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Significance of Off-hours in Centralized Primary Percutaneous Coronary Intervention Network

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Aim To analyze the efficacy of a regionally organized primary percutaneous coronary intervention (PCI) network at the Heart Center, Semmelweis University Budapest, part of the "Budapest model," and the factors that influence it.

Methods In order to investigate the differences between regular and off-hours patient care in a 24-hour myocardial infarction primary care system, we included 1890 consecutive, unselected patients with ST-segment elevation myocardial infarction and followed them until at least one year. The follow-up was complete for all participants.

Results The difference between regular hours and off-hours mortality was not significant either after 30 days (8.6% vs 8.8%, respectively) or after 1 year (15.3% vs 14.7%, respectively). The rate of patients with re-infarction, frequency of re-intervention, and major adverse cardiac events, including death, re-infarction, re-intervention, and coronary artery bypass graft surgery, were similar in both patient groups. The time delay between the onset of chest pain and arrival to the clinic was 5.9±5.8 hours (mean± standard deviation) during regular hours and 5.2±4.6 hours during off-hours ($P=0.235$). Direct transport caused significant decrease in the 30-day and 1-year mortality independent of duty time (7.2% vs 9.9%, $P=0.027$; 12.6% vs 16.7%, $P=0.028$; respectively).

Conclusion Centralized primary PCI network of the "Budapest model" achieved the same level of patient care during both off-hours and regular hours.

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The generally accepted treatment of acute ST elevation myocardial infarction (STEMI) within 12 hours is primary percutaneous coronary intervention (PCI). However, the outcome of PCI may be influenced by several factors, like annual number of procedures (1-4), experience of the operating physician, time delay to treatment (5-8), and organization level of myocardial infarction care (9-16). In case of organized primary PCI network, the most important factor that influences the clinical outcome is the time of the arrival to the PCI center. Patients treated during off-hours can have a higher incidence of failed operation procedure and consequently a worse prognosis than patients treated during regular hours (17-22).

Assali et al (18) reported that the unadjusted mortality at 1 month was significantly higher in patients treated during the night than in those treated during the day (9.7% vs 3.1%) (18). Henriques et al (19) demonstrated that the admittance of patients between 8:00 AM and 6:00 PM was associated with an angioplasty failure rate of 3.8%, compared with 6.9% between 6:00 PM and 08:00 AM Thirty-day mortality was 1.9% in patients with hospital admission between 8:00 AM and 6:00 PM, compared with 4.2% in patients with hospital admission between 6:00 PM and 8:00 AM (19). A related study of 231 164 STEMI patients (20) showed that the 30-day mortality was significantly higher for patients admitted on weekends (12.9% vs 12.0%). A cohort study of 68 439 patients with STEMI (21) showed that these patients had substantially longer door-to-balloon times during off-hours (116.1 minutes) than during regular hours (94.8 minutes; difference, 21.3 minutes; 95% confidence interval, 20.5-22.2).

There are only limited data about organized primary PCI networks in large European cities (11-13,23,24). Despite the fact that it has been shown that high-quality organization of the primary PCI network may improve the outcome (25,26), a well organized, 24-hour available "service" for every citizen is rarely available (11).

Five years ago we established a centralized myocardial infarction primary care model for the Budapest region, called the "Budapest model" (16), in which all the patients from the region requiring reperfusion therapy are primarily transported for PCI. The model comprises 5 PCI centers that perform primary PCI care on weekdays during regular hours, while during off-hours 1 of the 5 centers is on duty and admits all the patients.

The aim of our study was to analyze the efficacy of the primary PCI network in Budapest and central Hungary, and to study the differences between regular and off-hours patient care in a 24-hour myocardial infarction primary care system.

METHODS

The Budapest model

Coronary intervention in acute myocardial infarction with an on-site team in a 24/7 system has been organized in the region of Central Hungary, including the city of Budapest (2.9 million inhabitants on a territory of 6880 km^2), since January 1, 2003. The region is divided into 5 sub-regions with 5 interventional centers responsible for providing primary PCI care from Monday to Friday between 8 AM and 6 PM In off-hours, ie, every weekday from 6 PM until 8 AM the next day and from 6 PM Friday until 8 AM Monday, one of the interventional centers performs the PCI of all STEMI patients. The interventional center on duty has to provide a pair of invasive cardiologists, a pair of physicians, one of whom is an intensive care specialist, and a full staff of hemodynamic and radiology assistants for the off-hour duty.

Heart Center, Semmelweis University

The primary PCI center of the "Budapest model" is Heart Center, Semmelweis University, a large university interventional center. The main task of the clinic is PCI care of patients with STEMI. Annually, the clinic performs 2500 PCIs, approximately 1800 for acute coronary syndromes. Each interventional cardiologist performs on average 400 PCIs per year. All the patients assigned to our center are consecutively enrolled and treated in the university clinic. Except these patients, all patients after unsuccessful thrombolysis (rescue PCI) or cardiogenic shock patients up to 36 hours (emergency PCI) are also admitted to the department. Coronary care unit permanently offers 2 operating rooms in the catheterization laboratory, which can be used simultaneously, 15 intensive care unit beds, 8 respirators, 6 intraaortic balloon pumps, and a local continuous veno-venous hemodiafiltration. On-site heart surgery is provided 24/7. Permanently available are two interventional cardiologists, one intensive care specialist, one resident, two hemodynamic assistants, and two radiologic assistants (both in regular hours and off-hours).

Patients

Between January 1, 2003, and December 31, 2005, altogether 1890 patients with STEMI were admitted

to our clinic for acute coronary angiography. In 1821 cases, primary PCI was performed within 12 hours after the onset of chest pain. Rescue PCI was performed in 31 cases and emergency PCI was performed in other 31 cases. During 3 years, 671 patients were admitted during regular hours and 1219 during off-hours.

Demographic data (age, sex), comorbidities (hypertension, diabetes, stroke), history of coronary artery disease (previous myocardial infarction, PCI, coronary artery bypass graft surgery), and angiographic data (door-to-balloon time, 2 or more vessel PCI, left main PCI) of patients who underwent acute coronary angiography were collected. The resources of patients' demographic and clinical data were the Hungarian Health Insurance Institution, the patient registry of Semmelweis University, and the personal follow-up of patients.

The time from the onset of chest pain was divided into 3-hour long intervals (0-3 hours, 3-6 hours, 9-12 hours, and more than 12 hours). Comparisons were made for the whole patient group, as well as for time-interval subgroups.

Based on the large number of patients involved in the study, subgroup analyses were performed to examine clinical outcome of patients with hemodynamic complications such as cardiogenic shock. The way of transport to the invasive center was also analyzed based on the reports of the first medical examination (ambulance, general practitioner, or other hospital). Direct transport means that the patient is transported by the ambulance from the field directly to the PCI center, while secondary or indirect transport means that the patient is transported first to a non-invasive center and afterwards to a PCI center.

Statistical analysis

Results are presented as mean ± standard deviation for continuous variables. Because some of the data were not normally distributed, Wilcoxon signed-ranks test and Mann-Whitney U test for paired and unpaired data were performed to investigate the differences between the 2 variables. Frequencies of occurrence in subpopulations were compared using Pearson χ^2 test or Fischer exact test. Logistic regression adjusted for age and sex was used to calculate mortality data. Probability values lower than 0.05 were considered significant. Calculations were performed with SPSS 15.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Over 3 years, 671 (35.5%) patients with STEMI were admitted to our university clinic during regular hours and 1219 (64.5%) during off-hours. Demographic, clinical, and procedural data of the patients enrolled in the study are presented in Table 1. General clinical data and incidence of known cardiovascular risk factors did not differ between the 2 patient groups. The success rate, frequency of multivessel PCI, and the rate of left main PCI were similar in both groups. The door-to-balloon time was significantly shorter during off-hours (45 ± 5 vs 41 ± 5 minutes $P < 0.010$). The difference between regular hours and off-hours mortality at 30 days and at 1 year was not significant (Table 2). Similar results were found when the cardiogenic shock patient subgroup was analyzed (Table 2). The incidence of re-infarction within the first 30 days was about 1% in both groups ($P = 0.548$). The rate of re-infarction increased from approximately 1% to 10% until the end of the first year but was not different between the groups. The frequency of re-intervention (rePCI) was similar in both groups ($P = 0.539$). The incidence of major adverse cardiac events (death, re-infarction, rePCI, and coronary artery bypass graft [CABG]) was similar in both groups.

The large number of patients involved in the study allowed the analysis of specific but small subgroups. Rescue PCI following unsuccessful thrombolysis was performed

TABLE 1. Demographic, clinical, and angiography parameters of STEMI patients admitted to Heart Center Semmelweis University between 2003-2005*

	Admission to hospital		
Parameter	regular hours (n = 671)	off-hours (n = 1219)	*P*
Age (mean±SD)†	64.09 ± 13.54	63.37 ± 13.46	0.286
Men (%)‡	426 (63.5)	772 (63.33)	0.960
Diabetes mellitus (%)‡	141 (21)	266 (21.8)	0.725
Hypertension (%)‡	343 (51.1)	668 (54.8)	0.135
Previous MI (%)‡	85 (12.7)	166 (13.6)	0.571
Previous PCI (%)‡	30 (4.5)	64 (5.3)	0.508
Previous CABG (%)‡	16 (2.4)	32 (2.6)	0.764
Previous stroke (%)‡	36 (5.4)	73 (6.0)	0.608
Successful PCI (%)‡	659 (98.2)	1198 (98.3)	1.000
Two or more vessels PCI (%)‡	59 (8.8)	98 (8.0)	0.614
Left main PCI (%)‡	14 (2.1)	21 (1.7)	0.605
Door-to-balloon time (min)†	45 ± 5.1	41 ± 4.6	0.005

*Abbreviations: STEMI – ST-segment elevation myocardial infarction; MI – myocardial infarction; PCI – percutaneous coronary intervention; CABG – coronary artery bypass graft; SD – standard deviation.
†t test.
‡Pearson χ^2 test.

TABLE 2. Short term (30 d) and long term (1 y) clinical outcomes in of STEMI patients admitted to Heart Center Semmelweis University between 2003-2005*

	No (%) of patients with outcomes at					
	30 days			1 year		
Clinical outcome	regular hours (n=671)	off-hours (n=1219)	P†	regular hours (n=671)	off-hours (n=1219)	P†
Mortality of all patients	58 (8.6)	107 (8.8)	0.921	103 (15.3)	179 (14.7)	0.697
Mortality of all patients without cardiogenic shock	41 (6.4)	79 (6.8)	0.752	82 (12.8)	145 (12.5)	0.835
Mortality of patients with cardiogenic shock	17 (53.1)	28 (48.3)	0.659	21 (65.6)	34 (58.6)	0.514
Re-infarction	7 (1.0)	9 (0.7)	0.488	70 (10.4)	100 (8.2)	0.105
Re-PCI	10 (1.5)	22 (1.8)	0.612	63 (9.4)	126 (10.3)	0.511
CABG	0 (0)	1 (0.1)	0.458	6 (0.9)	12 (1.0)	0.847
Stroke	2 (0.3)	9 (0.7)	0.229	9 (1.3)	23 (1.9)	0.379
MACE†	75 (11.2)	138 (11.3)	0.925	216 (32.2)	371 (30.4)	0.429

*Abbreviations: STEMI – ST-segment elevation myocardial infarction; PCI – percutaneous coronary intervention; CABG – coronary artery bypass graft, MACE – Major Adverse Cardiac Events.
†Pearson χ^2 test.

TABLE 3. Incidence of myocardial infarction diagnosed by the ambulance on-site and rate of direct transport to the percutaneous coronary intervention center in time intervals

	No (%) of patients					
	diagnosed in the ambulance at			transferred directly to Center		
Time interval from onset of the first complain	regular hours	P*	off-hours	regular hours	P*	off-hours
<3 h	122 (48.0)	0.025	226 (50.4)	151 (59.4)	0.065	289 (64.5)
4-6 h	63 (25.7)	0.159	164 (33.7)	83 (33.9)	0.286	202 (41.5)
7-9 h	8 (11.0)	0.005	47 (29.6)	16 (21.9)	0.055	58 (36.5)
10-12 h	8 (13.3)	0.300	11 (11.6)	9 (15.0)	0.857	21 (22.1)
>12 h	4 (10.3)	0.213	3 (10.0)	5 (12.8)	0.150	4 (13.3)

*Pearson χ^2 test.

in 13 (1.9%) cases during regular hours and in 18 (1.5%) cases during off-hours without significant difference even at 1-year follow-up (15.4 vs 5. 6%, respectively, $P=0.364$). Moreover, the frequency of PCIs following cardiopulmonary resuscitation (CPR) was also similar in 2 groups; 32 cases (4.8%) during regular hours and 52 cases (4.3%) during off-hours. There was also no difference in 1-year mortality between the groups (56.3 vs 59.6%, respectively, $P=0.988$).

The time delay between the onset of chest pain and arrival to the clinic was 5.9±5.8 hours during regular hours and 5.2±4.6 hours during off-hours ($P=0.235$). Ambulance team – when National Ambulance Service was called first – made the diagnosis of myocardial infarction on the field in 205 (30.6%) cases during regular hours and in 451 (37%) cases during off-hours ($P=0.075$). The rest of the patients received primary care from the general practitioner or in another hospital. Table 3 shows the frequency of myocardial infarction diagnosed by the ambulance on-site and the rate of direct transport to the PCI center according to the time intervals defined previously. Significant difference was only found in the 4-9 hours time interval. The rate of myocardial infarction diagnosed by the ambulance on-site and the rate of direct transport to a primary PCI center were significantly higher in off-hours than in regular hours. Thirty two (4.7%) patients with cardiogenic shock arrived at our clinic for PCI during regular hours and 58 (4.7%) patients arrived during off hours. An important finding was a significant decrease in mortality among patients arriving by direct transport in the 30-day and the 1-year follow-up (7.2% vs 9.9%, $P=0.027$; 12.6% vs 16.7%, $P=0.028$; respectively).

DISCUSSION

Our study demonstrated that there was no difference in the clinical outcome of myocardial infarction during regular and off-hours in a large PCI center within the primary PCI network of the "Budapest model." The results are based on 3-year follow-up of patients treated in the

Heart Center of Semmelweis University, and although the study was not designed to test the effects of new service system, they suggest an improvement in the clinical outcomes of acute myocardial infarction.

As opposed to previous studies that found higher mortality of myocardial infarction patients during off-hours than during regular hours (5,17-21), our results showed that there were no diurnal differences in patient care in an a well organized medical care system.

The fact that our study focused on a single out of 5 PCI centers in the Budapest region and did not include the results of all the PCI centers in the whole system could be considered a limitation. However, since our clinic is on duty regularly twice a week and treats almost 30% of STEMI patients in the region, our findings give a good overview of the everyday patient care in the "Budapest model."

Mortality data of unselected consecutive patient population in our study are comparable with the results of other large studies (20,21,24,27). Short term, as well as long term, mortality results were similar during regular hours and off-hours. The same results were demonstrated even when smaller patient groups were analyzed, ie, groups in which rescue PCI or PCI following CPR were performed. Moreover, there was also no significant difference between 2 groups in substantial endpoints like re-infarction, rePCI, or CABG.

In 3 years, almost twice as many patients were admitted during off-hours than during regular hours. The reason for this is that during off-hours all the STEMI patients are transported to the interventional center that is on duty at the time (16). An explanation for diminished differences in mortality of acute myocardial infarction between regular hours and off-hours observed in former studies may lie in the quality work of the medical team, which is probably enhanced by the fact that, unlike in other primary PCI networks, the team of experts is on off-hour duty only every fifth day.

In the region of Central Hungary, most of the patients may get into an interventional center in less than 60 minutes. The transport time (from the onset of symptoms to the primary PCI center) was not longer during off-hours than during regular hours. Since in the "Budapest model" the ambulance may take the patient with the diagnosis of STEMI directly to a PCI center (60% of patients), on-site diagnosis by the ambulance has a large impact – it determines the type of emergency therapy and even the transportation route of patients to the proper hospital care (11,28). Our data showed that during regular hours STEMI patients arrived to the PCI center by direct transport at a lower rate, which might have delayed the beginning of adequate medical therapy (29). Short and long term mortality rates were significantly lower in patients arriving by direct transport. The percentage of STEMI diagnosed on site by the ambulance within 3 hours was 50%, independently of the time of the day. At the same time, the percentage of patients who were directly transported to the PCI center was about 60% in both groups.

Although there was no difference according to the time of the day, it is noteworthy that the number of patients directly transported to the PCI center was relatively small (10%) in the cases when the first diagnosis of acute myocardial infarction was not made by the ambulance. Since the territory of the region is not very large and the maximum transport time suggested in the current guidelines (<90 minutes) should be sufficient for direct transport, more cases of direct transport were expected (1). Although this kind of discrepancy was not found in more-than-12-hour STEMI group, optimization of the direct transport system may improve its efficacy (3,5,9-11,21,30). The rate of on-site myocardial infarction diagnostics and primary transport to PCI center was significantly higher in the 4-9 hours STEMI patient group during off-hours. Thus, patient care during off-hours did not worsen the life expectancy of myocardial infarction patients; moreover, it improved medical care.

When only patients with cardiogenic shock were analyzed – similarly as the whole patient population – there were no differences between the groups admitted during off-hours and regular hours. Almost twice as many patients with myocardial infarction and cardiogenic shock arrived within 3 hours after the onset of symptoms during off-hours than during regular hours. A similar difference did not appear in patients in cardiogenic shock for more than 3 hours. It is remarkable that in both groups, more than 20% of patients in cardiogenic shock for more than 12 hours were admitted. These patients arrived from other hospitals without PCI facilities and in most cases they had unstable hemodynamic status and PCI was their last chance to survive.

In summary, we analyzed the efficacy of an organized primary PCI network in a large city and the surrounding region for the first time in Hungary. Our data demonstrated that the "Budapest model" of primary PCI care was organized to provide optimal medical care for patients with STEMI during regular hours, as well as during off-hours.

The well-defined patient routes may have a remarkable effect on progression and mortality of this life-threatening disease. The work of the organized, always on-site, highly qualified, and experienced medical team may have a key role in the efficiency of the "Budapest model." Good results of the "Budapest model" can probably be explained by the fact that each of the 5 invasive cardiology centers is on 24-hour duty only every fifth day. It seems that this system is better and less expensive than those in which the cardiologist is on call every day.

Today, approximately 90% of the Hungary is covered by primary PCI service. Beside Budapest and the Central Hungary region, 24/7 primary PCI care is provided by a single center in each region. Based on our results, primary PCI care in every region of the country should be organized as the "Budapest model." With such a system we could provide high level primary PCI service with almost hundred-percent coverage.

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