Haemodynamic patterns in ST-elevation myocardial infarction: incidence and correlates of elevated filling pressures

A. Bergstra, T. Svilaas, D.J. van Veldhuisen, A.F.M. van den Heuvel, I.C.C. van der Horst, F. Zijlstra

Objectives. We sought to study the incidence and clinical correlates of elevated filling pressures in ST-elevation myocardial infarction (STEMI) patients, without physical signs of heart failure and treated with primary coronary angioplasty.

Background. Haemodynamic data, as measured with a Swan-Ganz catheter, are not routinely obtained in STEMI patients. At admission, low blood pressure, increased heart rate, sweating, increased respiration rate, rales, oedema, and a third heart sound are indicative of heart failure.

Methods. All consecutive STEMI patients were monitored by a Swan-Ganz catheter and central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP), pulmonary artery pressure (PAS) and cardiac index (CI) were measured. To investigate the clinical correlates of the haemodynamic status patients were classified according to previously defined haemodynamic criteria.

Results. We studied 90 patients, aged 60.5 ± 13.1 year, 76% were male. Mortality at 30 days was 2/90 (2.2%). Patients with impaired haemodynamics presented later and had larger myocardial infarct sizes. CVP, PCWP and PAS were above normal in 36 (40%) patients.

Conclusion. A large proportion of STEMI patients without physical signs of heart failure have elevation of right- as well as left-sided cardiac filling pressures. (*Neth Heart J* 2007;15:95-9.)

Keywords: haemodynamics, myocardial infarction, ST-segment elevation, percutaneous coronary intervention, classification (Killip)

The clinical outcome of patients presenting with ST-elevation myocardial infarction (STEMI) has been improved considerably over the last decades. Reperfusion therapy, in particular primary coronary angioplasty, and pharmacological intervention with antiplatelet and antithrombin agents, β -blockers and angiotensin-converting enzyme inhibitors, have resulted in low 30-day mortality rates as well as excellent long-term clinical outcome.¹⁻⁴ Nevertheless, even with an optimal modern therapeutic approach, a minority of patients do not fare well. Failed reperfusion therapy, advanced age and clinical signs of heart failure are clear risk factors for morbidity and mortality.^{5,6} In the setting of acute myocardial infarction, heart failure is usually defined by the Killip classification, developed and described four decades ago.⁷ This classification is still widely used and provides important prognostic information. Killip class I, defined as the absence of physical signs of heart failure, was one of the entry criteria for participation in the Glucose-Insulin-Potassium Study (GIPS-2).⁸ The methodology and outcome of this trial have been published. A substudy was performed to establish the influence of this therapy on cardiac filling pressures and cardiac output, which provided the opportunity to investigate the haemodynamic patterns as measured with a Swan-Ganz catheter in a consecutive cohort of 90 patients presenting with STEMI, but without clinical signs of heart failure.⁹

Methods

Study population

Between January and August 2004, STEMI patients who presented to the University Medical Centre Groningen were considered for entry in the haemodynamic study. Inclusion criteria were: 1) the diagnosis of acute MI defined by chest pain suggestive of myocardial ischaemia for at least 30 minutes, the time from

A. Bergstra
T. Svilaas
D.J. van Veldhuisen
A.F.M. van den Heuvel
I.C.C. van der Horst
F. Zijlstra

Department of Cardiology, University Medical Centre Groningen, University of Groningen, Groningen, the Netherlands

Correspondence to: A.F.M. van den Heuvel
Department of Cardiology, University Medical Centre Groningen,
PO Box 30.001, 9700 RB Groningen, the Netherlands
E-mail: a.f.m.van.den.heuvel@thorax.umcg.nl

onset of the symptoms less than six hours before hospital admission, and an ECG recording with ST-T segment elevation of more than 1 mV in two or more leads, 2) eligibility for primary PCI, and 3) informed consent. Exclusion criteria were: 1) physical signs of heart failure at admission defined as the existence of either one of the following symptoms: a heart rate over 90 beats/min and/or a systolic blood pressure <100 mmHg (both in the case of an anterior myocardial infarction), a third heart sound, or rales more than one hand wide or 2) the existence of a life-threatening disease with a life-expectancy of less than six months. There was no upper age limit. Patients of both treatment arms were included in the present study as it was assumed that the volume status was not affected by the GIK infusion during percutaneous coronary intervention (PCI), since immediately after PCI the haemodynamic measurements were performed.

Therapy

The patients were transported as soon as possible to the catheterisation laboratory for emergency coronary angiography and if indicated, primary coronary angioplasty and stenting was performed according to local routine. Additional standard treatment consisted of heparin, nitroglycerin, aspirin and clopidogrel. Standard therapies including β -blockers, lipid-lowering agents and angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers were used according to the guidelines of the European Society of Cardiology/American College of Cardiology.

Haemodynamic measurements

During the primary coronary angioplasty procedure a Swan-Ganz catheter (Edwards Lifesciences, Irvine, USA) was introduced into the pulmonary artery and connected to the physiological measurement system (Cathcor, Siemens AG, Erlangen, Germany). The following pressures (mmHg) were measured: pulmonary artery pressure, systolic (PAS), diastolic (PAD) and mean (PAM), pulmonary capillary wedge pressure (PCWP), central venous pressure (CVP) and systemic arterial pressure, systolic (SAS), diastolic (SAD) and mean (SAM). Then arterial and mixed venous blood samples were taken for determination of arterial (SaO_2) and mixed venous (SvO_2) oxygen saturation, arterial (PaO_2 , kPa) and mixed venous (PvO_2 , kPa) oxygen tension and haemoglobin concentration (cHb, mmol·l⁻¹) by a blood gas analyser (ABL 700, Radiometer, Copenhagen, Denmark). The heart rate (HR, beats·min⁻¹) was read from the ECG and pressure recordings. Based on the haemodynamic measurements patients were divided into patients with values within the normal range and those with values outside the normal range.

Also subanalysis was performed depending on high- and low-peak creatine kinase (CK), with a cut-off point of 2000 IU l⁻¹.

Calculations

Cardiac output (CO, l·min⁻¹) was calculated using assumed oxygen consumption (VO_2 , ml·min⁻¹), according to Fick:

$$\text{CO} = \frac{\text{VO}_2}{(\text{SaO}_2 - \text{SvO}_2) \cdot \text{cHb} \cdot \beta + (\text{PaO}_2 - \text{PvO}_2) \cdot \gamma}$$

where SaO_2 and SvO_2 are arterial and mixed venous oxygen saturation successively, PaO_2 and PvO_2 are arterial and mixed venous oxygen tension (kPa) and cHb the haemoglobin concentration (mmol·l⁻¹).¹⁰ For the oxygen binding capacity of haemoglobin, β , 21.92 ml·mmol⁻¹ is used and for the solubility factor of oxygen in blood plasma, γ , 0.2273 ml·l⁻¹·kPa⁻¹. Cardiac index (CI, l·min⁻¹·m⁻²) was calculated using the body surface area (BSA, m²) according to DuBois and DuBois.¹¹ The systemic vascular resistance:

$$\text{SVR} = \frac{80 \cdot (\text{SAM} - \text{CVP})}{\text{CO}} \quad \text{dynes} \cdot \text{s} \cdot \text{cm}^{-5}$$

where 80 is the factor for the adjustment of units, SAM is mean arterial pressure (mmHg), CVP central venous pressure (mmHg) and CO cardiac output (l·min⁻¹).

Baseline characteristics and data recording

Baseline demographic and clinical characteristics were reported in a case record form (CRF). Clinical data from the CRF together with the haemodynamic data were recorded in a dedicated database. The follow-up consisted of a 30-day and one-year visit to the out-patient clinic. If the patient visited another hospital after PCI, then follow-up was performed by a telephone call at the same time points.

Statistical analysis

Differences in baseline characteristics between patients with and without haemodynamic values in the normal range were analysed using student's t test for continuous variables and Fisher's exact test for categorical variables. The design provides P values for the differences of the effects. The Greenhouse-Geisser adjustment of degrees of freedom was used for all variables, as the assumption of sphericity could not be met. Effects were assumed to be statistically significant with P values <0.05. In text, tables and figures, the results are shown as the mean $\pm$ standard deviation (SD) for continuous data and as frequencies (%) for categorical data. The Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 11.0.1 was used for all statistical analysis.

Results

The major baseline characteristics of all patients are given in table 1. A total of 11 patients had no successful reperfusion therapy as determined by the absence of

Table 1. Baseline characteristics at admission of the population.**Characteristic**

Number of patients	90
Age $\pm$ SD, years	60 $\pm$ 13
Male gender, n (%)	68 (76)
Hypertension, n (%)	25 (28)
Diabetes, n (%)	8 (9)
Previous CVD, n (%)	16 (18)
Positive family history, n (%)	46 (51)
Systolic BP $\pm$ SD, mmHg	136 $\pm$ 25
Diastolic BP $\pm$ SD, mmHg	80 $\pm$ 17
Heart rate $\pm$ SD, beats/min	77 $\pm$ 18
Length $\pm$ SD, cm	175 $\pm$ 8
Weight $\pm$ SD, kg	82 $\pm$ 12
Glucose $\pm$ SD, mmol·l ⁻¹	7.3 $\pm$ 2.1
Haemoglobin $\pm$ SD, mmol·l ⁻¹	8.2 $\pm$ 0.9
Ischaemic time, minutes, median (range)	222 (40-645)
Anterior location, n (%)	36 (40)
Culprit, n (%)	
- RCA	37 (41)
- CX	14 (16)
- LAD	39 (43)
Proximal lesion, n (%)	32 (36)
TIMI pre-intervention (n=89), n (%)	
- 0	55 (62)
- 1	9 (10)
- 2	10 (11)
- 3	15 (17)
TIMI post-intervention (n=89)	
- 1	2 (2)
- 2	9 (10)
- 3	78 (88)
Blush grade 2 & 3 (n=87), n (%)	67 (77)
Peak CK, IU·l ⁻¹ , median (range)	887 (81-6664)
LVEF (n=76), n (%)	
- <30	3 (4)
- 30-50	57 (75)
- >50	16 (21)
30-day mortality, n (%)	2 (2)

CVD=cardiovascular disease, SD=standard deviation, BP=blood pressure, RCA=right coronary artery, CX=circumflex, LAD=left anterior descending, CK=creatinine kinase, LVEF=left ventricular ejection fraction.

TIMI 3 flow in combination with a myocardial blush grade 2 or 3 after PCI. No patients received an intra-aortic balloon pump or artificial breathing support. Two patients died within 30 days, a 74-year-old female and an 87-year-old male, both patients had a low CI and high PCWP.

Characteristics of patients with haemodynamic values within or outside the normal range are presented in detail in table 2. Patients with a normal cardiac index

were less likely to have had a previous cardiovascular event and the infarction location was less often the anterior site (29.0 vs. 44.8%, $p<0.05$).

Table 3 presents the means of the haemodynamic data in predefined subgroups. Patients with a culprit in the left anterior descending (LAD) or circumflex (CX) have a higher CVP and PAS and a lower CI compared with patients with a right coronary artery (RCA) lesion. Accordingly patients with an anterior location of their STEMI have a higher CVP. Patients with a history of either a myocardial infarction, coronary artery bypass grafting (CABG), or cerebrovascular accident (CVA), and patients with an ischaemic period longer than 180 minutes had a higher PVR.

Discussion

In our STEMI patients early invasive haemodynamic measurements unravelled haemodynamic impairment in patients without physical signs of heart failure. In an earlier study 7 out of 17 patients with Killip class I had a low cardiac output.¹² It could also be concluded that physical examination is not adequate to determine whether STEMI patients have compromised haemodynamics or not. Patients with haemodynamic disturbances developed larger sized infarcts, irrespective of the site of the culprit lesion and the haemodynamic disturbances could be an early indicator of impaired outcome. In the above-mentioned study of 17 Killip class I patients, no relation between a decreased cardiac output and enzymatic infarct size was observed.¹² In another study a relation between infarction site and haemodynamic profile was found, probably depending on whether the right ventricle was involved.¹³ The results underlined the importance of early recognition and treatment of myocardial dysfunction. It makes more sense to hypothesise that impaired left ventricular function and increased enzymatic infarct size are the consequence of late presentation than that patients with impaired haemodynamic function and larger infarct sizes tend to present later. Although a chest X-ray might have identified patients with signs of left ventricular dysfunction, many patients with a STEMI have normal chest X-rays, but impaired haemodynamics.¹⁴

Some haemodynamic parameters (PVR, SVR) may have been affected by the neurohormonal activation, caused by the profound physical and psychological stress of STEMI.¹⁵ Effects of neurohormonal intervention (β -blockade), however, may have negative effects secondary to a further increase in catecholamine levels that is associated with an increase in SVR.¹⁶

The present study reports that it is not possible to identify these patients with haemodynamic impairment by physical examination for a large group of patients in the setting of acute myocardial infarction. The knowledge that many of these patients do have haemodynamic impairment may generate the hypothesis that nitroglycerin should not be stopped too soon in these MI patients, although primary PCI is performed.

Table 2. Haemodynamic measurements during catheterisation.

	Normal range	Mean±SD	Below range	Inside range	Above range
Heart rate (min ⁻¹)	60-100	82±15	4	78	10
PAS (mmHg)	16-30	30.2±9.7	4	50	36
PAD (mmHg)	4-13	16.6±6.4	-	45	57
PAM (mmHg)	9-18	22.4±7.8	2	25	63
PCWP (mmHg)	6-12	15.9±6.9	4	26	60
CVP* (mmHg)	1-5	9.2±4.2	1	18	70
CI (l·min ⁻¹ ·m ⁻²)	2.4-4.2	3.1±0.7	12	71	7
PVR (dyne·s·cm ⁻⁵)	80-120	90±41	39	33	18
SVR* (dyne·s·cm ⁻⁵)	900-1200	1173±405	24	27	38
SAS (mmHg)	90-140	124±22	4	68	18
SAD (mmHg)	70-90	72±13	19	63	8
SAM (mmHg)	80-110	92±16	37	44	9

* n=89. PAS=systolic pulmonary artery pressure, PAD=diastolic pulmonary artery pressure, PAM=mean pulmonary artery pressure, PCWP=pulmonary capillary wedge pressure, CVP=central venous pressure, CI=cardiac index, PVR=pulmonary vascular resistance, SVR=systemic vascular resistance, SAS=systolic systemic artery pressure, SAD=diastolic systemic artery pressure, SAM=mean systemic artery pressure.

Table 3. Relation between baseline characteristics and haemodynamic measurements.

Characteristic	HR	PAS	PAD	PAM	PCWP	CVP	CI	PVR	SVR	SAS	SAD	SAM
Age ≤60 years	83	31.3	17.4	23.5	17.2	9.8	3.2*	84	1085*	123	72	91
Age >60 years	80	29.1	15.8	21.2	14.7	8.7	2.9	96	1263	125	73	93
Male gender	80*	30.4	16.5	22.3	15.8	9.4	3.1	89	1125	122	73	91
Female gender	88	29.7	16.7	22.6	16.6	8.9	2.9	93	1319	131	72	94
Previous CVD	72	31.9	17.0	23.3	16.1	8.3	2.9	108*	1245	130	71	92
No previous CVD	83	29.9	16.5	22.2	15.9	9.4	3.1	86	1157	123	73	92
Ischaemic time ≤180	79	29.1	16.2	21.6	16.0	9.2	3.1	79*	1196	126	73	93
Ischaemic time >180	83	31.1	16.9	23.0	15.9	9.3	3.0	99	1154	122	72	91
Anterior location	82	31.0	16.7	22.7	16.6	7.7*	2.9	88	1269	125	73	93
Non anterior location	81	29.7	16.5	22.2	15.6	10.2	3.1	91	1111	123	72	91
Culprit CX & LAD	81	30.8	16.8	22.6	16.4	8.2*	2.9*	91	1289**	126	74	94
Culprit RCA	82	29.4	16.2	22.0	15.3	10.7	3.2	88	1011	121	71	88
Proximal lesion	85	31.3	17.2	23.2	16.7	10.5	3.0	91	1149	124	72	91
Distal lesion	80	29.6	16.2	21.9	15.5	8.5	3.1	89	1187	124	73	92
Low peak CK	80	27.5**	14.3**	19.9**	13.6**	8.5	3.2*	84	1137	126	72	93
High peak CK	84	33.5	19.3	25.3	18.8	10.1	2.9	97	1217	121	73	91

Data are mean. *p<0.05, **p<0.01, HR=heart rate, PAS=systolic pulmonary artery pressure, PAD=diastolic pulmonary artery pressure, PAM=mean pulmonary artery pressure, PCWP=pulmonary capillary wedge pressure, CVP=central venous pressure, CI=cardiac index, PVR=pulmonary vascular resistance, SVR=systemic vascular resistance, SAS=systolic systemic artery pressure, SAD=diastolic systemic artery pressure, SAM=mean systemic artery pressure, CVD=cardiovascular disease, CX=circumflex, LAD=left anterior descending, CK=creatinine kinase.

Furthermore it would be interesting to know in which subgroup of patients IABP treatment is indicated.^{17,18} To answer these questions further studies are required.

Study limitations

In the present study, no measurements before PCI are available; this implicates that there is no real baseline for the haemodynamics. We considered it not to be ethical to delay the PCI procedure until right heart catheterisation had been performed. Whether inter-

ventions that affect haemodynamics do alter clinical outcome is unknown. Moreover, we are not sure how detrimental a mildly increased preload is in the setting of myocardial infarction.

Conclusion

A large proportion of STEMI patients without physical signs of heart failure have moderate or even severe elevation of right- as well as left-sided cardiac filling pressures.

Acknowledgements

The authors gratefully acknowledge the assistance of the staff at the catheterisation laboratory and the coronary care unit. The research by T. Svilaas was made possible by a grant (2003B277) from the Netherlands Heart Foundation. ■

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