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Adverse events and modes of failure related to the Impella percutaneous left ventricular assist devices: a retrospective analysis of the MAUDE database

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Introduction

Percutaneous left ventricular assist devices (pLVAD) are indicated to provide short-term mechanical circulatory support in patients with cardiogenic shock, acute myocardial infarction (AMI) with cardiogenic shock, and for high-risk percutaneous coronary intervention (HRPCI)[1]. The Impella® device (Abiomed Inc., Danvers, MA, USA) is a non-pulsatile microaxial flow pump that continuously propels blood from the left ventricle (LV) to the ascending aorta. The Impella system is placed retrogradely across the aortic valve under fluoroscopic guidance, with its inflow in the LV and outflow in the ascending aorta. The Impella platform consists of several different models that vary in calibre, insertion technique, and maximum haemodynamic support capabilities. There are limited published post-approval surveillance data on the most commonly reported complications and failure modes associated with the Impella devices. We analysed the US Food and Drug Administration (FDA) Manufacturer and User Facility Device Experience (MAUDE) database to report these endpoints.

Methods

The MAUDE database is a searchable online repository created by the FDA to capture major adverse events involving medical devices[2]. MAUDE reporting can be mandatory (for manufacturers and device user facilities) or voluntary (for healthcare professionals, patients, and consumers). Established in the 1990s, the database is updated monthly, and each medical device report (MDR) contains information on the device, event date, whether the device was returned to the manufacturer, date returned, and description of the event by the user and manufacturer. Based on their severity, events are classified into four categories: death, injury, malfunction, or other. The database was last accessed on 31 August 2018. Two independent reviewers quarried the database from 1 August 2008 to 31 August 2018 for Impella devices, yielding 448 medical device reports. After excluding the Impella RP and incomplete reports, 407 reports were included in the final analysis. Percentages represent the proportion of total submitted MAUDE reports.

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Results

The most commonly reported Impella type in our analysis was the Impella CP **(Figure 1)**. Of the 407 MDRs, 131 lacked information regarding clinical indication. Impella devices were most commonly placed for HRPCI **(Supplementary Table 1)**.

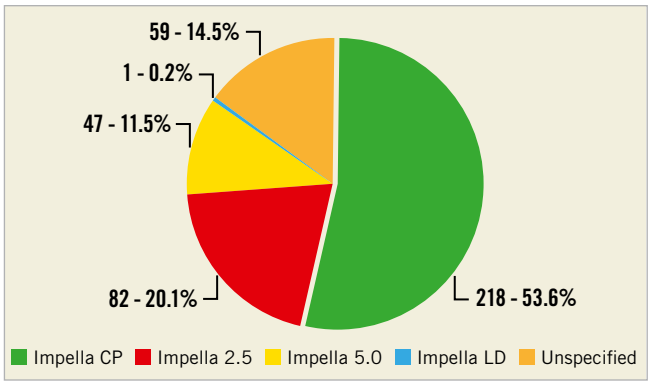

Figure 1. *Adverse events stratified by the different Impella device types.*

The most commonly reported complication was bleeding, which represented 38% of MAUDE reports, of which 70.3% required transfusion of packed red blood cells. Significant vascular complications, including dissection and perforation, were documented in 67 reports (16.4%). Of the 407 MAUDE reports, 168 (41.2%) confirmed that the Impella device was returned to the manufacturer for analysis; the remaining were either discarded or held at the facility at the time of this analysis. The most commonly reported failure mode was failure of the device components, noted in 29.9% of reports. Device malfunction and device separation were reported in 70 (17.2%) and 39 (9.5%) reports, respectively. **Supplementary Table 2** and **Supplementary Table 3** summarise proportions of reported complications and failure modes. **Figure 2** outlines the temporal trends for annual reporting of the adverse events related to different Impella devices.

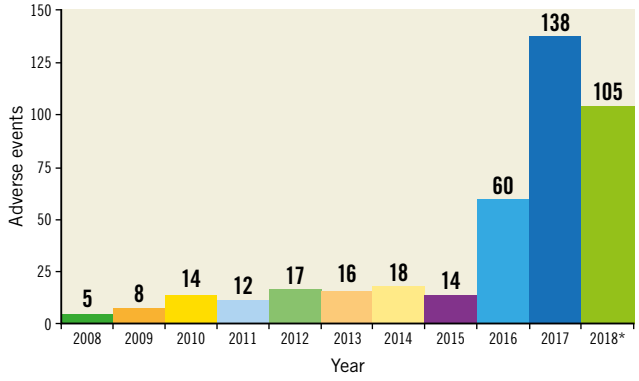

Figure 2. *Temporal trends for annual reporting of the adverse events related to different Impella devices. *Incomplete year – data reported to 31 August 2018.*

Discussion

The salient findings of our analysis are: a) the highest number of device-related adverse events was for the Impella CP, b) the majority of patients received the Impella for HRPCI, c) the most commonly reported complications were bleeding requiring blood transfusion and vascular complications, d) the most commonly reported failure modes included mechanical damage of the device components and device malfunction, and e) annual reporting trends for Impella MDRs show an upward trajectory, probably reflecting increased use of Impella devices.

Data regarding the incidence of adverse events related to Impella devices are scarce. In the pivotal trials of the Impella 2.5 in HRPCI patients, the incidence of major adverse events was 20% in PROTECT I, 8% in USpella, and 35.1% in PROTECT II[3]. In the Europella registry, bleeding and vascular complication rates were reported at 6.2% and 4%, respectively[3]. In the USpella registry patients developing AMI with cardiogenic shock and receiving Impella 2.5, reported complication rates were bleeding requiring transfusion (17.5%), vascular complication with surgical repair (9.7%), renal failure (18.1%), and haemolysis (10.3%)[4]. A prospective analysis of an Impella database reported vascular complication rates of 17%, with amputation rates of 4.4%[5]. It is important to understand that our analysis provides insights into the mechanism of device-related complications but cannot verify causality, neither does it provide information regarding incidence rates for individual complications. The total number of Impella units implanted during the study period remains unknown; however, the Impella Quality database reports this number to exceed 46,000 between 2009 and 2017[6].

In our analysis, the majority of patients received the Impella device for HRPCI. Use of the Impella is feasible in these patients[3]; however, limb ischaemia, bleeding requiring transfusion, and vascular access-related complications are important potential complications to consider[1,5]. pLVADs have a clear role in select cases of HRPCI; however, it is not clear that these devices should be the standard of care for all HRPCIs. Rather, pLVADs should remain a standby adjunctive therapy in many cases. More data are needed to define better the patient population that will derive the greatest benefit from these devices while minimising the risk of complications. The onus falls on both the clinicians to individualise patient care on a case-by-case basis and the cardiovascular device industry to continue improving device technology to achieve optimal outcomes. Newer device iterations, with smaller calibre sheath dimensions for example, may help to mitigate many of these adverse events.

Limitations

Without on-site evaluation, causality attribution cannot be established between the Impella device and adverse events. A minority of the devices were returned to the manufacturers for evaluation following the procedure, preventing a complete analysis of failure modes. Incidence rates for each complication could not be determined because of the lack of a denominator. Some general limitations of the MAUDE database include the fact that adverse events may be

reported by users and manufacturers, leading to duplicate reports. Since the reporting is mostly voluntary, an unknown number of complications remains unregistered. Adverse events caused by clinician error may be underreported or inappropriately attributed to device failure. The database may contain incomplete and unverified data.

Conclusions

Analysis of the MAUDE database demonstrates that, in real-world practice, Impella devices are associated with important complications. Judicious use, appropriate patient selection, and operator experience can all help to mitigate these complications.

Impact on daily practice

The management of patients requiring mechanical haemodynamic support is rapidly evolving, and there is a need for continued surveillance of safety profiles, patient outcomes, and failure modes for pLVADs. The MAUDE database serves as an important platform for both clinicians and manufacturers to improve device performance and optimise clinical outcomes.

Conflict of interest statement

R. Waksman reports being an Advisory Board/Board Member and consultant for Abbott Vascular, Amgen, Pi-Cardia Ltd, CardioSet, Medtronic, Philips (Volcano), and Boston Scientific Corp., a consultant for Biosensors and Biotronik, receiving grant support from Abbott Vascular, AstraZeneca, Biosensors, Biotronik, Chiesi, and Boston Scientific Corp., being on the speaker's bureau of AstraZeneca and Chiesi, and being an investor in MedAlliance. T. Rogers is a consultant and proctor for Medtronic, and a proctor for Edwards Lifesciences. The other authors have no conflicts of interest to declare.

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Supplementary data

Supplementary Table 1. Different indications for Impella placement among reports submitted to the MAUDE database.

Supplementary Table 2. Summary of complications among reports submitted to the MAUDE database.

Supplementary Table 3. Commonly reported proportions of failure modes for Impella.

The supplementary data are published online at: http://www.pcronline.com/eurointervention/152nd_issue/9

Supplementary data

Supplementary Table 1. Different indications for Impella placement among reports submitted to the MAUDE database.

Indications for placement	n=276
HRPCI	95 (34.4%)
Cardiogenic shock	50 (18.1%)
Acute myocardial infarction/cardiogenic shock	42 (15.2%)
Acute myocardial infarction	23 (8.3%)
Rhythm disturbances	24 (8.6%)
Preoperative or preprocedural	14 (5.0%)
Pre-CABG	9 (3.2%)
Pre-surgical valve repair or replacement	3 (1.08%)
Pre-CABG + valve repair or replacement	2 (0.72%)
Pre-balloon valvuloplasty	2 (0.72%)
Periprocedural complications with haemodynamic instability	14 (5.0%)
PCCS	13 (4.7%)
VT ablation	3 (1.08%)
Pre-OHT	2 (0.72%)
Research	2 (0.72%)
Ventricular septal defect / Cardiogenic shock	1 (0.36%)

Results reported as N (%). Percentages represent proportion of total number of MAUDE reports.
CABG: coronary artery bypass graft; HRPCI: high-risk percutaneous coronary intervention; OHT: orthotopic heart transplantation; PCCS: post-cardiotomy cardiogenic shock; VT: ventricular tachycardia

Supplementary Table 2. Summary of complications among reports submitted to the MAUDE database.

Complication	n=407
Bleeding/haematoma	155 (38%)
Required transfusion	109 (26.7%)
Limb ischaemia	28 (6.8%)
Amputation*	6 (1.4%)
Embolectomy or thrombectomy	6 (1.4%)
PAD	2 (0.49%)
Vascular complications	67 (16.4%)
Dissection	60 (14.7%)
Femoral artery	34 (8.3%)
Iliac artery	6 (1.4%)
Axillary artery	3 (0.73%)
SFA	2 (0.5%)
Profunda femoris artery	1 (0.2%)
Vertebral artery	1 (0.2%)
Aorta	1 (0.2%)
Unspecified	12 (2.9%)
Perforation	7 (1.7%)
Femoral artery	3 (0.7%)
Iliac artery	2 (0.5%)
Profunda femoris artery	1 (0.2%)
Unspecified	1 (0.2%)
Vascular repair	35 (8.6%)
Surgical	25 (6.1%)
Percutaneous repair (balloon angioplasty or covered stents)	10 (2.5%)
LV perforation	25 (6.1%)
Other chamber perforation	1 (0.2%)
Pericardial effusion	15 (3.7%)
Haemolysis	27 (6.6%)
Renal failure	9 (2.2%)
Dialysis	9 (2.2%)
RP bleed	9 (2.2%)
Thrombus/clot	18 (4.4%)
Air in LV	1 (0.2%)
Stroke	5 (1.2%)
Valvular complications	20 (4.9%)
AI	11 (2.7%)
MR	9 (2.2%)
Death	81 (19.9%)
Care withdrawn	9 (2.2%)

Results reported as N (%).

Percentages represent proportion of total number of MAUDE reports.

* One patient underwent bilateral lower extremity amputation.

AI: aortic insufficiency; LV: left ventricular; MR: mitral regurgitation; PAD: peripheral artery disease; RP: retroperitoneal; SFA: superficial femoral artery

Supplementary Table 3. Commonly reported proportions of failure modes for Impella.

Modes of device failure	n=407
Detached/separated	39 (9.5%)
Thrombus/clot/biomaterial in the Impella system	10 (2.4%)
Malfunction	70 (17.2%)
Pump stopped *	26 (6.3%)
Inadequate flow augmentation	11 (2.7%)
High motor current	4 (1.0%)
Console working screen malfunction	3 (0.7%)
Incorrect waveform	2 (0.5%)
Coil shorting	2 (0.5%)
Programming issues {}	1 (0.2%)
Structural damage	122 (29.9%)
Sheath	28 (6.9%)
Pigtail	20 (4.9%)
Repositioning unit	16 (3.9%)
Haemostatic valve	13 (3.2%)
Impeller blades	12 (2.9%)
Introducer	11 (2.7%)
Inlet area	8 (2.0%)
Cannula	8 (2.0%)
Catheter	7 (1.7%)
Guidewire	6 (1.5%)
Twin pin fracture	4 (1.0%)
Outlet area	3 (0.7%)
Red Impella plug	3 (0.7%)
Motor housing	2 (0.5%)
Purge assembly	
Elevated purge pressure	9 (2.2%)
Purge line/tubing	6 (1.5%)
Purge cassette	5 (1.2%)
Device entrapment	31 (7.6%)
Explanted	30 (7.3%)
Surgically	20 (4.9%)
Snare	8 (2.0%)
Manually	1 (0.2%)
Unspecified	1 (0.2%)
Abandoned []	1 (0.2%)
Positioning issues	
Pump migration or malposition	12 (2.9%)
Placement signal lost	3 (0.7%)
User error	11 (2.7%)
Incorrect anticoagulation	3 (0.7%)
Peelaway introducer or Impella left in place for extended time #	3 (0.7%)
Patient factors (movement or fall)	2 (0.5%)

Results reported as N (%).
Percentages represent proportion of total number of MAUDE reports.
* Indicates mechanical failure. In these cases, the device stopped without any warning or precipitating event and failed to restart despite troubleshooting or reprogramming the device.
{} In this case Impella CP was implanted; however, it was incorrectly registering as Impella 2.5 on the Automated Impella Console. The device was returned to the manufacturer and after thorough evaluation was found to have improper programming of the Electrically Erasable Programmable Read-Only Memory during the production of the product.
[] In one patient, the Impella CP was abandoned in the patient's body as the patient expired during the procedure (multivessel PCI in a patient with cardiogenic shock).
One of these patients developed limb ischaemia requiring endarterectomy. In another, the Impella CP remained in a patient for 110 hours (Impella Instructions for Use recommend maximum use for 4 days) that resulted in pump failure due to high motor current and rpm deviation although the patient received no harm.