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ORIGINAL PAPER

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Percutaneous coronary interventions in Europe

Prevalence, numerical estimates, and projections based on data up to 2004

Abstract *Aims* A registry mandated by the European Society of Cardiology collects data on trends in interventional cardiology within Europe. Special interest focuses on relative increases and ratios in new techniques and their distributions across Europe. We report the data through 2004 and give an overview of the development of coronary interventions since the first data collection in 1992. *Methods and results* Questionnaires were distributed yearly to delegates of all national societies of cardiology represented in the European Society of Cardiology. The goal was to collect the case numbers of all local institutions and operators. The overall numbers of coronary angiographies increased from 1992 to 2004 from 684 000 to 2 238 000 (from 1250 to 3930 per million inhabitants). The respective numbers for percutaneous coronary interventions (PCIs) and coronary stenting procedures increased from 184 000 to 885 000 (from 335 to 1550) and from 3000 to 770 000 (from 5 to 1350), respectively. Germany was the most active country with 712 000 angiographies (8600), 249 000 angioplasties (3000), and 200 000 stenting procedures (2400) in 2004. The indication has shifted towards acute coronary syndromes, as demonstrated by rising rates of interventions for acute myocardial infarction over the last decade. The procedures are more readily performed and perceived safer, as shown by increasing rate of "ad hoc" PCIs and decreasing need for emergency coronary artery bypass grafting (CABG). In 2004, the use of drug-eluting stents continued to rise. However, an enormous variability is reported with the highest rate in Switzerland (70%). If the rate of progression remains constant until 2010 the projected number of coronary angiographies will be over three million, and the number of PCIs about 1.5 million with a stenting rate of almost 100%. *Conclusion* Interventional cardiology in Europe is ever expanding. New coronary revascularization procedures, alternative or complementary to balloon angioplasty, have come and gone. Only stenting has stood the test of time and matured to the default technique. Facilitated access to PCI, more complete and earlier detection of coronary artery disease promise continued growth of the procedure despite the uncontested success of prevention.

Key words
coronary angiography – PTCA – PCI – coronary interventions – coronary stent – registry

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Introduction

Coronary artery disease is pandemic in the western world, and its prevalence has paralleled the prevalence of risk factors (smoking, obesity, diabetes mellitus) since the end of the twentieth century. The last decade has witnessed break-through discoveries in prevention and treatment of coronary artery disease. Among them, invasive strategies have benefited the well being of patients throughout Europe. Few reliable data exist to predict trends in interventional cardiology [1–3, 5, 6, 8–15, 17, 18]. The aim of the current report is to show trends in cardiac catheter interventions in Europe over the last decade and projects figures until 2010. It summarizes catheter-based cardiac interventions with an overview of specific interventions in 30 European countries, the majority of which are members of the European Society of Cardiology.

Methods

Since 1992, a detailed questionnaire, with instructions and examples for completion, has been sent annually to the presidents, or their designated delegates, of the 31 national societies of cardiology represented in the European Society of Cardiology. It was then forwarded in every nation to all facilities performing diagnostic or interventional cardiac catheterization. A summary data sheet, completed by the national representatives, was used to report the national data sets. It was also possible to complete the forms online using the ESC Web services. Finally, the data were analyzed in a central database. In the case of missing or incomplete data, the national representatives were repeatedly contacted until all the information was obtained. In April 2006, the registry was closed for the 2004 report. Sufficient data were reported from 30 of the 31 countries included in the survey, representing almost 570 million people. Despite numerous reminders, Ireland failed to provide data for several years and was deleted from all analyses. Prior to publication, the national representatives reviewed the figures of the manuscript for accuracy. Definitions of pathologies and procedures as well as questionnaires were used according to previously published reports [2, 3, 8–13, 15, 17, 18].

Prediction of angiography, angioplasty (PCI), and stenting procedures through 2010

The previsions for the years until 2010 were based on the "consumption method" for prediction medicine. It was assumed that the current pattern was in a steady state, and would continue for coming years. The 12-year period of observation allowed for a six-year forecasting period ("50% rule"). Using the 1992–2004 observation period, a line was fitted to the data using a polynomial function, using the year as the independent variable and the number of procedures as the dependant variable. Deltagraph Pro 5.6 for Windows was used (RockWare Inc., Golden, CO, USA). The polynomial equation was then used to predict the estimated number of procedures through 2010. Finally, in order to evaluate potential growth area within European countries, a ratio between country-specific PCI number and WHO estimates [7] of disability-adjusted life years (DALYs) lost has been calculated.

Results

Coronary angiography

A total of 2 238 478 coronary angiograms were performed in Europe in 2004, which corresponds to a 3.2-fold increase since 1992 (Fig. 1), and an 11% increase compared to 2003. For the first time, 2 000 000 angiograms were exceeded. On a population base, the numbers also augmented, with 3928 angiograms per million inhabitants (3487 in 2003). In 2004, Germany reported the highest absolute and relative numbers, namely 712 142 angiograms or 8632 per million inhabitants. This was a relative increase of 11% compared to 2003. With the exception of Hungary, Iceland, Portugal, and Turkey, the population adjusted number of angiograms increased in all European countries. Bulgaria reported the largest rise with 90%.

Coronary angioplasty

A total of 885 347 PCIs procedures were reported for 2004, a 20% increase compared to 2003. Compared to the first yearly survey in 1992 this constitutes an almost six-fold increase in percutaneous procedures (Fig. 2). The mean population-adjusted number in 2004 was 1553 procedures per million inhabitants, representing an increase of 20% compared with 2003. With 248 909 PCIs or 3017 PCIs per million inhabitants, Germany reported by far the highest numbers again (Fig. 4b). The smallest numbers of procedures per million people were reported from Romania (189), Bulgaria (403), and Slovakia (411). With the exception of Iceland (a decrease of 11%),

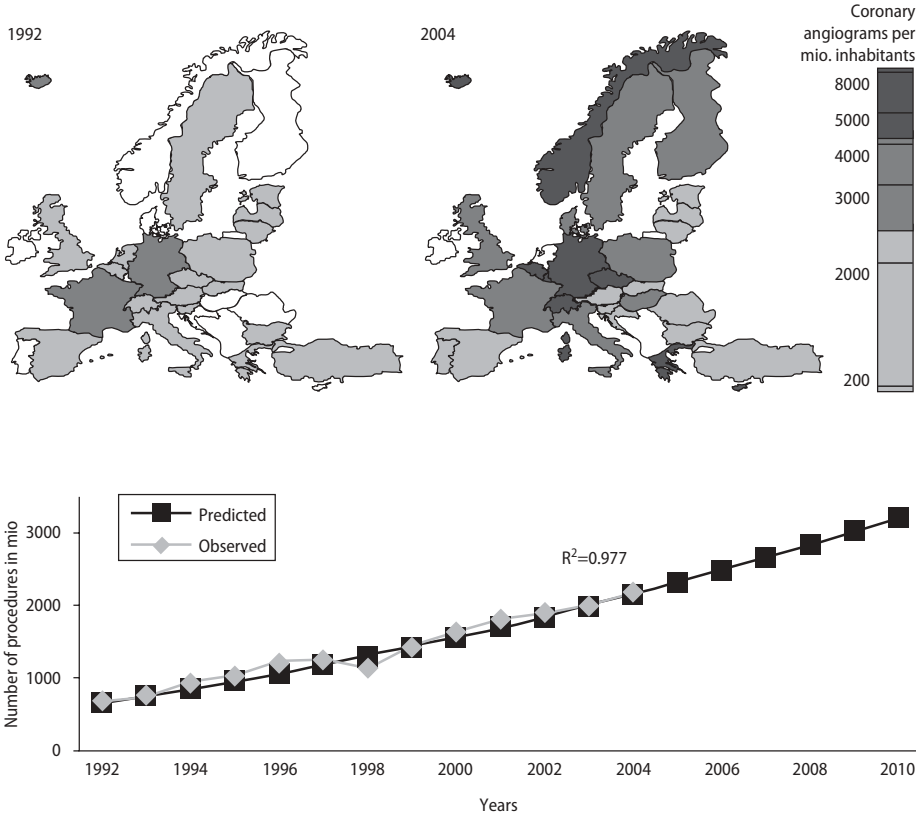

Fig. 1 Top: Coronary angiograms in 1992 and 2004 per million inhabitants in Europe. Bottom: Coronary angiograms from 1992 to 2010 in Europe in thousands of procedures

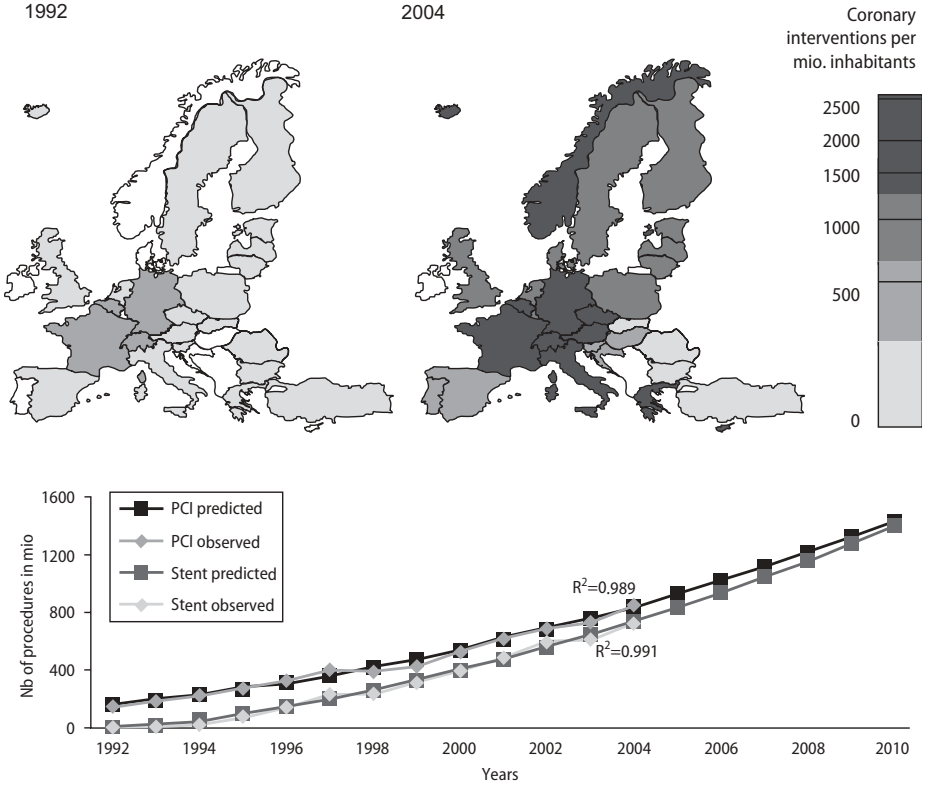

Fig. 2 Top: Percutaneous coronary interventions (PCIs) in 1992 and 2004 per million inhabitants in Europe. Bottom: Coronary angioplasty (PCI) and coronary stenting from 1992 to 2010 in Europe in thousands of procedures

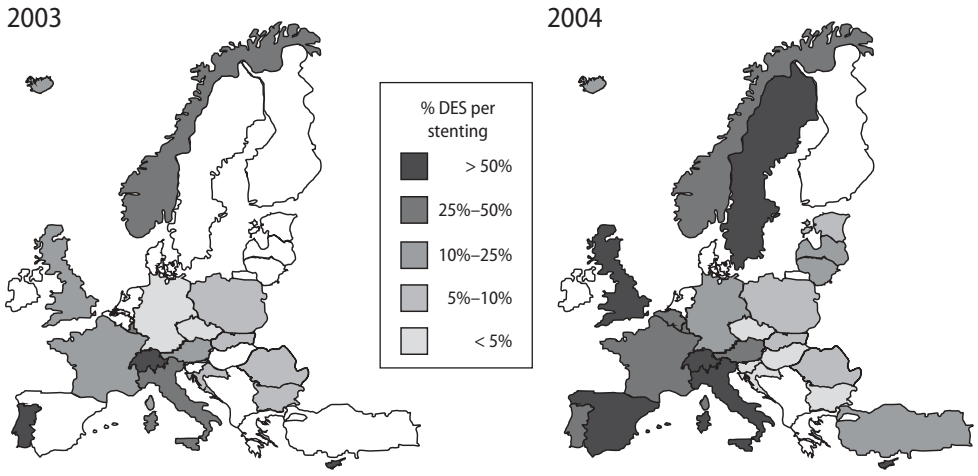

Fig. 3 Percentage of drug-eluting stent use pro PCIs in 2003 and 2004 in Europe

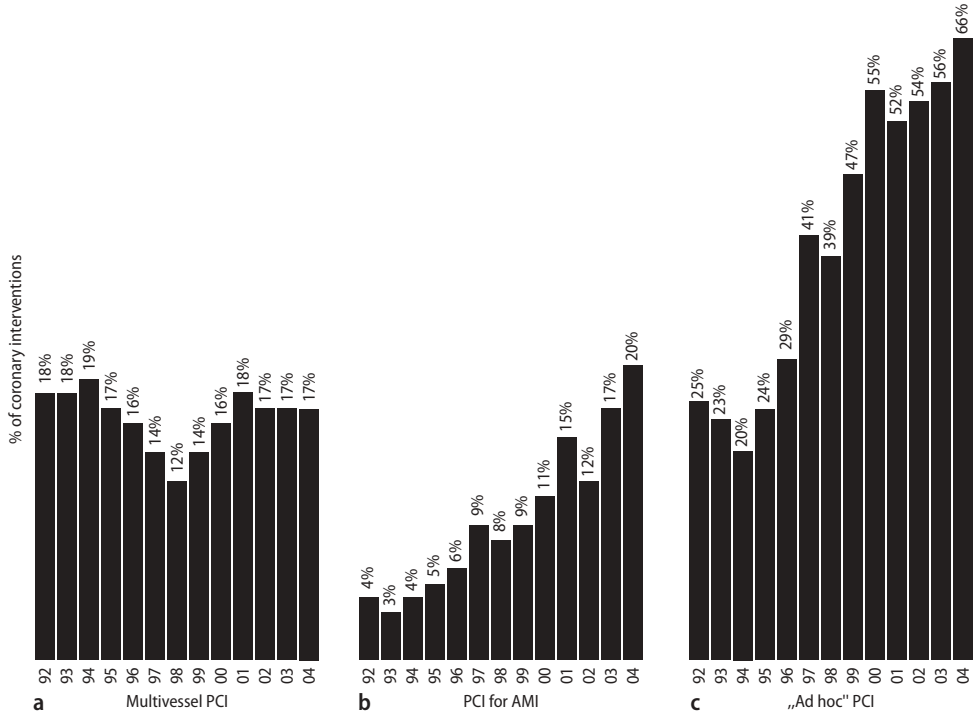

Fig. 4 Percutaneous coronary intervention (PCI) rate for intervention on multiple vessels (Panel A), for acute myocardial infarction (AMI-Panal B), and "ad hoc" PCI (Panel C) in Europe in 2004

all countries reported increases in procedures. Some European countries were reporting particularly high relative increases (Latvia +92%, Spain +45%, Turkey +41%, Bulgaria +40%). "Ad hoc" procedures accounted for 67% of all PCIs (2003: 56%). The mean ratio of PCIs to coronary angiograms was 0.41 (2003: 0.36). The ratio of PCIs to coronary angiograms ranged from 0.28 in Romania to 0.55 in France. Multivessel interventions in one session were performed in 18% in 2004. In the 12-year period no clear trend emerged, i.e. no relative increase in multivessel procedures (Fig. 4a). Interventions for acute myocardial infarction in 2004 accounted for 19% of all coronary procedures. The 12-year overview showed an increase of interventions for acute myocardial infarction per PCI from 4% to 19%. From 1992 to 2004 the proportion of ad hoc PCI procedures increased from 25% to 67% (Fig. 4c).

Coronary stenting

Approximately 769766 stenting procedures were reported in 2004 (Fig. 2), resulting in an increase of

22% compared to 2003 (approximately 610 300 procedures). Germany reported the highest absolute numbers for 2004 (200 230). The ratio of coronary stenting to PCI procedures averaged 0.85 (2003: 0.83). Most countries reported ratios of 0.70 or above. Drug eluting stents (DES) were introduced in 2001. In 2004, all but four countries reported their use (2003: 16). Overall DES have been used in 26% of stenting procedures and all countries except Portugal reported higher rates than in 2003 (15%). The highest rate was encountered in Switzerland (70%) and the lowest in Estonia (2%) (Fig. 3).

Other devices

Other therapeutic devices (directional atherectomy, rotablator, laser catheter or wire, ultrasound therapy, brachytherapy, clot catcher/remover) were reported in a total of 8838 cases (20 670 in 2003) in 2004 (see Table 1 for details). There were no significant changes over the last decade. The two diagnostic techniques, intravascular ultrasound and intracoronary pressure measurements, were still the most often used addition to balloon and stent; nonetheless they were used in less than 2% of PCI procedures.

Complications

Mortality has remained virtually unchanged since 1992 and was reported to be 0.5% in 2004. The need for emergency coronary artery bypass grafting (CABG) slightly decreased to 0.2%. The incidence of PCI-induced myocardial infarction was reported to be 1.0% (Fig. 5).

Catheterization facilities

The number of cardiac catheterization facilities per million inhabitants in Europe in 2004 remained unchanged with 2.6 compared to 2003. The highest density existed in Iceland (6.9) and in Norway (6.2), the lowest in Slovakia and Bulgaria (1.3). A mean of 1054 (619 to 1796) coronary angiographies and 400 PCIs (278 to 699) were performed per catheterization room. The numbers of coronary angiographers per million people ranged from 2 in Romania to 24 in Austria and Iceland, and respective number of PCI operators from 1 in Romania to 17 in Austria, Belgium, and Iceland.

Forecast 1992 through 2010 (Table 2)

Based on the trend drawn in Fig. 1 ($R^2 = 0.977$ for the year 1992 through 2004), coronary angiograms were predicted through 2010. The average approximate yearly growth is assumed to be 6.3% with an absolute number of more than three million coronary angiograms (3 212 000) to be expected in Europe for the year 2010. Accordingly, PCI and stenting procedure numbers were also based on the trends

Table 1 Diagnostic and therapeutic cardiac and non-cardiac interventions in relation to PCI

	Coronary interventions				
	Directional atherectomy	Rotablator	Laser catheter or wire	Ultrasound therapy	Brachytherapy
% of PCI	0.1	0.4	< 0.1	< 0.1	0.3
	Thrombus therapy		Diagnostic tools for coronary artery disease		
	GP IIb/IIIa antagonist	Clot catcher/clot remover	Intracoronary pressure	Intracoronary Doppler	Intracoronary ultrasound
% of PCI	19.3	1.8	1.7	0.3	1.8
	Assist devices		Non-cardiac percutaneous interventions		
	Intra-aortic balloon pump	Percutaneous left ventricular assist pump	Iliac or leg artery	Renal artery	Carotid artery
% of PCI	1.3	< 0.1	2.8	0.6	0.7
	Non-coronary percutaneous interventions				
	Coarctation angioplasty	Alcohol ablation for septal hypertrophy	Mitral valvuloplasty	Aortic valvuloplasty	Pulmonary valvuloplasty
% of PCI	0.1	0.1	0.3	0.1	0.2
	PDA closure	PFO closure	ASD closure	VSD closure	Left atrial appendage occlusion
% of PCI	0.2	0.6	0.6	< 0.1	< 0.1

ASD = atrial septal defect; PDA = patent ductus arteriosus; PFO = patent foramen ovale; VSD = ventricular septal defect

Table 2 Forecast 1992 through 2010 (per million inhabitants)

	1992	2004	2010
Angiography	684	2230	3212
PCI	148	850	1431
Stent	3	723	1400

displayed in Fig. 2 (PCI: $R^2 = 0.989$ for the year 1992 through 2004; stenting procedures: $R^2 = 0.991$ for the year 1992 trough 2004). The average approximate yearly growth of PCI and stenting procedures is projected to be 8.8% and 9.8%, respectively. Interestingly, based on these previsions, the stenting rate should continue to rise and reach 98% of the 1 431 000 PCI procedures in 2010. These projections were strictly based on the observed numbers in the preceding years, and it was assumed that the growth patterns from 1992 to 2004 would continue unchanged over the next 6 years. Therapeutic progress, improved preventive strategies or financial aspects are some of the many factors that may have an impact on projections.

In order to evaluate potential growth areas within European countries, ratios between country-specific PCI numbers and disability-adjusted life years (DALYs) lost were calculated and are presented in Fig. 6: As illustrated there, the lowest rates, and therefore the countries with highest potential growth, are some of the former Soviet Union countries and Turkey. This score reflects the fact that while these countries have up to 5 times more disabled patients due to heart disease per mio inhabitants (DALYS) as western European countries [7] such as France, the number of PCI per thousand inhabitants was low.

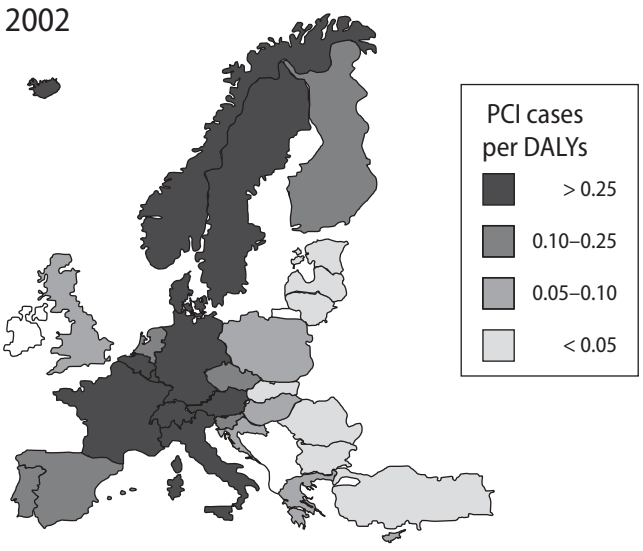

Fig. 6 Coronary angioplasty (PCI) rate (pro mio inhabitants) divided by WHO estimates of disability-adjusted life years (DALYs, pro mio inhabitants) lost

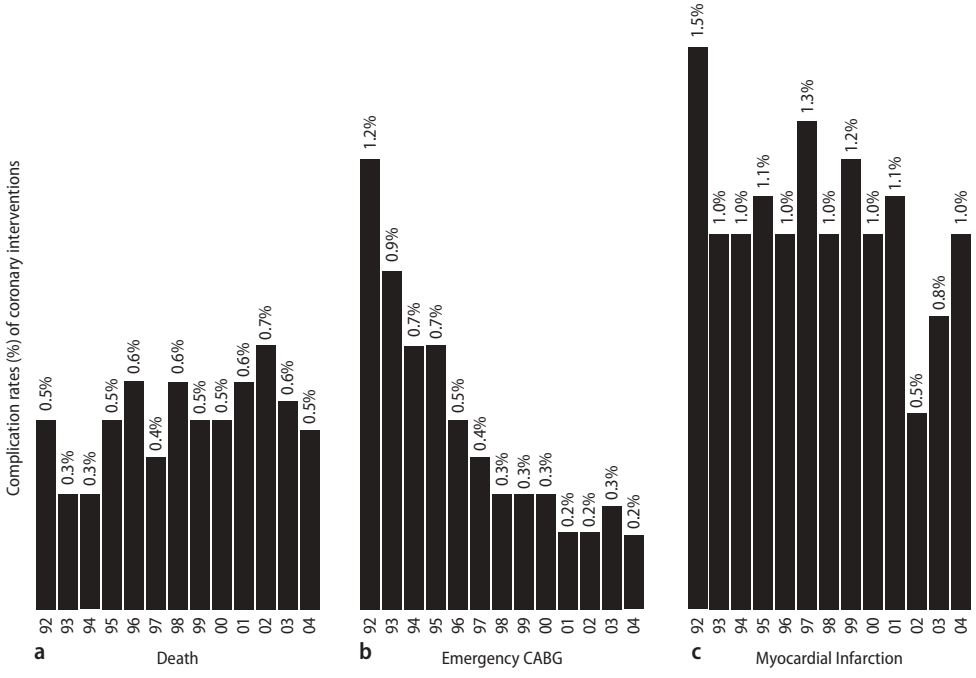

Fig. 5 Complication rates (%) of PCIs from 1992 to 2004 in Europe

Discussion

The geographical variations of angiograms, percutaneous coronary interventions (PCI), and stenting rates have been assessed in Europe since 1992 and their trends have been estimated until 2010. The current European registry of reported coronary interventions is intended to give a global picture of interventional activity per country with aggregated registry data and represents the most up-to-date overview of PCI in the western world. Although registries with real time detailed procedural data collection on a per patient basis should offer better accuracy and respective pilot trials are in progress in a number of European centers, comprehensive continent-wide case per case recordings are still far from being accomplished.

The global figures of coronary angiographies have risen steadily throughout Europe. Between 1992 and 2004, they rose from 1250 to more than 3900 per million inhabitants. Therapeutic percutaneous procedures increased almost six-fold compared with the first yearly survey. Stenting is being increasingly used and based on our estimate is bound to be the default procedure by the end of 2010. Drug-eluting stenting (DES), of which the use exploded in Europe since 2001, represented 26% of the 2004 stenting procedures. It remains to be seen, whether DES, as we know them today but with better deliverability and safety profiles, or new biodegradable stents will be the stents used by the end of 2010.

The indication has shifted towards acute coronary syndromes, as demonstrated by rising rates of interventions for acute myocardial infarction over the last decade. The procedures are more readily performed and perceived safer, as shown by an increasing rate of "ad hoc" PCI and a decreasing need for emergency CABG. An upsurge of multivessel angioplasty has been announced for over a decade, but failed to come true. This is somewhat at odds with the technical improvements that occurred during that time period and clearly against the general opinion. It may be partially due to staging of multivessel procedures. Yet, technical improvements should have decreased staged procedures over time. Notwithstanding, the absolute number of multivessel PCI increased steadily, albeit commensurate with the number of single vessel PCI.

Comparing the WHO report on heart disease [7] with our data, we highlight that although certain countries, such as Turkey or some of the former Soviet Union, have many potential patients (high disability-adjusted life years – DALYs), their PCI numbers were low, suggesting the highest potential growth in these countries during the next decades. In line with this concept, the creation of "reperfusion networks" significantly contributed to increasing the PCI rates in the Czech Republic and Poland [4, 16] during past years. The coming years will show the effects of new drug-eluting stents on interventional policies.

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