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# Percutaneous coronary angioplasty in elderly patients: Assessment of in-hospital outcomes

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## Abstract

**Background:** *We aimed to assess in-hospital outcomes of percutaneous transluminal coronary angioplasty (PTCA) in elderly subjects.*

**Methods:** *A total of 1000 consecutive patients, who had all been admitted for interventional treatment of symptomatic coronary artery disease, were retrospectively analysed.*

**Results:** *Elderly patients (≥ 70 years of age) were more likely to be diabetic, hypertensive and of female gender. They more frequently were diagnosed with chronic heart failure as well as prior stroke. Significantly higher proportions of the elderly population presented with cardiogenic shock and underwent PTCA as a result of acute coronary syndromes. Multivessel coronary disease affected a large majority of senior patients. Although stenting dominated in both age groups, balloon angioplasty was relatively more frequently applied in the elderly. Coronary angioplasty in elderly patients was associated with fewer direct stenting procedures, longer exposure to X-rays and a higher volume of the contrast medium. The efficacy of intervention, assessed according to clinical and angiographic criteria, was high in both groups, although revascularisation was significantly less complete while crude in-hospital mortality higher in the elderly group. Advanced age remained an independent predictor of both increased in-hospital mortality and longer exposure to X-rays after an adjustment for the baseline characteristics in multivariable analyses.*

**Conclusions:** *Despite frequent comorbidities and more extensive coronary athersoclerosis, a high rate of procedural success was achieved in the elderly population who underwent PTCA. However, after an adjustment for the baseline characteristics advanced age was still associated with a less favourable in-hospital outcome and a higher degree of procedural complexity.* (Cardiol J 2007; 14: 143–154)

**Key words: elderly patients, percutaneous transluminal coronary angioplasty, comorbidities, procedural characteristics, in-hospital mortality**

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## Introduction

The dynamic progress made in medical technologies over the last couple of decades has provided modern, technologically advanced and increasingly more effective therapeutic options, resulting in extension of the human life span. The continuous ageing of the population is becoming a serious problem for healthcare systems in highly developed countries since the burden of coronary artery disease (CAD) increases with the ageing of society.

The choice of optimal CAD treatment in the elderly remains a difficult task within the context of the evidence-based medicine so commonly incorporated into decision-making chains nowadays. The elderly population is only poorly represented in randomised trials on CAD management [1–5]. Therefore the approach in this particular clinical setting has not been firmly established.

In subjects presenting with ST-segment elevation myocardial infarction (STEMI) the major limitations of pharmacological reperfusion therapy (numerous contraindications, poor tolerance, increased risk of bleeding and low final effectiveness) often make this method of treatment inappropriate for this age group. It is estimated that only one third of elderly STEMI patients are eligible to receive fibrynolytic therapy [6]. On the other hand, invasive strategy in elderly people is also believed to be associated with a higher procedural risk, owing to advanced disseminated atherosclerotic lesions, and also with a higher rate of antiplatelet therapy-related complications [7–9].

The aim of our study was to assess in-hospital outcomes of percutaneous transluminal coronary angioplasty (PTCA) in patients ≥ 70 years of age as compared with younger patients.

## Methods

### Study design and patients

A total of 1000 consecutive patients were retrospectively enrolled into a single academic centre registry. All the subjects were admitted to the Department of Cardiology and Internal Diseases of the University Hospital in Bydgoszcz between June 2002 and April 2003 for interventional treatment of symptomatic CAD. The participants were divided according to age into two subgroups of ≥ 70 years of age (233 patients) and < 70 years of age (767 patients).

Percutaneous transluminal coronary angioplasty was performed in three modes, the choice depending on the clinical status of the individual patient:

- elective, for stable angina (SA) — 492 patients (49.2%);
- urgent, for unstable angina (UA)/non-ST-segment elevation myocardial infarction (NSTEMI) — 164 patients (16.4%);
- emergency, for STEMI — 344 patients (34.4%).

The inclusion criterion was the presence of significant (> 50% of artery diameter) stenosis in ≥ 1 coronary artery supplying viable myocardial tissue. Patients with significant stenosis of the left main trunk were excluded from the study. All intervention was carried out in compliance with standard guidelines using a Toshiba CAS-10A angiography device. Each PTCA procedure was preceded by an angiographic study. Bare metal stents were implanted at the operator's discretion. In each case the patient's written informed consent for coronary angioplasty was required. The study protocol was approved by the local ethics committee.

The patients' invasive treatment charts, their angiographic recordings and their hospital medical records were analysed. The demographic and clinical characteristics of the study population are presented in Table 1, while the distribution of selected angiographic and procedural features in the groups compared are displayed in Table 2.

Patient management depended on the mode of qualification for the invasive procedure. Elective procedures were preceded by oral administration of aspirin (75–150 mg once daily) to all patients and additional administration of ticlopidine 250 mg twice daily at least 72 hours prior to the intervention. Patients qualified for urgent/emergency procedure were pretreated with a 300 mg loading dose of clopidogrel. Independently of the mode of management, unless contraindicated, each patient was given unfractionated heparin intravenously (100 IU/kg) and an intracoronary bolus of nitroglycerin (0.3 mg) directly prior to the procedure. Only iso-osmolar or low-osmolar non-ionic contrast media were used. After stent implantation each patient received 75 mg aspirin once daily indefinitely and ticlopidine 250 mg twice daily for 4 weeks. Other medications were given when indicated by international recommendations [10–12].

### Statistical analysis

Quantitative and qualitative data were respectively expressed as arithmetical mean ± standard deviation and the sum and percentage of patients within the analysed group presenting with a particular feature. Arithmetical means and percentage

**Table 1.** Demographic and clinical characteristics of the groups analysed.

| Parameters | Patients ≥ 70 years (n = 233) | Patients < 70 years (n = 767) | p |
|---|---|---|---|
| Gender [male/female] | 138/95 | 563/204 | < 0.00004 |
| Age [years] | 74.6 ± 4.6 | 55.7 ± 8.0 | < 0.000001 |
| Indications for PTCA: | | | |
| stable angina | 89 (38.2%) | 403 (52.5%) | |
| unstable angina/non-ST-elevation myocardial infarction | 52 (22.3%) | 112 (14.6%) | < 0.0004 |
| ST-elevation myocardial infarction | 92 (39.5%) | 252 (32.9%) | |
| Cardiogenic shock on admission | 18 (7.7%) | 23 (3.0%) | < 0.002 |
| Previous myocardial infarction | 105 (45.1%) | 349 (45.5%) | NS |
| Chronic heart failure | 56 (24.0%) | 89 (11.6%) | < 0.00001 |
| Previous stroke | 19 (8.1%) | 36 (4.7%) | < 0.05 |
| Peripheral arterial disease | 15 (6.4%) | 51 (6.6%) | NS |
| Hypertension | 163 (69.9%) | 443 (57.7%) | < 0.001 |
| Diabetes mellitus | 56 (24.0%) | 136 (17.7%) | < 0.04 |
| Smoking: | | | |
| ever | 99 (42.5%) | 532 (69.4%) | < 0.00001 |
| never | 134 (57.5%) | 235 (30.6%) | |
| Body mass index [kg/m$^2$] | 27.0 ± 3.8 | 27.5 ± 3.8 | 0.053 |
| Hypercholesterolaemia | 168 (72.1%) | 640 (83.4%) | < 0.0002 |
| Family history of ischaemic heart disease | 37 (15.9%) | 241 (31.4%) | < 0.00001 |

values were rounded off to one decimal place and relative risk values and the results of multiple regression to two and four decimal places respectively. Examination of normal distribution of quantitative variables was performed using the Kolmogorov-Smirnow test. Continuous variables showing normal distribution were compared using the t-test for the difference between two means of independent variables. The Mann-Whitney test was applied to compare variables which did not show Gaussian distribution. Independent prognostic factors of the short-term outcome were determined with the logistic regression model. Relations between the variables investigated and the likelihood of in-hospital mortality were estimated with the use of odds ratios (OR) and their 95% confidence intervals (95% CI). A multiple-regression model was used to evaluate the independent impact of multiple variables on a continuous variable. Qualitative data were analysed and compared using the $\chi^2$ test (applying Yeats' correction when indicated) or using the Fisher exact test. A value of $p < 0.05$ was considered statistically significant, $0.05 \leq p < 0.1$ was regarded as a trend towards statistical significance, and $p \geq 0.1$ was marked as NS. The abbreviation NM indicates failure in test performance as a result of the violation of test assumptions. All computations were carried out with Statistica, version 7.1 (StatSoft, Tulsa, USA).

## Results

### Patient and procedure characteristics

As indicated in Table 1, elderly patients were more likely to be diabetic, hypertensive and of female gender. They more frequently had a history of chronic heart failure and stroke as well as presenting more often with cardiogenic shock on admission. A significantly higher proportion of them underwent percutaneous revascularisation as a result of acute coronary syndromes. In contrast, univariate analysis revealed more past and current smokers, a greater prevalence of hypercholesterolaemia and a family history of CAD in subjects aged under 70 years.

Multivessel coronary disease affected a large majority of elderly patients (81.1% *vs.* 63.8% in younger subjects, $p < 0.00001$) (Table 2). The elderly and younger subjects did not differ in terms of the localisation of the culprit lesion or baseline TIMI flow in the culprit vessel. The final TIMI flow achieved was also comparable in the two groups. Although coronary stenting dominated in both age groups, balloon angioplasty was relatively more frequently applied in elderly patients. Furthermore, in univariate analysis we observed fewer direct stenting procedures in the latter group. Recanalisation of chronically occluded vessels and simultaneous multivessel interventions were performed in

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**Table 2.** Distribution of selected angiographic and procedural features in the groups compared.

| | Patients ≥ 70 years (n = 233) | Patients < 70 years (n = 767) | p |
|---|---|---|---|
| Coronary artery disease: | | | |
| single-vessel | 44 (18.9%) | 278 (36.2%) | < 0.00001 |
| multivessel | 189 (81.1%) | 489 (63.8%) | |
| Localisation of culprit lesion: | | | |
| right coronary artery | 79 (33.9%) | 292 (38.1%) | |
| left coronary artery | 153 (65.7%) | 467 (60.9%) | NS* |
| saphenous venous graft | 1 (0.4%) | 7 (0.9%) | |
| left internal mammary artery | 0 (0%) | 1 (0.1%) | |
| Baseline blood flow in the culprit vessel: | | | |
| TIMI 0 or 1 | 86 (36.9%) | 274 (35.7%) | NS |
| TIMI 2 or 3 | 147 (63.1%) | 493 (64.3%) | |
| Final blood flow in the culprit vessel: | | | |
| TIMI 0 or 1 | 16 (6.9%) | 47 (6.1%) | NS |
| TIMI 2 or 3 | 217 (93.1%) | 720 (93.9%) | |
| Usage of abciximab | 51 (21.9%) | 135 (17.6%) | NS |
| Recanalisation | 23 (9.9%) | 85 (11.1%) | NS |
| Multivessel PTCA | 11 (4.7%) | 18 (2.9%) | NS |
| Applied PTCA method: | | | |
| POBA | 52 (23.4%) | 126 (16.5%) | < 0.04 |
| stenting | 181 (76.6%) | 641 (83.5%) | |
| Direct stenting | 46 (19.7%) | 225 (29.3%) | < 0.004 |
| Maximal stent or balloon length [mm] | 18.1 ± 6.0 | 17.2 ± 5.4 | < 0.04 |
| Maximal stent or balloon diameter [mm] | 3.0 ± 0.5 | 3.1 ± 0.5 | < 0.003 |
| Maximal inflation pressure [atm] | 13.1 ± 3.3 | 13.6 ± 3.4 | 0.069 |
| Number of used balloons: | | | |
| 0 | 47 (20.2%) | 199 (25.9%) | |
| 1 | 121 (51.9%) | 378 (49.3%) | NS |
| 2 | 54 (23.2%) | 162 (21.1%) | |
| 3 | 11 (4.7%) | 28 (3.7%) | |
| Number of implanted stents: | | | |
| 0 | 52 (22.3%) | 126 (16.4%) | |
| 1 | 145 (62.2%) | 547 (71.3%) | NS |
| 2 | 28 (12.0%) | 81 (10.6%) | |
| 3 | 8 (3.5%) | 13 (1.7%) | |
| X-ray exposure time [min] | 11.1 ± 7.3 | 9.5 ± 6.2 | < 0.001 |
| Duration of PTCA [min] | 40.7 ± 22.2 | 38.5 ± 20.0 | NS |
| Volume of dye used [ml] | 160.2 ± 87.2 | 149.2 ± 75.1 | 0.060 |
| Angiographic outcome of PTCA: | | | |
| effective | 213 (91.4%) | 718 (93.6%) | NS |
| ineffective | 20 (8.4%) | 49 (6.4%) | |
| Revascularisation: | | | |
| complete | 28 (12.0%) | 205 (26.7%) | < 0.0001 |
| incomplete | 205 (88.0%) | 524 (73.3%) | |
| Qualification for further treatment: | | | |
| conservative | 180 (77.3%) | 643 (83.8%) | |
| PTCA | 45 (19.3%) | 110 (14.3%) | 0.052 |
| CABG | 8 (3.4%) | 14 (1.9%) | |

*Saphenous venous grafts and left internal mammary arteries were analysed as one group; POBA — plain old balloon angioplasty, PTCA — percutaneous transluminal coronary angioplasty, CABG — coronary artery bypass grafting

similar proportions in the two groups. Culprit stenoses were markedly longer, while reference lumen diameters were narrower in the elderly subjects. In this population stents were deployed and balloons inflated with lower maximal pressure than in younger individuals. However, the average number of implanted stents and used balloons did not differ between the groups. Coronary angioplasty in the elderly population was associated with a remarkably longer exposure to X-rays. We also noted a trend towards a higher volume of the administered contrast medium in senior patients. The efficacy of intervention was high in both groups (angiographic effectiveness in 91.4% *vs.* 93.6% of cases, final TIMI 2 or 3 flow in culprit vessel 93.1% *vs.* 93.9%), although in the elderly group revascularisation was significantly less complete and qualification for staged percutaneous procedures was more frequent.

## In-hospital mortality and duration of hospitalisation

We observed an unadjusted in-hospital mortality rate of 6.9% in senior patients compared with 2.1% in subjects aged below 70 years ($p < 0.0003$). A subgroup analysis of the in-hospital mortality with respect to the indications for PTCA revealed a statistically higher rate of mortality among elderly patients after emergency PTCA carried out for STEMI (Fig. 1). Although after the exclusion of subjects presenting with cardiogenic shock on admission absolute mortality rates substantially decreased, a significant difference in in-hospital mortality in STEMI patients ≥ and < 70 years old persisted (Fig. 2). We noticed high in-hospital mortality

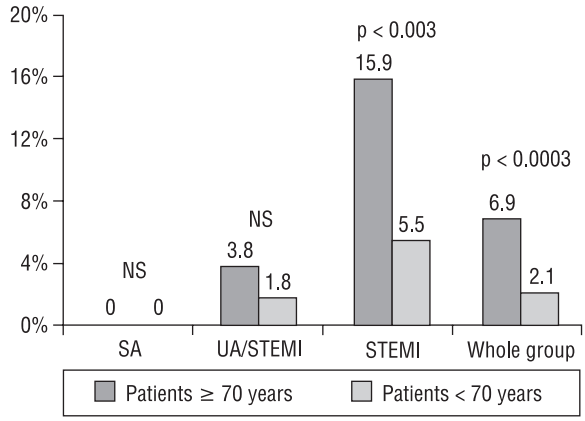


**Figure 1.** Comparison of in-hospital mortality rates; SA — stable angina; UA — unstable angina; STEMI — ST-elevation myocardial infarction; NSTEMI — non-ST-elevation myocardial infarction

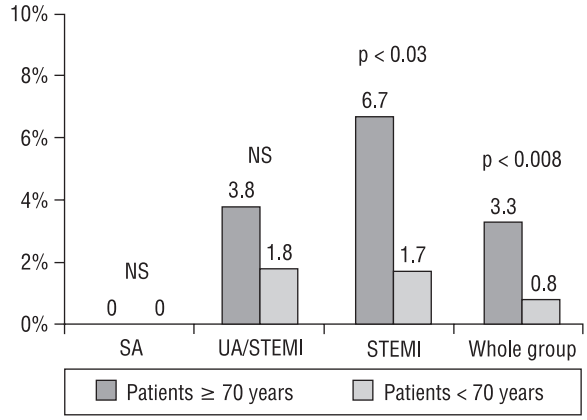


**Figure 2.** Comparison of in-hospital mortality rates after excluding patients with cardiogenic shock; SA — stable angina; UA — unstable angina; STEMI — ST-elevation myocardial infarction; NSTEMI — non-ST-elevation myocardial infarction.

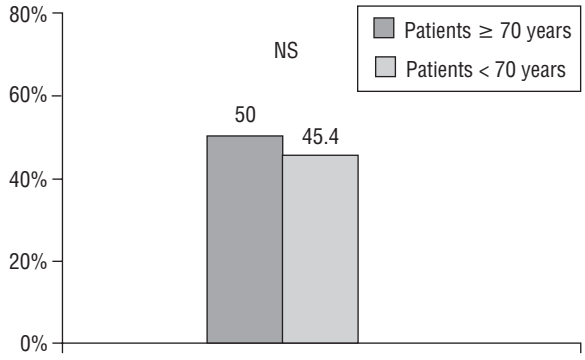


**Figure 3.** Comparison of in-hospital mortality among patients with ST-elevation myocardial infarction complicated with cardiogenic shock.

in STEMI subjects, complicated with cardiogenic shock without any difference with respect to age (Fig. 3).

The total duration of hospitalisation was significantly greater in the case of patients aged ≥ 70 years than for younger ones (Table 3). As far as the relation between the duration of hospitalisation and particular indication for PTCA was concerned, a significant prolongation of in-hospital stay was noted in elderly patients assigned a diagnosis of UA/NSTEMI or STEMI.

## Multivariable analysis

After adjustment for variables from Tables 1 and 2 advanced age remained an independent predictor of increased in-hospital mortality in the

**Table 3.** Duration of hospitalisation according to indications for percutaneous transluminal coronary angioplasty in the groups compared.

| Duration of hospitalisation [days] | Patients ≥ 70 years (n = 233) | Patients < 70 years (n = 767) | p |
|---|---|---|---|
| All indications | 6.5 ± 6.3 | 4.9 ± 5.3 | < 0.0003 |
| Stable angina | 2.8 ± 2.5 | 2.9 ± 4.4 | NS |
| Unstable angina/non-ST-segment elevation myocardial infarction | 9.1 ± 8.9 | 6.2 ± 7.1 | < 0.02 |
| ST-segment elevation myocardial infarction | 8.6 ± 5.4 | 7.4 ± 4.2 | < 0.03 |

**Table 4.** Independent predictors of in-hospital mortality in the entire investigated population and in the age-related subgroups of patients.

| Variable | Variant | OR | 95%CI | p |
|---|---|---|---|---|
| **The entire population** | | | | |
| Cardiogenic shock on admission | Present *vs.* absent | 35.74 | 11.39–112.20 | < 0.0001 |
| Final flow in the culprit vessel | TIMI 0 or 1 *vs.* TIMI 2 or 3 | 6.09 | 1.77–20.99 | < 0.005 |
| Indication for PTCA | STEMI *vs.* SA | 10.43 | 1.72–63.43 | < 0.02 |
| | STEMI *vs.* UA/NSTEMI *vs.* SA | 3.23 | 1.31–7.96 | < 0.02 |
| History of diabetes mellitus | Diabetic patients *vs.* non-diabetic patients | 5.00 | 1.70–14.73 | < 0.004 |
| Gender | Male *vs.* female | 3.68 | 1.13–12.01 | < 0.04 |
| Age | Patient ≥ 70 years *vs.* patients < 70 years | 2.90 | 1.08–7.75 | < 0.04 |
| | 1 year increase in age | 1.05 | 1.01–1.10 | < 0.03 |
| History of myocardial infarction | Prior myocardial infarction *vs.* lack of prior myocardial infarction | 2.97 | 1.06–8.36 | < 0.04 |
| Body mass index | 1 kg/m$^2$ increase in body mass index | 1.14 | 1.01–1.29 | < 0.04 |
| History of statin therapy | Prior statin therapy *vs.* lack of prior statin therapy | 0.18 | 0.06–0.55 | < 0.003 |
| **Elderly patients ≥ 70 years old** | | | | |
| Cardiogenic shock on admission | Present *vs.* absent | 16.46 | 3.71–72.96 | < 0.0003 |
| Indication for PTCA | STEMI *vs.* SA | 11.04 | 0.84–145.50 | 0.066* |
| | STEMI *vs.* UA/NSTEMI *vs.* SA | 3.32 | 0.91–12.06 | 0.066* |
| Final flow in the vessel with the tightest stenosis | TIMI 0 or 1 *vs.* TIMI 2 or 3 | 8.76 | 1.83–41.93 | < 0.007 |
| History of diabetes mellitus | Diabetic patients *vs.* non-diabetic patients | 4.21 | 1.04–16.95 | < 0.05 |
| **Younger patients < 70 years old** | | | | |
| Cardiogenic shock on admission | Present *vs.* absent | 46.87 | 11.63–188.94 | < 0.0001 |
| Indication for PTCA | STEMI *vs.* SA | 31.44 | 2.58–382.99 | < 0.007 |
| | STEMI *vs.* UA/NSTEMI *vs.* SA | 5.61 | 1.61–19.57 | < 0.007 |
| Smoking | Non-smokers *vs.* current or past smokers | 10.62 | 2.64–42.67 | < 0.001 |

*Borderline significance; PTCA — percutaneous transluminal coronary angioplasty, STEMI — ST-segment elevation myocardial infarction, NSTEMI — non-ST-segment elevation myocardial infarction, UA — unstable angina, SA — stable angina

logistic regression model (Table 4). In addition, advanced age was associated with longer exposure to X-rays as a surrogate of procedure complexity (Table 5). Nevertheless, we did not establish any relation between age and the volume of contrast media administered.

## Discussion

The continuous ageing of the population is becoming a serious problem, affecting the social and healthcare systems of many countries by generating high expenses. According to the latest

**Table 5.** Impact of variables from Tables 1 and 2 on X-ray exposure time in the entire population. Model characteristics: R = 0.54; $R^2$ = 0.30; p < 0.000001.

| | Coefficient BETA | Standard error of coefficient BETA | Slope B | Standard error of slope B | P |
|---|---|---|---|---|---|
| Intercept | | | –6.3153 | 1.9478 | < 0.002 |
| Indication for PTCA STEMI *vs.* UA/NSTEMI *vs.* SA | –0.1025 | 0.0321 | –0.7381 | 0.2315 | < 0.002 |
| Age | 0.0848 | 0.0283 | 0.0507 | 0.0169 | < 0.003 |
| Body mass index | 0.0574 | 0.0268 | 0.0983 | 0.0459 | < 0.04 |
| Hypercholesterolaemia absent *vs.* present | 0.0670 | 0.0280 | 1.1051 | 0.4615 | < 0.02 |
| Recanalisation | 0.0759 | 0.0294 | 1.5892 | 0.6160 | < 0.02 |
| Number of dilated arteries | 0.0908 | 0.0279 | 3.3454 | 1.0295 | < 0.002 |
| Baseline flow in culprit vessel TIMI 2 or 3 *vs.* TIMI 0 or 1 | 0.0869 | 0.0348 | 1.1770 | 0.4706 | < 0.02 |
| Number of used balloons | 0.3723 | 0.0289 | 3.0130 | 0.2338 | < 0.000001 |
| Number of implanted stents | 0.2320 | 0.0303 | 2.3926 | 0.3121 | < 0.000001 |
| Angiographic outcome of PTCA effective *vs.* ineffective | 0.2466 | 0.0326 | 6.2824 | 0.8306 | < 0.000001 |
| Revascularisation complete *vs.* incomplete | 0.0892 | 0.0285 | 1.3041 | 0.4161 | < 0.002 |

PTCA — percutaneous transluminal coronary angioplasty, STEMI — ST-segment elevation myocardial infarction, NSTEMI — non-ST-segment elevation myocardial infarction, UA — unstable angina, SA — stable angina

demographic research, the population of elderly people in Poland is constantly growing [13]. An approximately twofold increase in the number of pensioners is expected in Poland by the year 2030 [14].

Since the pioneer PTCA procedure performed by Gruntzig in 1977, the method has undergone continual improvement (for instance in the introduction of stenting and potent adjunctive pharmacotherapy). It is currently the most common approach to myocardial revascularisation for different manifestations of CAD. Although the risk of periprocedural complications is higher in elderly patients, the continuous development of invasive cardiology is bringing about an increase in the efficacy and safety of this therapeutical method [15, 16].

Our study provides evidence for the effectiveness of PTCA in elderly patients in the real world setting. Investigating a relatively large sample of subjects undergoing percutaneous revascularisation we characterised senior patients clinically and angiographically and identified factors unfavourably affecting in-hospital outcome in the elderly as well as the general population.

Elderly patients in our registry when compared to younger subjects were characterised by a higher prevalence of diabetes mellitus, arterial hypertension, chronic heart failure and prior stroke, along with a lower proportion of those of male gender, smokers, those with a family history of CAD and subjects with hypercholesterolaemia. This distribution of risk factors and comorbidities corresponds to previous reports [17–19] and, as demonstrated in our study, has a profound impact on the clinical outcome.

As regards the extent of coronary atherosclerosis, the populations compared displayed differences in the number of vessels affected with atherosclerothic lesions. As expected, multivessel CAD was detected more frequent in elderly than in younger patients (81.1% *vs.* 63.8%; p < 0.00001). This finding is consistent with data from the literature, which report the presence of multivessel CAD in symptomatic elderly patients to be clearly more common than in younger ones. More complex morphology (type B or C according to AHA/ACC classification) and tighter stenoses are observed in atherosclerotic lesions in the elderly [7–9, 15]. These findings were also confirmed in angiographic research by Thompson et al. [20], who demonstrated the occurrence of triple-vessel coronary disease in 44% of patients aged 65–74 compared with 63% of patients aged over 75. In the year 2000 an analysis of data from the National Cardiovascular Network was published, in which a group of 7 472 patients aged 80 years and over (mean age 83 years) was compared with a population of 102 236 younger patients (mean age 62 years). In keeping with our results, the occurrence of multivessel coronary disease was significantly higher in elderly patients (57% *vs.* 45%; p < 0.01). Additionally, a higher incidence of involvement of the left main and

proximal left anterior descending artery was observed in the elderly group [15]. In our study we excluded patients with involvement of the left main coronary artery and did not differentiate segments of the major coronary branches. No direct comparison may therefore be made.

The introduction of stenting within the context of invasive cardiology has created new therapeutical possibilities. The percentage of stent implantations rapidly increased from 6% in 1994 to 66% in 1997 and has been growing further [15]. It is currently estimated that 80–90% of PTCA procedures incorporate stent implantation [21]. With regard to the incidence of balloon angioplasty in comparison with coronary stenting, we found that the first was a relatively more common practice in the group of patients ≥ 70 years of age (23.4% *vs.* 16.5%, $p < 0.04$), while the latter was more frequently performed in younger patients (83.5% *vs.* 76.6%; $p < 0.04$). The background for this finding could be the fact that stent implantation in older individuals is likely to be more complicated as a result of the tortuosity of the coronary vessels and the greater extent of atherosclerotic lesions, often accompanied by massive calcifications (type C according to ACC/AHA classification) [22]. In 2003 Kobayashi et al. [23] performed an analysis of the in-hospital and long--term outcome of patients with multivessel coronary artery disease treated with stent implantation and divided according to age into two groups: those 80 years and over (n = 75) and those below 80 years of age (n = 894). The authors concluded that, despite the high degree of technical feasibility, there was a higher incidence of early cardiac and non-cardiac complications as well as a higher mortality in one-year follow-up in the older group [23].

Our study also demonstrated that PTCA procedures in patients over 70 years of age tend to be more time and labour-consuming, which is likely to be due to the presence of more advanced atherosclerotic lesions within the coronary arteries. In this group of patients the total procedure duration was longer. However, the difference did not reach statistical significance. Similarly, PTCA procedures in this age group also required markedly longer exposition to X-rays. This was confirmed in univariate as well as multivariate analysis. The volume of contrast media utilised in elderly patients was also higher. The above-mentioned factors may indicate a higher degree of procedural difficulty in older patients.

A trial comparing PTCA procedures performed between 1994 and 1997 on patients over 80 years of age showed a gradual improvement in the effectiveness of this method (from 81% to 86%; $p = 0.009$) [15]. In our study the efficacy of coronary interventions estimated on the basis of clinical and angiographic criteria was high and equal to 91.4% in the elderly and 93.6% in the younger group.

The possibility of performing complete revascularisation depends heavily on the age of the patient. The number, localisation and morphology of coronary lesions, as well as the anatomy of the coronary vessels themselves, have been identified as the factors which have the strongest direct influence on the outcome of PTCA procedures. In elderly patients the following angiographic changes are common findings: total occlusion of a coronary vessel, calcified eccentric stenoses localised at vessel bends or bifurcations and tortuosity of the coronary arteries [22, 24]. The features given above reduce the probability of successful dilatation or recanalisation of the stenotic regions and so the chance of total revascularisation decreases [20, 25]. Lack of complete revascularisation increases the risk of a recurrence of symptoms in elderly people and is associated with poorer long-term prognosis. De Gregorio et al. [26] compared a group of patients aged ≥ 75 years (n = 137) with a group of patients aged < 75 years (n = 2551) who underwent PTCA with stenting between March 1993 and July 1997. Complete anatomical revascularisation was achieved in 56% of the younger patients but in only 31% of patients from the first group ($p = 0.008$) [26]. In our research the percentage of complete revascularisations in patients < 70 years old was also significantly higher (26.7% *vs.* 12.0% for those ≥ 70 years old; $p < 0.0001$). The main explanation for the difference between our results and the results from the study cited above is the high percentage of patients treated for STEMI in our population (39.5% in the elderly and 32.9% in the younger group) and the significantly lower prevalence of CAD risk factors (diabetes mellitus and hypertension) in the study by de Gregorio when compared to our material. Our approach to patients presenting with STEMI without cardiogenic shock was immediate PTCA limited to the culprit lesion, while further stages of revascularisation were usually postponed and performed electively. The study cited above [26] included no STEMI patients at all, which must have affected the statistics and hence the difference in the final outcomes of the invasive procedures, including the rate of complete revascularisations.

Another interesting issue, which deserves separate comment, is the in-hospital mortality of elderly patients treated for CAD with invasive procedures.

Numerous retrospective analyses of clinical trials indicate that age is a powerful risk factor for complications of coronary invasive procedures [27, 28]. A retrospective analysis performed in the Mayo Clinic between 1979–1997 on 1597 patients treated with PTCA for myocardial infarction demonstrated in-hospital mortality rates of 4%, 9%, 13% and 21% for patients aged 50–59, 60–69, 70–79 and ≥ 80, respectively [29]. Sakai et al. [30] confronted the results of invasive treatment for acute myocardial infarction in patients over and below 75 years of age. The first group demonstrated a significantly higher in-hospital mortality rate than the younger patients (8.4% *vs.* 3.7%; $p < 0.01$) [30], despite similarity in the rates for successful reperfusion (93% *vs.* 95%, p = NS). In the context of the results of this study, successful reperfusion had the strongest impact on the final outcome in both age groups. The in-hospital mortality rate in the elderly group was equal to 6.6% when the reperfusion attempt was successful, but rose to 33% in the case of reperfusion failure ($p < 0.0001$). The percentages for the younger group were less harsh and equalled 3.0% and 18% respectively ($p < 0.0001$) [30]. The directly proportional relation between the age of the patients and the risk of the PTCA procedure was demonstrated by a study by Taddei et al. [31], where elective and emergency PTCA procedures performed on 21 516 patients were analysed. The in-hospital mortality rate in the study group was 0.42% for patients of 50–59 years old, 1.22% for patients of 70–79 years old and 2.93% for patients over 80 years of age. The mortality rate after 5 years was 7%, 24% and 35% respectively. In a report on patients treated with PTCA delivered in the year 2000 by the National Cardiovascular Network a marked increase in mortality was noted among patients over 85 years old when compared with those below 55 years of age (5% *vs.* 0.5%) [15]. In our study the overall in-hospital mortality rate in elderly patients was significantly higher than for younger patients (6.9% *vs.* 2.1%; $p < 0.0003$). We ascertained that of the different manifestations of CAD myocardial infarction is, as expected, characterised by the highest mortality rate (15.9% in the elderly *vs.* 5.5% in the younger group; $p < 0.003$). This observation is consistent with the studies conducted by Tresch et al. [32], who found that in-hospital mortality due to myocardial infarction is three times as high in the elderly population as in younger patients. To a certain degree this high mortality rate could be explained by a beneficial modification in the course of myocardial infarction as a result of prior ischemia-related preconditioning of the heart muscle in younger individuals, which is, however, absent in patients over 70 years old [33].

We report a significantly higher proportion of patients with STEMI complicated with cardiogenic shock in the elderly population. In the SHOCK registry such subjects were less likely to be treated with invasive therapies than younger patients with shock. Covariate-adjusted modelling revealed that elderly patients selected for early revascularisation had a lower mortality rate than those undergoing a revascularisation procedure later or not at all [5]. In this challenging subgroup our data showed an in-hospital mortality of 50% when compared to 48% in the SHOCK registry.

To date the best evidence for establishing invasive or surgical treatment as the most efficient method of treatment of coronary disease was delivered in the APPROACH study [34]. Among patients aged 70–79, subjected in a non-randomised manner to different methods of treatment for CAD the survival rate at a 4-year follow-up was 87.3% for CABG, 83.9% for PTCA and 79.1% for conservative treatment. The corresponding results for the population over 80 years of age were generally poorer and equalled 77.4%, 71.6% and 60.3% respectively. Subsequently it was in this particular age group that the superiority of invasive treatment could most clearly be seen. Klein [35] is of the opinion that coronary angioplasty, as less invasive than coronary artery bypass grafting and requiring a shorter recovery time, provides particular benefits in the elderly with coexisting non-cardiac disorders that pose significant additional operative risk. A simplified approach frequently adopted for senior patients, with incomplete PTCA or PTCA of the culprit lesion only, may be an option even in multivessel disease. According to Rossi et al. [36], this minimises periprocedural complications while still allowing a meaningful clinical recovery in patients with inherent functional limitations related to age itself. Unfortunately, our study does not address these issues.

We demonstrated that hospitalisation was of seriously longer duration for elderly than for younger patients. This was related to numerous comorbidities which coexisted in the elderly patients, leading to pharmacotherapeutical differences between the two age groups and to a slower pace of intensification of pharmacological treatment in the elderly group, which eventually resulted in prolongation of the recovery period in this group [37].

The study limitations include the use of registration data and its retrospective character and restriction to the experience of a single centre. Although we investigated a heterogeneous population

in terms of CAD manifestation, we adjusted for the clinical presentation in a multivariable analysis. It would also be valuable to compare the outcomes of percutaneous revascularisations with coronary artery bypass grafting as well as medical therapy in the elderly population and to identify subjects in whom particular treatment confers a survival advantage. Nevertheless, randomised large-scale prospective trials are warranted to obtain conclusive results. Surprisingly, in a multivariate analysis male gender was associated with a 3.8-fold increased OR of in-hospital mortality. In the published data women referred for interventional treatment consistently presented with unfavourable baseline characteristics [38–47]. Although recent studies have indicated improved short-term prognoses for women [38] or even a lack of gender impact on in-hospital outcome [39–42], our finding is not a common belief [43–45]. Nevertheless, BARI investigators reported that female gender was an independent predictor of increased 5-year survival in surgical as well as interventional arm [46]. Similarly, Berger et al. [47], after a recent analysis of 4284 patients undergoing coronary angioplasty, concluded that female gender conferred a long-term survival advantage despite more high-risk characteristics. Light has been cast on the tendency observed in recent trials for outcome to be improved for women by the frequent use of new evidence-based medical therapies and interventional devices. However, we cannot fully exclude the possibility that our analysis, like other retrospective studies without randomisation, may have been confounded by unrecognised variables or selection bias.

Currently a clopidogrel loading dose of 300 mg is only recommended when administered at least 6 hours before the intervention, ideally the day before. Otherwise, 600 mg of clopidogrel is advised [48].

Although a large majority of our patients were treated with stenting, use of this device has constantly been on the increase over recent years. Coronary stenting, particularly in elderly patients, may therefore be more widespread currently than shown in our data.

## Conclusions

To sum up, despite frequent comorbidities and more extensive coronary athersoclerosis, a high rate of procedural success was demonstrated in the elderly population undergoing PTCA. However, after adjustment for the baseline characteristics advanced age was still associated with a less favourable in-hospital outcome and greater procedural complexity.

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