, which is a sign for laboratory detectable intravascular hemolysis in the absence of increased free plasma hemoglobin and LDH levels. (fig. 1-2)

Moreover, low or completely depleted haptoglobin is often seen in patients supported by ventricular assist devices. Heilmann et al. showed that the degree significantly depends on the type of VAD: extracorporeal pulsatile devices presented the lowest haptoglobin level and centrifugal LVADs the highest [1]

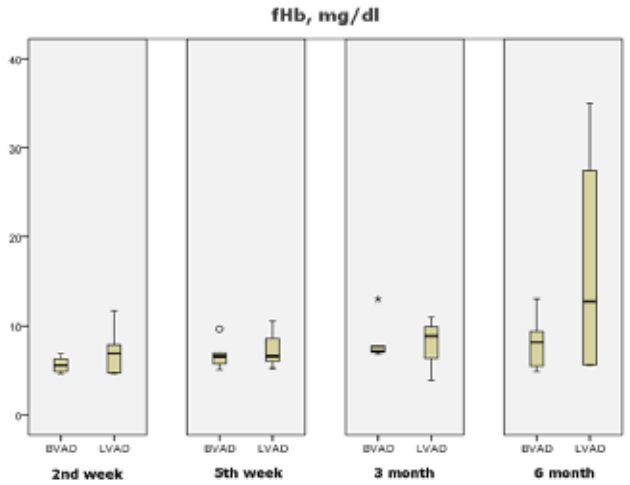

Fig. 1. Postoperative course of free plasma haemoglobin.

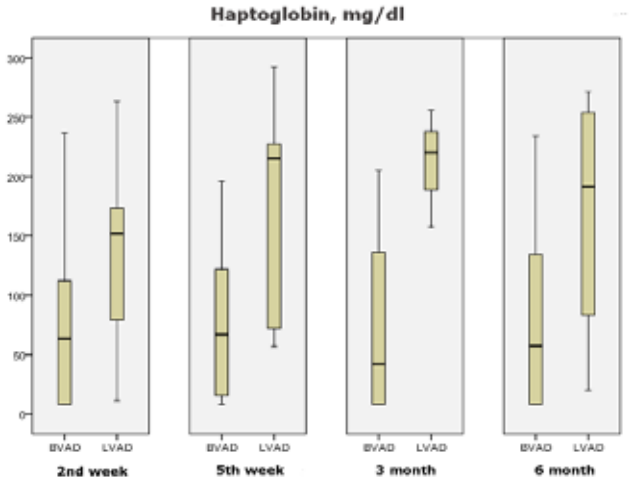

Fig. 2. Postoperative course of plasma haptoglobin.

Several factors, such as individual patient characteristics, RVAD pump adaptation and blood viscosity, may contribute to the observed difference in haptoglobin level in our patient groups both supported by centrifugal pumps. Mechanical heart valve prostheses could add a certain degree of intravascular hemolysis, which is suspected in one of our BiVAD recipients who received the BiVAD as a reoperation and had in his past medical history mechanical mitral valve replacement. Surgical modification of an LVAD for use in the pulmonary circulation with size reduction of the RVAD outflow prosthesis and potential turbulence of blood flow after the stenosis could also impact on the degree of hemolysis in BiVAD recipients despite higher anticoagulation targets. Hence, there is no reliable data regarding clinical differences in coagulation status between venous and arterial blood, which may have an additional influence on HeartWare RVAD function and red blood cell damage. Postoperative onset of heparin induced thrombocytopenia and the related change in anticoagulation regime (use of direct thrombin inhibitors i.v.) could again impact on blood viscosity and lead to an increase in device-related hemolysis with depletion of haptoglobin. However, all these factors did not contribute to a difference in free plasma hemoglobin or LDH in our patients. Two centrifugal pumps running at more or less the same rpm in different circulation conditions (pulmonary and systemic) did not cause increased red blood cell trauma.

Three of our BiVAD recipients experienced clinically relevant bleeding episodes after hospital discharge compared to none of the LVAD recipients. This potentially contributed to the lower hemoglobin and hematocrit level in BiVAD recipients seen at 6 months.

There is no consensus on quantification of the degree of hemolysis in VAD recipients, especially reflecting the exact levels of free plasma hemoglobin, LDH and haptoglobin or other additional parameters (hemopexin or reticulocyte level), and these values together with clinical symptoms should be taken as the cut-off for definition of the clinical degree of VAD related-hemolysis and the required staged therapy approach. Genovese et al. [9] presented plasma free hemoglobin > 40 mg/dl in association with clinical signs of hemolysis occurring within the first 72 hours post implantation as a definition of VAD related hemolysis; however, free plasma hemoglobin alone did not clarify the degree of hemolysis and related therapy options. [1, 9] Similarly, according to the INTERMACS definition, VAD-associated hemolysis is characterized by a plasma-free hemoglobin value greater than 40 mg/dl, in association with clinical signs of hemolysis (e.g., anemia, low hematocrit, hyperbilirubinemia) occurring after the first 72 hours post-implant [10]. However, this definition is difficult to apply in daily practice, especially for delayed

LVAD-related hemolysis. Hence, this hemolysis value may already be an indication for surgical device exchange.

Hence, the criteria and severity of intravascular hemolysis given in several prosthetic valve studies [11, 12] are not sufficient for VAD patients. Anemia, hemoglobinuria and need for frequent blood transfusion in the absence of bleeding are sometimes extreme definitions of severe VAD-related hemolysis. Definitions for slight and mild forms of device-related hemolysis and their clinical importance in the chronic setting, especially in the case of permanent support, need to be intensively investigated in further studies.

Based on our study we may conclude that levels of free plasma hemoglobin together with LDH obtained in the second week after surgery on optimal anticoagulation could be reference or baseline parameters for later outpatient follow-up and monitoring of pump function. An increase of more than twofold in these markers associated with increased/decreased device energy consumption together with recurrence of heart failure symptoms may be a definition for suspicion of pump thrombotic dysfunction requiring close observation of the patient in a specialized MCS unit.

Our retrospective analysis of BiVAD HeartWare and LVAD HeartWare recipients showed a lack of a clinically important degree of hemolysis when two centrifugal HeartWare pumps are used for biventricular support.

There are several limitations of our study. We analyzed a small number of patients with very variable clinical situations, which may potentially impact on outcomes. Studies with more patients may clarify our findings. Additionally, analysis of patients' hemopexin levels, which appear more dependable for the quantification of intravascular hemolysis [13] and detection of hemoglobinuria, were not performed due to the retrospective study design.

CONCLUSION

Concomitant use of two implantable centrifugal pumps is not related to clinically relevant hemolysis in the early postoperative period and for up to 6 months of support.

DISCLOSURE

The authors have no potential conflict of interest of disclose.

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References

1. *Heilmann C., Geisen U., Benk C., Berchtold-Herz M., Trummer G., Schlensak C. et al.* Haemolysis in patients with ventricular assist devices: major differences between systems. Eur J Cardiothorac Surg. 2009; 36: 3: 580-584.
2. *Bhamidipati C.M., Ailawadi G., Bergin J., Kern J.A.* Early thrombus in a HeartMate II left ventricular assist device: a potential cause of hemolysis and diagnostic dilemma. J Thorac Cardiovasc Surg. 2010; 140: 1: 7-8.
3. *Meyer A.L., Kuehn C., Weidemann J., Malehsa D., Bara C., Fischer S. et al.* Thrombus formation in a HeartMate II left ventricular assist device. J Thorac Cardiovasc Surg. 2008; 135: 1: 203-204.
4. *Potapov E.V., Loforte A., Weng Y., Jurmann M., Pasic M., Drews T. et al.* Experience with over 1000 implanted ventricular assist devices. J Card Surg. 2008; 23: 3: 185-194.
5. Decesare W., Rath C., Hufnagel C. Hemolytic Anemia of Mechanical Origin with Aortic-Valve Prosthesis. N Engl J Med. 1965; 272: 1045-1050.
6. *Chachques J.C, Marino J.P, Lajos P., Zegdi R., D'Attellis N. Fornes P. et al.* Dynamic cardiomyoplasty: clinical follow-up at 12 years. Eur J Cardiothorac Surg. 1997; 12: 4: 560-567.
7. *Hetzer R., Krabatsch T., Stepanenko A., Hennig E., Potapov E.V.* Long-term biventricular support with the heartware implantable continuous flow pump. J Heart Lung Transplant. 2010; 29: 7: 822-824.
8. *Wieselthaler G.M., O Driscoll G., Jansz P., Khaghani A., Strueber M.* HVAD Clinical Investigators. Initial clinical experience with a novel left ventricular assist device with a magnetically levitated rotor in a multi-institutional trial. J Heart Lung Transplant. 2010; 29: 11: 1218-1225.
9. *Genovese E.A., Dew M.A., Teuteberg J.J., Simon M.A., Kay J., Siegenthaler M.P. et al.* Incidence and patterns of adverse event onset during the first 60 days after ventricular assist device implantation. Ann Thorac Surg. 2009; 88: 4: 1162-1170.
10. Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) Official Website. Available from: http://www.intermacs.org/
11. *Skoularigis J., Essop M.R., Skudicky D., Middlemost S.J., Sareli P.* Frequency and severity of intravascular hemolysis after left-sided cardiac valve replacement with Medtronic Hall and St. Jude Medical prostheses, and influence of prosthetic type, position, size and number. Am J Cardiol. 1993; 71: 7: 587-591.
12. *Mecozzi G., Milano A.D., De Carlo M., Sorrentino F., Pratali S., Nardi C. et al.* Intravascular hemolysis in patients with new-generation prosthetic heart valves: a prospective study. J Thorac Cardiovasc Surg. 2002; 123: 3: 550-556.
13. *Delanghe J.R., Langlois M.R.* Hemopexin: a review of biological aspects and the role in laboratory medicine. Clin Chim Acta. 2001; 312: 1-2: 13-23.

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