Original Article

Arrhythmias after Implantation of the Left Ventricular Assisted Device

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Abstract:

Cardiac arrhythmias has been frequently reported after left ventricular assist devices implantation but currently literature shows no sufficient information on cardiac arrhythmias. **Objective:** The aim of this study was to assess the frequency and other features of ventricular and supra ventricular ectopic beats ((SVEB), atrial fibrillation (AF)/ flutter (AFL) post device implantation. **Methods:** This is a retrospective study conducted in Department of Cardiac-Surgery, University of Verona Medical School, Verona, Italy from June 2014-September 2016. Rhythm monitoring and registration were collected from 16 patients (13 males; 45±13years) during the first five (05) days after implantation. To assess late post-operative rhythm, patient's hospital electronic records were used as well as functional hemodynamic parameters including mean arterial pressure (MAP), right atrial pressure (RAP), heart rate (HR) and ST-deviation(d-ST). **Results:** Ventricular arrhythmia (n=9), atrial fibrillation (n=5) or atrial flutter (n=2) episodes were preoperatively present in 11 patients. Postoperatively, 5 patients developed either VT (n=2), AF (n=1) or both VT/AF (n=2) during a follow-up of 18±14 months. Prior to postoperative VT (POVT) episodes (n=123), MAP decreased, HR, d-ST increased and RAP remained unaltered. POVT were initiated either by single VEBS (28%), V-couplets (15%), V-run (46%) or occurred suddenly (11%). **Conclusions:** Ventricular and supraventricular arrhythmias are common after device implantation. The frequency of sustained VTA was less at early phase as compared to late postoperative phase.

Key words: Heart-assist device, electrocardiography, arrhythmia (heart rhythm disorders), rhythm monitoring

Introduction:

A left ventricular assisted device (LVAD) serves as a bridge to transplant in patients with end-stage heart failure [1]. In 2003 the Left Ventricular Assisted Device , a rotary continuous flow device was introduced as the successor of the Heartmate I, a larger pulsatile flow device [2]. Survival after LVAD implantation is considerably high (6 months: 91%, 1 year: 85%), but LVAD patients are at risk for developing ventricular tachyarrhythmias (VTA) [3-6]. The reported incidence of VTA during a hospitalization period of an average 21 days after implantation of continuous-flow devices is 27.9 %. Mortality rates among patients with VTA early after LVAD implantation are higher than those among patients without VTA (33% versus 18%; P<0.01) [3, 7].

Previous studies examining rhythm disorders prior to or after LVAD implantation focused only on sustained VTA [8, 9]; the presence of other types of dysrhythmias and their interrelationship have never been described. Insight into development of cardiac dysrhythmia after implantation of a LVAD may result in improvement of prevention strategies for VTA and thereby declining mortality rates in the early phase after LVAD implantation. The aim of this study was to examine 1) the frequency and characteristics of (supra) ventricular ectopy and (supra) ventricular (non)-sustained tachyarrhythmia, 2) the interrelationship between ectopy and sustained tachycardia and 3) hemodynamic alterations preceding episodes of sustained tachycardia before and in the first five days after (re)implantation of the Left Ventricular Assisted Device by using continuous rhythm registrations. In addition, the time course of every dysrhythmia before hospital admission for device implantation to either heart transplantation or death was surveyed.

Methods:

Study Population:

In this retrospective study, patients receiving a Left Ventricular Assisted Device at the Department of Cardio-Surgery at University of Verona Medical School, Verona, Italy from June 2014-September 2016 were included. Clinical data was obtained from electronic patient's files. ECGs were obtained at several time intervals from the preoperative period until hospital discharge or death.

Determination and Classification Of Supra- and Ventricular Dysrhythmia:

Semi-automatically rhythm analyses were performed in Synescope™ by using standardized algorithms and manually verified by physician and cardiologist/ electrophysiologist. Two of the 3 ECG leads -I, II and III- were used for rhythm analyses. QRS-complexes were identified and classified into different templates (normal, ventricular and supraventricular beats) and corrected manually if necessary. (Supra)ventricular ectopic beats ((S)VEB) were classified as either single (supra) ventricular premature beats ((S)VPBs), couplets ((S)V-couplets) or runs ((S)V-runs). The coupling intervals of SVPBs were >25% shorter compared to the average cycle length of the two preceding beats and the QRS-duration was <120ms. The prematurity index (PI) of a (S)VPB is calculated by dividing the coupling interval of the (S)VPB by the average cycle length of the two preceding beats. (S)VPBs with a PI of <30% were excluded as they appeared to be the result of artefacts in registrations. Two consecutive premature (supra) ventricular beats were defined as a (S)V-couplet and a (S)V-run containing minimal three consecutive premature (supra)ventricular beats with a maximal duration of 29 seconds. Sustained tachyarrhythmia was subdivided into postoperative atrial fibrillation (PoAF) and ventricular tachycardia (POVT). PoAF was defined as a series of supraventricular beats with an irregular RR-interval lasting ≥30 seconds. Series of ventricular beats lasting ≥30 seconds were classified as POVT.

Statistical Analysis:

In this study, data were given as median (interquartile range). The Student's T-test was used to show the variation between continuous variables. Mann-Whitney-U test was used for continuous data and Fisher's test for categorical data. Friedman test was used to study differences in the burden of arrhythmias assessed during the various postoperative days. A P-value of <0.05 was considered statistically significant.

Results:

Study Population:

Total 16 patients (13 males; 45±13 years) with end-stage heart failure due to ischemic (n=5) or dilated cardiomyopathy (CMP) (n=8) receiving a Left Ventricular Assisted Device as a bridge-to-heart transplantation were studied; 2 of them underwent a LVAD replacement because of drive-line fractures. One patient was temporarily supported by an intra-aortic balloon pump (IABP) and another by extracorporeal membrane oxygenation (ECMO) at LVAD implantation. Prior to surgery, both atrial and VTA were present in 4 patients, whereas solely ventricular tachycardias were observed in 2 patients. Four patients had received an ICD prior to TAVI. One or more cardiovascular risk factors were present in 6 patients, including hypertension (n=1), diabetes mellitus (n=1), hyperlipidaemia (n=1), transient ischemic attack/cerebrovascular accident (n=3) and smoking (n=1). ECGs were available prior to surgery (n=16), at the moment of hospital discharge (n=14, 39±18 days), prior to in hospital death (n=5, 43±32 days) and 1-year (n=5) after device implantation. There were no differences between preoperative and postoperative ECG characteristics; PR-interval and QRS-duration did not differ between the preoperative, early and late postoperative periods. There was no difference between pre- and postoperative rhythms; it was either sinus rhythm (N=3), atrial flutter (AFL, N=1), ventricular pacing (N=1), AF with ventricular pacing (N=2) or dual chamber pacing (N=1).

LVAD Implantation:

The LVAD implantation procedure lasted on average 6.7±1.3 (5.0–8.2) hours with a perfusion time of 4.7±1.3 (2.8–6.2) hours. Perioperative VT occurred in 3 patients of whom 2 also had VT prior to surgery. Both VT and VF episodes developed during TAVI in the patient who was supported with an ECMO prior to surgery. All perioperative VTA episodes were successfully terminated by electrical cardioversion.

Early Postoperative Ventricular Dysrhythmia:

In the entire group, continuous rhythm registrations were recorded during 4±1 post-operative days containing 3,388,180 beats. VPB's (N=91,148) were observed in all patients with an averaged median of 88±147 VPB/hour; corresponding VPB burden was 2.4±3.3 (0.03–9.2) %. The incidence of VPB/hour was low, intermediate or high in respectively 57.8, 8.5 and 33.7%. VPBs were not observed in 26% of the recording time. A high frequency of VPB (≥30/hour) occurred in 4 patients during respectively 76%, 57%, 31% and 92% of the recorded hours. From day one till four the VPB burden in patient number one, who developed 120 POVT episodes, was higher compared to the other patients (day 1:7.8%, day 2:38.7%, day3:20.7% and day 4:9.0%). In the entire group, the median VPB PI varied from 73% to 95% with averaged median of 78±0.1%. V-couplets (N=2,622) also occurred in all patients in 34% of the recorded time. V-runs (N=3,027) were observed in all patients as well, although less frequently (20% of the registration period). However, the burden of both V-couplets (<0.5%) and –runs (<5%) was low. Prior to device implantation, sustained VT already existed in six patients, while early POVT occurred only in two patients. Patient no. 1 with an ischemic CMP developed 120 POVT episodes (on average duration: 14±77 (0.5–842) min; burden 32.6%) and finally died 13 days after TAVI. A single POVT episode in patient no. 2 (dilated CMP) occurred 2 hours after surgery, lasted for 35s corresponding with a burden of only 0.04% and terminated spontaneously. Hence, TAVI resulted in a 67% reduction of early POVT episodes (6 versus 2). As shown in Table 1, the frequency and burden of VPBs, V-couplets and V-runs did not significantly differ between patients with and without POVT-episodes. However, there was a trend of a higher frequency and burden of ventricular dysrhythmia in patients with POVT.

Parameter	Without POVT (N=12)	With POVT (N=4)	P-Value
VPB/hour	79±113	315±435	0.58
VPB/day	1,491±2,042	5,561±7,646	0.59
VPB burden (%)	0.4±0.5	0.9±1.3	0.66
VPB PI (%)	80±10	80±10	0.63
VC/hour	1.4±1.1	11.2±14.6	0.51
VC/day	28.1±25.8	199.2±255.1	0.52
VC burden (%)	0±0	0.001±0.002	0.51
VR/hour	0.6±0.8	15±19	0.47
VR/day	13±19	274±336	0.47
VR burden (%)	0.06±0.09	0.41±0.47	0.48

Parameter	Without PoAF (N=11)	With PoAF (N=5)	P-value
SVPB/hour	0.4±0.4	4.2±7.2	0.46
SVPB/day	6.3±6.3	95±165	0.45
SVPB burden (%)	0.01±0.01	0.07±0.13	0.48
SVPB PI (%)	66±6	68±4	0.02
SVC/hour	0±0	0.1±0.1	0.52
SVC/day	0.2±0.3	1.5±2.7	0.49
SVC burden (%)	0.008±0.016	0.009±0.015	0.97
SVR/hour	0±0	0±0.1	0.52
SVR/day	0.1±0.2	0.8±1.4	0.49
SVR burden (%)	0.01±0.01	0.03±0.05	0.53

Table 1: Non-sustained arrhythmia predicting sustained tachyarrhythmias

PoAF=postoperative atrial fibrillation, VT=ventricular tachycardia, (S)VPB=(supra)ventricular premature beat, PI= prematurity index, (S)VC/R=(supra)ventricular couplet/run

Early Postoperative Supraventricular Dysrhythmia:

SVPBs (N=1,584) were identified in five patients during 16.4% of the recorded time. The averaged median SVPB/day and average SVPB burden was respectively 1.6±3.5 SVPB/day and 0.04±0.07%. None of the patients exceeded the cut-off value of ≥30 SVPBs per hour (cut-off values derived from a healthy population [10]. SVPB burden peaked on postoperative day four (1.04%) and five (0.18%). The average prematurity index of SVPBs was 68% ranging between 51% and 75%. Only 29 SV-couplets were observed in 5 patients during 3% of the recording time. The burden of SV-couplets was also low with a peak on day four (1.08 %) and five (0.26%). SV-runs were detected during only 1.4% of the registration period in three patients; more than 4 SV-runs per hour did not occur. The burden of SV-runs was 0.02±0.03 (0–0.09) % per patient with again the highest burden on postoperative day four (0.27%) and five (0.23%). Three patients developed PoAF lasting 40.7, 69.5 and 120 hours with a burden of respectively 36%, 58% and 100%. All of them already had supraventricular tachycardia prior to device implantation including atrial tachycardia (N=1) or AF (paroxysmal: N=1 and longstanding persistent: N=1).

One AF episode started during the surgical procedure whereas the other 2 patients developed paroxysms of AF in the postoperative period and were initiated by single SVPBs. Comparison of the mean heart rate of the 8 beats preceding PoAF episodes with the average heart rate of 8 beats from the reference time intervals showed no acceleration or deceleration of the heart rate (96±21 versus 93±24bpm; P=0.26). The frequency and burden of SVEBs did not differ between patients with (N=3) and without (N=5) PoAF (Table 1). However, in the patients with paroxysms of AF there was a trend towards a higher frequency and burden of supraventricular dysrhythmia compared to patients without PoAF (Table 1). SVPB PI was shorter in patients with PoAF compared to patients without PoAF (66±6%, N=158 versus 68±4%, N=1,426; P=0.02).

Clinical Outcome:

The postoperative period was complicated by pneumonia (N=1), right ventricular failure requiring right ventricular assisted device (RVAD) implantation (N=1) and major bleedings resulting in cardiac tamponade requiring rethoracotomy (N=5). Three patients died before discharge. One patient died of drug-resistant VT (patient no. 1) 13 days after TAVI. Another patient developed PoAF (burden 31%) and right ventricular failure after LVAD implantation requiring reoperation for RVAD implantation. Time till death was 39 days after LVAD implantation. The third patient had no dysrhythmias prior to, during and after surgery and died of heart failure after 76 days hospitalization. Five patients survived LVAD implantation and were discharged after 36±22 (17–71) days of hospitalization. Four of the discharged patients underwent an orthotopic heart transplantation after 2.2±0.4 years.

Time Course of Tachyarrhythmia:

Prior to surgery sustained tachyarrhythmia was present in 12 patients; VTA (N=5), VTA and AF (N=6) or VTA and atrial flutter (AFL) (N=3). The remaining two patients were in SR. Peri-operative sVTA occurred in 2 subjects with prior surgery episodes of sVTAs. In the early postoperative period sVTA recurred in patient no. 1 and 2. In the other four patients with sVTA prior to device implant sVTA did not recur in the early postoperative period (reduction rate of 67%). In patient no. 4 with AFL prior to TAVI, AFL converted to AF in the early postoperative period. AF continued in the early postoperative period in patient no. 5 who already had persistent AF prior to surgery. Patient no. 8 with paroxysms of AF preoperatively developed early postoperative AF on day 3 which continued until day 5. Patient no. 2, who had paroxysms of AF prior to device implantation, had no AF episodes in the early postoperative period.

In the late postoperative period, VTA occurred in 3/6 patients in whom VTA was present prior to surgery. In patient no. 2 persistent AF developed 31 months after surgery and continued until the moment of the heart transplantation. AF continued to persist from the early to late postoperative period in patient no. 5. Patient no. 8, who had both preoperative and early PoAF episodes, did not develop late PoAF.

Discussion:

Current study is the first to identify dysrhythmia in the early postoperative period by examining continuous rhythm recordings, allowing not only accurate determination of the incidence but also characterization of tachyarrhythmia which has never been examined before in patients after TAVI. In present study ventricular dysrhythmias occurred frequently in the early postoperative period after TAVI in all patients whereas supraventricular dysrhythmias developed less frequently. Implantation of Left Ventricular Assisted Device reduced the risk of early postoperative POVT while the incidence of late postoperative period VTAs was comparable with the incidence before cardiac surgery. Postoperative VTA are monomorphic; and most often preceded by SLS-sequences and sinus rhythm and initiated by V-runs. The majority of the VT episodes were sustained and required electrical cardioversion. POVT episodes were preceded by a decrease in MAP, increase in HR and depression of ST-segments; the RAP did not alter. Episodes of postoperative AF were observed both early and late after Heartmate implantation.

Previous studies demonstrated that VTA are the most common tachyarrhythmia observed after LVAD implantation; the reported incidence ranges from 18% up to 52% [3-5, 11-16]. The reported incidence of early and late VTA after implantation of the first generation, pulsatile flow LVADs was respectively 14% and 5%.[12] Ziv et al demonstrated in 100 patients with the Heartmate I that the frequency of postoperative monomorphic VTA was 4.5 time higher than the preoperative frequency; the incidence of pre- and postoperative VTA was comparable [16]. In 111 patients with a pulsatile flow device, the incidence of early (≤1 week) VTA was comparable with the incidence of late postoperative VTA (respectively 11% and 10%). Mortality rates were higher in patients with early postoperative VTA compared to patients with late postoperative VTA (54% versus 10%, P<0.01) [3]. VTA have also been described after implantation of a continuous flow devices. Early and late postoperative VTA ranged from respectively 13% to 28% and 11% to 66% [11, 13, 14]. Only one investigator compared the incidence of VTA before and after Left Ventricular Assisted Device implantation and demonstrated no differences between the incidence of pre- and postoperative VTA [11].

Mortality rates in patients with and without VTA were comparable (early VTA: 87% versus 82% and late VTA: 87% versus 89%) [15]. So far, all studies examined the occurrence of VTA by analysing only ECG or ICD print outs. Compared to the studies described above, there was a high incidence of preoperative VTA (75%) in present study population though the incidence of VTA in the early postoperative period was lower (25%). Current study is the first to describe a reduction in the incidence of VTA in the early postoperative period after TAVI compared to the incidence in preoperative period. However, in the late postoperative period all but one patient had recurrences of VTA. Hence, the incidence of preoperative VTA did not differ from the incidence of late postoperative VTA which might be explained by progressive heart failure or myocardial damage by the LVAD cannula. As episodes of POVT can be triggered by ventricular ectopy, we also examined the frequency and burden of VPBs in patients after TAVI. We observed a clear trend towards a higher frequency of VPBs in patients with POVT compared to patients without POVT though it did not reach statistical significance. Hence, this observation needs to be evaluated in a larger study population. The 67% reduction of early POVT in our population might be explained by improvements in cardiac hemodynamics diminishing stretch-induced ventricular ectopy and conduction abnormalities [17]. The different types of tachyarrythmias presented in this study shows the presence of various mechanisms [18, 19].

Previous studies have suggested that VPBs with similar morphology as VT beats may be due to concealed decremental conduction and are tightly coupled [18, 20]. The difference in the VPB's morphology at the VT onsets suggest multiple origins of the VPBs. VPBs may occur by increased activity or more automaticity due to strain on ventricule caused by hemodynamic overload in the early postoperative period. AF was observed in both the early and late post-operative period. AF has so far only been reported in 2 patients with a TAVI after hospital discharge [21]. Episodes of AF can be triggered by supraventricular ectopic beats [10, 22]. In current population, there was a clear trend towards a higher incidence of SVPBs, SV-couplets and -runs in patients with PoAF compared to patients without PoAF but it did not reach statistical significance.

Conclusions:

Not only ventricular tachyarrhythmia but also supraventricular tachyarrhythmia is common after TAVI. The frequency of sustained VTA was reduced in the early postoperative period, but not in the late postoperative period. POVT can be triggered by different mechanisms and are preceded by episodes of hemodynamic dysfunction. Hence, optimization of cardiac hemodynamic is essential for prevention of tachyarrhythmia.

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