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ORIGINAL PAPER

Efficacy and limitations of a STEMI network: 3 years of experience within the myocardial infarction network of the region of Augsburg - HERA

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Abstract
Aims The HERA Registry investigates logistics, adherence to standards, time intervals, and mortality in a regional network for primary percutaneous coronary intervention (PPCI) in ST-elevation myocardial infarction (STEMI) in a mixed urban and rural area.
Methods and results We included 826 consecutive patients (pts) within the HERA network with its dedicated PPCI strategy (female $n = 243$, mean age 64 years, range 25–98 years) with acute STEMI (May 2007 until January 2010). 680 pts (82 %) received PPCI and 45 (5.4 %) acute bypass surgery. Of 512 pts seen by an emergency physician (EP) as first medical contact (FMC) 87 % received on-scene 12-lead ECG. ECG transmission rate to the PPCI center was 29 %. Median FMC-to-balloon time (CBT) was 135 min and door-to-balloon time (DBT) 70 min. With EP FMC DBT was 38 min with direct transfer to cath lab ($n = 70$), 69 min via ICU ($n = 240$), and 132 min via ER ($n = 91$, $p < 0.01$). Out of 826 pts, 143(17.3 %) presented in cardiogenic shock. In-hospital mortality was 8.8 % ($n = 73$), 35.7 % for shock pts versus 3.2 % for non-shock pts ($p < 0.01$). For pts receiving PPCI, in-hospital mortality was 6.2 %, for shock pts ($n = 107$) 28.0 %, and for non-shock pts ($n = 573$) 2.1 % ($p < 0.01$).
Conclusion Prehospital management, CBT and DBT compare favourably to data from studies and registries, but do not yet fulfill strict guideline requirements. Real world mortality in non-shock pts is very low. Direct transfer to cath lab reduces DBTs by 49 %. For this crucial improvement, transmission of a 12-lead ECG to the PPCI center is mandatory.

Keywords Networks · Acute myocardial infarction · Primary PCI · Door-to-balloon time · STEMI

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Introduction

The treatment of acute ST-elevation myocardial infarction (STEMI) requires rapid and effective reperfusion of the affected coronary artery [1–5]. Timely primary percutaneous coronary intervention (PPCI) is superior to thrombolytic therapy, as trials and registries show [1–14]. In case of PPCI, current ESC guidelines recommend a first medical contact (FMC)-to-balloon time (CBT) of 90 min, in selected cases of less than 60 min, and a door-to-balloon time (DBT) of less than 60 min in all cases [5]. Current ACC/AHA guidelines demand a CBT or DBT of a maximum of 90 min, respectively, or at least a DBT of less than 90 min in more than 75 % of all cases [1]. Of note, these challenging time frames are missed in all available registries and randomized studies, and therefore may be an ideal, but unrealistic aim [2, 6, 8, 9, 11–13, 15–25]. Nevertheless, even with these given time intervals in registries and studies, PPCI remains superior—in longer delays of more than 2 h at least not inferior—to thrombolysis with regard to mortality [7, 11, 13, 26].

Throughout the year 2006, 145,000 people died from the consequences of ischemic heart disease in Germany, of which 60,000 were due to an acute myocardial infarction [27]. To reduce mortality, it is essential to minimize the time from the development of symptoms to sufficient revascularization. One has to distinguish a patient-dependent interval—from onset of pain until FMC (PCT)—and

an organization-dependent interval—from FMC until PPCI (CBT); both correlate with mortality [28]. Measures to reduce organization-dependent time delays include, amongst others, the recording of a 12-lead ECG on site and its submission to the PCI center [17, 19], enabling simultaneous activation of the PPCI team without false alarm. In addition, all opportunities for optimization of processes in the hospital should be utilized [2, 16, 18, 23, 28]. Consequently, current ESC guidelines call for the implementation of dedicated regional myocardial infarction networks [5].

The HERA registry analyses relevant therapeutic time intervals over almost 3 years after (trans)regional network implementation with one tertiary care hospital (7/24 cath lab coverage) in a mixed urban and rural structure.

Methods

From May 1, 2007 until Jan 30, 2010, we included 826 consecutive patients (female $n = 243$, male $n = 583$) with a mean age of 64 years (range 29–98 years). Patients with PCT of >24 h were excluded. Patients with a PCT between 12 and 24 h ($n = 36$) were included only in case of ongoing ischemia (symptoms and/or ECG changes). Patients were admitted to the study region's single PPCI center (Klinikum Augsburg, academic teaching hospital of the University of Munich) providing both 24/7 PPCI and heart surgery facilities. All ambulance providers (ZRF Zweckverband Rettungsdienst Augsburg), emergency physicians, and five regional hospitals agreed upon direct transfer of patients to the PPCI center ("bypass version"). Emergency physicians were invited to the PPCI center for an informative meeting at the beginning of the registry and informed about the mandatory ECG onsite and its transmission. Medication on site, pain time, FMC time, ECG fax time, PPCI center phone contact time, arrival at PPCI center time, start of groin anesthesia time, and first dilatation time were recorded in each case. The onset of cardiac catheterization was defined as the time of the groin anesthesia. Balloon time was determined as the first dilatation or thrombus aspiration within the target vessel.

ST-elevation myocardial infarction was defined as ST elevation >0.1 mV in two adjacent limb leads, ST elevation >0.2 mV in two adjacent precordial leads, or definite new left bundle branch block. The location of STEMI diagnosis was determined as the venue where the physician definitively diagnosed "STEMI". For STEMI patients transferred to the emergency room with the entry diagnosis, "exclusion of ACS" and "suspected heart attack", et cetera, "ER", or "ICU" was entered as location of STEMI diagnosis (when applicable). Cardiogenic shock was defined as systolic blood pressure <90 mmHg, heart rate >110/min, or <40/min and presence of clinical features of shock (e.g., hypoperfusion of organs and extremities) [29]. Prehospital resuscitation included defibrillation and manual cardiac compression. Patients died on scene or during transport were not included in the registry.

Statistical analysis

All analyses were performed with statistical software (SPSS 17 for Windows). Categorical variables were presented as percentages and continuous variables as means and ranges. When comparing time periods, Wilcoxon-signed rank test was applied. For the comparison of frequencies Chi-square test was utilized. A difference with of a p value less than 0.05 was considered statistically significant.

Results

12-lead ECG on site

Five-hundred and twelve patients (62.0 %) received their first treatment by an emergency physician (EP). A 12-lead ECG was recorded in 444 (86.7 %) patients out of 512. In 51 (10.0 %) patients, a limb ECG only was registered (some in a resuscitation situation). 17 patients (3.3 %) received their first ECG in the ER. In 147 (28.7 %) cases only, the ECG was transmitted to the PPCI center.

Medication on site

Core medication consisting of iv administration of 500 mg aspirin, 5,000 IU heparin, and morphine was given to 90, 91, and 53 % of patients, respectively, on site by the EP ($n = 512$). IV beta blockers were given to 36.8 % and clopidogrel (300–600 mg) to 9.5 % of patients, respectively.

Location of STEMI diagnosis

ST-elevation myocardial infarction was diagnosed in 388 patients (47.0 %) out of 826 on scene, either at home or in the public sector (e.g., restaurant, tennis court, bus stop), see Fig. 1. 213 patients (25.8 %) received the diagnosis of STEMI in the emergency room. Of these, 47 patients presented individually to the emergency room, and 115 patients were transferred to the emergency room by the FMC emergency physician for further diagnosis. Four patients were delivered to the emergency room after the Rescue Coordination Centre dispatched paramedics without physician's company. Forty-seven patients were initially seen by their family/on-call doctor and subsequently

sent to the ER. In 103 patients (12.5 %), STEMI was diagnosed in the medical practitioner's or cardiologist's office. 102 patients (12.3 %) were transferred from an external hospital to the PPCI-center. 20 patients (2.4 %) were already inpatients at Klinikum Augsburg when their STEMI occurred.

Of 115 patients with STEMI having been transferred to the ER by the EP, 8.7 % ($n = 10$) received initially no ECG and 20.0 % ($n = 23$) limb leads only. In 71.3 % ($n = 82$), a regular 12-lead ECG was recorded. The latter was transferred to the intervention center in 7.3 % of cases ($n = 6$).

Revascularization treatment at the PPCI center

Six hundred and eighty out of 826 patients (82 %) underwent PPCI. Of these, 16 patients received first PPCI of the culprit lesion and subsequent, semi-elective surgical treatment of remaining stenoses during the hospital stay. One patient was transferred to surgery after PPCI for assist device implantation and one patient for ventricular rupture treatment. 45 patients (5.4 %) received immediate emergency surgery as reperfusion treatment. A conservative approach with no revascularization attempt was agreed upon for 22 patients (2.7 %), as a consequence of their multimorbid status. In addition, three patients (0.4 %) did not agree to undergo invasive catheterization. 47 patients (5.7 %) had no PCI requiring coronary artery occlusion/stenosis (e.g., Takotsubo cardiomyopathy), 11 patients (1.3 %) died ahead of cardiac catheterization. In 16 patients (1.9 %), PPCI attempt was unsuccessful (no wire crossing possible) and no further treatment was persecuted.

Procedural success of PPCI, i.e., TIMI-3 flow of the target vessel, was achieved in 94 % of PPCI patients. Periprocedural GP IIb/IIIa antagonists were selectively used only in less than 25 % of patients (cardiogenic shock or large thrombus burden of the infarct-related artery).

Time intervals across the total population

For all 680 patients with PPCI—regardless of the location of STEMI diagnosis—median PCT was 64 min, CDT was 53 min, DBT 70 min, and CBT 135 min, respectively (Table 1).

ESC guidelines [5] demanding PPCI within 60 min DBT were fulfilled with direct transfer to the cath lab in 87 %, whereas this target was reached with transfer to ICU or ER in 39 and 4 % only, respectively (total 38 %, Table 2). Time intervals were slightly better with EP as FMC due to a shorter prehospital time (Table 3). All PCI patients with direct transfer to the cath lab received their intervention within 2 h DBT compared to patients initially admitted to ER (48 % PPCI rate) or to ICU (90 %). A PPCI rate of 84 % was seen with a CBT of ≤120 min with direct cath lab transfer.

Time intervals with EP as FMC

Four hundred and twenty-two PPCI patients out of 680 were initially treated by an EP. PCT with 53 min (vs. 135 min, $p < 0.01$), CDT with 49 min (vs. 65 min, $p = 0.05$), and CBT (123 vs. 148 min, $p < 0.01$), respectively, was lower when compared to patients without initial emergency medical contact onsite ($n = 245$, Figs. 2, 3;

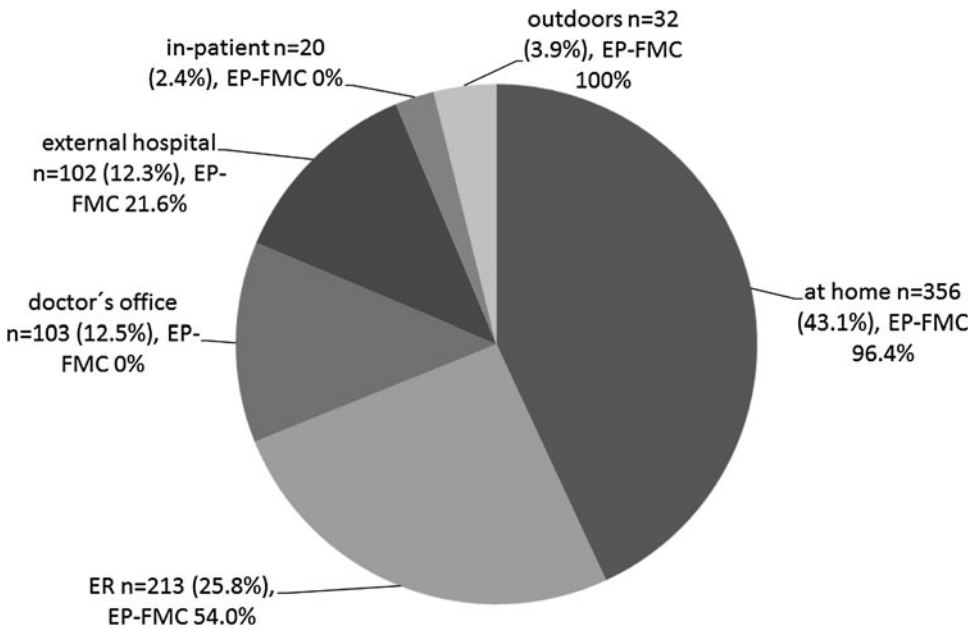

Fig. 1 Location of STEMI diagnosis for the total population ($n = 826$). 50. 6 % of STEMI were diagnosed not on site but in external hospitals, doctor's offices, or in the emergency department of the PCI center

Table 1 Time intervals in the HERA registry for the total population with PPCI ($n = 680$), for PPCI patients with ambulance emergency physician EP as first medical contact FMC ($n = 422$), and for PPCI patients without EP contact ($n = 245$)

	PCT	CDT	DBT	CBT
Total				
Median (min)	64	53	70	135
Interquartile range	30–176	37–75	49–104	103–183
Range	0–1,440	0–1,350	20–1,277	55–1,460
FMC: emergency physician				
Median (min)	53	49	69	123
Interquartile range	25–120	38–62	48–101	96–170
Range	0–1,440	0–1,350	20–1,277	55–1,460
FMC: no emergency physician				
Median (min)	135	65	74	148
Interquartile range	45–332	34–107	52–110	116–205
Range	0–1,440	0–990	29–1,440	60–1,200

PCT pain first medical contact time, *CDT* first medical contact door time, *DBT* door balloon time, *CBT* first medical contact balloon time, *PPCI* primary percutaneous coronary intervention

Table 2 Percentage of PPCI performed, dichotomized for different time intervals for the total population with PPCI ($n = 680$)

	Time delay in hours				
	<1	<2	<3	<4	<6
TIT					
Total	0.0	7.5	34.3	52.5	70.3
Direct CL	0.0	21.7	62.0	78.3	85.9
Via ICU	0.0	8.0	39.1	57.1	75.3
Via ER	0.0	2.4	18.6	41.3	64.1
CBT					
Total	0.6	39.3	71.2	83.2	90.1
Direct CL	2.2	83.7	97.8	98.9	98.9
Via ICU	0.0	44.2	85.9	94.2	96.5
Via ER	0.6	23.4	52.1	73.7	87.4
DBT					
Total	38.2	79.3	90.1	92.5	95.3
Direct CL	87.0	100.0	100.0	100.0	100.0
Via ICU	39.4	90.1	96.5	97.8	98.1
Via ER	4.2	47.9	77.2	83.8	94.0

TIT total ischemic time, *CBT* first medical contact balloon time, *DBT* door balloon time, *PPCI* primary percutaneous coronary intervention

Table 1). DBT (69 vs. 74 min) was not different in the two groups. A DBT <90 min was achieved in 64 % of all PPCI patients and in 68 % of patients with EP FMC.

A significant reduction of DBT was seen when patients were directly transferred by the emergency physician to the cath lab, bypassing ICU or ER. With EP as FMC DBT was 38 min for patients with direct transfer to the cath lab

Table 3 Percentage of PPCI performed, dichotomized for different time intervals for patients with PPCI and emergency physician as first medical contact ($n = 422$)

	Time delay in hours				
	<1	<2	<3	<4	<6
TIT					
Total	0.0	10.7	42.4	63.0	82.0
Direct CL	0.0	27.1	68.6	85.7	94.3
Via ICU	0.0	10.7	47.9	67.9	85.5
Via ER	0.0	1.1	17.0	45.5	72.7
CBT					
Total	0.5	47.6	77.7	88.2	93.8
Direct CL	2.9	94.3	100.0	100.0	100.0
Via ICU	0.0	51.3	89.4	94.5	97.0
Via ER	0.0	13.5	47.2	76.4	88.8
DBT					
Total	40.5	81.0	91.5	93.1	95.7
Direct CL	85.7	100.0	100.0	100.0	100.0
Via ICU	41.1	90.7	97.0	97.9	98.3
Via ER	2.2	42.7	74.2	79.8	91.0

TIT total ischemic time, *CBT* first medical contact balloon time, *DBT* door balloon time, *PPCI* primary percutaneous coronary intervention

compared to 69 min for patients transferred via ICU ($p < 0.01$). Detailed time intervals for various pathways to the cath lab are given in Fig. 3.

Thus, EP FMC shortens CDT by 16 min (from 65 to 49 min), and direct transfer to the cath lab improves DBT by 31 min (from 69 to 38 min).

Cardiogenic shock

Altogether, 143 patients out of 826 (17.3 %) presented with cardiogenic shock. 112 out of 512 patients (21.9 %) with EP FMC were in cardiogenic shock at first contact, transfer, or admission. 112 out of 143 (78 %) of all shock patients were initially treated by an EP, compared to 62 % for the whole population ($p < 0.01$). PCT in these patients was significantly shorter than in stable patients (42 vs. 59 min, $p < 0.01$). There was a trend for a slightly longer DBT in patients with cardiogenic shock (71 vs. 68 min, $p = 0.13$) due to a longer time interval between door time and start of angiography. Differences of CDT with 50 versus 48 min did not reach statistical significance.

Mortality

Total in-hospital mortality was 8.8 % (73 out of 826). For PPCI patients, in-hospital mortality was 6.2 % (42 out of 680). 29 of 73 patients (40 %) with fatal outcome had not received PPCI as treatment. Of all patients with lethal

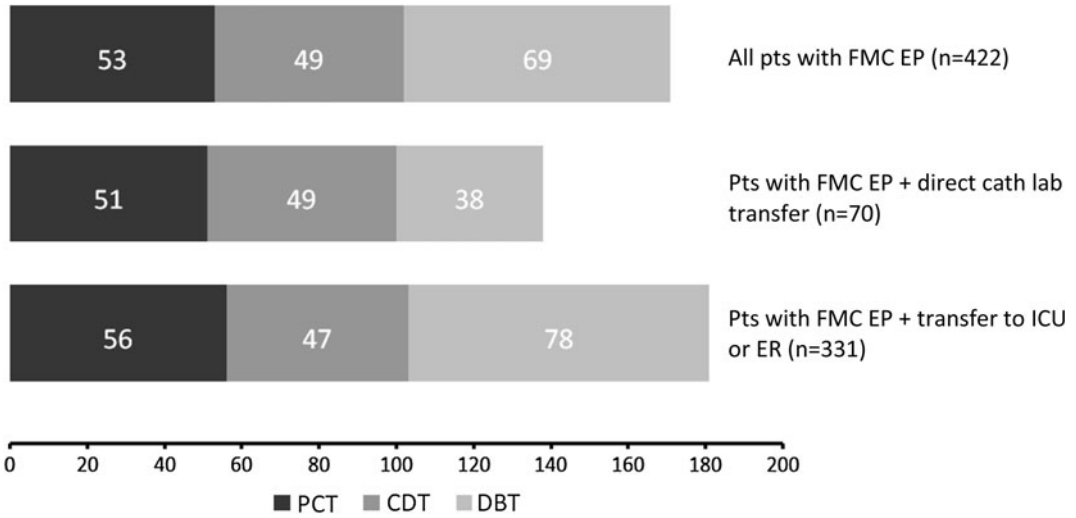

Fig. 2 Median time intervals in minutes for PPCI patients with emergency physician as first medical contact (EP FMC). *PCT* pain first medical contact time, *CDT* first medical contact door time, *DBT* door balloon time, *PPCI* primary percutaneous coronary intervention, *ICU* intensive care unit, *ER* emergency room

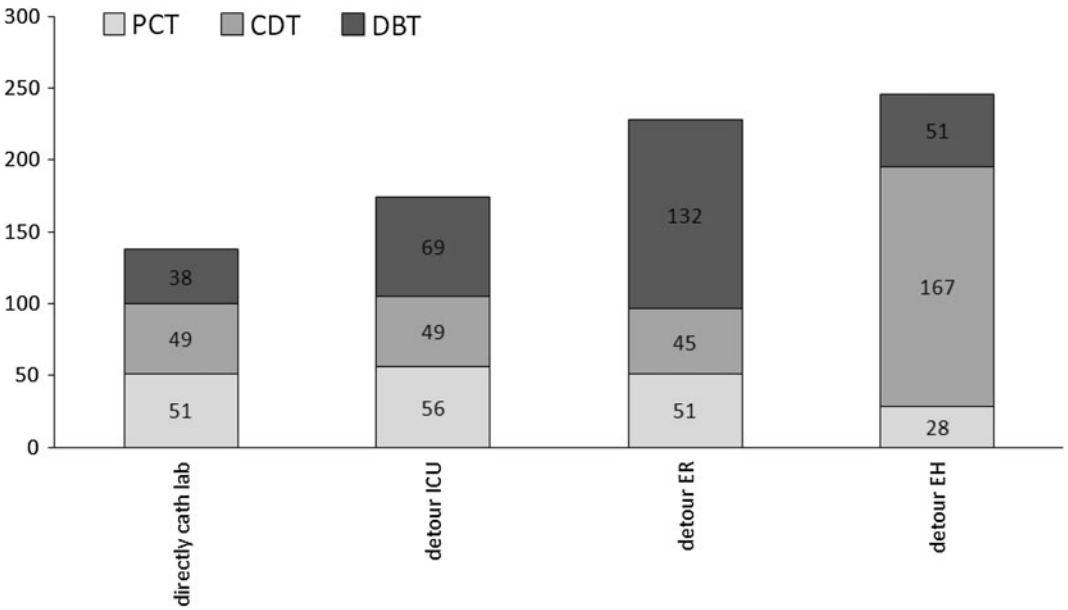

Fig. 3 Time intervals for pathways to cath lab for patients with emergency physician as first medical contact (total $n = 422$; directly CL $n = 70$; detour ICU $n = 240$, detour ER $n = 91$, detour EH $n = 21$). *PCT* pain first medical contact time, *CDT* first medical contact door time, *DBT* door balloon time, *CL* cath lab, *ICU* intensive care unit, *ER* emergency room, *EH* external hospital

outcome, 51 out of 73 (70 %) presented in shock. For the whole cohort of 826 patients, in-hospital mortality for patients with shock was 35.7 % (51 out of 143) versus 3.2 % (22 out of 683) for patients without shock. In-hospital mortality was 38.8 % for shock patients with initial presentation of ventricular fibrillation/flutter ($n = 29$). In-hospital mortality for patients receiving PPCI ($n = 680$) amounted to 28.0 % (30 out of 107) in patients with shock, and to 2.1 % (12 out of 573) in patients without shock. Detailed in-hospital mortality data for different time delays and patient admissions are given in Tables 4 and 5.

Mortality is significantly higher in case of admission of the patient in the ER compared to ICU or cath lab, and in longer (e.g., >3 h) compared to shorter (e.g., <3 h) PCT or total ischemic time (TIT), respectively. Mortality was 3.7 % in patients below the median CBT of 135 min and 8.6 % for patients above.

Bypassing the nearest hospital

Emergency physicians transferred 24 out of 512 (4.7 %) patients not to the PPCI center but to the nearest hospital

Table 4 In-hospital mortality in % for different time delays for the PPCI population ($n = 680$) and for PPCI patients with ($n = 107$) or without shock ($n = 573$), respectively

	<1 h	≥1 h	*p*	<2 h	≥2 h	*p*	<4 h	≥4 h	*p*
All pts with PPCI									
TIT				2.1 (1/48)	6.4 (38/596)	0.23	5.7 (20/351)	6.5 (19/293)	0.68
CBT				4.6 (12/260)	7.2 (28/389)	0.18	5.5 (31/565)	10.7 (9/84)	0.06
DBT	3.8 (9/239)	7.5 (32/426)	0.54	5.0 (27/539)	11.1 (14/126)	0.01	5.9 (37/628)	10.8 (4/37)	0.23
Without shock									
TIT				2.6 (1/39)	1.8 (9/503)	0.73	1.7 (5/286)	2.0 (5/256)	0.86
CBT				1.8 (4/222)	1.9 (6/323)	0.88	1.5 (7/474)	4.2 (3/71)	0.11
DBT	1.4 (3/210)	2.3 (8/351)	0.48	1.1 (5/462)	6.1 (6/99)	0.01	1.5 (8/529)	9.4 (3/32)	0.002
With shock									
TIT							23.1 (15/65)	35.7 (15/42)	0.16
CBT				21.1 (8/38)	33.3 (22/66)	0.18	26.4 (24/91)	46.2 (6/13)	0.14
DBT	20.7 (6/29)	32.0 (24/75)	0.25	28.9 (22/76)	28.6 (8/28)	0.97	29.3 (29/99)	20.0 (1/5)	0.66

Missing data TIT $n = 36$, CBT $n = 31$, DBT $n = 15$

TIT total ischemic time, *CBT* first medical contact balloon time, *DBT* door balloon time, *PPCI* primary percutaneous coronary intervention

Table 5 CBT and mortality for patients with EP as FMC, for different admission sites ($n = 401$), for PCT/TIT < and ≥3 h ($n = 422$)

	Cath lab	ICU	ER
n	70	240	91
CBT [min]	87	120	187
Mortality [%]	5.7	6.7	11.0*
	PCT <3 h	PCT ≥3 h	
n	327	95	
Mortality [%]	6.1	12.6*	
	TIT <3 h	TIT ≥3 h	
n	183	239	
Mortality [%]	4.9	9.6*	

*$p < 0.001$

ICU intensive care unit, *ER* emergency room, *CBT* first medical contact balloon time, *PCT* pain first medical contact time, *TIT* total ischemic time

with the consequence of subsequent transfer to the PPCI center. For this group, TIT was 265 min ($n = 21$) compared to 165 min for patients initially transferred to the PPCI center ($n = 401$, $p < 0.01$).

Discussion

Medication on site

A core medication of heparin (90 %) and aspirin (91 %) was given by EPs on scene to the overwhelming majority of STEMI patients. Daudelin et al. [30] reported a 75 % rate of aspirin given on site with an improvement to 82 % after giving feedback und taking quality improvement measures. Recent data from ''German chest pain unit registry'' report a similar use of aspirin (91.4 %) and heparin (82.5 % unfractionated, 13.7 % low-molecular weight heparin) [31]. The application of an ADP receptor blocker (during the observation period clopidogrel) with 10 % is clearly undersupplied when class 1C recommendations, ''as soon as possible'' and when ''PPCI is planned'' were adopted. However, randomized trials comparing pre- versus in-hospital or during angiography application of ADP receptor blockers are scarce [32]. Administration of the loading dose was not generally recommended on scene in our cohort when a timely start of the PPCI procedure was expected, explaining the low prehospital application rate. Newer platelet inhibitors like prasugrel or ticagrelor were not utilized during the observation period.

The selective use of beta-blocker therapy on site in about one-third of patients is not inadequate. Based on the COMMIT-CCS 2 trial [33], current guidelines are cautious on this issue when compared to earlier recommendations [5].

Only two-thirds of patients received morphine despite its class I–C indication for relief of pain and also of anxiety and dyspnea. A standardization of morphine administration in all patients is desirable.

ECG transmission and DBT

Early and reliable diagnosis of STEMI with 12-lead ECG on site and its transmission to the intervention center allows for simultaneous (rather than sequential) activation of the cardiac catheterization team without false alarms.

The essential role of immediate ECG recording is enhanced by a study by Diercks et al. [21], which shows that a delayed ECG worsens outcomes after 30 days. Dhruva et al. [34] demonstrated a shortened DBT by 65 min when a 12-lead ECG was transmitted to the Response Center. A strategy of direct transfer to the cath lab reduces DBTs considerably [17, 35–37]. In the HERA registry DBT was significantly reduced by 31 min with direct transfer of the patient to the cath lab (DBT 38 min vs. DBT 69 min in case of transfer via ICU). This is, however, only reasonable with ECG recording on scene and its obligatory transmission to the PPCI hospital to avoid false alarms.

PCT and prehospital time (PCT + CDT)

PCT was 64 min for the total population, which is shorter than anticipated. Prehospital time (PCT + CDT) sums up to 135 min. In the case of an emergency medical alert by the patient, PCT and prehospital time were even shorter at 53 and 110 min, respectively. It remains unclear, however, whether this a consequence of an initially worse condition with seeking help faster, or of a better informed patient with more rapid and correct interpretation of symptoms and quick emergency medical contact. The higher incidence of shock patients in the emergency physician treated compared to the whole population favours the first explanation. Nevertheless, EP FMC saves on average 15 important minutes of prehospital time.

A meta-analysis of 25 randomized trials investigating thrombolytic therapy or PPCI revealed a median PCT of 141 min [7]. "Real-world" registry data showed PCTs from 120 min [11] to 170 min [20] (Table 6).

Despite comparably encouraging short PCTs and prehospital time intervals, faster contact times and a higher rate of direct emergency medical alarm (at present 62 % only) by intensifying continuous public education are essential in the future, both to reduce the incidence of sudden cardiac death in the premedical interval as well as to shorten the TIT.

CBT and DBT

The median CBT of 135 min and the median DBT of 70 min for the total HERA population appear too long at first sight. In the aforementioned meta-analysis of 25 randomized trials, the median DBT was 76 min [7], in the GRACE registry 99 min in 1999 and non-significantly reduced to 80 min in 2006 [11], in the NRMI-registry 117 min [12], in the ALKK registry 65 min [25], in the MITRA/MIR registries 70 min [14], in the Vienna registry 81 min [9], and in the PREMIR registry (with obligatory pre-hospital diagnosis) 51 min [38], respectively (Table 6).

Table 6 Therapy-relevant median time intervals (in min) in randomized controlled trials and registries

	PCT	PCT + CDT	CBT	DBT	TIT
HERA	64	117	135	70	200
RCT					
Metaanalysis [7]	141			76	
Registries					
GRACE (INT[11])	120	133		80	200
NRMI (USA[12])				117	
Vienna-HI (A[9])	140			81[a]	258
FAST-MI (F[20])		170			
MITRA/MIR (G[14])		150		70	220
ALKK (G[25])				65	
PREMIR (G[40])	80			51	

RCT randomized controlled trials, *INT* international, *USA* United States of America, *A* Austria, *F* France, *G* Germany

[a] CBT or DBT combined

The goal DBT can be read in a subgroup of patients transferred directly to the cath lab. With 38 min, DBT was reduced by 49 %. Muller et al. [39] reported that a DBT of <30 min can be achieved in the majority of patients. However, TIT was more than 2 h longer in transferred patients (>50 % of patients).

From our data, it can be shown that there is a hierarchy of admission and handoff strategies for improving system delays. The DBT is shortest with 38 min in case of direct admission to cath lab, worse with admission to ICU (69 min), and inacceptable with admission to ER (132 min). The percentage of patients treated with a DBT <1 h/<2 h is 87 and 100 % with admission directly to the cath lab, 39 and 90 % with admission at ICU, and 4 and 48 % at ER. A CBT <2 h is achieved with handoff in the cath lab in 84 % of patients, via ICU in 44 %, and via ER in 23 %. Admission to an external hospital increased the CBT to inacceptable 201 min. Therefore, all efforts must concentrate on (1) direct transfer to the PPCI center, (2) always bypassing the ER, (3) reducing the rate of ICU admission together with increasing the rate of direct cath lab admissions. Direct cath lab handoff requires the presence of the intervention team. Whether this can be achieved with a team on call (as in most intervention centers, including ours) or with a 24 h in-house team, depends on the individual situation of the PPCI-center. The same strategies to reduce DBT were recently confirmed by data from the FITT-STEMI registry [40]. In congruence, ESC guidelines request both, direct transfer to the PPCI center and bypassing the ER of the center [5].

A tendency for longer DBTs in patients in cardiogenic shock results from patient stabilization, which should be performed simultaneously to angiography, thus aiming at a

maximum shortened DBT especially for these high risk patients. This is supported by our mortality data for patients presenting in shock which rise rapidly beyond a DBT >1 h.

Current guidelines with a CBT of <90 min for all patients and individually <60 min [5]. or a CBT or DBT of <90 min [1] strongly conflict with data from studies or "real-world" registries on actually achieved CBTs or DBTs [2, 6–14, 16, 20, 25, 38, 41]. This underscores the need for the implementation of infarction networks with a defined protocol, continuous evaluation and an attempt of permanent additional improvements [42]. However, the guidelines' time request has been determined arbitrarily. The data from randomized trials or registries supporting a *median* CBT of 120 min as a critical limit were turned into the demand of a CBT of less than 120 min in the previous [3] and less than 90 min in the present guideline [5] in *all* cases. A median CBT of 120 min, however, implies by definition that 50 % of patients are beyond this time. A real world situation on its way to the ideal scenario to be achieved in increasingly more patients.

Mortality

In-hospital mortality in our PPCI group was 6.2 % (42 out of 680), very low in non-shock patients with 2.1 % (12 out of 573), and reasonable in shock patients with 28 % (30 out of 107). The GRACE registry reports a slight decrease of in-hospital mortality from 6.9 to 5.4 % between 1999 and 2006 (together with a non-significant reduction of the DBT from 99 to 80 min). However, less than 5 % of patients were in cardiogenic shock [8]. The Swedish RIKS-HIA registry reports a 7 days mortality in PPCI patients of 3.5 % (26.205 patients included in 1999–2004, 8.8 % of patients in shock) [13]. In the Vienna myocardial infarction registry in-hospital mortality in PPCI patients amounted to 8.1 %, in the absence of shock 2.9 %, in the presence of shock 47.3 % [9]. The ALKK-registry in Germany reported in 4,815 STEMI patients treated with PPCI between 1994 and 2000 an in-hospital mortality of 4.0 % in non-shock patients, and 41.6 % in shock patients (14.1 % of the whole population) [25]. As the DBT in this registry is almost identical to our DBT and the percentage of shock patients is comparable (14.1 vs. 17.3 %), the lower mortality in our population may result from technical and pharmacological improvements over the last decade, not from a decline in time intervals.

Mortality in low risk patients without shock does not rise before a DBT >2 h. In stable patients, we found a tendency for increasing mortality at a CBT >4 h. However, shock patients strongly benefit from a DBT of less than 1 h (Table 4). These observations are in congruence with data from randomized controlled trials and registries [2, 6–14, 16, 20, 25, 38, 41]. The conclusion should be to speed up with shock patients, but not at all to lose time with low risk patients, since for all patients a prolonged TIT or CBT is associated with worse survival.

A limitation of this study is that we could not include all patients who were initially treated in an outside hospital due to insufficient documentation of time intervals and medication. In addition, this investigation is a single centre study and subject to related restrictions on transferability.

Conclusion

The patient (PCT) and organization-dependent (CBT and DBT) time intervals in the HERA network are comparable to or slightly better than published data, although they do not meet guideline demands. In-hospital mortality in non-shock PPCI patients is very low (2.1 %) and encouraging in shock patients (28 %). However, strong efforts must be made to further reduce the TIT. These comprise patient education including correct interpretation of symptoms and appropriate action (emergency medical alert, which was present in 62 % of patients only in our population). Emergency physician as FMC reduces the CDT by at least 16 min. Further improvement is mandatory with routine transmission of a 12-lead ECG recorded on site to the PPCI center for simultaneous activation of the catheterization team. External non-PPCI centers as well as the ER of the PPCI center should be bypassed whenever possible. The ideal is a direct transfer of the definite STEMI patient by the emergency physician to the cath lab. This reduces the DBT by 31 min (49 %) and doubles the percentage of patients reperfused within a DBT <1 h and a CBT <2 h.

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Conflict of Interest The authors declare that they have no conflict of interest.

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