Diploma Thesis

The infarct associated cardiogenic shock

submitted by

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Affidavit

I hereby declare that this thesis is my own original work and that I have mentioned by name all persons and organisations that contributed to the research for this thesis.
I have not used any sources other than those specified in the thesis itself and clearly attributed any used concepts or quotations applicable to these sources.

Graz, August 14th 2022 Bastian Paul Gerjol eh.

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Abbreviation list

AMS……..Altered mental status
AI……..……..Aortic insufficiency
Alpha-r…….……..Alpha-receptor
ARDS……..…..Acute respiratory distress syndrome
AST……...……..Aortic stenosis
AV……..……..Atrio-ventricular
Beta-1-r……..Beta-1-receptor
BMI……..Body mass index
CABG…….…..Coronary artery bypass grafting
CCU……..Critical care unit
CHF……..Congestive heart failure
CI……..Cardiac index
cmH_2O……..……..Centimeter of water column
COPD…….……..Chronic obstructive pulmonary disease
CPR…….……...Cardiopulmonary resuscitation
CRF……..Case report form
CS……..Cardiogenic shock
DGAI……..……..Deutsche Gesellschaft für Anästhesiologie & Intensivmedizin
DGIIN……....Deutsche Gesellschaft für Internistische Intensivmedizin und Notfallmedizin
DGfK……...…….Deutsche Gesellschaft für Kardiotechnik
DGK…….……...Deutsche Gesellschaft für Kardiologie
DGNI……...……...Deutsche Gesellschaft für NeuroIntensiv- und Notfallmedizin
DGTHG……..Deutsche Gesellschaft für Thorax-, Herz- und Gefäßchirurgie
DIH……...……..Died in hospital
DIVI……..…….Deutschen Interdisziplinären Vereinigung für Intensiv- und Notfallmedizin
dL……..Deciliter
D-r……..……..Dopamine-receptor
ECMO……..Extracorporeal membrane oxygenation
EF……...……..Ejection fraction
ELGA……..……..Elektronische Gesundheitsakte

FiO_2……..……Fraction of inspired oxygen

g……...……Gram

GRC……...……German resuscitation council

HTX……Heart transplant

IABP……Intra-aortic balloon pump

IHCA……..……In-hospital cardiac arrest

ICS……...……Infarct-related cardiogenic shock

IL-1……..……Interleukin-1

IL-6……..……Interleukin-6

IQL……..……Interquartile range

KAGES……..……Krankenanstaltengesellschaft

HIS……..……Hospital information system

LAD……..……Left anterior descending artery

LCx……...……Left circumflex artery

LM……..……Left main artery

LV……...……Left ventricle

MAP……..……Mean arterial pressure

MCS……...……Mechanical circulatory support

Medocs……Hospital information system

MI……..……Myocardial infarction

mmHg……...……Millimeter of mercury

MOA……...……Mechanism of action

n……...……Number

NO……Nitrogen oxide

OHCA……Out of hospital cardiac arrest

OR……...……Odds ratio

p……Statistical significance

PAE……..……Pulmonary artery embolism

PCI……...……Percutaneous coronary intervention

PCWP……Pulmonary capillary wedge pressure

PEA……...……Pulseless electrical activity

PEEP……Positive end-expiratory pressure

PICIS……..……Intensive care information system

P-insp.……..……..…Inspiratory pressure

pPCI……...…Primary percutaneous coronary intervention

r……Correlation coefficient

RCA……...…..Right coronary artery

ROSC…….……Return of spontaneous circulation

RR……Blood pressure

RRsyst……...……Sysctolic blood pressure

RV……Right ventricle

SAVE……Survival after veno-arterial ECMO

SBP…….……Systolic blood pressure

SD……...……Standard deviation

SOP……...……Standard operating procedure

SSS……...……Sick sinus syndrome

STEMI…….ST-elevation myocardial infarction

UO……..……Urin output

VA……...……Veno-arterial

VAD……..……Ventricular assist device

VAV……...……Veno-arterial-venous

VT……..……..…Ventricular tachycardia

VV……..…….……Veno-venous

VVA……..…….……Veno-veno-arterial

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Zusammenfassung

Einleitung

Herz-Kreislauf-Erkrankungen gehören zu den häufigsten Ursachen für Morbidität und Mortalität. Dabei stellt der infarktassoziierte kardiogene Schock eine gefürchtete Komplikation eines akuten Myokardinfarkts dar, mit einer Sterblichkeitsrate von etwa 50 % (1). Trotz der Implementierung neuer medikamentöser Therapien und mechanischer Kreislaufunterstützungsverfahren sind die Studiendaten zu deren Wirksamkeit noch spärlich und benötigen weiteren Studien. Ziel dieser Studie ist es, individuelle Risikofaktoren und prognostische Marker für Patient*innen mit infarktassoziiertem kardiogenen Schock zu identifizieren und etablierte Therapieansätze zu bewerten.

Methoden

In dieser monozentrischen retrospektiven Datenanalyse wurden insgesamt 214 Personen mit katecholaminpflichtigem kardiogenen Schock eingeschlossen und hinsichtlich der Krankenhausaufenthalts-, Beatmungs- und CCU-Dauer, sowie der intrahospitalen Mortalität evaluiert. Die Krankendaten wurden mit Hilfe des Krankenhausinformationssystems Medocs und des Intensivpflege-Dokumentationsprogramms PICIS erfasst.

Ergebnisse

Die absolute Krankenhaus-Mortalität lag bei 43 % (n=92), wobei Männer eine Mortalität von 46% (n=71) und Frauen eine von 35% (n=21) aufwiesen (OR=1,6; RR= 1,3; p=0,167). Als unabhängige prognostische Marker, zeigten sich der initiale pH-Wert, der initiale Laktatwert, der initiale Hämoglobinwert, die CRP-Werte in den ersten 5 Tagen und der CPR-Status vor Zuweisung. Die Mortalität betrug 61 % (n=72) in der CPR-Gruppe und 20 % in der Gruppe ohne CPR (OR = 5,95; RR = 2,91; $p < 0,001$).

Conclusio

Der kardiogene Schock stellt nach wie vor ein großes Problem für die behandelnden Ärzt*innen dar und ist mit einer hohen Mortalität und Morbidität verbunden. Neue therapeutische Ansätze wie mechanische Kreislaufunterstützungssysteme sollten dazu beitragen, das Outcome der Patienten*innen zu verbessern, jedoch sind Studien diesbezüglich noch spärlich und weitere Forschung ist erforderlich, um sie zu evaluieren.

Abstract

Introduction

Cardiovascular diseases are among the most frequent causes of morbidity and mortality. Here, the infarct-associated cardiogenic shock presents a dreaded complication of an acute myocardial infarction, with a mortality rate of ~50% (1). Despite new drug therapies and the development of mechanical circulatory support devices in recent years, study data regarding their efficacy are still sparse and thus require further evaluation. This study aims to identify individual risk factors and prognostic markers for the outcome of patients with infarct-associated cardiogenic shock and to evaluate established therapeutic approaches.

Methods

In this monocentric retrospective data analysis, a total of 214 patients who received treatment for catecholamine-requiring cardiogenic shock were included and evaluated for duration of hospitalisation, invasive ventilation and duration spend on CCU as well as in-hospital mortality. Patient data were collected using the hospital information system Medocs and the intensive care documentation program PICIS.

Results

Overall, in-hospital mortality was 43% (n=92). In dependence of the sex, a mortality of 46% (n=71) for men and 35% (n=21) for women was shown, indicating a higher in-hospital mortality of men compared to women (OR=1.6, RR= 1.3, p=0.167).

Further, initial pH, CRP values over the first 5 days, initial hemoglobin, initial lactate, and CPR status before admission were shown to be independent prognostic markers. The mortality rate was shown to be 61% (n=72) in the CPR-group, compared to 20% in the no-CPR-group (OR = 5.95, RR = 2.91, $p < 0.001$).

Conclusion

Cardiogenic shock remains a major challenge for treating physicians with a high mortality and morbidity. New therapeutic approaches such as mechanical circulatory support systems might help to improve the outcome of patients, but current studies are still sparse and further research is needed to evaluate them.

1 | Introduction

Cardiovascular diseases are among the most important diseases in the developed world and are still associated with high mortality and morbidity. According to the Austrian statistics institute "Statistik Austria", 35.7% of deaths in Austria in the year 2020 were attributable to cardiovascular diseases (Statistik Austria, 2020). The clinical picture hereby ranges from chronic progressive diseases to acute life-threatening events, such as acute myocardial infarction and its complications, with one being the infarct-associated cardiogenic shock, which is associated with high mortality and morbidity and therefore poses a great challenge for treating medical personnel. Hence, it is of little surprise that cardiovascular diseases are the subject of current research, and that new therapeutic approaches and preventive measures are constantly being developed and implemented in everyday clinical practice.
However, in order to understand current therapeutic interventions and also possible new therapeutic approaches, it is important to have a basic knowledge of the physiology and pathophysiology of the cardiovascular system.

1.1 | Physiology

The main task of the cardiovascular system is to provide the body with blood, thereby ensuring the supply and removal of essential substances and metabolic waste.
This is achieved with a system of vessels that allow the passage of blood, with the interposed heart taking on the role of a central pump. The circulation of the blood is divided into two separate circuits, which partly take over different functions.

The pulmonary circulation, which ensures the enrichment of the blood with oxygen in the lungs, is divided from the systemic circulation, which serves to transport oxygen to the target cells, where it plays an essential role in metabolic processes and is thus of critical importance for maintaining important body functions. Regardless of the particular circulation, vessels leading away from the heart are called arteries, whereas vessels leading toward the heart are called veins.

Interposed between the arteries and veins are the capillaries, which represent the smallest vessels and are the place of substance and gas exchange between cells and blood. Like all organs, the heart itself requires adequate blood flow and pressure to allow its sufficient perfusion and therefore its proper function. This occurs via the coronary vessels, which are specialized arteries that arise from the proximal part of the ascending main artery, the aorta.

The coronary arteries are of great interest in medicine, due to being a frequent origin of cardiac problems, including acute infarction, and are therefore the target of many drug- and interventional therapies. It is important to keep the blood pressure in an optimal range to avoid hypoperfusion of tissues or the damaging effect of an elevated blood pressure. This is controlled by different autonomic mechanisms, which are also targets of different drug therapies.

Frank-Starling mechanism

The Frank-Starling mechanism describes the increased contractility of the heart, in relation to the end-diastolic filling volume of the heart (preload), within a certain range.

Here, an increased filling pressure leads to a greater stretching of the cardiac muscle fibers, resulting in an optimal contraction of the cardiac muscle with an increased ejection volume (2). These increased filling pressures, however, are at the expense of the heart‘s oxygen demand. With increasing wall-tension, the oxygen demand of the heart also increases, a mechanism that is also targeted by various drug therapies (3).

Sympathetic regulation

The arterial baroreflex assumes an important role in the short-term regulation of blood pressure. Its main function is to prevent rapid fluctuations in blood pressure. Baroreceptors in the carotid sinus and in the aortic arch register blood pressure fluctuations and react, depending on the blood pressure, with an increased vagotone or with a reduced inhibition of sympathetic tone, which eventually results in a decreased or increased heartrate and cardiac contractility (4).

1.2 | Cardiogenic shock

1.2.1 | Definition

Cardiogenic shock is a state of hemodynamic instability resulting from a malfunction of the myocardium, pericardium, valves, or conduction system of the heart, or from a combination of these factors (5). It is defined as an insufficient pumping action of the heart due to a primary cardiac pathology associated with inadequate tissue perfusion.

Classic signs of CS are volume-restricted hypotension requiring mechanical or pharmacologic support and clinical signs of end-organ damage, although the presence of hypotension is not mandatory for diagnosis (5). The SHOCK Trial further included a Cardiac index of < 2.2 and a PCWP of >15 mmHG as diagnostic criteria (6).

1.2.2 | Etiologies

The CS has a wide range of possible etiologies, which can be broadly divided into ischemic and nonischemic causes, whereas non-ischemic causes only make up for a small percentage of all CS (7). The most notable causes of non-ischemic CS are shown below (*table 1*).

Tab. 1 Causes of non-ischemic cardiogenic shock (8)	
Pharmacologic	• Beta blockers • Calcium channel blockers • Digoxin toxicity
Primary ventricular dysfunction	• Acute myocarditis • Stress cardiomyopathy i.e.: Takotsubo • Nonischemic cardiomyopathy i.e.: Amyloidosis, Sarcoidosis & Haemochromatosis
Outflow obstruction	• Valvular stenosis • Left ventricular outflow obstruction i.e.: hypertrophic cardiomyopathy
Acute valvular regurgitation	• Trauma • Degenerative disease • Endocarditis
Endocrine	• Sever hypothyroidism
Pericardial disease	• Cardiac tamponade • Pericardial constriction
Tachyarrhythmias	• Supraventricular tachyarrhythmias • Atrial tachyarrhythmias • Monomorphic VT • Polymorphic VT i.e.: Torsades de Pointes
Bradyarrhythmias	• Sinus node dysfunction • i.e.: SSS • AV node dysfunction
AV atrioventricular, **SSS** sick sinus syndrome, **VT** ventricular tachyarrhythmia.	

Far more common than the non-ischemic CS, are CS due to cardiac ischemia, with a large proportion of cardiac ischemia being due to acute myocardial infarction, which is the most common cause of cardiogenic shock at 79% (7). Ischemic cardiogenic shock can be further subdivided depending on the underlying mechanical disorder. The main mechanical disorders of CS, following cardiac ischemia, are listed in *table 2* (7).

Tab. 2 Underlying mechanical malfunctions of ischemic CS (7)	
Cause	**Frequency**
Predominant left ventricular failure	78.5%
Acute sever mitral regurgitation	6.9%
Ventricular septal rupture	3.9%
Isolated right ventricular failure	2.8%
Cardiac tamponade/rupture	1.4%
Others	6.7%
CS cardiogenic shock	

1.2.3 | Pathophysiology of infarct-related CS

The infarct-associated cardiogenic shock is a complex clinical picture. The precipitating event is decreased perfusion of the myocardium, which can lead to both systolic and diastolic dysfunction of the heart, which in turn leads to decreased cardiac output and ultimately to potentially life-threatening hypotension (9).

Compensatory, several mechanisms intervene to maintain an adequate supply of vital organs, which are:

- **Peripheral vasoconstriction**

  Sympathetically activated peripheral vasoconstriction helps to maintain adequate blood pressure. However, this occurs at the cost of increased afterload, which leads to increased work for the already damaged heart and can thereby overload it. This vicious circle, in turn, leads to hypoperfusion of organs, including the heart, worsening the situation even further (9).

- **Increase in heart rate**

  The increase in heart rate is aimed at maintaining blood pressure and thus organ perfusion. However, the increase in heart rate is accompanied by increased myocardial oxygen demand, which further promotes cardiac ischemia (9).

The above-mentioned compensatory mechanisms are opposed by pathological, systemic vasodilation. The cause of this systemic vasodilation is the release of interleukins (IL-1 & IL-6) and tumor necrosis factor - alpha. In addition, there is an increased release of NO and Peroxynitrite, which further promote vasodilation and are known to have cardiotoxic properties (9, 10).

1.2.4 | Diagnostic

To date, there is no uniform recommendation for the diagnosis of cardiogenic shock. Diagnostic criteria range from clinical presentation to invasive diagnostics. A diagnostic criterion for cardiogenic shock recognized by many authors is a reduction in systolic blood pressure to <90 mmHg or <100 mmHg, although a reduction in systolic blood pressure is not obligatory and is absent in about 25% of patients (6, 11-15). In patients with known hypertension, blood pressure values >30 mmHg below normal may be indicative of shock (11).

An overview of the various definitions and diagnostic criteria of cardiogenic shock is provided in *table 3* (16).

Tab. 3

Diagnostic criteria of various guidelines/studies for cardiogenic shock (16)

Clinical trial/guideline	Criteria
SCHOCK Trial (1999)(6)	• SBP <90 mm Hg for >30 min or vasopressor support to maintain SBP >90 mm Hg • Evidence of end-organ damage (UO <30 mL/h or cool extremities) • Hemodynamic criteria: CI <2.2 and PCWP >15 mmHg
IABP-SOAP II (2012)(12)	• MAP <70 mm Hg or SBP <100 mm Hg despite adequate fluid resuscitation (at least 1 L of crystalloids or 500 mL of colloids) • Evidence of end-organ damage (AMS, mottled skin, UO <0.5 mL/kg for 1h, or serum lactate >2 mmol/L)
EHS-PCI (2012)(13)	• SBP <90 mm Hg for 30 min or inotropes use to maintain SBP >90 mm Hg • Evidence of end-organ damage and increased filling pressures
ESC-HF Guidelines (2021)(17)	• Clinical signs of hypoperfusion: cold extremities, oliguria, narrow pulse pressure, dizziness, mental confusion. • Laboratory: metabolic acidosis, elevated serum lactate, elevated serum creatinine
KAMIR-NIH (2018)(15)	• SBP <90 mm Hg for >30 min or supportive intervention to maintain SBP >90 mm Hg • Evidence of end-organ damage (AMS, UO <30 mL/h, or cool extremities)

AMS altered mental status; **CI** cardiac index; **EHS PCI** Euro Heart Survey Percutaneous Coronary Intervention Registry; **ESC HF** European Society of Cardiology Heart Failure; **IABP-SOAP II** intra-aortic balloon pump in cardiogenic shock II; **KAMIR-NIH** Korean Acute Myocardial Infarction Registry-National Institutes of Health; **MAP** mean arterial pressure; **PCWP** pulmonary capillary wedge pressure; **SBP** systolic blood pressure; **SCHOCK** Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock; **UO** urine output.

1.2.4 | Therapy

The goal of ICS therapy is to restore adequate organ perfusion and reperfusion of occluded coronary arteries. The prognosis of ICS-patients is hereby determined by the earliest possible reperfusion of the blocked coronary vessels using pPCI and, less frequently in selected cases, by reperfusion using CABG (11). If neither of these procedures is available, the treatment of choice is fibrinolysis followed by cardiac catherization (11). The main objective of cardiovascular support is to maintain a MAP above 65 mmHg. However, values between 55 mmHg and 65 mmHg are tolerated if there is sufficient clinical stability or if the clinical picture tends to improve (11).

In the event of a non-sufficient MAP, cardiovascular support can be provided in several ways:

- Medical cardiovascular support (*table 4*)
- Mechanical cardiovascular support
    - ECMO
        - VA
        - VV
        - VAV
        - VVA
        - I-Cor®
    - LVAD
        - TandemHeart®
        - Impella
    - Others
        - IABP

1.2.5 | Medical cardiovascular support

Despite the regular use of vasopressors and inotropic agents, data is scarce and there are few studies comparing the different drugs in the context of ICS. Current guidelines advocate the administration of an inotropic agent in combination with a vasopressor (11).

When comparing dopamine with norepinephrine, studies have shown an increased 28-day mortality, as well as an increased risk of adverse events, including arrhythmia, when using Dopamine over Norepinephrine as the first line vasopressor in the treatment of CS (18). An overview of the most frequently used vasoactive substances is given in *table 4*.

Tab. 4

Vasopressor support in cardiogenic shock (16)

Drug	MOA	Note
Norepinephrine	▪ Alpha < Beta agonist	First-line vasopressor in ICS
Dobutamine	▪ Beta agonist	Second-line inotrope in ICS
Dopamine	▪ Dose dependent agonist D-r → Beta-1-r → Alpha-r	Seconds-line agent in ICS
Epinephrine	Alpha << Beta agonist	Second-line agent in ICS
Phenylephrine	Alpha-1 agonist	Increases afterload
Vasopressin		Risk of hyponatremia
Levosimendan	Ca^{2+} sensitizer K^{+} channel modifier	Used in acute decompensation of CHF

D-r dopamine receptor, **Beta-1-r** Beta-1 receptor, **CHF** Congestive heart failure, **D-r** Dopamine receptor **ICS** infarct associated cardiogenic shock, **MOA** mechanism of action

1.3 | Mechanical cardiovascular support

At this time, there are only a few mechanical circulatory supports that are routinely used in clinics. These differ both in their indications and contraindications, their method of implantation, as well as the localization and thus also the type of support they provide.

1.3.1 | ECMO

Extracorporeal membrane oxygenation (ECMO) is a modified heart-lung machine that, in the event of cardiac or pulmonary insufficiency, can support the function of these organs. Oxygen-depleted blood is withdrawn from the patient, oxygenated and decarbonated via a membrane, and pumped back into a main vein or artery (19). Depending on the vascular access, different types of ECMO can be distinguished.

- **Veno-arterial ECMO**

  Bypassing both the lungs and the heart, this type of ECMO provides both pulmonary and circulatory support. Therefore, it is suitable for acute cardiac insufficiencies, e.g. in the context of an infarction or myocarditis, decompensated chronic heart failures, as well as failure to recover after cardiopulmonary bypass (20). Common venous cannulation sites are the femoral vein or the jugular vein, arterial cannulation sites are the femoral artery or the subclavian artery, whereas the latter requires surgical placement and is associated with a higher risk of nerve or vessel injury (20).

- **VV ECMO**

  In contrast to VA-EMCMO, VV-ECMO does not bypass the heart and therefore does not provide circulatory support. It is mainly used in acute respiratory failure and has recently gained popularity due to its widespread use in Covid-19 associated respiratory failure and Covid-19 associated ARDS (20, 21).

- **VVA ECMO**

The veno-veno-arterial ECMO, is usually implied as an extension of a pre-existing veno-arterial ECMO, if its venous drainage is not sufficient. Common causes for extension are pulmonary hypertension, small vessel lumen, hemolysis due to high flow velocities, intracardiac shunts, harlequin syndrome & left ventricular distension. The second catheter is most commonly placed in the right atrium or right ventricle (20).

- **VAV ECMO**

Similar to the veno-veno-arterial ECMO, the veno-arterial-venous ECMO is usually established as an extension of an existing veno-arterial or veno-venous ECMO, mainly in the context of cardiac insufficiencies with secondary pulmonary decompensation and vice versa (20). With the help of a clamp, the preload, afterload, oxygenation, and the position of the watershed zone can be specifically controlled by the individual blood distribution through the two supplying catheters, which ensures an individual therapy, depending on the specific need (20).

Predictive scores for mortality during VA-ECMO-therapy

SAVE – Score

The Survival After Veno-arterial ECMO - Score, or SAVE - Score, was developed to estimate the probability of survival of patients with refractory cardiogenic shock undergoing veno-arterial ECMO therapy. It is based on 13 questions about the patient's condition prior to VA-ECMO and includes age, weight, etiology of cardiogenic shock, and involvement of other organ systems (22).

ENCOURAGE - score

The ENCOURAGE-score (ENCOURAGE = prEdictioN of Cardiogenic shock OUtcome foR AMI patients salvaGed by vaECMO) was developed to estimate the outcome of refractory cardiogenic shock patients in the context of VA-ECMO therapy, depending on various risk factors (23).

The ENCOURAGE score is based on 7 pre-interventional parameters (23):

- Age
- Female sex
- BMI < 25 kg/m^2
- Reduced Glasgow-Coma-Scale (<6)
- Creatinine <1,7 mg/dl
- Elevated lactate
- < 50% reduced prothrombin activity

The correlation of the probability of survival, depending on the Encourage score, is as follows (23):

- 0-12 points = 80%
- 13-18 points = 58%
- 19-22 points = 25%
- 23-27 points = 20%
- ≥ 28 points = 7%

1.3.2 | Left ventricular assist device

Impella

The Impella is a transvalvular pump that extends from the left ventricle into the aorta, which can be either implanted alone or in combination with other hemodynamic support system, including ECMO (24). Common indications for the implantation of an Impella are bridge to LVAD, bridge to HTx, weaning of ECMO and for hemodynamic stabilization during high-risk PCIs (25).

As of now, 3 different types of Impella are available, which differ in size, flow-rate and placement procedure (26). While the smaller sized devices, namely Impella 2.5 & Impella CP, are generally placed via an femoral artery catheter, guided through either fluoroscopy or echocardiography, the larger sized devices, namely Impella 5.0 & Impella 5.0/LD, usually require a placement via arteriotomy (26).

With flow rates of up to 2.5 l/min (Impella 2.5), 4 l/min (Impella CP) and 5 l/min (Impella 5.0 & Impella 5.0/LD), Impella devices lead to a significant increase in cardiac output and thus to an increase in MAP, as well as to a reduction in oxygen demand, by reducing myocardial work, which makes it a popular therapy of choice in cardiogenic shock, despite data being sparse in terms of overall survival (24).

Tandem Heart

The Tandem heart is a ventricular assist device that can be used both in the emergency setting, as a bridging device until a definite therapy decision is made, and prophylactically, for high risk coronary interventions (27).

Unlike many other VADs, Tandem Heart does not require surgical intervention for placement. Using a venous catheter, a transseptal puncture is performed via the right atrium, through which the outflow catheter is placed in the left atrium. The arterial return catheter is usually placed via the femoral artery at the level of the aortic bifurcation (27).

Studies by Smith L. et al. (28) have shown that patients experienced a significant improvement of their hemodynamic situation after implantation of the Tandem heart. Average cardiac output was increased significantly from 1.8 +/- 0.6 to 3.1 +/- 1.0 L/min/m^2 (p= 0,007), yet mortality remained high (28).

Intra-aortic balloon pump

In the past, the intra-aortic balloon pump was one of the most commonly used mechanical support procedures in the treatment of infarct-associated cardiogenic shock (29).

With only minimal effect on cardiac output (0,5 L/min), the IABP´s function is mainly based on the diastolic expansion of an intra-aortic balloon, which, by displacing blood to the periphery, is intended to reduce the afterload of the heart and thus the left ventricular wall stress and, subsequently, cardiac oxygen consumption (30, 31).

Although studies have demonstrated the positive effect of IABP on certain hemodynamic parameters, no evidence of a positive effect on overall-survival has been

Provided, which led to the decrease in the use of the IABP in CS (12, 29, 32, 33).

1.3.3 | Decision making algorithms

Interventionally implanted, mechanical assist devices, such as Impella and VA-ECMO, at the University Hospital Graz are going to be used exclusively as a bridging procedure until improvement, HTX, another device, or a definitive decision is made.

Indications and contraindications for the implantation of an assist device, as well as the choice of the appropriate device, were elaborated with accordance to the most recent international experiences in the field of these kind of therapies. Depending on the resuscitation status, the two following decision-making algorithms are going to be used:

Decision-making algorithm in refractory cardiogenic shock without CPR:

Initial check upon arrival (based on criteria of the SHOCK trial (7)):

- (Biological) Age <70 years
- Highly restricted LV/RV-EF
- RRsyst. <90mmHg for > 30 minutes and/or requiring catecholamines
- Oliguria (<30ml/h)
- Lactate > 2mmol
- Insufficient organ perfusion (especially cerebral- and skin-signs)

Contraindications:

- Relevant co-morbidities (COPD ≥ III, neurological, internistic or especially hemato-oncological underlying diseases with palliative approach)
- pH <7,1 and/or Lactate >15

Decision algorithm for cardiac arrest:

Initial check (based on Consensus statement of DGIIN, DGK, DGTHG, DGfK, DGNI, DGAI, DIVI and GRC (34)):

- Biological age <60 years
- No-flow-time < 5 minutes
- $EtCO_2$ > 10mmHg while CPR
- CPR < 30 minutes

Contraindications:

- No bystander-CPR or No-flow time >10 minutes
- Relevant co-morbidities (COPD ≥ III, neurological, internistic or especially hemato-oncological underlying diseases with palliative approach)
- pH <6,8 and/or Lactate >20
- CPR >45 minutes without ROSC
- Contraindication against anticoagulation (active bleeding, relevant trauma, hemothorax post CPR)

Additional evaluation of exclusion criteria in the cardiac catheterization laboratory based on a BGA (arterial BGA preferred):

- Lactate >15
- pH <7,1

If ≥1 criteria: critical reevaluation of indication for assist device

If, based on the algorithms described above, there is an indication for the implementation of an assist device and there are no contraindications, the respective personnel requirements must still be met in order to allow an intervention.

The decision between Impella and ECMO is made following an arterial BGA and an ultrasound according to the following criteria:

- Horowitz-Index <100mmHg ECMO
- Horowitz-Index >150mmHg Impella
- AST ECMO
- AI Impella
- Significant right-heart involvement ECMO
- Mechanical infarct complication Impella

2 | Methods and materials

2.1 | Study design

A single-center retrospective data analysis was performed with consecutive patient inclusion of all patients (n=214), treated with catecholamine-requiring cardiogenic shock over a period of 2 years from April 2017 to March 2019.
The study included all patients aged 18-99 years who received pharmacological circulatory stabilization measures using Arterenol (norepinephrine) prior to or during cardiac catheterization at the University Hospital Graz for suspected cardiogenic shock.

Objective of the study is to estimate morbidity and mortality as a consequence of vasopressor-requiring infarct-associated cardiogenic shock in relation to individual risk factors and preexisting conditions, and to evaluate the outcome of patients fitted with a mechanical assist device (Impella).
In addition, this study serves as a basis for a comparative study, based on a prospective study, after implementation of routine VA-ECMO therapy at the Heart Center of the University Hospital Graz, over a 2 year-period, following the same CRF.

2.1.1 | Prognostic markers and preexisting conditions

As individual prognostic markers, emphasis was placed on preexisting conditions and known cardiovascular risk factors, including sex, BMI, known hypertension, hypercholesterolemia, smoking history, renal insufficiency, peripheral artery disease, prior PCI, prior MI, prior CABG, heart failure and significant valvular disease.
In addition, patient's outcome was assessed in relation to clinical and prehospital cardiopulmonary resuscitation, its delay and duration, as well as the time to PCI and, if applicable, the time to Assist device placement.

2.1.2 | Assessment

Vital signs and laboratory chemical markers were determined at 0, 4, 8, and 24 hours after hospitalisation and then measured twice daily for an additional 5 days, with latter also including invasive or noninvasive ventilation data, in accordance with a standardized CRF.

2.1.3 | Study endpoints

The primary endpoint was defined as the in-hospital mortality.

Secondary endpoints were defined as BARC 2-5 bleedings, duration of intensive care and ventilator dependency, total hospitalisation duration, and duration of mechanical circulatory support.

2.1.4 | Procedures

No study-specific measures were taken during the study, nor were any study medications administered. Treatment was performed according to an SOP in accordance with current guidelines for the treatment of cardiogenic shock.

2.1.5 | Study population

All vasopressor-requiring patients of the cardiac catheterization laboratory of the University Hospital Graz, in the time of April 2017 to March 2019 were included.

2.1.6 | Recruitment

Patients were selected by trained specialists of the cardiac catheterization laboratory of the University Hospital Graz, according to defined inclusion and exclusion criteria.

Subsequently, the inclusion and possible exclusion criteria were rechecked with the help of the hospital information system Medocs and the intensive care documentation program PICIS.

2.1.7 | Inclusion criteria

All patients with vasopressor need in the cardiac catheter laboratory of the University Hospital Graz.

2.1.8 | Exclusion criteria

All patients under 18, as well as those over 99.

2.2 | Data collection

Data were collected from the hospital information system Medocs, as with the critical care information system PICIS. The data obtained during treatment, which was performed according to the SOP of the University Hospital Graz for cardiogenic shock, was collected retrospectively according to a standardized CRF.

The documentation of the vasopressor requirement, as well as patient data necessary for clear identification, were documented in a non-publicly accessible protocol.

2.3 | Ethics

The approval of the Ethics Committee (No. 31-323 ex18/19) was obtained in accordance with Austrian law.

2.4 | Privacy

The patient records are anonymized and consecutively numbered. The correlating names are stored separately in a location that is not publicly accessible.

2.5 | Statistical analysis

Statistical analyses, as well as graphs and tables were created using both Microsoft Excel 16.54 and R 4.1.3. p-values < 0.05 were considered statistically significant.

3 | Results

3.1 | Study population

During a 2-year period from March 2017 to April 2019, 214 subjects received periinterventional circulatory support with catecholamines in the cardiac catheterization laboratory of the University Hospital Graz and thus matched the inclusion criteria. The median age of the study population was 69 (IQR: 60-78), with the youngest patient being 26 and the oldest being 92 years old.

Figure 1 shows the age distribution of the entire study population. The gender distribution was 60 (28%) women and 154 (72%) men. 55.1 % (n=118) of the patients required cardio-pulmonary resuscitation before admission to the cardiac catheterization laboratory (CPR group).

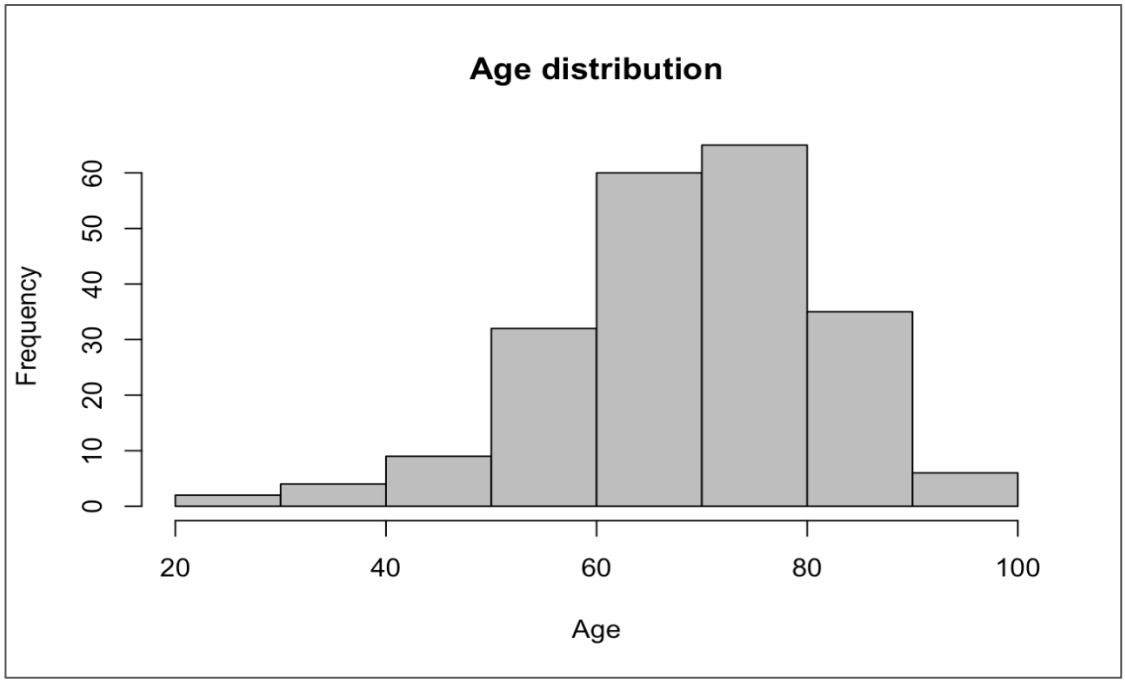

Fig. 1 Age distribution of study population

3.1.1 | Characteristics by CPR status

Table 5 shows the demographic data grouped according to the resuscitation status of the patients.

Tab. 5
Patient characteristics grouped by CPR status

Characteristics of included patients	All patients (n= 214)	CPR patients (n= 118)	No CPR patients (n= 96)	CPR vs. no CPR (OR [95% CI])
Age [years], median (IQR) - Age > 60 years, n (%) - Age > 70 years, n (%)	69 (60-78) 166 (77.6) 106 (49.5)	68 (59-76) 86 (72.9) 53 (44.9)	71 (63-79) 80 (83.3) 53 (55.2)	p= 0.05 OR 0.61 [0.31-1.22] p= 0.16 OR 0.70 [0.41-1.22], p= 0.209
BMI, median (IQR)	27.7 (24.7-30.9)	27.8 (24.7-30.9)	27.4 (24.4-30.8)	p= 0.46
Female gender, n (%)	60 (28)	36 (31)	24 (25)	OR 1,32 [0.69-2,54] p= 0.44
Known diabetes, n (%)	43 (20)	25 (21.1)	18 (18.8)	OR 1.16 [0.56-2.45] p= 0.73
Known hypertension, n (%)	111 (51.9)	58 (49.2)	53 (55.2)	OR 0.79 [0.44-1.39] p= 0.41
Known dyslipidemia, n (%)	48 (22.42)	33 (28)	15 (15.6)	OR 2.09 [1.01-4.46] p= 0.033
Known smoker/ex- smoker, n (%)	40 (24.2)	9 (7.6)	31 (32.3)	OR 0.70 [0.27-1.65] p= 0.440
Known prior MI, n (%)	21 (9.8)	13 (11.4)	8 (8.3)	OR 1.36 [0.49-3.96] p= 0.645
Known prior PCI, n (%)	19 (8.18)	12 (10.1)	7 (7.3)	OR 1.44 [0.5- 4.5] p= 0.63
Etiology of CS, n (%) - acute MI - others	145 (67.8) 69 (32.2)	86 (72.9) 32 (27.1)	59 (61.5) 37 (38.5)	OR 1.69 [0.91-3.13] p= 0.08
Initial lactate [mmol/L], median (IQR)	1.9 (1.3-4.4)	2.95 (1.48-6.58)	1.5 (1.1-2)	p= 0.012
Initial pH-value, median (IQR)	7.34 (7.24-7.4)	7.29 (7.18-7.37)	7.38 (7.32-7.44)	p= 0.42
Initial $RR_{syst.}$ [mmHg], median (IQR)	105 (84-121)	98 (79-123)	107 (90-118)	p= 0.35

Intubated at arrival, n (%)	127 (59.3)	102 (86.4)	25 (26)	OR 24.14 [11.38-51.21] p< 0.001
Decision to implant MCS device, n (%)	14 (6.5)	9 (0.8)	5 (5.2)	OR 1.56 [0.50-4.82]
Successful implantation, n (%)	14 (100)	9 (100)	5 (100)	p= 0.44
Length of CCU stay [days], median (IQR)	4 (2-9)	5 (1-12)	3 (2-5)	p= 0.014
Length of CCU stay after surviving day 1 [days], median (IQR)	5 (3-11)	8.5 (4-15)	4 (3-5)	p= 0.002
Length of hospital stay [days], median (IQR)	8 (3-16.8)	8 (1-20)	8 (5-14.25)	p= 0.139
Respirator duration [days], median (IQR)	1 (0-5)	3 (1-8)	0 (0-1)	P< 0.001
Bleeding event, n (%)	39 (18.2)	31 (26.3)	8 (8.3)	OR 4.11 [1.79-9.45] p< 0.001
Intrahospital mortality, n (%)	93 (43.5)	54 (45.8)	38 (40.0)	OR 1.29 [0.75-2.22] p= 0.36

BMI Body Mass Index, **CCU** Critical Care Unit, **CI** Confidence Interval, **CPR** Cardiopulmonary Resuscitation, **CS** Cardiogenic Shock, **OR** Odds Ratio, **IQR** Interquartile Range, **MCS** Mechanical **C**irculatory **S**upport, **MI** Myocardial Infarction, **PCI** Percutaneous **C**oronary **I**ntervention, **RR_{syst}** Systolic Blood Pressure, **SOP** Standard Operating Procedure

Only 28% (n=60) of the included patients were female, of which 60% (n=36) required resuscitation. The median age of the no-CPR group was 3 years higher than the CPR group (71 vs. 68 years).

Figure 1 shows the total age distribution of all included patients.

The no-CPR group contained more smokers (32.3%, n=31), than the reanimated group, (7.6%, n=7). The most common underlying cause of cardiogenic shock in both groups was shown to be the acute myocardial infarction, with a total prevalence of 67,8%.

The resuscitated group showed statistically significant higher initial lactate values, higher rates of respirator dependency, longer CCU stay, and more bleeding events.

3.1.2 | Characteristics by in-hospital survival

Furthermore, the patient characteristics were assessed in relation to intrahospital survival (table 6). A statistically significant difference in the group of patients deceased during initial hospitalisation was a higher median age (71 vs. 67, p=0.002), a median initial lactate of 2.9 mmol/L higher (1.5 vs. 4.4, p=0.008), and a median initial blood pressure of 12 mmHg lower, compared to the group of patients that were discharged.

Tab. 6
Characteristics in dependence of intrahospital death

	Died in hospital (n=92)	**Survivors (n=121)**	**Mortality**	
Age [years], Median (IQR)	71 (65-79)	67 (59-76)		p=0.002
- Age > 60, n (%) - Age < 60, n (%)	76 (82.6) 16 (17.4)	89 (73.6) 33 (16.4)	46.1% 32.7%	OR 1.76 [95% CI (0.86-3.64); p=0.10]
- Age > 70, n (%) - Age < 70, n (%)	67 (72.8) 25 (27.2)	64 (52.9) 57 (47.1)	51.1% 30.5%	OR 2.39 [95% CI (1.28-4.45); p=0.004]
BMI, Median (IQR)	26.3 (24.53-29.85)	27.8 (26-31.25)		p=0.126
Known diabetes mellitus, n (%)	19 (20.7)	24 (19.8)	44.2%	OR 1.05 [95% CI (0.51-2.18); p=1]
Gender, n (%) - Male - Female	 64 (69.6) 28 (30.4)	 90 (74.4) 31 (25.6)	 41.6% 47.5%	OR 0.79 [95% CI (0.41-1.5); p=0.444]
CPR, n (%) - IHCA, n (%) - OHCA, n (%)	72 (78.3) 25 (34.7) 47 (65.3)	46 (38) 9 (19.6) 37 (80.4)	61% 73.5% 56%	OR 5.87 [95% CI (3.04-11.43); p<0.001] OR 0.46 [95% CI (0.17-1.18); p=0.096]
Initial lactate [mmol/L], median (IQR)	4.4 (2-9.65)	1.5 (1-2.28)		p=0.008
Lactate within first 4 hours [mmol/L], median (IQR)	3.45 (1.4-6.35)	1.3 (0.9-2.1)		p=0.005
Initial pH-value, median (IQR)	7.28 (7.16-7.38)	7.36 (7.31-7.41)		p=0.383
RRsyst [mmHg], median (IQR) - Initial - 4h - 8h - 24h	 95 (74-113) 115 (93-131) 110 (94-125) 115 (100-127)	 107 (91-122) 115 (103-131) 115 (104-130) 114 (103-125)		 p=0.05 p=0.084 p=0.10 p=0.945
Intubated upon arrival, n (%)	75 (81.5)	52 (43)	59.1%	OR 5.85 [95% CI (2.96-11.68); p<0.001]
Complete revascularization achieved, n (%)	18 (19.6)	48 (39.7)	27.3%	OR 0.37 [95% CI (0.19-0.73); p=0.002]

BMI Body Mass Index, **CI** Confidence interval, **CPR** Cardiopulmonary Resuscitation, **IHCA** in-hospital cardiac arrest, **OHCA** out of hospital cardiac arrest, OR odds ratio, RRsyst systolic blood pressure

Table 7 further compares risk factors, as well as key initial parameters by patient admission, depending on in-hospital mortality.

Tab. 7
Risk factors

Characteristics of included patients	All patients (n= 214)	Died in hospital (n=92)	Survived (n=121)	Died in hospital vs. survived (OR [95% CI])
Age [years], median (IQR)	69 (60-78)	71 (65-79)	67 (59-76)	p= 0.002
- age > 60 years, n (%)	166 (77.6)	76 (82.6)	89 (73.6)	OR 1.82 [0.87-3.83] p= 0.096
- age > 70 years, n (%)	106 (49.5)	54 (58.7)	51 (55.2)	OR 1.95 [1.09-3.51], p= 0.019
BMI, median (IQR)	27.7 (24.7-30.9)	26.3 (24.5-29.9)	27.8 (26-31.3)	p= 0.126
female gender, n (%)	60 (28)	28 (30.4)	31 (25.6)	OR 1.27 [0.67-2,43] p= 0.44
Initial rhythm				
- VF/VT	52 (24.3)	24 (26.1)	28 (23.1)	
- PEA	17 (7.9)	13 (14.1)	4 (3.3)	
- Asystole	16 (7.5)	14 (15.2)	2 (1.7)	
- Unknown	33 (15.4)	21 (22.8)	12 (9.9)	
BLS				
- yes	115	69	46	OR 0.02
- no	3	3	0	[<0.001-2,95]
- no BLS needed	96	20	75	p= 0.28
No-flow time [min], n (%)				
- 0	90	56	34	
- 0-10	5	5	0	
- Unknown	23	11	12	
Low-flow time [min], median (IQR)	20 (10-45)	35 (15-63)	12.5 (9.5-20)	
Initial lactate [mmol/L], median (IQR)	1.9 (1.3-4.4)	4.4 (2-9.7)	1.5 (1-2.3)	p= 0.008
Initial pH-value, median (IQR)	7.34 (7.24-7.4)	7.28 (7.16-7.38)	7.36 (7.31-7.41)	p=0.38
$RR_{syst.}$ [mmHg], median (IQR)				
- Initial	105 (84-121)	95 (74-113)	107 (90-122)	p= 0.05
- 4h	115 (101-131)	115 (93-131)	115 (103-131)	p= 0.084
- 8h	114 (101-128)	110 (95-125)	115 (104-130)	p= 0.1
- 24h	114 (103-126)	115 (100-127)	114 (103-125)	p= 0.94
Intubated at arrival, n (%)	127 (59.3)	75 (81.5)	52 (43)	OR 5.85 [2.96-11.68] p<0.001

BLS basic life support, **BMI** Body Mass Index, **CCU** Critical Care Unit, **CI** Confidence Interval, **CPR** Cardiopulmonary Resuscitation, **CS** Cardiogenic Shock, **OR** Odds Ratio, **IQR** Interquartile Range, **MCS** Mechanical **C**irculatory **S**upport, **MI** Myocardial Infarction, **PEA** pulseless electrical activity, **PCI** Percutaneous **C**oronary **I**ntervention, **RR_{syst}** Systolic Blood Pressure, **SOP** Standard Operating Procedure**, VF ventricular fibrillation, VT ventricular tachycardia**

The group of deceased patients showed a statistically significant higher age, higher initial lactate, and a higher intubation rate at admission.

The most frequent initial rhythm of resuscitated patients at first medical contact was found to be ventricular fibrillation or ventricular tachycardia in both groups.

The group of patients who died in hospital has almost 3 times the median low-flow time of the survivor group. In addition, the survivor group in this study has no patients with a delay to the start of cardiovascular resuscitation.

With a median of 95 mmHg, the group of in-hospital decedents has an initial blood pressure 12 units lower than the survivor group.

4h, 8h & 16h after admission, no significant median blood pressure differences were found between both groups.

3.2 | Underlying disease

Most frequent reason for CS was the acute ST-elevation myocardial infarction (STEMI) with 41% (n=89), followed by ongoing CPR without pre-hospital evidence of acute myocardial infarction, or st. p. CPR with 39% (n=80), non-ST-elevation myocardial infarction (NSTEMI) with 14% (n=31), others with 6% (n=13), and PAE with 0.4% (n=1) (*table 8*).

Tab. 8

Underlying disease of CS

Underlying disease	**Frequency**
STEMI	89 (41.6%)
CPR	80 (37.4%)
NSTEMI	31 (14.5%)
Other	13 (6.1%)
PAE	1 (0.4%)
Total	**214**

CPR Cardiopulmonary resuscitation, **CS** Cardiogenic shock, **NSTEMI** Non-ST-Elevation Myocardial Infarction, **STEMI** ST-Elevation Myocardial Infarction, **PAE** Pulmonary artery embolism

3.3 | Outcome depending on CPR status

When comparing the outcome of patients by CPR status, the study was able to show a statistically significant increase in median CCU stay (5 vs. 3 days, p=0.014), median CCU stay for patients surviving the first day after admission (6 vs. 3 days, p=0.002), median respirator duration (3 vs. 0 days, p<0.001), as well as number of bleeding events (31 vs. 8, p<0.001).

The biggest difference could be seen at the in-hospital mortality, with 61% (n=72) of patients in the CPR group dying during their initial hospitalisation, whereas only 20.8% (n=20) of those who did not receive CPR suffered a fatal outcome (p<0.001) (*table 9*).

Tab. 9
Outcome by CPR-status

Category	CPR (n=118)	No-CPR (n=96)	CPR vs. No-CPR
Length of CCU stay [days], median (IQR)	5 (1-12)	3 (2-5)	p= 0.014
Length of CCU stay after surviving day 1 [days], median (IQR)	6 (4-9)	3 (3-5)	p= 0.002
Length of hospital stay [days], median (IQR)	8 (1-20)	8 (5-12.5)	p= 0.13
Respirator duration [days], median (IQR)	3 (1-8)	0 (0-1)	P< 0.001
Bleeding event, n (%)	31 (26.3)	8 (8.3)	OR 3.92 [1.61-9.85] p< 0.001
In-hospital mortality, n (%)	72 (61)	20 (20.8)	OR 5.95 [3.1-11.6] p<0.001

CCU Cardiac care unit, **CPR** Cardiopulmonary resuscitation, **IQR** Interquartile range

3.4 | Mortality

The absolute in-hospital mortality was 43% (n=92), with an average mortality of 46% (n=71) among men and 35% (n=21) among women, indicating a higher mortality in men than women (OR= 1,6; RR: 1,3; p=0,167).

The majority of in-hospital deceased patients died within the first 10 days after hospitalisation (77%, n=70), with 49% (n=30) of those dying on the day of admission (*figure 2*).

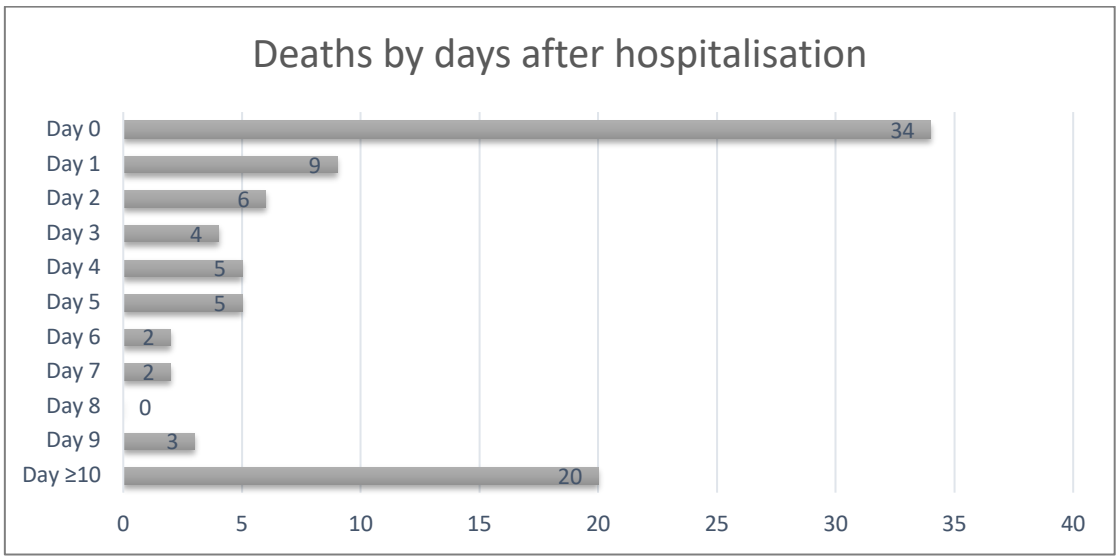

Fig. 2 Deaths by days after admission

3.4.1 | Mortality of patients depending on CPR status

In *table 10 & 11*, the in-hospital mortality was also considered in relation to the risk factors age, sex, initial lactate, and initial pH, separately for the groups CPR and no-CPR.

Tab. 10
Outcome of patients with CPR prior to admission

	Died in hospital (n=72)	Survivors (n=46)	Mortality	
Age [years], n (%) • >= 60 • < 60	 64 (88.9%) 8 (11,1%)	 34 (73.9%) 12 (26,1%)	 65.3% 40%	OR=2.82 [95% CI (0.96-8.49), p=0.043]
Age [years], n (%) • >= 65 • < 65	 56 (77.8%) 16 (22.2%)	 25 (54.3%) 21 (45.7%)	 69.1% 43.2%	OR=2.94 [95% CI (1.22-7.11), p=0.009]
Age [years], n (%) • >= 70 • < 70	 50 (69.4%) 22 (30.6%)	 20 (43.5%) 26 (56.5%)	 71.4% 45.8%	OR= 2.95 [CI (1.28-6.88), p=0.007]
Sex, n (%) • Male • female	 48 (66.7%) 24 (33.3%)	 34 (73.9%) 12 (26.1%)	 58.5% 66.7%	OR= 0.71 [CI (0.29-1.73), p=0.422]
Initial lactate [mmol/L], median (IQR)	5.6 (2.45-10.4)	1.8 (1.8-3.53)		p= 0.023
Initial pH, median (IQR)	7.24 (7.14-7.38)	7.34 (7.25-7.37)		p=0.358

CI 95% Confidence interval, CPR Cardiopulmonary resuscitation, **IQR** Interquartile range, **OR** Odds ratio

For the CPR group, a significantly increased mortality was shown for persons >60, which tends to increase with higher age.
In addition, individuals who died during the initial hospitalisation had a median lactate level 3.8 mmol/L higher than the group of individuals who were discharged alive.

For the no-CPR group, a statistically significant increase in mortality during initial hospitalisation could be seen for patients >70 years. Further, as the patients who received CPR, an increased initial lactate could be seen in patients who suffered a fatal course during hospitalisation.

Tab. 11
Outcome of patients without CPR prior to admission

	Died in hospital (n=20)	Survivors (n=75)	Mortality	
Age [years], n (%) • >= 60 • < 60	 18 (94.7%) 1 (5.3%)	 65 (86.7%) 10 (13.3%)	 21.7% 9.1%	OR=2.77 [95% CI (0.32-62.58), p=0.452]
Age [years], n (%) • >= 65 • < 65	 18 (94.7%) 1 (5.3%)	 56 (74.7%) 19 (25.3%)	 24.3% 5%	OR=6.1 [95% CI (0.76-132.7), p=0.065]
Age [years], n (%) • >= 70 • < 70	 17 (89.5%) 2 (10.5%)	 44 (58.7%) 31 (41.3%)	 27.9% 6.1%	OR= 5.99 [CI (1.19-40.54), p=0,014]
Sex, n (%) • Male • female	 16 (80%) 4 (20%)	 56 (74,7%) 19 (25.3%)	 22.2% 17.4%	OR= 1.36 [CI (0.36-5.5), p=0,773]
Initial lactate [mmol/L], median (IQR)	2.1 (1.4-4.6)	1.4 (1-1.8)		p= 0.033
Initial pH, median (IQR)	7.35 (7.28-7.43)	7.38 (7.32-7.44)		p=0.169

CI 95% Confidence interval, **CPR** Cardiopulmonary resuscitation, **IQR** Interquartile range, **OR** Odds ratio

3.4.2 | Mortality by culprit vessel

In 85% (n=183) of the patients, a causative coronary vessel could be identified during the initial cardiac catheterization. In 15% (n=32), no underlying coronary artery disease could be identified. Among the 15% of non-vascular causes, decompensated heart disease (18%), valvular recovery (6%), aortic dissection (6%), arrhythmias (3%), and vasospasm (3%) were identified as causative. In 59% of non-vascular originated shocks, no definite cause could be identified.

Figure 3 provides an overview of the in-hospital mortality depending on the identified culprit vessel.

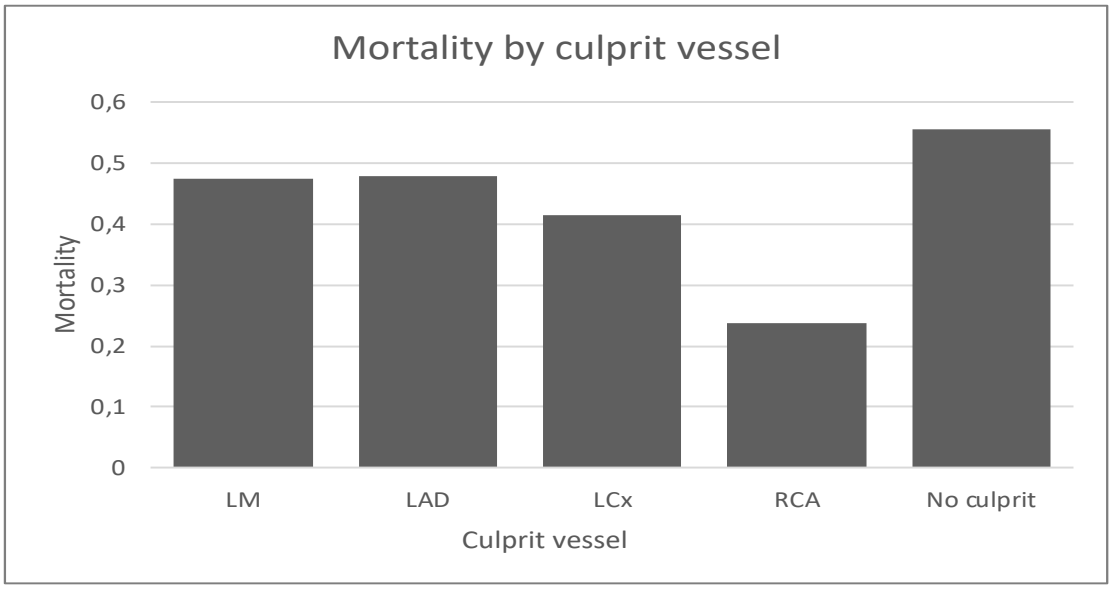

Fig. 3 In hospital mortality by culprit vessel; **LAD** Left Anterior Descending, **LCx** Left Circumflex, **LM** Left Main, **RCA** Right Coronary Artery

3.4.3 | Mortality by risk factor

In addition, an analysis of in-hospital mortality was performed, depending on the risk factors sex, age, BMI, CPR, and initial lactate level at admission, which showed a significantly increased mortality for patients with CPR prior to admission (*table 12*).

Tab. 12
In-hospital mortality by risk factors

	In-hospital death	**Discharged**	
Gender • male • female	 46% (n=71) 35% (n=21)	 53% (n=83) 65% (n=39)	OR = 1.59, p = 0.167
Age • > 60 • < 60	 45% (n=82) 30% (n=9)	 55% (n=99) 69% (n=22)	OR = 2.02, p = 0.11
BMI, mean [SD]	27,7 [+/- 5]	28,9 [+/- 6]	p = 0.41
CPR before admission	61% (n= 72)	39% (n= 46)	OR = 5,95, p=0.0
Lactate on arrival [mmol/L] • 0-5 • 6-10 • 11-15 • >16	 28% (n=33) 72% (n=13) 100% (n=10) 100% (n=4)	 72% (n=85) 28% (n=5) 0% (n=0) 0% (n=0)	

BMI Body Mass Index, **OR** Odds Ratio, **SD** Standard Deviation

3.4.4 | Mortality by day of admission

In comparison between the admission days of patients on fully occupied working days of the cardiac catheter laboratory of the University Hospital Graz from Monday to Friday, with admission days on the days Saturday & Sunday, occupied only for emergencies, there was no difference in relative mortality. The average mortality was 42% (n=65) on weekdays and 43% (n=27) on weekends.

Average mortality by day of the week is shown in *figure 4*.

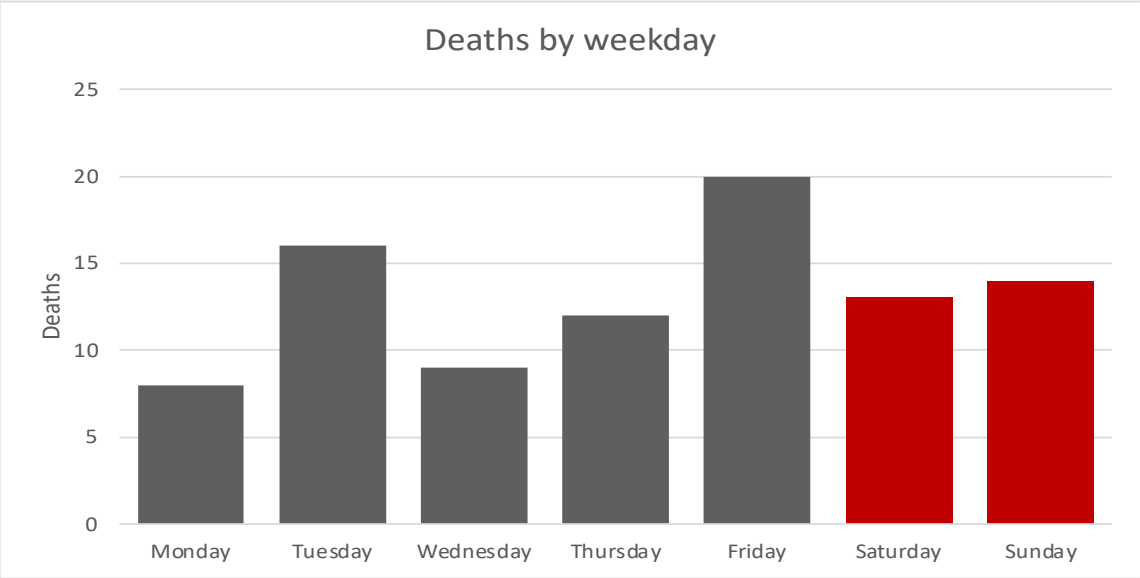

Fig. 4 Average deaths by weekday

3.4.5 | Mortality by time of admission

Furthermore, an analysis was performed regarding in-hospital mortality with respect to the patients' admission time. The regular working hours in the period from 08:00 a.m. to 4:00 p.m., in which the cardiac catheterization laboratory is fully staffed, were compared with the period from 4:01 p.m. to 07:59 a.m., in which the cardiac catheterization laboratory is in emergency standby with a reduced staffing ratio.

The comparison showed a significant increase in mean mortality (p=0.038) from 36,1% (n=39) outside regular operating hours to 50% (n=53) within regular operating hours (*figure 5*).

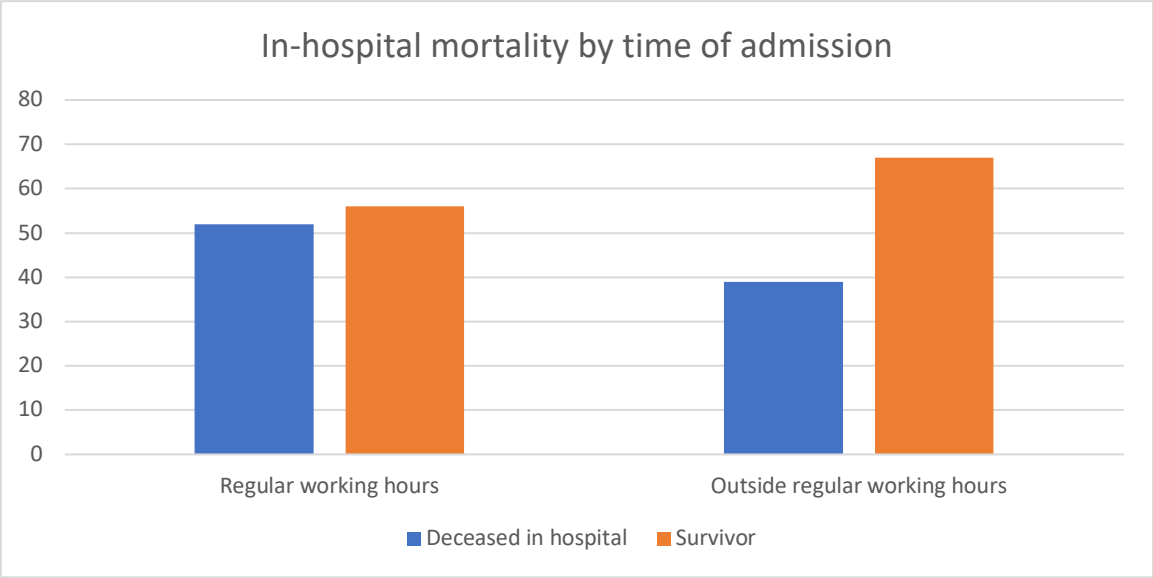

Fig. 5 Comparison of in-hospital mortality by time of admission. Mortality is given in %

The analysis revealed an uneven distribution of admissions of patients with cardiogenic shock. In the period from 8:00 a.m. to 4:00 p.m., a total of 108 patients presented to the cardiac catheterization laboratory, whereas in the period from 4:00 p.m. to 8:00 p.m., which is twice as long, only 106 patients were admitted.

3.4.6 | Mortality by MCS status

In the resuscitated (CPR) group, there was no significant difference in mortality between patients provided with a MCS and patients who were not provided with one, but who would have been eligible for a MCS according to the SOP implemented after this study period. Similarly, when considering the no-CPR group, no significant difference in mortality was observed between individuals who received a MCS and individuals who did not receive a MCS.

Tables 13-16 provide an overview of the mortality depending on the initial lactate value and the initial pH value, for the groups CPR with MCS, CPR without MCS, no CPR with MCS & no CPR without MCS. All groups showed an increase in mortality with increasing lactate levels. Patients with missing values were included in the group's total patient count (n) but were excluded in the further process.

Tab. 13
CPR patients with MCS, Correlation of lactate and pH with in-hospital mortality

	Died in hospital (n=9)	Survivors (n=0)	Mortality
Initial lactate [mmol/L], n (%)			
- <2	1	0	100%
- <4	2	0	100%
- <6	3	0	100%
- <8	3	0	100%
- <10	5	0	100%
- >10	1	0	100%
- >15	0	0	100%
- >20			
Initial pH-value, n (%)			
- >7.3	2	0	100%
- <7.3	6	0	100%
- <7.2	4	0	100%
- <7.1	1	0	100%
- <7.0	0	0	100%
- <6.9	0	0	100%
- <6.8	0	0	100%

CPR Cardiopulmonary resuscitation, **MCS** Mechanical circulatory support

Tab. 14
CPR patients without MCS, Correlation of lactate and pH with in-hospital mortality

	Died in hospital (n=63)	Survivors (n=47)	Mortality
Initial lactate [mmol/L], n (%)			
- <2	7	22	24.1%
- <4	17	32	34.7%
- <6	20	37	35.1%
- <8	26	38	40.6%
- <10	29	39	42.6%
- >10	7	1	87.5%
- >15	2	0	100%
- >20	1	0	100%
Initial pH-value, n (%)			
- >7.3	12	25	32.4%
- <7.3	23	15	60.5%
- <7.2	15	4	78.9%
- <7.1	5	1	83.3%
- <7.0	3	1	75%
- <6.9	1	1	50%
- <6.8	0	0	-

CPR Cardiopulmonary resuscitation, **MCS** Mechanical circulatory support

Tab. 15
No-CPR patients with MCS, Correlation of lactate and pH with in-hospital mortality

	Died in hospital (n=2)	Survivors (n=3)	Mortality
Initial lactate [mmol/L], n (%)			
- <2	1	1	50%
- <4	2	1	66.7%
- <6	2	1	66.7%
- <8	2	1	66.7%
- <10	2	1	66.7%
- >10	0	0	-
- >15	0	0	-
- >20	0	0	-
Initial pH-value, n (%)			
- >7.3	2	1	66.7%
- <7.3	0	0	-
- <7.2	0	0	-
- <7.1	0	0	-
- <7.0	0	0	-
- <6.9	0	0	-
- <6.8	0	0	-

CPR Cardiopulmonary resuscitation, **MCS** Mechanical circulatory support

Tab. 16
No-CPR patients without MCS, Correlation of lactate and pH with in-hospital mortality

	Died in hospital (n=18)	Survivors (n=72)	Mortality
Initial lactate [mmol/L], n (%)			
- <2	6	40	13%
- <4	9	47	16.1%
- <6	10	49	16.9%
- <8	11	49	18.3%
- <10	12	49	19.7%
- >10	2	0	100%
- >15	0	0	-
- >20	0	0	-
Initial pH-value, n (%)			
- >7.3	9	43	17.3%
- <7.3	5	6	45.5%
- <7.2	2	0	100%
- <7.1	2	0	100%
- <7.0	1	0	100%
- <6.9	0	0	-
- <6.8	0	0	-

CPR Cardiopulmonary resuscitation, **MCS** Mechanical circulatory support

3.5 | Lab values

The laboratory data were evaluated on day 0 (day of admission) at 0, 4, 8 & 24 hours after hospitalisation and then measured twice daily, once in the morning and once in the evening. The analysis included lactate, pH value, hemoglobin, CRP, and coagulation parameters. In addition, the morning and evening mean blood pressure values, as well as the ventilation parameters were analyzed.

The analysis of the data with regard to the distinction between the groups "died in hospital" and "discharged" showed a clear difference for the values lactate, CPR and hemoglobin. For the determination of those laboratory values that were measured twice daily, the medians of the morning and evening values were formed, and the respective daily mean value of those values was calculated.

When comparing both the morning- and the evening pH-value measures taken on day 1 to day 5 for the groups “died in hospital” and “survivors”, an overall median difference of 0.01 (p=0.001) could be seen (figure 6). The overall 5-day median pH-value in the group of deceased patients was 7.43 (IQR: 7.38-7.47), whereas the group of survivors had a median pH of 7.44 (IQR: 7.41-7.48).

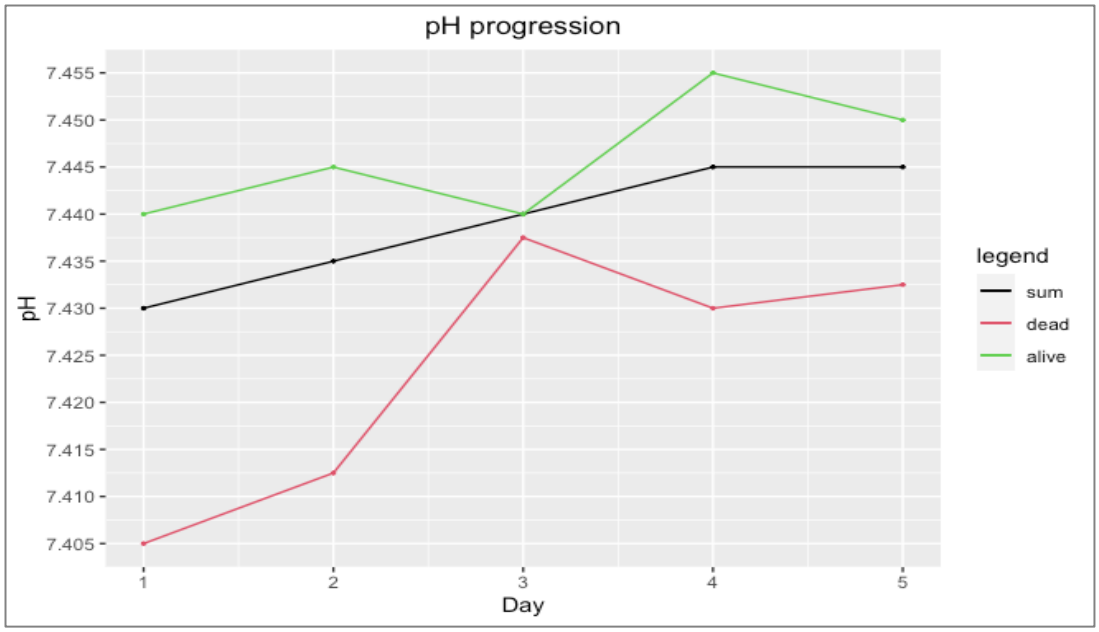

Fig. 6 Average pH-value; dead: died in-hospital, alive: discharged, sum: both

A comparison of CRP values over the first 5 days after hospitalisation between the "deceased in hospital" and "discharged" groups showed a significantly increased median CRP on day 2 ($p<0.001$), day 3 ($p=0.02$) & day 5 ($p=0.03$) for the group with a fatal course.

The first documented CRP measurement is represented by the measurement on day 1, in which the group that suffered a fatal outcome had a median CRP of 50 (IQR: 32-149), compared to 47 (IQR: 17-88) for the group of survivors.

Figure 7 shows the median CRP progression in the first 5 days of both groups, with day one representing the first day after admission.

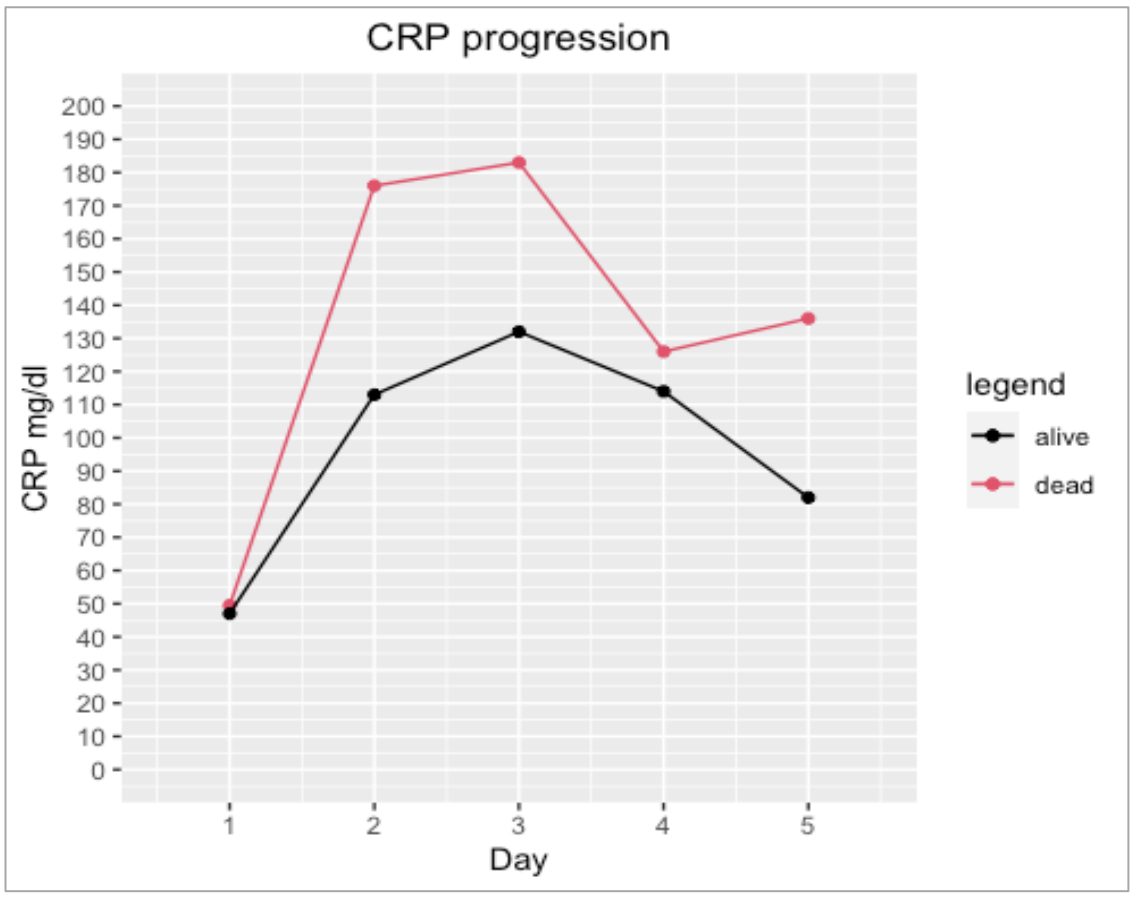

Fig. 7 Median CRP progression, dead: died in hospital, alive: discharged.

CRP C-reactive protein

With regard to the hemoglobin values, both groups showed a similar declining trend, whereby the group of the deceased, with a median value of 11.4 g/dl (IQR: 10.4-13.1) exhibited a value that was 1.3 g/dl lower than the reverence group of survivors with 12.7 g/dl (IQR: 11.4-13.7) on day 1 after admission (p=0.09). Comparing the median Hb values for day 5 after admission, a similar relation could be seen. Here, the median Hb value of the deceased group was 9.4 mg/dl (IQR: 8.6-11.1), compared to 10.6 mg/dl (IQR:9.1-11.8) for the group of survivors (p=0.07). The trend of average hemoglobin levels in relation to in-hospital mortality is shown in figure 8.

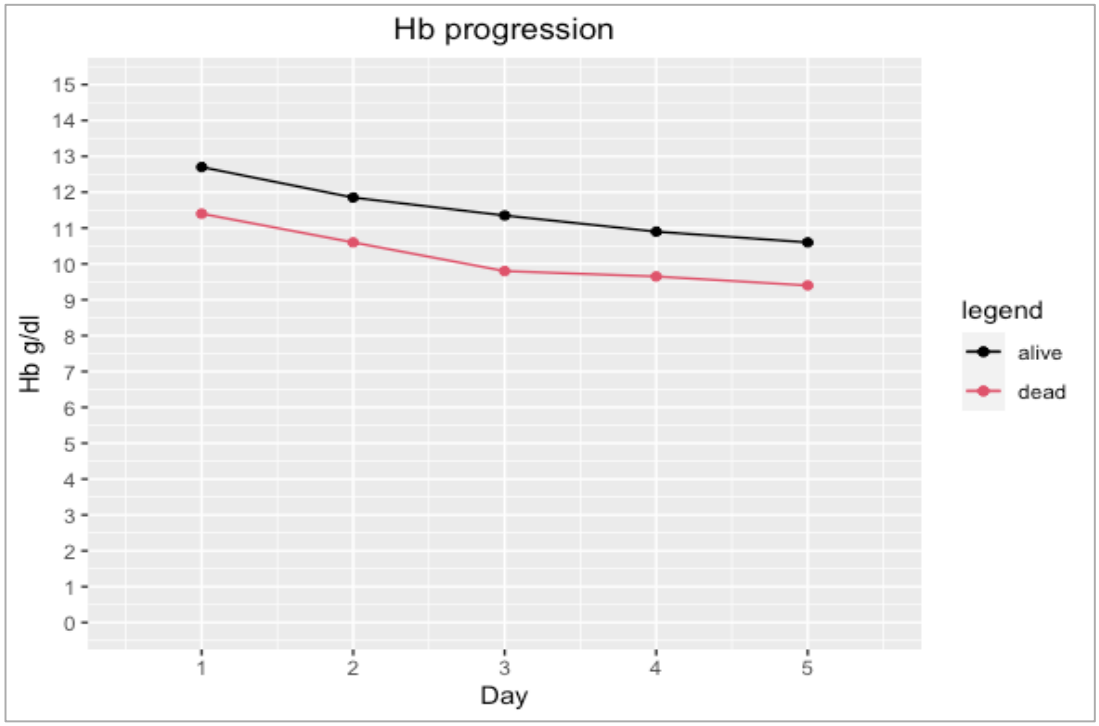

Fig. 8 Median hemoglobin concentration divided by groups: **Hb** Hemoglobin

3.6 Duration of hospitalisation

Considering the entire patient population, the median length of hospitalisation was 8 days (IQR: 3-17). For the further analyses the patients were divided into two groups. The first group consisted of patients who survived their hospitalisation (survivors), while group two consisted of those patients who died in hospital (died in hospital). In the survivor-group the average length of hospital stay was 12 days (IQR: 7-21), with the shortest stay being 2 days and the longest 55 days. For the group of patients that deceased during their initial hospitalisation, the median hospital stay was 2.5 days (IQR: 1-7), with 1 day being the shortest survival duration, indicating death upon the day of admission, and 39 days being the longest.

When excluding those who died on the day of admission, the deceased-in-hospital group showed a median survival of 6 days (IQR: 3-12).

An overview of the duration of hospitalisation by gender, excluding those patients that deceased during their initial stay, is provided in *figure 9*.

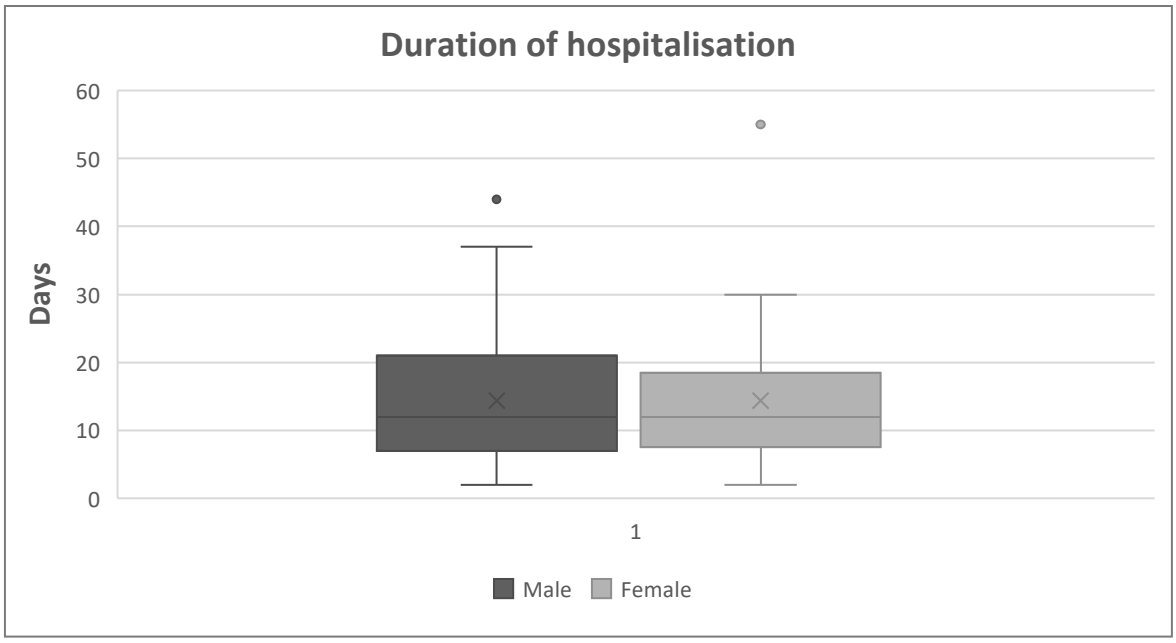

Fig. 9 Duration of hospitalisation by gender (DIH excluded)

Considering the data depending on the CPR status, both the CPR group, as well as the no-CPR group show the same median hospitalisation duration of 8 days.
However, when looking at the interquartile range, a higher variability was seen for the CPR group (IQR: 1-20), compared to the no-CPR group (IQR: 5-14).

3.6.1 | Duration of hospitalisation by initial lactate

Furthermore, the duration of hospitalisation in regard to the initial lactate level, which represents the first lactate value after admission, was examined. For this purpose, the data were divided into 4 groups: Initial lactate <1, 1-2, 2-3 & >3 mmol/L. Here, the median total hospital stays were 5 days (IQR: 3-11), 4 days (IQR: 3-7), 7 days (IQR: 5-12) and 14 days (IQR: 9-18) for the groups <1, 1-2, 2-3 & >3, respectively (*figure 10*).

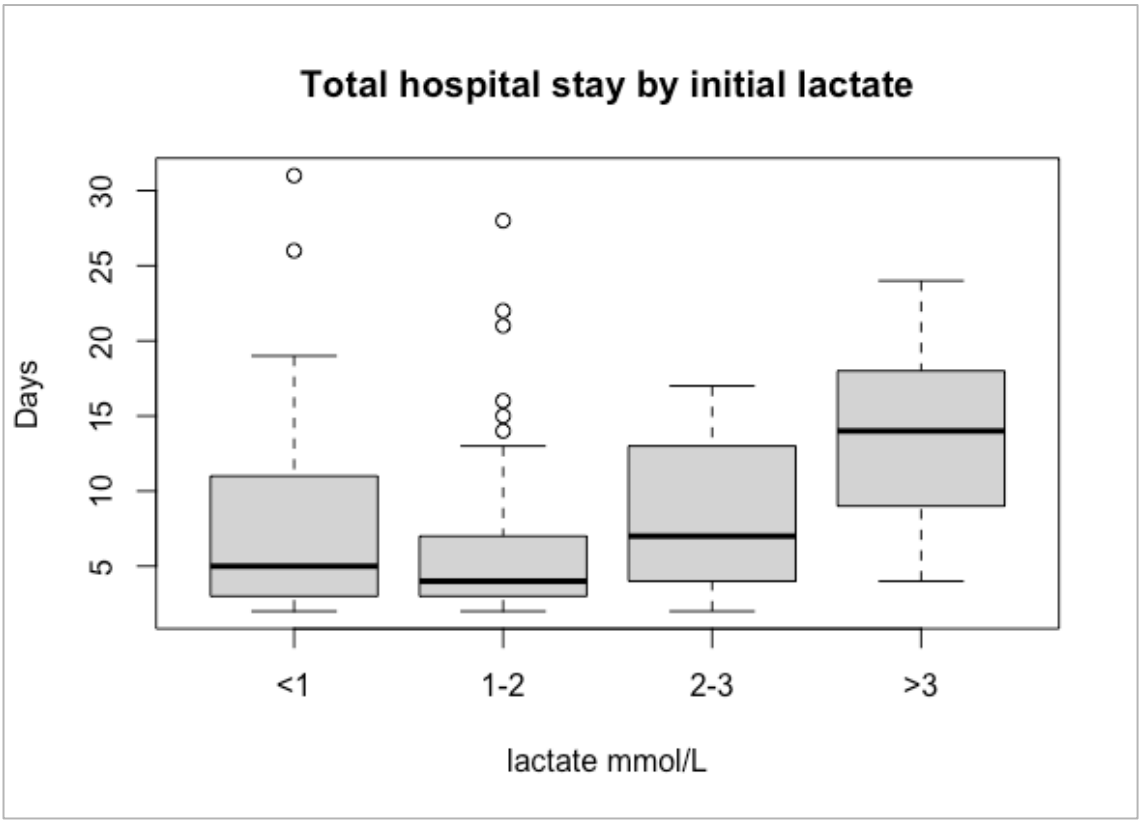

Fig. 10 Duration of hospitalisation by initial lactate (Survivors)

3.6.2 | Duration of ICU stay

Considering the entire patient population, the median CCU duration was 4 days (IQR: 2-9). When considering patients according to risk factors, the longest CCU duration was seen in those patients who required a catecholamine dose between 6 and 8 ml/h for circulatory flow stabilization at the time of referral, followed by patients with an initial lactate value between 2-3 mmol/L (*table 17*). The study could not show a direct correlation of initial lactate values and the CCU duration (r=0.28; p=0.007) (figure 11).

Tab. 17
CCU length of stay by risk factors

Risk factor	Days on CCU	SD
Gender, median [IQR]		
• male	4 [2-9]	7
• female	4 [2-6]	6
Reanimation status, median [IQR]		
• CPR	5 [1-12]	8
• no CPR	3 [2-5]	5
Initial catecholamine dose, median [IQR]	5 [3-9]	5
• < 2	5 [3-13]	7
• 2-4	4 [2-9]	7
• 4-6	7 [4-12]	8
• 6-8	2 [1-3]	4
• >8		
Lactate, median [IQR]		
• < 1	5 [3-11]	8
• 1-2	4.5 [3-9]	8
• 2-3	6 [3-8]	5
• >3	4 [1-10]	7

CCU critical care unit, **CPR** cardiopulmonary resuscitation, **IQR** Interquartile range, **SD** standard deviation

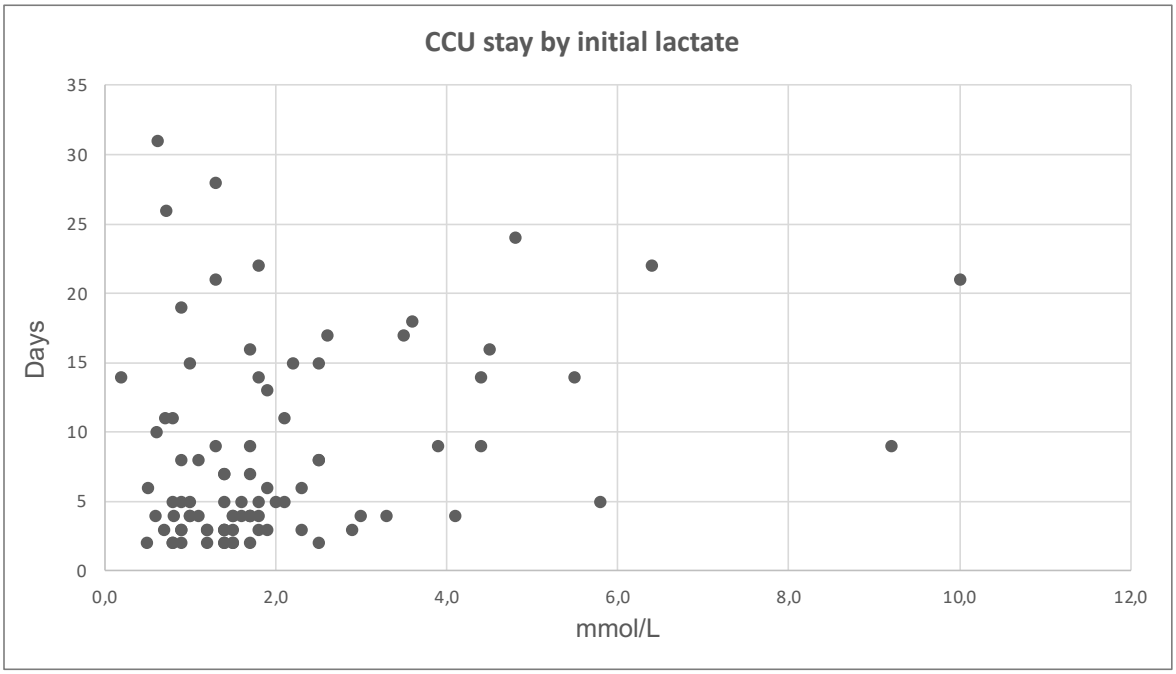

Fig. 11 Correlation of initial lactate with days of CCU stay

3.7 | Ventilation

59% of patients in this study were found to be intubated upon arrival or shortly after.

The study was able to demonstrate a significant difference in in-hospital mortality depending on the initial ventilatory status.

In the group of patients who died in hospital, 81% of patients were intubated initially, whereas the group of patients who could be discharged had an initial intubation rate of only 43% (OR=5.8, RR=2.9, $p<0.01$).

The median intubation duration for the group that died in hospital was 2 days (IQR: 1-5), making it 3 days shorter than the group of successfully discharged patients with 5 days (IQR: 2-10).

An overview of the most important ventilation parameters is provided in *table 18*.

Tab. 18

Median ventilation settings by group

Parameter	Day	Died in hospital	Discharged	Unit
PEEP (IQR)	1:	7 (6.8)	6 (6-8)	**mmHG**
	2:	7 (6-8)	7 (6-8)	
	3:	7 (6-8)	7 (6-8)	
	4:	7 (6-8)	6 (6-8)	
	5:	6 (6-7)	7 (6-8)	
P-insp. (IQR)	1:	20 (18-25)	20 (18-23)	**cmH_2O**
	2:	20 (17-23)	21 (17-23)	
	3:	20 (16-23)	22 (17-24)	
	4:	19 (16-23)	21 (17-23)	
	5:	19 (16-22)	22 (18-23)	
FiO_2 (IQR)	1:	40 (34-60)	41 (33-50)	**%**
	2:	40 (30-50)	45 (35-54)	
	3:	40 (30-51)	45 (39-55)	
	4:	40 (30-50)	45 (40-50)	
	5:	41 (34-45)	43 (40-52)	

cmH_2O Centimeter of water, **FiO_2** fraction of inspired oxygen, **mmHG** millimeters of mercury**, PEEP** positive end-expiratory pressure, **P-insp.** Plateau inspiratory pressure

3.8 Risk factors

Comparing the groups "deceased in hospital" and "discharged", the study could not show a significant difference in mortality depending on the risk factors hypertension, hyperlipoproteinemia, diabetes mellitus, smoking history, renal failure, peripheral vascular disease, prior PCI, prior MI, prior CABG, and known heart failure.

3.9 Assist device

At the time of this study, the Impella was the only MCS device in use at the University Hospital of Graz. The decision for or against the installation of an Impella was made at the discretion of the treating cardiologist and did not follow a standardized algorithm.

To evaluate patients for a possible indication for a mechanical circulatory support device according to new SOPs, which were implemented after the study period of this work, patients were divided into 2 groups, as does the current algorithm. One group represents those patients who did not receive CPR prior to referral to the cardiac catheterization laboratory (no-CPR), whereas the second group includes all those who required resuscitation prior to referral to the cardiac catheterization laboratory (CPR).
Group one (no-CPR) included at least 28 patients who would have been eligible for an assist device, whereas group two (CPR) included 6 patients who would have met the requirements for an assist device, according to current SOPs. Of these patients, altogether only 14 were provided with an Impella.

In the group of patients who did not receive a MCS (no device), the median age was 70 years (IQR: 60-78), with the oldest patient being 92 years and the youngest being 26 years old.

In the group of patients who were provided with a MCS, the median age was 66 years (IQR: 60-76), with the oldest patient being 85 years and the youngest 59 years old. The group "device", herby includes 14 patients, who were provided with an MCS. Only 6 of those fitted with an MCS would have been eligible for a device implantation, according to new SOPs at the university hospital of the Medical University of Graz. Figure 12 provides an overview of the age distribution by group (device vs no device).

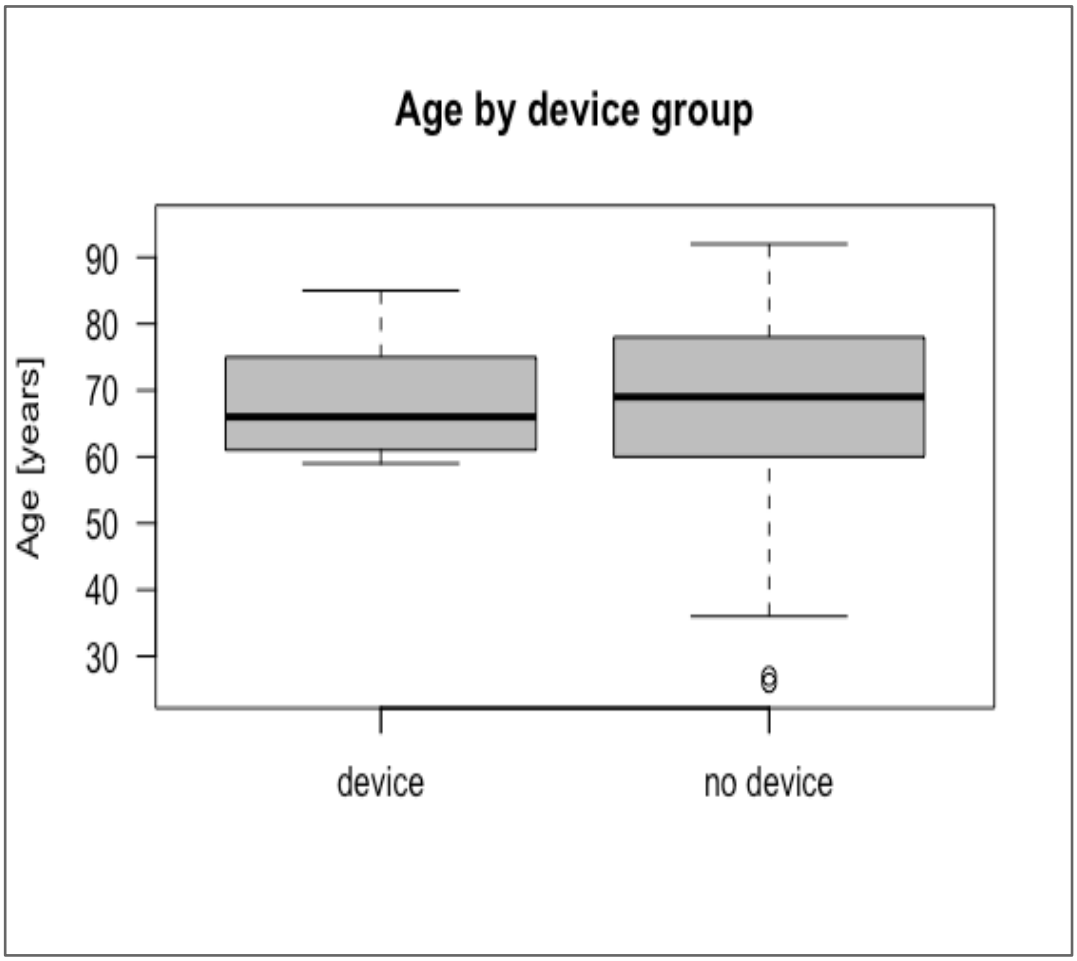

Fig. 12 Age distribution by device group

Table 19 further shows a separate analysis of patient characteristics for the subgroup of patients who received an MCS along with those, who did not receive mechanical circulatory support.

Tab. 19
Characteristics of patients fitted with an MCS

	Impella (n=14)	**No device (n=200)**
Age [years], median (IQR)	66 (60-76)	70 (60-78)
BMI, median (IQR)	26 (24.7-27.6)	27.7 (24.7-31)
Gender, n (%)		
- **male**	11 (78.6)	143 (71.5)
- **female**	3 (21.4)	57 (28.5)
Etiology of CS, n (%)		
- **acute MI**	8 (57.1)	111 (55.5)
- **others**	6 (42.9)	89 (44.5)
CPR, n (%)		
- **yes**	9 (64.3)	109 (54.5)
- **no**	5 (35.7)	91 (55.5)
Lactate [mmol/L], median (IQR)		
- **initial**	6.1 (4.2-10.7)	1.8 (1.3-3.8)
- **after 4h**	12.2 (6-14.9)	1.5 (1-3)
pH-value, median (IQR)		
- **initial**	7.23 (7.19-7.31)	7.35 (7.25-7.41)
- **after 4h**	7.31 (7.15-7.38)	7.36 (7.29-7.44)
$RR_{syst.}$ [mmHg], median (IQR)		
- **initial**	72 (64-87)	106 (85-121)
- **after 4h**	76 (46.5-110)	115 (101-130)
Intubated at arrival, n (%)	10 (71.4)	117 (58.5)

BMI Body mass index, **CPR** Cardiopulmonary resuscitation, **IQR** Interquartile range, **MCS** Mechanical circulatory support, **RR_{syst}** Systolic blood pressure

Of those patients who received MCS, 11 were male and 3 were female (21.4%) which is 6.6% lower than the relative number of females in the total study-population.

The median age in the MCS subgroup was shown to be 4 years lower, compared to the entire study population. The median BMI of the MCS group was also shown to be lower (26 vs. 27.7, p=0.063).

At 57%, the acute MI was the most frequent cause for the placement of an MCS.

The median initial lactate value was significantly elevated in the MCS group (6.1 vs. 1,8, p=0.05), as was the lactate 4 hours after admission (12.2 vs. 1.5, p=0.01).

The initial pH-value of the device group was on median 0.12 lower, compared to the remaining study population (7.23 vs. 7.35, p=0.22).

With 64.3 %, the CPR rate prior to admission was 9.8% higher for the device group compared to the remaining study population.

A further subdivision of the CPR group was performed depending on the device status.

It was found that the group of device patients had a higher percentage of in-hospital cardiac arrests (IHCA) than the group of patients without device (35.7% vs. 14.5%) (*table 20*).

Tab. 20
CPR status by MCS group

	Gesamt (n=214)	**No MCS (n=200)**	**Impella (n=14)**
CPR, n (%) - OHCA, n (%) - ICHA, n (%)	118 (55,1%) - 84 (71.1%) - 34 (28.8%)	109 (54.5%) - 80 (40%) - 29 (14.5%)	9 (64.3%) - 4 (28.6%) - 5 (35.7%)
No CPR, n (%)	96 (44.9%)	91 (45.5%)	5 (35.7%)

CPR Cardiopulmonary resuscitation, **IHCA** in-hospital cardiac arrest, **OHCA** out of hospital cardiac arrest, **MCS** Mechanical Circulatory Support

4 | Discussion

Infarction-associated cardiogenic shock, following acute myocardial infarction, is a feared complication and, with a mortality rate of about 50%, represents a major challenge for treating physicians.
Although various drug and mechanical circulatory support procedures are currently available, data a sparse and require further large-scale studies. Two randomized trials are currently in the recruiting process and might be able to display beneficial outcomes for CS-patients treated with VA-ECMO (35, 36).

This retrospective data analysis aims to help identify individual risk and predictive factors of patients with infarct-associated cardiogenic shock in relation to in-hospital mortality, length of hospital stay, duration of ventilation, and time spent at the intensive care unit.
In addition, it is considered a comparative study for a follow-up study, which will analyze characteristics and outcome of a similar patient population after the establishment of a full percutaneous extracorporeal membrane oxygenation in April 2019 at the university Hospital Graz.

Factors such as age, sex, resuscitation status, cardiovascular risk factors, initial and ongoing laboratory parameters, and individual therapeutic interventions such as mechanical cardiovascular assist devices or coronary reperfusion therapies were considered to evaluate their prognostic value on the primary and secondary endpoints of the study.

Also, non-patient-dependent factors such as the outcome depending on time of day and day of week were considered in order to show a possible correlation between admission within or outside regular working hours and the associated differences in staffing at the Institute of Cardiology of the University Hospital Graz.

The study did not show a difference in mortality depending on the day of admission (42% vs. 43%, weekday/weekend), although no statistical significance could be demonstrated, and a larger patient population is needed to prove a possible relationship.

In contrast, when mortality was compared between assignment within regular operating hours (08:00 am - 04:00 pm) and assignment outside regular operating hours, a 14.3% higher mortality (p=0.038) was observed.
A possible influencing factor might be the lower morbidity, as well as the shorter delay to adequate care in the cardiac catheterization laboratory of patients who suffer a cardiogenic shock during elective PCIs, which almost exclusively take place within the regular operating hours.

A comparison of the initial lactate value at admission between patients with a lethal course with those who were discharged alive shows a median lactate-value that is 2.9 units lower in the group of deceased patients.
This is most likely to be interpreted as a marker of advanced shock and is therefore a negative prognostic marker with regard to in-hospital mortality. This is also in line with previous studies (37, 38).

Similarly, when considering the CRP, the group of deceased patients showed a 56% increased median CRP on day 2 after admission, which is in line with current literature (39), which indicates that the level of CRP correlates with the extent of myocardial damage and is therefore associated with a worse outcome in terms of mortality (39).

The study found no significant difference in in-hospital mortality between patients who received a device and patients who did not receive a device.
This was true for patients in the group that received CPR (CPR) as well as for patients in the group that did not receive CPR (no-CPR).
Looking at the age distribution of patients receiving both CPR and an MCS device, the maximum age was 85 years, with 8 patients being 60 years or older. This is particularly noteworthy as the current SOPs set the maximum age for device implantation in resuscitated patients at 60 years.
Looking at the group of patients that received a MCS device but no CPR, the maximum age was 77, with all 5 patients being 60 years or older, meaning that none of them would have received a MCS device according to current SOPs.
This can be explained by the fact that during our study, no SOPs for the implantation of MCS devices existed and the decision for or against the implantation of a MCS device was

up to the treating physician`s assessment and estimation of the biological age, as well as other prognostic factors.
However, due to the low number of patients (n=14), no statistically significant conclusions can be drawn about the therapeutic benefit of this deviation from the current SOPs.

One of the most important prognostic factors in the study was shown to be the resuscitation status prior to patient admission, which is in line with current literature (40). Improving prehospital resuscitation could potentially benefit patient outcome in terms of in-hospital mortality, but further studies are needed to demonstrate a possible correlation of CPR delay, CPR sufficiency, and CPR duration with the outcome of patients with cardiogenic shock.

4.1 | Limitations

One of the major limitations of this study is the small number of cases (n=214), which largely precludes the demonstration of correlation, especially for rare measures, risk factors, and complications in this study.
This is further reinforced by the retrospective nature of this study, as some of the data sets were not complete with no possibility of obtaining them subsequently.

Further limitations of the study are the partly insufficient determination of pre-existing diseases and risk factors.
Wherever possible, these were ascertained during the course of the clinical stay, through a targeted history by the medical team. However, in many cases, due to the nature of cardiogenic shock, a complete medical history could not always be taken and therefore, risk-factors and preexisting conditions often were ascertained solely based on prior hospital reports.
In those cases, the data were obtained from the federal state-wide HIS "Medocs", which only includes a part of the Styrian health care institutions.
A possible approach to reduce this limitation would be the broad implementation and use of central health databases (e.g.: ELGA) to access country-wide health data.

The last point to mention is a certain selection bias inherent in this study.
This is due to the fact that patients who died before transfer to the University Hospital Graz could not be evaluated.
In order to take these patients into account within a certain limit, close cooperation with pre-hospital health care providers would be necessary, among other things.

4.2 | Conclusion

Cardiogenic shock remains a major challenge for treating physicians with a high mortality and morbidity.
New therapeutic approaches such as mechanical circulatory support systems should help to improve the outcome of patients, but current studies are still sparse and further research is needed to evaluate them.

This monocentric retrospective data analysis with a total of 214 patients who received treatment for catecholamine-requiring cardiogenic shock intends to detect risk factors affecting the duration of hospitalisation, invasive ventilation and duration spend on CCU and in-hospital mortality, as well as the impact on MCS devices on those factors.

The results of this study were able to confirm existing hypotheses regarding risk factors for patient mortality.
It could not provide evidence for a positive effect of MCS devices on hospital mortality.
However, the study successfully identified patients who would have been eligible for an MCS device according to current SOPs and thus provides a basis for the planned comparative study in terms of patient outcome after implementation of the VA-ECMO at the University Hospital Graz, which will allow to evaluate its effect on patient morbidity and mortality.

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Appendix

Sticker

Date of shock: __ __ __ / __ __ __ / __ __ __ __

Admission time: __ __ : __ __

Transferred from: _____

Underlying disease: _____

Cardiopulmonary resusc. OHCA IHCA

Observed YES NO

Basic life support YES NO

Initial rhythm at FMC VF/VT Asystole PEA

No-flow time*: _____ mins **Low-flow time**:** _____ mins
*Total duration of no circulation without ALS/BLS **Total duration of BLS/ALS

RISK PROFILE

Gender MALE FEMALE

Weight _____ kg **Height** _____ cm **BMI** _____ kg/m2

Hypertension YES NO

Hypercholesterolemia YES NO

Diabetes mellitus YES NO

Smoking YES NO EX

Renal insufficiency YES NO **GFR:**_____

Periph. artery disease YES NO

PostPCI YES NO

PostMI YES NO

PostCABG YES NO

Known heart failure YES NO **EF:**_____%

Sign. valvular disease _____

ARRIVAL

P_{sys} _____ mmHg **Heart rate** _____ /min

SaO2 _____ % **PaO2** _____ mmHg

pH _____ **Lactate** _____ mmol/L

Intubated YES NO

Arterenol YES NO **Perfusor** _____mL/hrs

4 HOURS

P_{sys} _____ mmHg **Heart rate** _____ /min

SaO2 _____ % **PaO2** _____ mmHg

pH _____ **Lactate** _____ mmol/L

Intubated YES NO

Arterenol YES NO **Perfusor** _____mL/hrs

8 HOURS

P_{sys} _____ mmHg **Heart rate** _____ /min

SaO2 _____ % **PaO2** _____ mmHg

pH _____ **Lactate** _____ mmol/L

Intubated YES NO

Arterenol YES NO **Perfusor** _____mL/hrs

24 HOURS

P_{sys} _____ mmHg **Heart rate** _____ /min

SaO2 _____ % **PaO2** _____ mmHg

pH _____ **Lactate** _____ mmol/L

Intubated YES NO

Arterenol YES NO **Perfusor** _____mL/hrs

ASSIST DEVICE

NONE **IABP** **IMPELLA** **ECMO** **iCOR**

SHOCK-TO-ASSIST: _____ mins **DOOR-TO-ASSIST:** _____ mins

Access #1 _____ **Access #2** _____

Antegrade perfusion YES NO

Acute complication YES NO

Specify:_____

_____

DEFINITIVE THERAPY

Specify:_____

IF PCI

Date of procedure: __ __ __ / __ __ __ / __ __ __ __

Time of restored flow: __ __ : __ __

Timing PCI first Assist first Not applicable

Coronary status Single VD Multi VD

Culprit vessel LM LAD LCx RCA

Intervention on… Native Bypass

Revascularization Cons. Single VD Multi VD CABG

Full revasc. achieved YES NO

Comments:_____

In-cathlab reanimation YES NO

Antiplatelet #1 _____ **Antiplatelet #2** _____

ACT #1 _____ secs **ACT #2** _____ secs

DAY #1

$MAP_{morning}$ _____ mmHg **$MAP_{evening}$** _____ mmHg

$PEEP_{morning}$ _____ cmH_2O **$PEEP_{evening}$** _____ cmH_2O

P-$INST_{morning}$ _____ cmH_2O **P-$INST_{evening}$** _____ cmH_2O

$FiO_{2\ morning}$ _____ % **$FiO_{2\ evening}$** _____ %

$pH_{morning}$ _____ **$pH_{evening}$** _____

$Lactate_{morning}$ _____ mmol/L **$Lactate_{evening}$** _____ mmol/L

INR _____ **AT III** _____

Fibrinogen _____ **Xa** _____ **Hb** _____

XIII _____ **D-dimer** _____ **CRP** _____

DAY #2

$MAP_{morning}$ _____ mmHg **$MAP_{evening}$** _____ mmHg

$PEEP_{morning}$ _____ cmH_2O **$PEEP_{evening}$** _____ cmH_2O

P-$INST_{morning}$ _____ cmH_2O **P-$INST_{evening}$** _____ cmH_2O

$FiO_{2\ morning}$ _____ % **$FiO_{2\ evening}$** _____ %

$pH_{morning}$ _____ **$pH_{evening}$** _____

$Lactate_{morning}$ _____ mmol/L **$Lactate_{evening}$** _____ mmol/L

INR _____ **AT III** _____

Fibrinogen _____ **Xa** _____ **Hb** _____

XIII _____ **D-dimer** _____ **CRP** _____

DAY #3

$MAP_{morning}$ _____ mmHg **$MAP_{evening}$** _____ mmHg

$PEEP_{morning}$ _____ cmH_2O **$PEEP_{evening}$** _____ cmH_2O

P-$INST_{morning}$ _____ cmH_2O **P-$INST_{evening}$** _____ cmH_2O

$FiO_{2\ morning}$ _____ % **$FiO_{2\ evening}$** _____ %

$pH_{morning}$ _____ **$pH_{evening}$** _____

$Lactate_{morning}$ _____ mmol/L **$Lactate_{evening}$** _____ mmol/L

INR _____ **AT III** _____

Fibrinogen _____ **Xa** _____ **Hb** _____

XIII _____ **D-dimer** _____ **CRP** _____

DAY #4

$MAP_{morning}$ _____ mmHg **$MAP_{evening}$** _____ mmHg

$PEEP_{morning}$ _____ cmH_2O **$PEEP_{evening}$** _____ cmH_2O

P-$INST_{morning}$ _____ cmH_2O **P-$INST_{evening}$** _____ cmH_2O

$FiO_{2\ morning}$ _____ % **$FiO_{2\ evening}$** _____ %

$pH_{morning}$ _____ **$pH_{evening}$** _____

$Lactate_{morning}$ _____ mmol/L **$Lactate_{evening}$** _____ mmol/L

INR _____ **AT III** _____

Fibrinogen _____ **Xa** _____ **Hb** _____

XIII _____ **D-dimer** _____ **CRP** _____

DAY #5

$MAP_{morning}$ _____ mmHg **$MAP_{evening}$** _____ mmHg

$PEEP_{morning}$ _____ cmH_2O **$PEEP_{evening}$** _____ cmH_2O

P-$INST_{morning}$ _____ cmH_2O **P-$INST_{evening}$** _____ cmH_2O

$FiO_{2\ morning}$ _____ % **$FiO_{2\ evening}$** _____ %

$pH_{morning}$ _____ **$pH_{evening}$** _____

$Lactate_{morning}$ _____ mmol/L **$Lactate_{evening}$** _____ mmol/L

INR _____ **AT III** _____

Fibrinogen _____ **Xa** _____ **Hb** _____

XIII _____ **D-dimer** _____ **CRP** _____

OUTCOME

CCU stay _____ days **HOSPITAL stay** _____ days

Respirator _____ days **Assist device** _____ days

Dialysis _____ days **Sepsis** YES NO

Bleeding event YES NO specify:_____

☐ **Discharge – date:** __ __ __ / __ __ __ / __ __ __ __

☐ **In-hospital death – date:** __ __ __ / __ __ __ / __ __ __ __

FOLLOW-UP

Date of 6-months FU: __ __ __ / __ __ __ / __ __ __ __

Date of 12-months: __ __ __ / __ __ __ / __ __ __ __

☐ **Event – date:** __ __ __ / __ __ __ / __ __ __ __

Specify: _____

_____

☐ **Any rehospital. – date:** __ __ __ / __ __ __ / __ __ __ __

Specify: _____

_____

☐ **Death – date:** __ __ __ / __ __ __ / __ __ __ __

☐ **MI – date:** __ __ __ / __ __ __ / __ __ __ __

☐ **Stroke – date:** __ __ __ / __ __ __ / __ __ __ __