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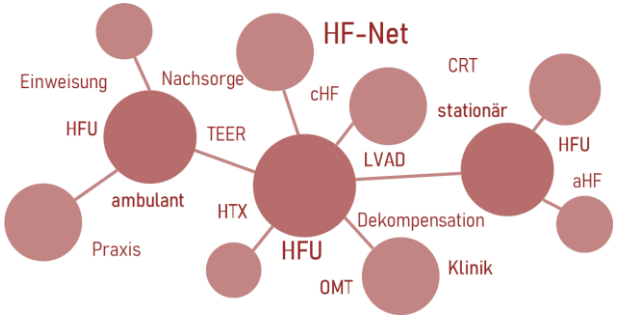


Assist Devices und Antikoagulation

Dr. med. Philipp Schlegel

UK HD

Disclosures

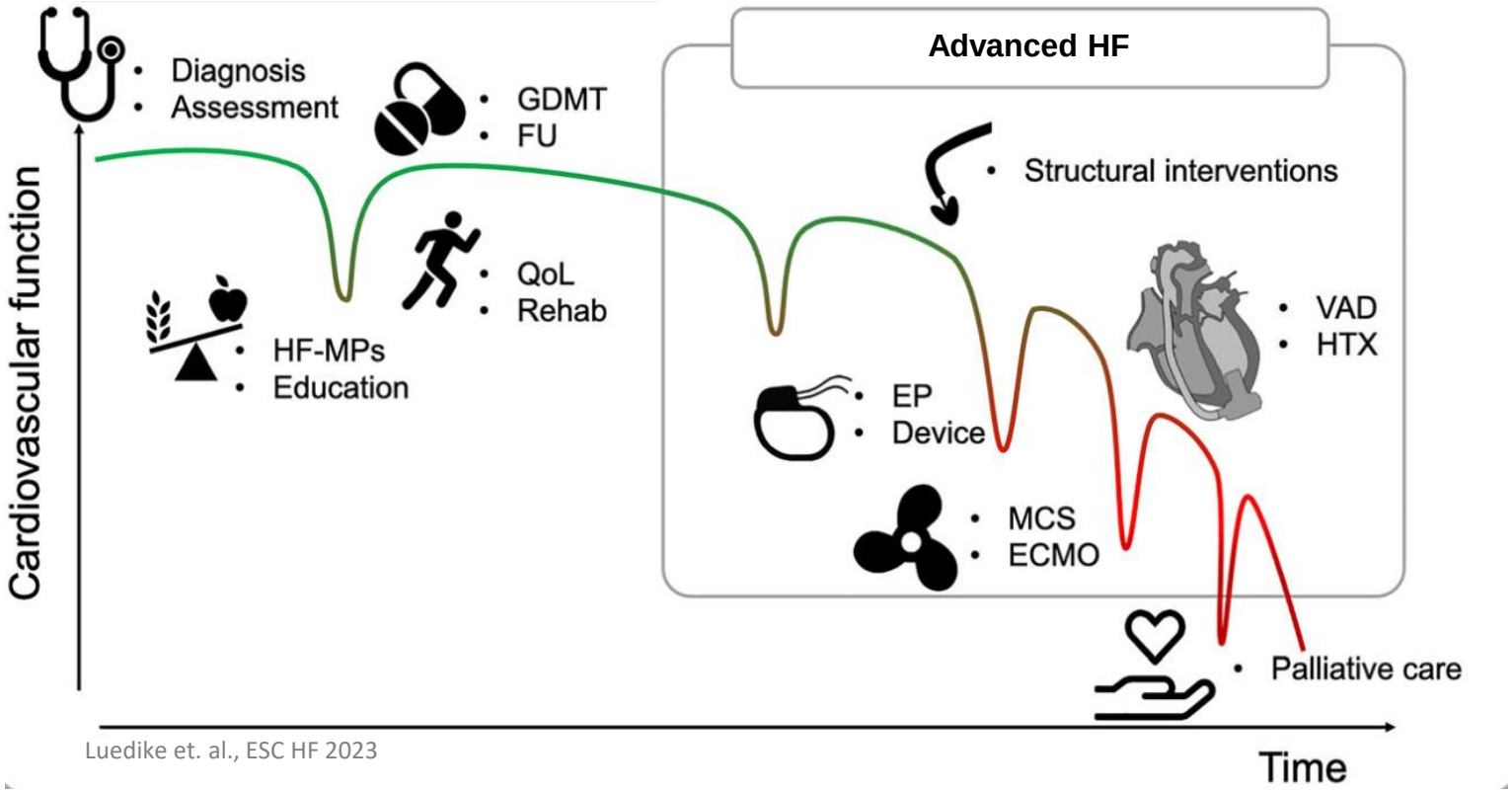
- Referentenhonorar: Edwards lifesciences, Bayer Vital, Boehringer Ingelheim
- Forschungsförderung: Pfizer pharmaceuticals, Abbott
- Beratervertrag: Boehringer Ingelheim

Agenda

- Assist Devices Welches für Wen und Wann?
- Gerinnnungsmanagement
- Gerinnungsassoziierte Komplikationen
- Notfallmanagement

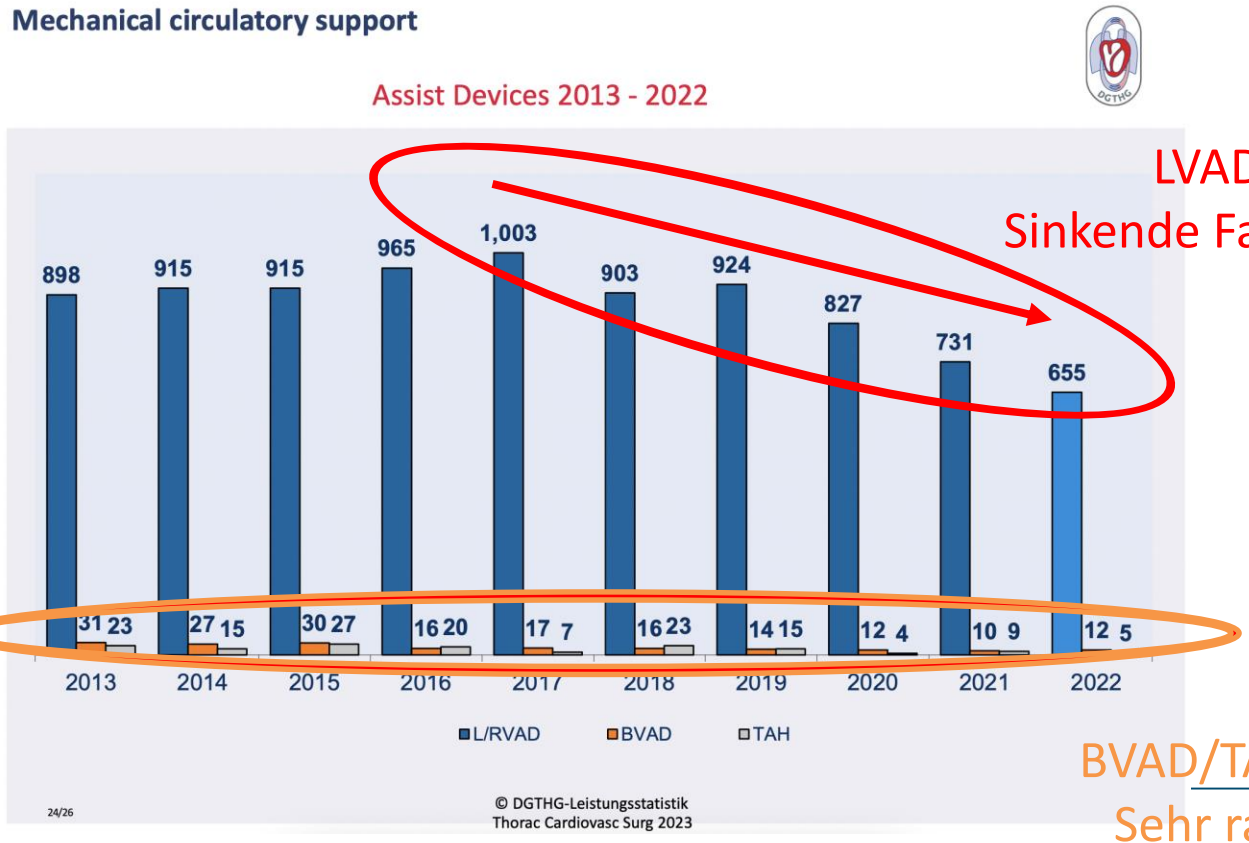
Was für Wen und Wann?

Herzinsuffizienz – viele Therapieoptionen

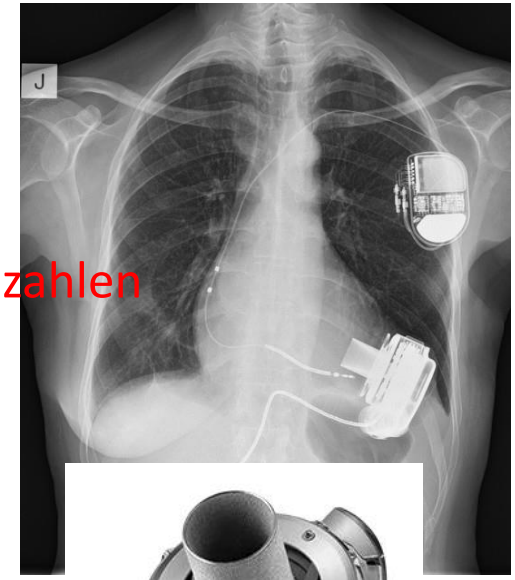


Luedike et. al., ESC HF 2023

Kunstherzpanorama in Deutschland



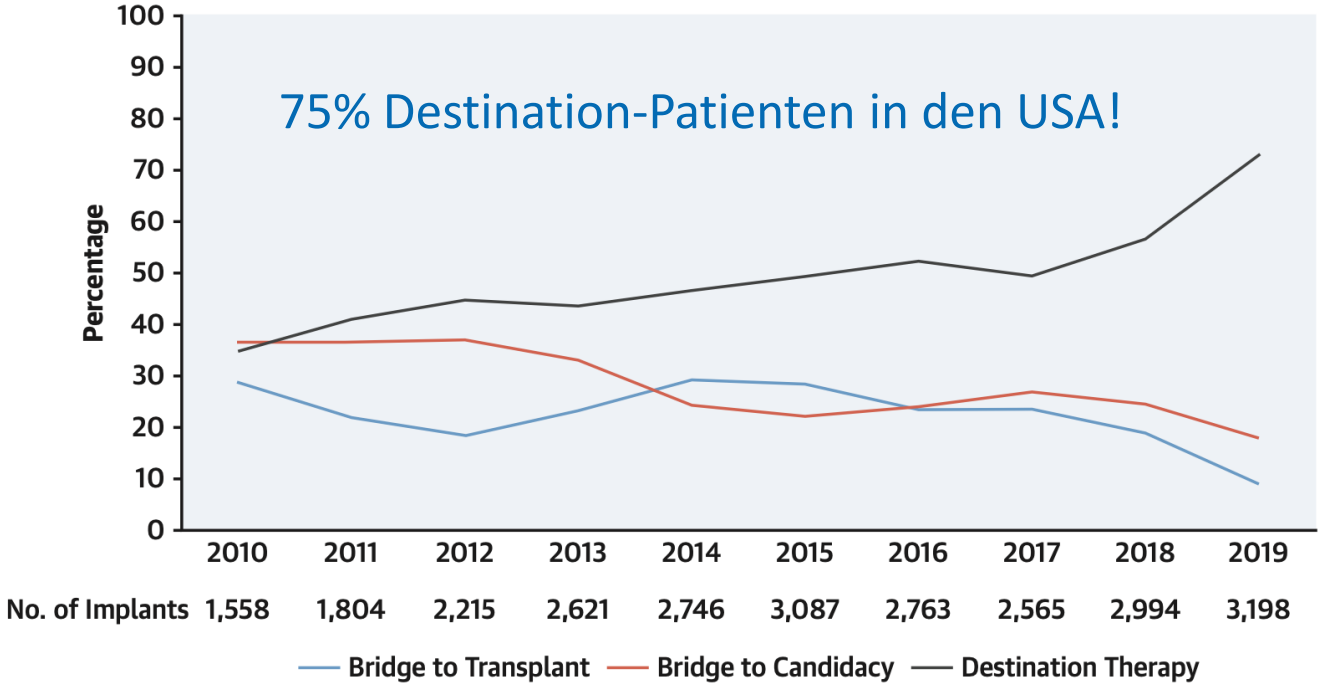
LVAD:
Sinkende Fallzahlen



Heartmate 3 (Abbott)

BVAD/TAH:
Sehr rar

LVAD Indikationen wandeln sich



→ Komplikationsvermeidung/-management lebenswichtig!!!

Varshney, JACC 2022

Die Hauptsysteme

Berlin Heart EXCOR®

Technical details:

- Pulsatile flow
- Different chamber siz

www.berlinheart.de

Meist als RVAD
+ HM3 LVAD

Heart Mate 3

Technical details:

- Centrifugal pump
  fully magnetically levitated flow
- Speed: 4,800-6,500 rpm
- Flow: 3-10l/min

www.cardiovascular.abbott.com

Gerinnungsmanagement

Das Antikoagulationsmanagement

Heart Mate 3

- Aspirin 100 mg/d
- Marcumar INR 2-3

Heartmate 3 (Abbott)

Berlin Heart EXCOR

- Aspirin 100 mg/d
- Marcumar INR 3-3,5

www.berlinheart.de

LVAD assoziierte Gerinnungsstörungen

Klassifikation des von Willebrand Syndroms

- **Typ 1:** quantitativer Defekt im vWF, häufigster Typ (70%), alle Multimere reduziert
- **Typ 2:** qualitativer Defekt im vWF
  - Type 2A: Fehlen der großen Multimere
  - Type 2B: Multimere mit erhöhter Affinität zur GPIb
  - Type 2M: Defizit in der primären Hämostase
  - Type 2N: Reduzierte Affinität des vWFs zu Faktor VIII
- **Typ 3:** quantitativer Defekt, starke Reduktion des vWF

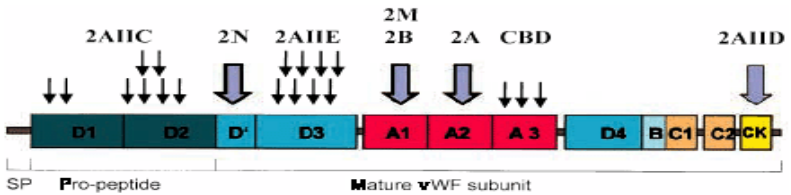
Von Willebrand Syndrom

Funktion des von Willebrand Faktors:

- Primäre Hämostase:
  Endothel-Thrombozyten Bindung
- Sekundäre Hämostase:
  Bindung und Stabilisierung von zirkulierendem Faktor VIII

Von Willebrand Factor:

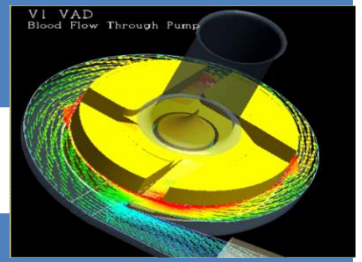
- Multimer Glykoprotein mit 500-20,000 KD
- Rezeptoren für
  - Faktor VIII
  - Kollagen
  - Thrombozyten GP Ib and GP IIb/IIIa
  - Heparin



(Schneppenheim et al. Inborn and acquired von Willebrand disease. Hämostaseologie 2005)

Pathophysiologie

Große Multimere des von Willebrand Faktors



Scherkräfte

Elongation des von Willebrand Faktors

ADAMTS13 (Metalloprotease)

Gespaltener von Willebrand Faktor

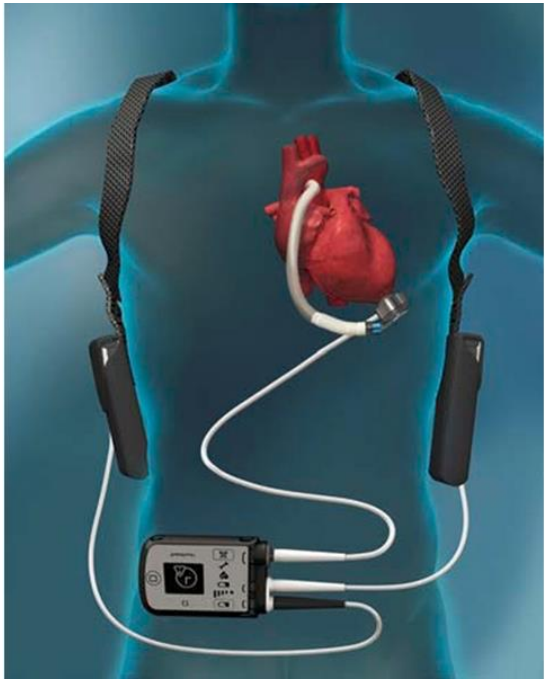
Symptome

- Schleimhautblutungen
  - Epistaxis
  - Gastrointestinale Blutungen
  - Gingiva Blutungen
  - Hämaturie

- Verlängerte Blutungszeit

Komplikationen am LVAD

Komplikationen am LVAD

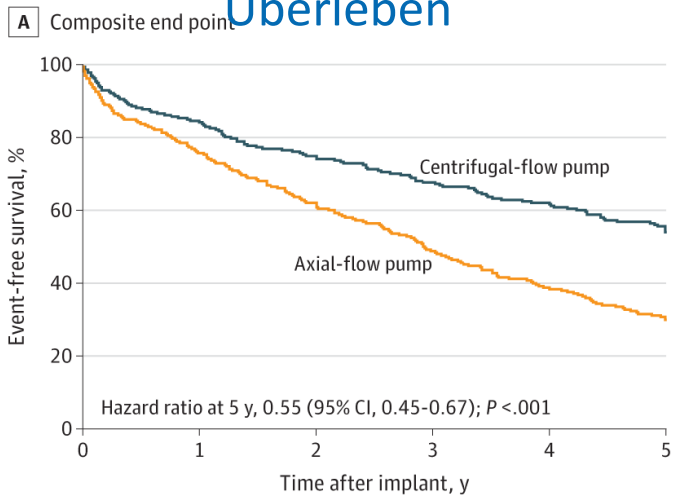


Heartmate 3 (Abbott)

Häufigste Komplikationen?

Komplikationen am LVAD

Event-freies 5-Jahres Überleben

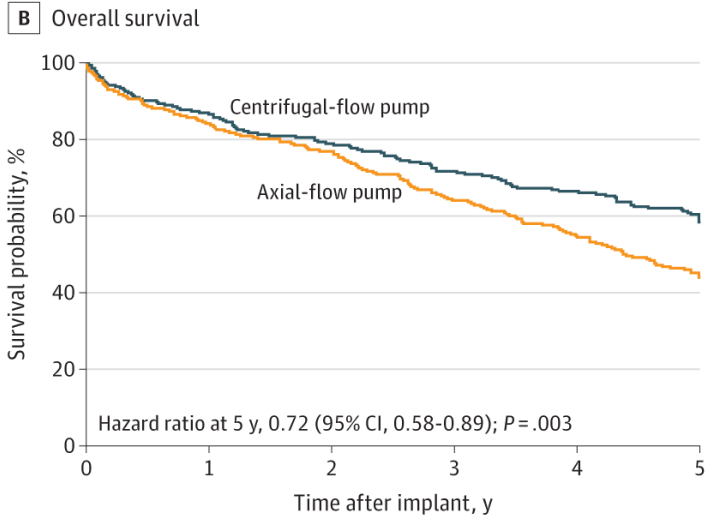


No. of patients

Centrifugal-flow pump	515	373	280	208	177	138
Axial-flow pump	505	321	223	147	106	71

→ Über 50% der Patienten haben keine schwere Komplikation innerhalb der ersten 5 Jahre!!!

5-Jahres Überleben



	515	383	289	213	184	141
	505	339	247	165	124	85

→ Fast 60% Überleben nach 5 Jahren!!!

Mehra, MOMEMTUM 3, JAMA 2022

Komplikationen am LVAD

ESC European Society of Cardiology
European Journal of Heart Failure (2021) 23, 1392–1400
doi:10.1002/ejhf.2211
RESEARCH ARTICLE

Primary results of long-term outcomes in the MOMENTUM 3 pivotal trial and continued access protocol study phase: a study of 2200 HeartMate 3 left ventricular assist device implants

Mandeep R. Mehra[1]*, Joseph C. Cleveland Jr[2], Nir Uriel[3], Jennifer A. Cowger[4], Shelley Hall[5], Douglas Horstmanshof[6], Yoshifumi Naka[3], Christopher T. Salerno[7], Joyce Chuang[8], Christopher Williams[8], and Daniel J. Goldstein[9], on behalf of the MOMENTUM 3 Investigators

Adverse Events

Table 2 Comparison of adverse events between the pivotal and continued access protocol cohorts

Adverse event	Pivotal cohort (n = 515)	CAP cohort (n = 1685)	Pivotal cohort (n = 515) EPPY	CAP cohort (n = 1685) EPPY	Adjusted rate ratio (95% CI)*	P-value*
Suspected pump thrombosis	7 (1.4%)	18 (1.1%)	0.01	0.01	0.74 (0.31–1.81)	0.51
Any stroke	51 (9.9%)	153 (9.1%)	0.08	0.07	0.86 (0.63–1.16)	0.32
Haemorrhagic	25 (4.9%)	74 (4.4%)	0.03	0.03	0.86 (0.55–1.35)	0.51
Ischaemic	29 (5.6%)	87 (5.2%)	0.04	0.04	0.86 (0.57–1.29)	0.45
Disabling	26 (5.0%)	73 (4.3%)	0.04	0.03	0.76 (0.50–1.17)	0.21
Any bleeding	225 (43.7%)	844 (50.1%)	0.61	0.71	1.09 (0.99–1.21)	0.09
Gastrointestinal	126 (24.5%)	488 (29.0%)	0.31	0.36	1.07 (0.93–1.24)	0.33
Requiring surgery	50 (9.7%)	225 (13.4%)	0.08	0.10	1.16 (0.88–1.55)	0.29
Any major infection	300 (58.3%)	968 (57.4%)	0.82	0.73	0.86 (0.79–0.94)	0.001
Driveline	120 (23.3%)	390 (23.1%)	0.23	0.21	0.92 (0.77–1.09)	0.32
Sepsis	78 (15.1%)	259 (15.4%)	0.13	0.13	0.92 (0.74–1.15)	0.48
Localized	210 (40.8%)	620 (36.8%)	0.46	0.39	0.83 (0.73–0.94)	0.003
Any right heart failure	176 (34.2%)	630 (37.4%)	0.27	0.27	1.03 (0.88–1.20)	0.73
Requiring RVAD	21 (4.1%)	125 (7.4%)	0.03	0.05	1.68 (1.06–2.68)	0.028
					0.82 (0.71–0.94)	0.004
					0.76 (0.61–0.95)	0.014
					0.85 (0.71–1.03)	0.09
					0.83 (0.69–1.01)	0.06
Renal dysfunction	73 (14.2%)	251 (14.9%)	0.11	0.11	0.87 (0.68–1.11)	0.27

CAP, continued access protocol; CI, confidence interval; EPPY, events per patient-year; RVAD, right ventricular assist device.
*Adjusted rate ratios and P-values are calculated with Poisson regression. Rate ratios are presented for CAP vs. pivotal cohorts and are adjusted for age, sex, race (Caucasian or non-Caucasian), intended use (bridge to transplant or candidacy, or destination therapy), and INTERMACS profile (1–3 or 4–7).

Komplikationen n. Häufigkeit:

GI-Blutung ca. 30%

Driveline-Infekt ca. 25%

Schlaganfall ca. 10%

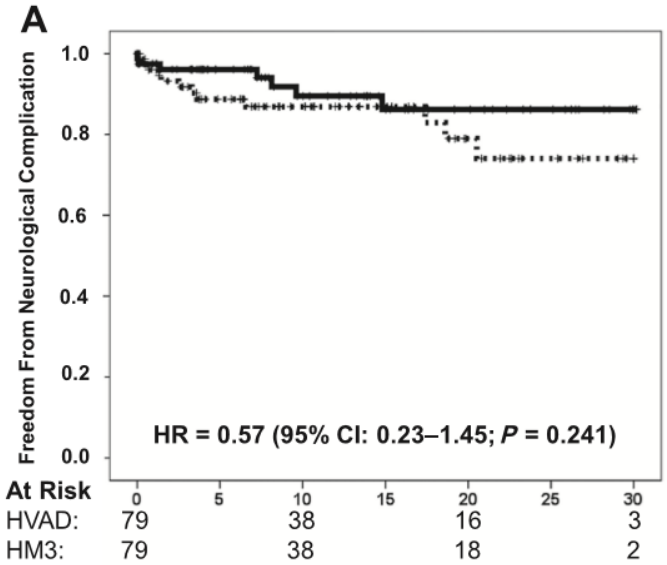
RV-Versagen ca. 5%

Pumpenthrombose ca. 1%

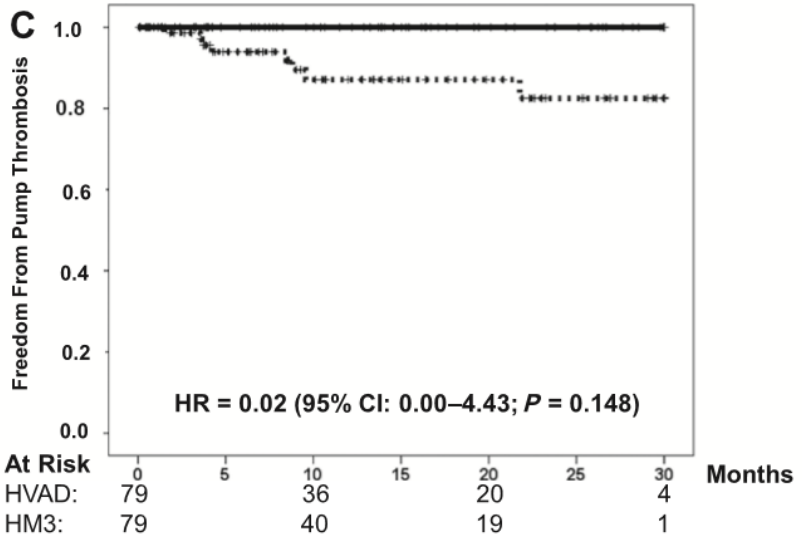
→Kaum noch Pumpenversagen!!!

Mehra, EHF 2021

Pumpenspezifische Komplikationen



Stroke

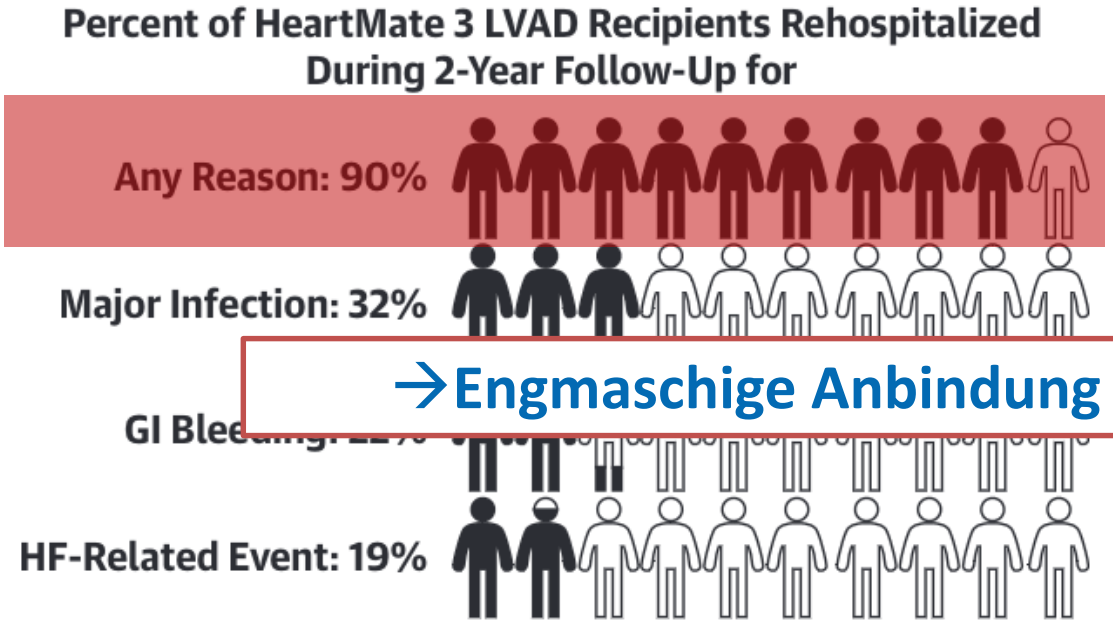


Pumpenthrombose

Schramm R. et al. ESC Heart Fail. 2020 Jun; 7(**3**): 908–914

Komplikationen am LVAD

Komplikationsbedingte Hospitalisierungen



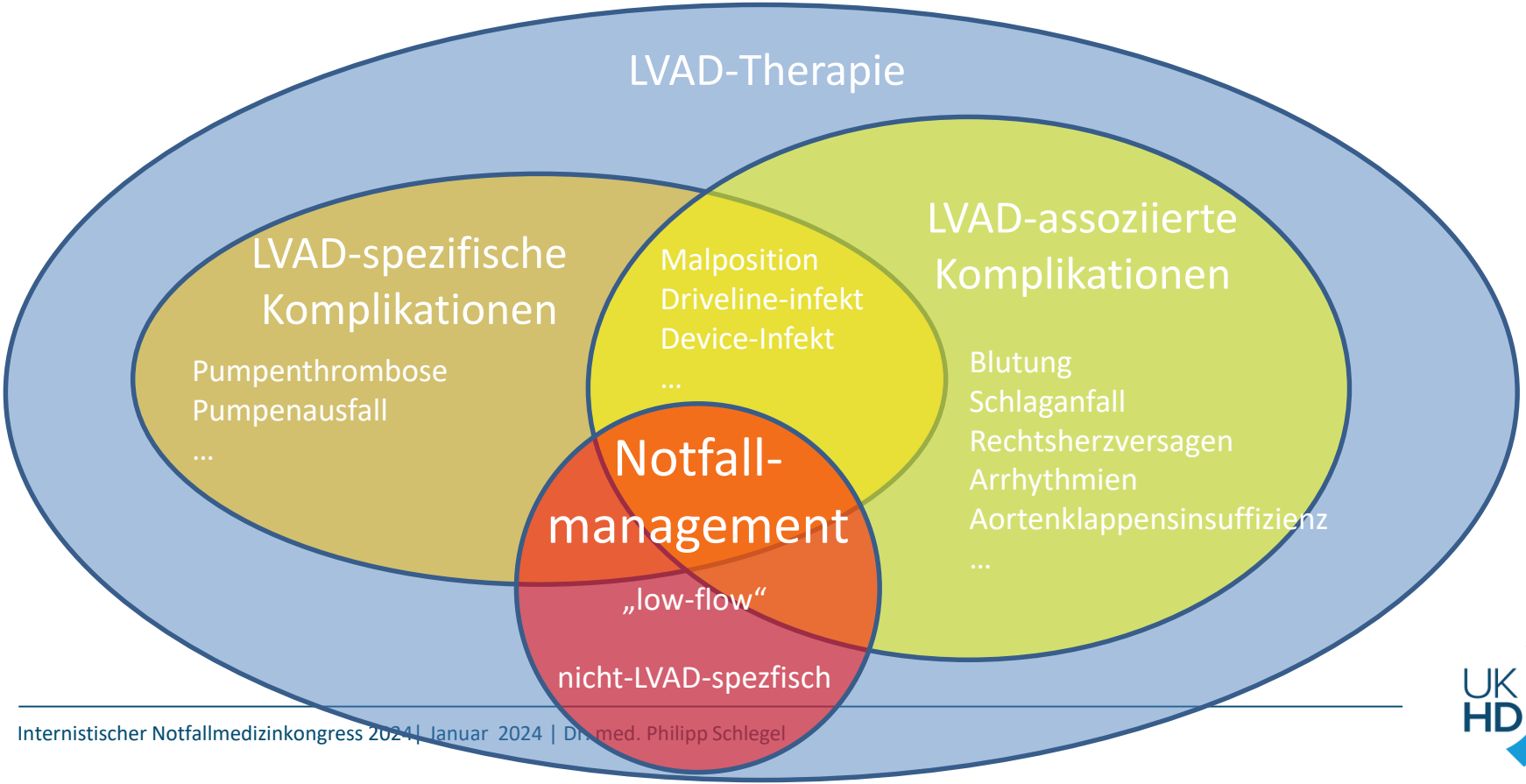
→ Sehr hohe Re-Hospitalierungsrate nach LVAD-Implantation

→ ca. 90% innerhalb der ersten 2 Jahre

→Engmaschige Anbindung wichtig!

Vidula, JACC HF 2022

Komplikationsmanagement



Left Ventricular Assist Device – LVAD

Heart Mate 3™

Technical details:

- Centrifugial pump fully magnetically levitated flow
- Speed: 4,800-6,500 rpm
- Flow: 3-10l/min

www.cardiovascular.abbott.com

Blutungskomplikationen

Gastrointestinale Blutung…

…aber auch Blutungen an
Mund-, Nase-, Rachenschleimhaut

→ Substitution von gerinnungsaktiven Substanzen möglich

→ FFP
→ Thrombozyten-Konzentrate
→ **PPSB**

Kein Konakion
→ wirkt langsam, aber wirkt lange nach

→ Antikoagulation absetzen
(auch über längere Zeiträume möglich!)

Blutungskomplikationen

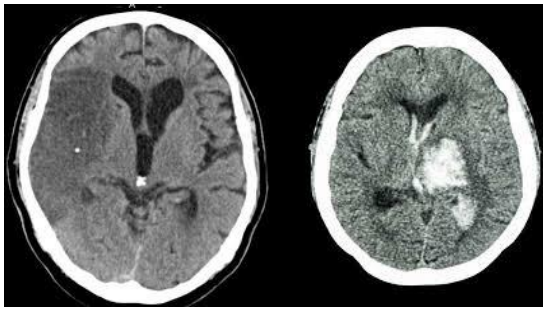
→ Interdisziplinäre Therapie mit entsprechender Fachabteilung

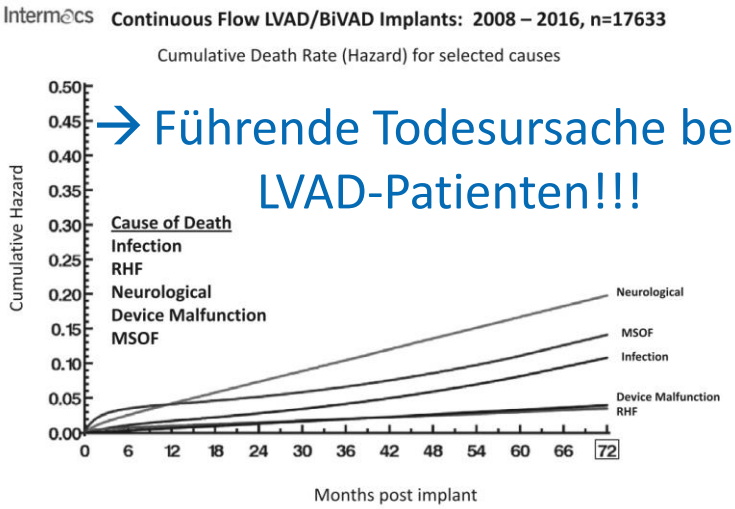
Gastrointestinale Blutung…

…aber auch Blutungen an Mund-, Nase-, Rachenschleimhaut

HM3 → Deutlich verbesserte Hämokompatibilität!!!

Schlaganfall





→ Führende Todesursache bei LVAD-Patienten!!!

→ Risikofaktoren: weibliches Geschlecht, Infektion, hoher Blutdruck

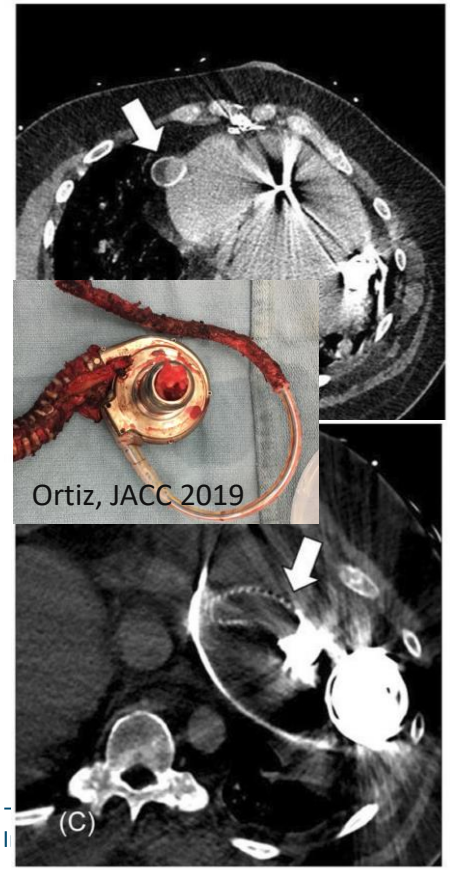
→ Prävention: engmaschige Blutdruckeinstellung MAD 75-85 mmHg!!!

→ Nach stattgehabten Schlaganfall Antikoagulationstherapie in enger Absprache mit Neurochirurgie/Neurologie

→ Abklärung Pumpenthrombose

Kirklin, 8th INTERMACS report, JHLT 2017

Pumpenthrombose



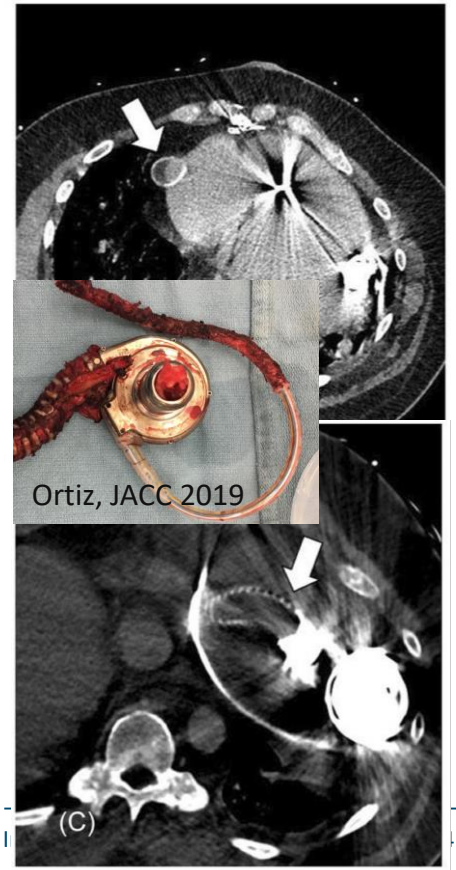
Wadiwalla, JCS 2022

Diagnostik

- Hämolyse (LDH 2.5x↑, fHb > 40, Hämaturie)
- Veränderung Pumpenparameter (Power ↑, Fluss ↓↑)
- Herzinsuffizienzzeichen
- Log-File Analyse
- „Rotor-Geräusche“
- Echo: eingeschränkte LV-Entlastung, peak velocity↓↑
- CT-Angio: Outflowgraft-Beurteilung

→ Typische Trias: Dunkler Urin, Wattzahl↑, LDH↑

Pumpenthrombose



Wadiwalla, JCS 2022

Therapie

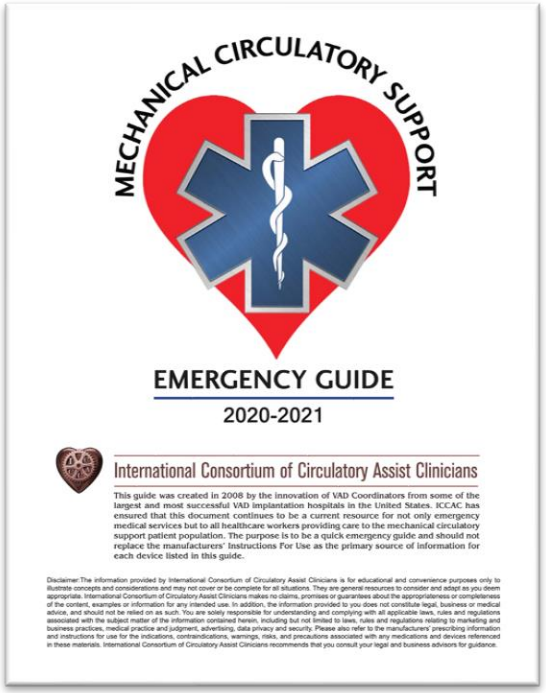
→ Umstellung Heparin oder Argatroban i.v.

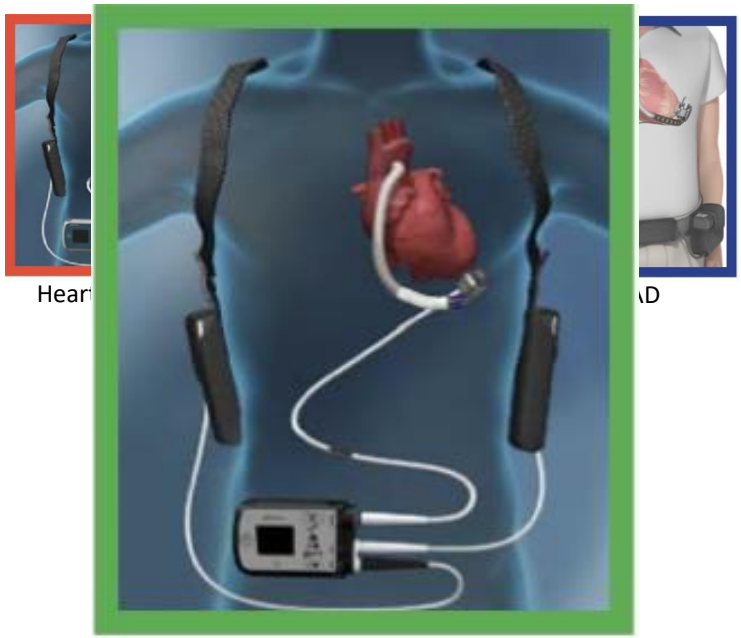
→ Individuelle Entscheidung:

- Systemische Lyse (unklarer Erfolg, Blutungsrisiko)
- Pumpentausch (hohes operatives Risiko)
- HU-Listung (beste Option, wenn Pat. stabil und transplantabel)

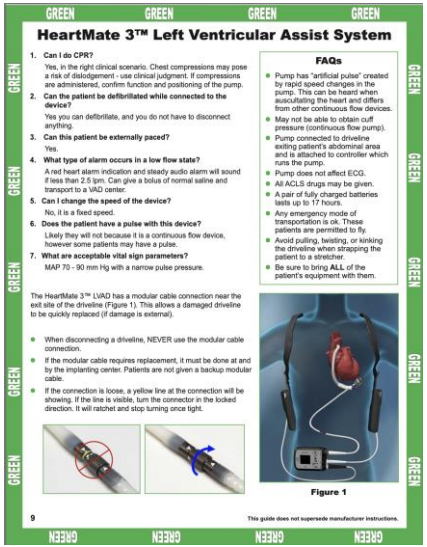
Know your pump!

→ Pumpenspezifische Besonderheiten





Know your pump!



HeartMate 3™ Left Ventricular Assist System

1. **Can I do CPR?**
   Yes, in the right clinical scenario. Chest compressions may pose a risk of dislodgement - use clinical judgment. If compressions are administered, confirm function and positioning of the pump.
2. **Can the patient be defibrillated while connected to the device?**
   Yes you can defibrillate, and you do not have to disconnect anything.
3. **Can this patient be externally paced?**
   Yes.
4. **What type of alarm occurs in a low flow state?**
   A red heart alarm indication and steady audio alarm will sound if less than 2.5 lpm. Can give a bolus of normal saline and transport to a VAD center.
5. **Can I change the speed of the device?**
   No, it is a fixed speed.
6. **Does the patient have a pulse with this device?**
   Likely they will not because it is a continuous flow device, however some patients may have a pulse.
7. **What are acceptable vital sign parameters?**
   MAP 70 - 90 mm Hg with a narrow pulse pressure.

FAQs

- Pump has "artificial pulse" created by rapid speed changes in the pump. This can be heard when auscultating the heart and differs from other continuous flow devices.
- May not be able to obtain cuff pressure (continuous flow pump).
- Pump connected to driveline exiting patient's abdominal area and is attached to controller which runs the pump.
- Pump does not affect ECG.
- All ACLS drugs may be given.
- A pair of fully charged batteries lasts up to 17 hours.
- Any emergency mode of transportation is ok. These patients are permitted to fly.
- Avoid pulling, twisting, or kinking the driveline when strapping the patient to a stretcher.
- Be sure to bring **ALL** of the patient's equipment with them.

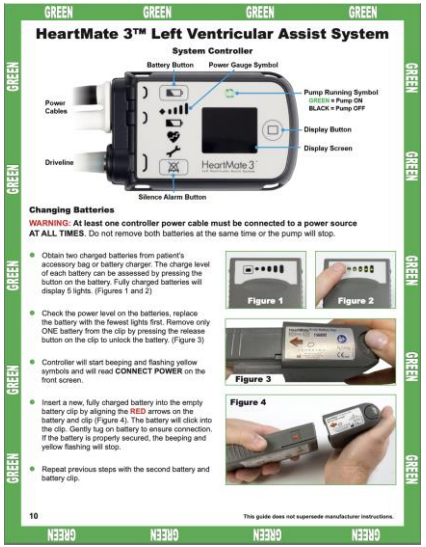
The HeartMate 3™ LVAD has a modular cable connection near the exit site of the driveline (Figure 1). This allows a damaged driveline to be quickly replaced (if damage is external).

- When disconnecting a driveline, NEVER use the modular cable connection.
- If the modular cable requires replacement, it must be done at and by the implanting center. Patients are not given a backup modular cable.
- If the connection is loose, a yellow line at the connection will be showing. If the line is visible, turn the connector in the locked direction. It will ratchet and stop turning once tight.

Figure 1

9

This guide does not supersede manufacturer instructions.



HeartMate 3™ Left Ventricular Assist System

System Controller

Battery Button
Power Gauge Symbol
Power Cables
Pump Running Symbol
GREEN = Pump ON
BLACK = Pump OFF
Display Button
Display Screen
Driveline
Silence Alarm Button

Changing Batteries

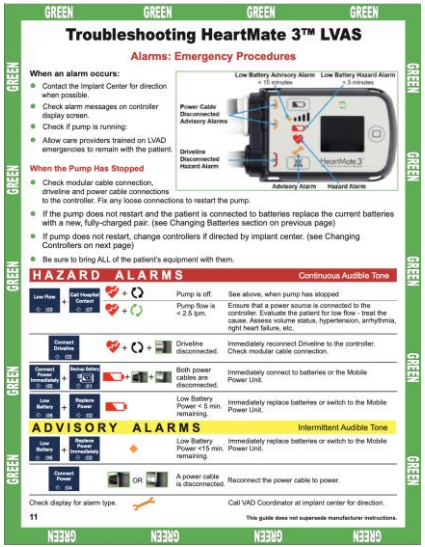
WARNING: At least one controller power cable must be connected to a power source AT ALL TIMES. Do not remove both batteries at the same time or the pump will stop.

- Obtain two charged batteries from patient's accessory bag or battery charger. The charge level of each battery can be assessed by pressing the button on the battery. Fully charged batteries will display 5 lights. (Figures 1 and 2)
- Check the power level on the batteries, replace the battery with the fewest lights first. Remove only ONE battery from the clip by pressing the release button on the clip to unlock the battery. (Figure 3)
- Controller will start beeping and flashing yellow symbols and will read **CONNECT POWER** on the front screen.
- Insert a new, fully charged battery into the empty battery clip by aligning the RED arrows on the battery and clip (Figure 4). The battery will click into the clip. Gently tug on battery to ensure connection. If the battery is properly secured, the beeping and yellow flashing will stop.
- Repeat previous steps with the second battery and battery clip.

Figure 1
Figure 2
Figure 3
Figure 4

10

This guide does not supersede manufacturer instructions.



Troubleshooting HeartMate 3™ LVAS

Alarms: Emergency Procedures

When an alarm occurs:

- Contact the Implant Center for direction when possible.
- Check alarm messages on controller display screen.
- Check if pump is running:
- Allow care providers trained on LVAD emergencies to remain with the patient.

Low Battery Advisory Alarm < 15 minutes
Low Battery Hazard Alarm < 5 minutes
Power Cable Disconnected Advisory Alarms
Driveline Disconnected Hazard Alarm
Advisory Alarm
Hazard Alarm

When the Pump Has Stopped

- Check modular cable connection, driveline and power cable connections to the controller. Fix any loose connections to restart the pump.
- If the pump does not restart and the patient is connected to batteries replace the current batteries with a new, fully-charged pair. (see Changing Batteries section on previous page)
- If pump does not restart, change controllers if directed by implant center. (see Changing Controllers on next page)
- Be sure to bring ALL of the patient's equipment with them.

HAZARD ALARMS	Continuous Audible Tone	
Low Flow + Call Hospital Contact	Pump is off.	See above, when pump has stopped
	Pump flow is < 2.5 lpm.	Ensure that a power source is connected to the controller. Evaluate the patient for low flow - treat the cause. Assess volume status, hypertension, arrhythmia, right heart failure, etc.
Connect Driveline	Driveline disconnected.	Immediately reconnect Driveline to the controller. Check modular cable connection.
Connect Power Immediately + Replace Battery Immediately	Both power cables are disconnected.	Immediately connect to batteries or the Mobile Power Unit.
Low Battery + Replace Power	Low Battery Power < 5 min. remaining.	Immediately replace batteries or switch to the Mobile Power Unit.
ADVISORY ALARMS	**Intermittent Audible Tone**	
Low Battery + Replace Power Immediately	Low Battery Power <15 min. remaining.	Immediately replace batteries or switch to the Mobile Power Unit.
Connect Power OR	A power cable is disconnected.	Reconnect the power cable to power.

Check display for alarm type.
Call VAD Coordinator at implant center for direction.

11

This guide does not supersede manufacturer instructions.

Troubleshooting HeartMate 3™ LVAS

Changing the System Controller

Step 1: Have the patient sit or lie down since the pump will momentarily stop during this procedure.

Step 2: Place the replacement Controller within easy reach,along with the batteries/battery clips. The spare Controller is usually found in the patient's travel case.

Step 3: Attach the battery clips to the replacement controller by lining up half circles, firmly pushing together, and tightening connector nut. Insert the batteries into the clips by aligning the RED arrows.

Step 4: On the back of the replacement controller, slide the safety lock so the red release button is fully visible. Repeat this step on the original controller.

Step 5: Disconnect the drive-line from the original controller by pressing the red release button and pulling it out. The pump will stop and an alarm will sound. Note: The alarm will continue until the original controller is turned off. You can silence the alarm by pressing the silence alarm button.

Getting the replacement controller connected and the pump restarted is the first priority!

Step 6: Connect the replacement Controller by aligning the WHITE ARROWS on the driveline and replacement Controller and firmly pushing the driveline into the replacement Controller. The pump should restart, if not complete the following steps:

- Firmly press the Silence Alarm or Battery Button to restart the pump.
- Check the power source to ensure that power is going to the controller.
- Ensure the driveline is fully inserted into the socket by gently tugging on the metal end. **DO NOT** pull the driveline.

Step 7: After the pump restarts, slide the safety lock on the new controller so the red release button is fully covered. If unable to close the safety lock into fully locked position, gently push the driveline into the controller to ensure proper connection. Retry to close safety lock.

Step 8: Disconnect power from the original Controller.

Step 9: Hold down battery symbol for 5 full seconds for complete shutdown of old controller.

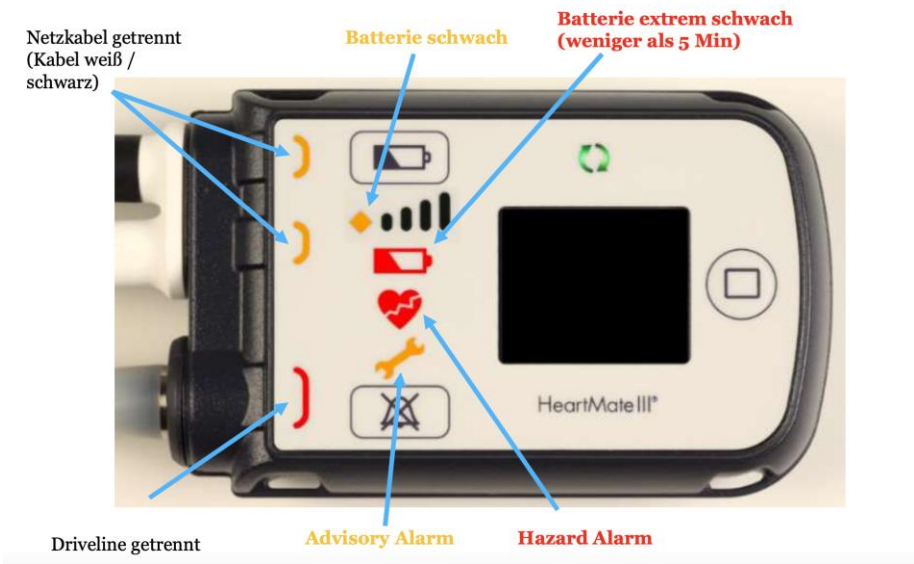
Step 3
Step 4
Step 7
Step 5
Step 6
Step 9

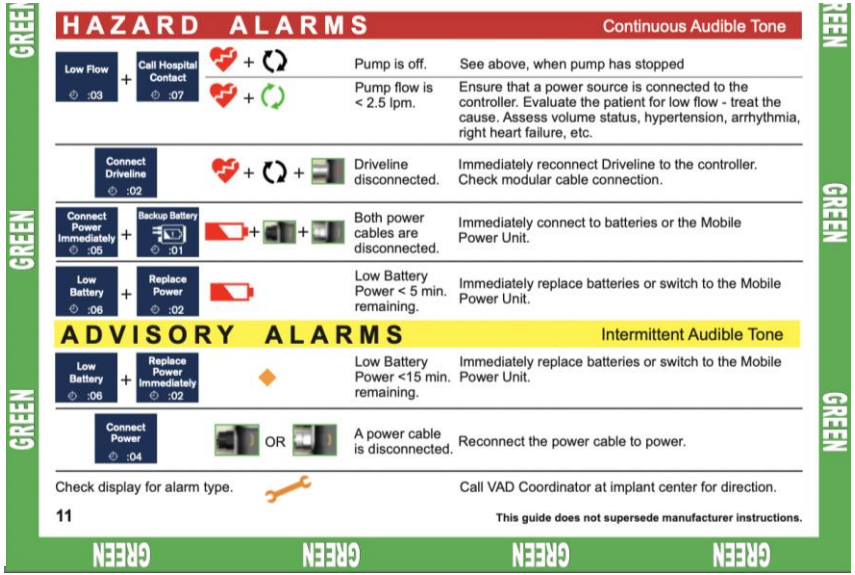
12

This guide does not supersede manufacturer instructions.

ICCAC Emergency guide 2021

Pumpenalarme





→ Hazard Alarm: Low Flow!

→ Advisory: Low Battery!

ICCAC Emergency guide 2021

Ersteinschätzung

Pilarczyk, Kardiologe 2020

ABCDE- Patient

- **A**irway (Atemweg)
- **B**reathing (Beatmung)
- **C**irculation (Kreislauf)
- **D**isability (Defizit)
- **E**nvironment (Umfeld)

ABCDE- LVAD

- **A**uskultation
- **B**atterie
- **C**ontroller
- **D**riveline
- **E**chokardiographie

	HVAD	HM II	HM III
Pumpenfluss (l/min) *Alarmgrenzen*	3-6 *Frei wählbar mind. 1 l/min*	3-7 *Fixed < 2,5 l/min*	3-6 *Fixed < 2,5 l/min*
Pumpendrehzahl (min^{-1})	2400-3200	8000-10000	5000-6000
Power (Watt)	3-7	5-8	4,5-6,5

Bewusstsein?

Hämodynamik?

LVAD?

→ Zusätzlich LVAD-Evaluation!

Basiskonzepte

- nicht-pulsatiles System (ggfs. Puls nicht messbar!)
  → RR-Messung? Pulsoxymetrie?
- Vorlastabhängiges System
  → Hypovolämie = low flow
- Nachlastsensible Pumpe
  → RR ↑ = Pumpenfluss ↓
- Nur passive RV-Unterstützung (Nachlast↓)
  → LVAD abhängig von RV-Funktion
- Flusswert anhand Drehzahl+Leistung berechnet
  → falsch hoher Fluss bei Pumpenthrombose

Besonderheit LVAD-Patienten

Kreislaufstatus?

- MAD (ggfs. Dopplersonographisch): > 50 mmHg ✓
- LVAD-Fluss (Controller): > 1,5 L/min ✓
- ETCO2 >20 mm Hg
- Surrogatparameter:
  Hautfarbe, -temperatur, mentaler Status, capillary refill, Halsvenenfüllung, Doppler Fluss über A. carotis/femoralis, $ETCO_{2}$...

→ Indikation zur mechanischen Herzdruckmassage kritisch prüfen!

Kardiopulmonale Reanimation

Nichtansprechbarer LVAD-Patient mit fehlenden Zeichen einer ausreichenden Kreislauffunktion

→ Advanced-Cardiac-Life-Support (ACLS)-Algorithmus

→ Defibrillation nach ERC-Leitlinie

→ Herzdruckmassage nach ERC-Leitlinie

→ Zeitnah eCPR in Erwägung ziehen

→ ggfs LVAD-Stillstand beheben
(cave: thrombembolisches Risiko↑)

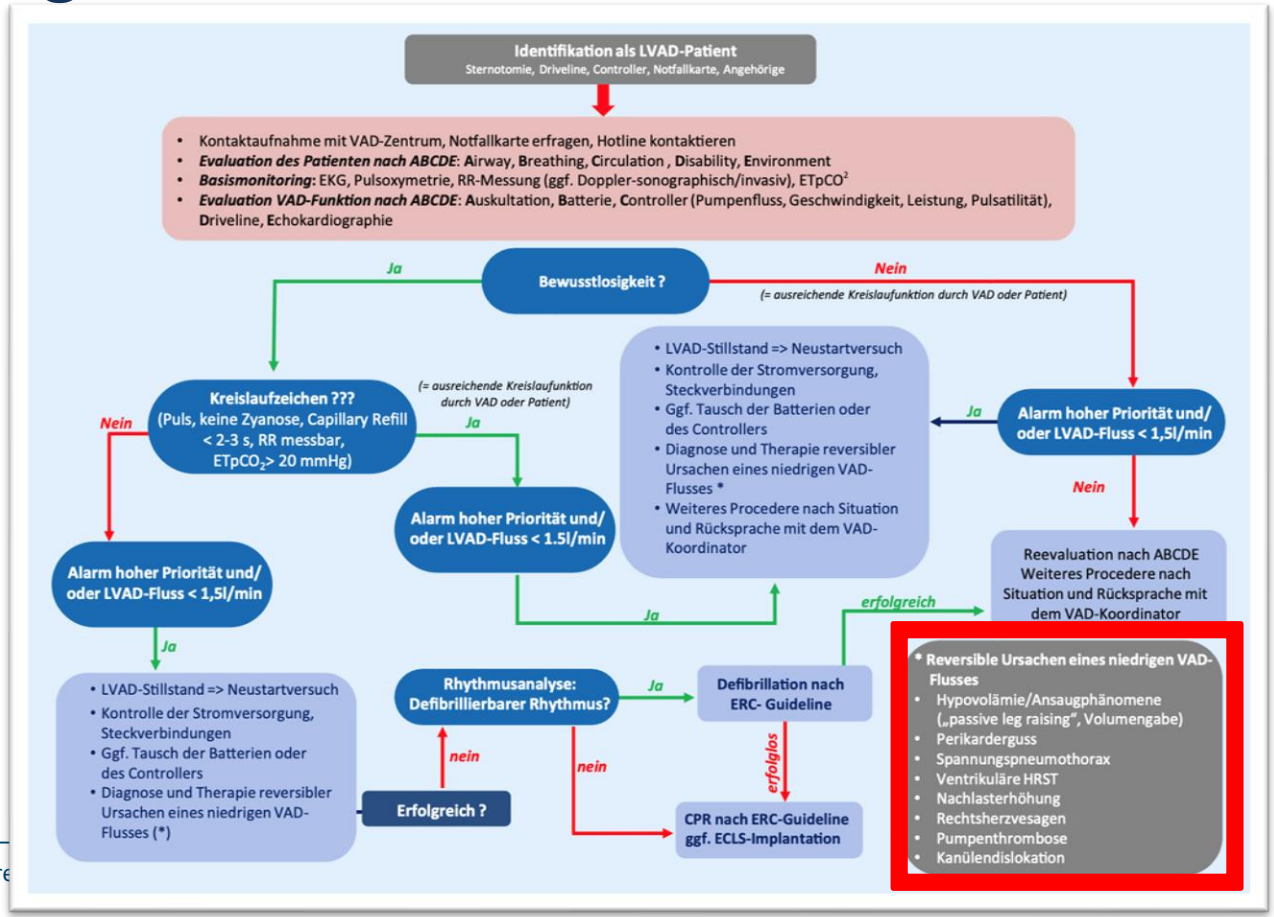
→ Leitliniengerechte CPR!!!

Notfallmanagement

Empfehlungen zum Notfallmanagement von Patienten mit permanenten Herzunterstützungssystemen

Konsensuspapier der DGTHG, DIVI, DGBN, DGAI, DGINA, DGIK und DGK

Pilarczyk, Kardiologe 2020



Management niedriger Pumpenfluss

Management niedriger Pumpenfluss

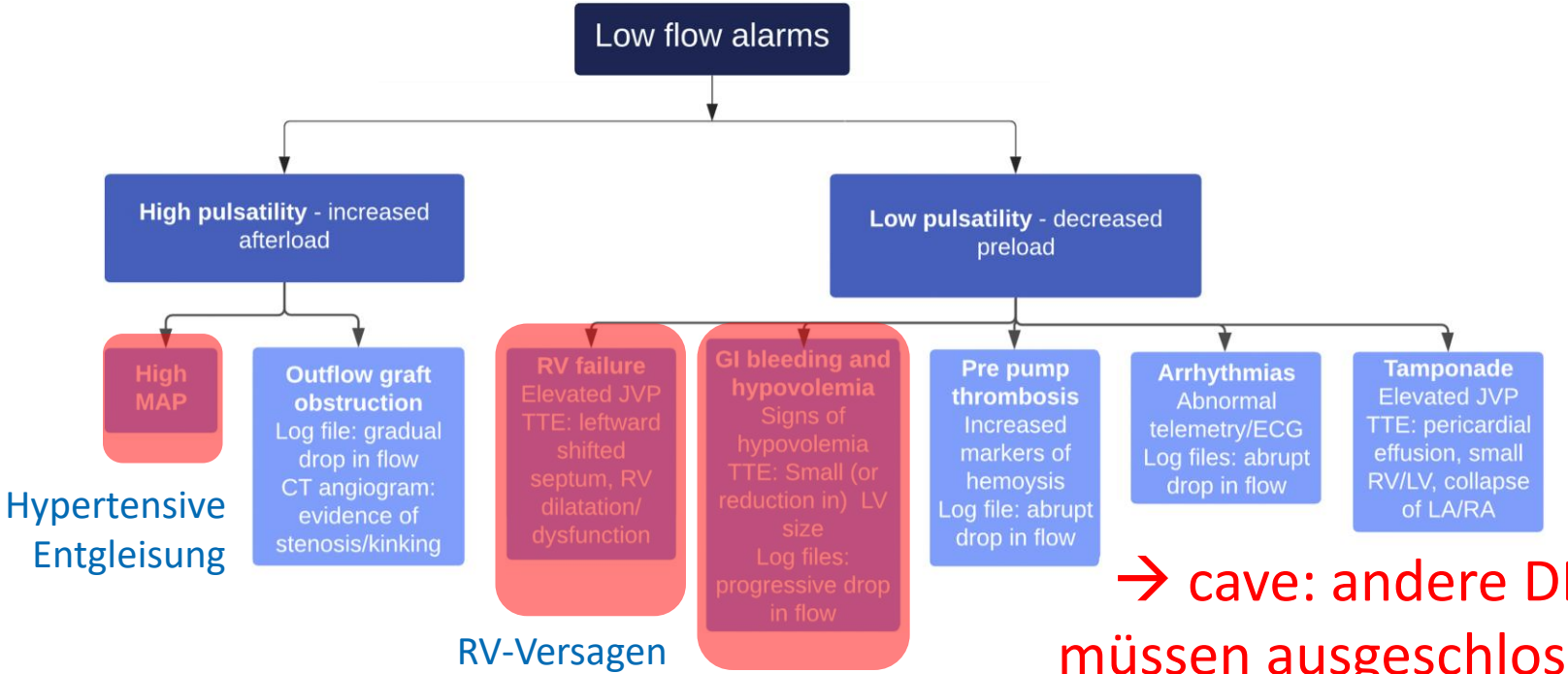
Heartmate 3 (Abbott)

LVAD-Fluss < 2,5 L/min

nicht kompensiert/ kreislaufinstabil → Notfallalgorithmus

kompensiert/ ausreichende Rest-LV-Funktion → Diagnostik + Therapie

Differentialdiagnosen niedriger Pumpenfluss



→ cave: andere DD müssen ausgeschlossen werden!!!

Devesa, JACC: Case Reports 2021

Diagnostik – Low-Flow

Basis-Diagnostik
(Klinische Untersuchung, EKG, Labor,…)

+

„volume challenge“
(passive leg raise oder 500ml Ringer-Lösung)

↓

Pumpenfluss ↑ → Hypovolämie
Pumpenfluss =↓ → RV-Dysfunktion

Echokardiographie

↓

Volumenstatus
RV/LV-Funktion
u. Dimension
Perikarderguss/
Tamponade
Aortenklappenöffnung
Outflowgraft
Inflowkanüle
…

CT-Untersuchung

↓

Inflowkanülenposition
Outflowgraftobstruktion
Perikardtamponade
Infektion (PET-CT)
…

Take Home

- Die aktuellen LVAD-Systeme zeigen hervorragende Überlebensdaten, sind allerdings weiterhin mit LVAD-spezifischen und LVAD-assoziierten Komplikationen behaftet
- Die häufigsten Komplikationen sind GI-Blutungen (30%), Driveline-Infekte (25%), Schlaganfälle (10%) und RV-Versagen (5%). Pumpenthrombosen treten nur noch selten auf (1-2%).
- Häufigste Ursache für „low-flow“-Alarme ist die Hypovolämie, allerdings müssen andere Ursachen ausgeschlossen werden (→ Echo und ggfs CT nötig!).
- Aufgrund verbesserter Hämokompatibilität kann die Antikoagulation (auch über längere) Zeiträume wenn nötig pausiert werden.
- Interdisziplinärer und patientenzentrierter Approach beim Komplikationsmanagement.