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Spatial analysis of Percutaneous Transluminal Coronary Angioplasty (PTCA) in Austria

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Abstract. *Study objectives*: To investigate the geographical distribution of Percutaneous Transluminal Coronary Angioplasty (PTCA) and morbidity for coronary heart disease, angina pectoris and myocardial infarction by spatial analysis of the standardized morbidity rates (SMR) on district level. To identify clusters by Moran's *I* Statistic and the Regional Spatial Autocorrelation Coefficient (RSAC) of Munasinghe and Morris. To investigate demand factor morbidity and supply factor health care infrastructure on the district level as reasons for geographical disparity. To describe characteristics of the cluster population and intervention centres. *Study design*: Retrospective record linkage study. *Setting*: All hospitals and cardiological centres in Austria (n = 150) which performed the Minimum Basic Data Set (MBDS). *Patients*: All Austrian residents who were diagnosed for myocardial infarction, coronary heart disease or angina pectoris in 1995 (n = 87,174). *Measurements and main results*: One 'positive' PTCA cluster (all SMRs $\geqslant 0.96$) and one 'negative' PTCA cluster (all SMRs $\leqslant 0.59$) were identified. They differed significantly in morbidity rate, intervention rate and available cardiological beds. The tendency to inverse relation between PTCA utilization and morbidity in the 'negative' cluster supported the thesis of 'inverse care law'. Austrianwide no significant correlation was found between the SMR of PTCA-application and both demand factor and supply factors. Nevertheless, differences between the clusters concerning number and capacity of intervention centres and density of specialists pointed to supply factors as reasons for geographical disparity. The ongoing trend of steady expansion of existing intervention centres and establishment of new ones will reduce the extent of geographical variation in future.

Key words: Clustering, Coronary heart disease, Geographic epidemiology, Percutaneous Transluminal Coronary Angioplasty

Introduction

Geographical variation in utilization rates of health services have already been known for various medical interventions in Europe and overseas [1–4]. The same is true for the use of Percutaneous Transluminal Coronary Angioplasty (PTCA). Wide disparity exists not only between [5] but also within countries [6, 7]. Several reasons for this fact have been investigated: *economic* factors such as the national domestic product per capita, the operative health care system or different health care insurance levels [5]; *supply factors* such as number of cardiologists or accessibility and number of intervention centres [5, 8, 9]; *demand factors* like morbidity [8]; *person-related factors* like attitude of both medical doctors and patients towards PTCA [10]; *procedure-related factors* like prices of disposables, since they account for 55% of procedural PTCA costs [11].

Morbidity, seemingly the most obvious explanation for variation of utilization rates did not prove to be a factor of influence in most European countries [5, 8] and several areas of the USA [12]. The same was true for the *economic factors* national income and health spending [5], but not for the *supply factor* accessibility of an intervention centre [8]. Results on the *supply factor* number of cardiologists are conflicting: a survey on PTCA utilization conducted between 1986 and 1991 in 14 European countries [5] did not find correlations whereas a British study from 1992 to 1993 confirmed the number of cardiologists as a significant factor of influence [8].

In an attempt to investigate PTCA utilization rates in Austria, analyses were undertaken on data of 1993–1995 [13]. In this paper we firstly focused on spatial analysis of geographical distribution of morbidity and PTCA. Secondly, we were interested in demand factor morbidity and supply factor health care infrastructure on the district level (distribution of specialists for internal medicine/cardiologists and general practitioners in private praxis) as reasons for geographical disparity. Additionally, we compared the characteristics of both the cluster population (morbidity, PTCA/indication rate, health care infrastructure) and the intervention centres (number, staffing, served population).

Methods

Data sets

We used two different data sets: the census of 1991 on the district level and the Minimum Basic Data Set (MBDS)[1] for patients, data on age, sex, postal code, Federal state of residency, main and additional diagnoses according to the ICD-9 codes and therapy.

Study population

Our study population included all Austrian patients of 1995 who (a) were referred to an Austrian hospital performing the MBDS and who (b) were diagnosed with angina pectoris and/or myocardial infarction. The definitions of angina pectoris and myocardial infarction as used for this paper were created by comparison of the ICD-9 classifications [14] with the classifications of the Austrian guidelines for Coronary Angiography Referrals [15]. This was necessary for definition of more specified indicational diagnoses for PTCA than provided by the ICD-9 coding. The ICD-9 codes for the diagnoses under investigation are:

- for AP: 413, 413.0, 413.1, 413.2, 414 and 414.0[2]
- for MI: 410, 410.0, 410.1, 410.2, 410.3, 410.5, 410.6, 411, 411.0, 411.1, 411.3

The guidelines of the Austrian Cardiological Society are based on the guidelines of the American College of Cardiology and the American Heart Association [16]. Adaptations to the special conditions in Austria were done according to a consensus with physicians from all Austrian heart catheterization laboratories.

The ICD-9 categories, which serve as the basis of the MBDS, are not consistent with the categories of the guidelines. This problem was solved by creating the two indicational categories angina pectoris (AP) and myocardial infarction (MI) by the grouping of several ICD-9 groups and subgroups as described above. Category AP is consistent with the guideline groups A–C and category MI with the guideline group D. Further details are described elsewhere [13].

For estimation of the influence of specialist density on diagnosed cardiological diseases (SMR of indications) and consecutively performed interventions (SMR of PTCAs, intervention rate), we used the term ‘specialists’ for both specialists for internal medicine and cardiologists. This was necessary because the number of cardiologists in private praxis is rather limited (n = 122) and cardiological patients are mainly diagnosed and referred to intervention centres by specialists for internal medicine (n = 1164) [17].

Statistical methods

MBDS data were obtained from 150 hospitals and entered into Microsoft ACCESS 97 data base. Data of the two data sets were transferred to SPSS for Windows 8.0, EPI-INFO (Version 6.XX, CDC, Atlanta) and Microsoft EXCEL 97 for further processing. For calculation of the SMRs [18] of indications and PTCAs on the district level, census data of 1991 were used (census data were merged with the MBDS over postal code). SMRs and SRs were log-transformed to achieve a better approximation of the normal distribution. Pearson’s correlation coefficient (r) was used for estimation of the pairwise associations between demand and supply factors and distribution of SMR of PTCA, regression analysis was done for multiple associations. MATLAB 4.2b was used for Moran’s I statistic and S+ 4.0 was used for the Regional Spatial Autocorrelation Coefficient (RSAC). Log-transformation of SMRs for Moran’s I statistic was not necessary because bootstrap methods were used. All calculations were done case based and significances were accepted only for the 0.05 level (2-tailed). All geographic maps of the distribution of indications for PTCA and PTCA utilization were done by REGIO GRAPH 2.0.

Moran’s I Statistic was taken as a measurement for regional autocorrelation of SMR (autocorrelation = regional SMR values depend on those from neighbourhood districts) [19]. If W_{ij}^k characterizes the surrounding of the districts i and j with the distance k (W_{ij}^k – measure of spatial proximity of areas) and if x_i characterizes the SMR-values for the districts i, $i \in (1 \ldots n)$, n is the number of districts and $\bar{x}$ the mean of values of all districts, then Moran’s I Statistic for the neighbourhood or adjacent matrix of distance class k is defined as follows:

$$W_{ij}^k = \begin{cases} 1 & \text{if between } i \text{ and } j,\ i \neq j, \text{ minimal } k-1 \\ & \text{adjacent districts are localized} \\ 0 & \text{otherwise} \end{cases}$$

[1] In 1997, the federal financing system for hospitals based on service was created. Until then, several Austrian hospitals received financial aid from the Ministry for Social Affairs according to the sum of days of hospitalization for all patients. In order to obtain this financial aid, the responsible authorities of the hospitals had to perform the Minimum Basis Data Set.

[2] 414 (other chronic ischaemic heart diseases) and 414.0 (coronary heart disease) were grouped under the diagnosis angina pectoris for pragmatic reasons: although CHD is not an indication per se in the cardiological sense of meaning but only when with signs of ischaemia, it is the most often documented diagnosis in the context of PTCA.

$$I^k = \frac{n \sum_i \sum_j W_{ij}^k (x_i - \bar{x})(x_j - \bar{x})}{S_0 \sum_i (x_i - \bar{x})^2}$$

$$S_0 = \sum_i \sum_j W_{ij}^k$$

Moran's I Statistic (based on bootstrap methods) of the SMR of PTCA was calculated for ten distance classes. 95% confidence interval was estimated for each distance class.

For localization of clusters, we used the RSAC [20]. If x_i, $\bar{x}$ and n are defined as above, W_{ij} as neighbourhood matrix of the areas i and j (matrix of inverse distances between i and j), $i, j \in (1 \ldots n)$ is defined as

$$W_{ij} = \begin{cases} \frac{1}{k} & \text{if between } i \text{ and } j,\ i \neq j, \text{ minimal } k-1 \\ & \text{adjacent districts are localized} \\ 0 & \text{if } i = j \end{cases}$$

and $\bar{w}_{i\cdot}$ as mean of rows of district i of W then the RSAC R_i for the district i is described by

$$R_i = (x_i - \bar{x}) \frac{\sum_j (x_j - \bar{x})(W_{ij} - \bar{w}_{i\cdot})}{\sqrt{\sum_j (x_j - \bar{x})^2 (W_{ij} - \bar{w}_{i\cdot})^2}}$$

R_i is a measurement for regional autocorrelation of every district i. W_{ij} is a discrete measure of the regional interdependence of two districts (matrix of inverse distances 1 to k). Districts with significant regional autocorrelation were identified through testing against the null hypothesis (= no regional autocorrelation) [20].

Ethical aspects

Data are of official status and were gathered in accordance with the requirements of the Austrian Ministry for Social Affairs and the Austrian Ministry for Health and Consumer Protection.

Results

Distance classes

Significant positive regional autocorrelation was shown not only for adjacent districts (= distance class 1) but also for distance class 2. Significant negative results were shown for distance classes 4 and 5 (Figure 1). Distance classes 4 and 5 represented districts localised beyond the borders between two Federal States of Austria.

Clusters

Two PTCA-clusters were identified: *Cluster I*, the 'positive' cluster, comprised 11 districts of Upper Austria and two of Lower Austria (SMR range 1.19–2.88) (Table 1a). *Cluster II*, the 'negative' cluster, comprised 9 districts of Styria and two of Burgenland

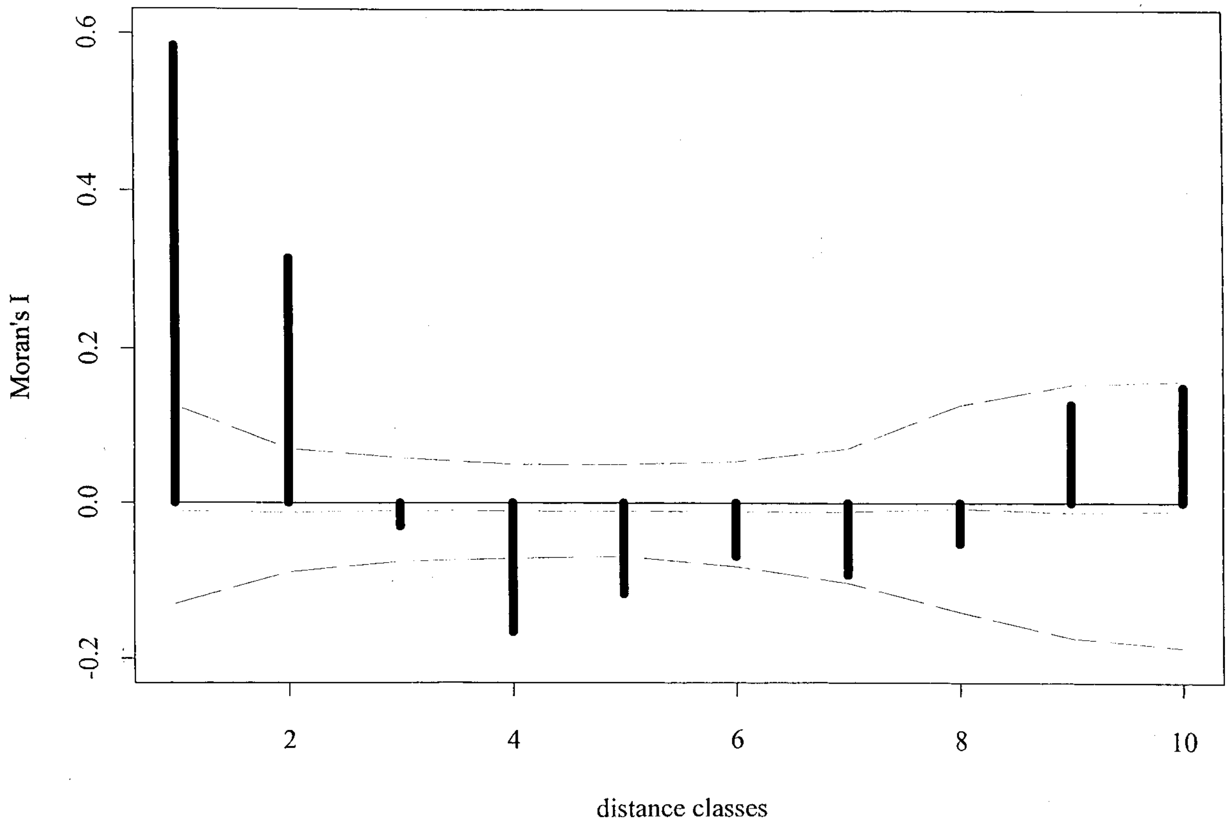

Figure 1. Moran's I of PTCA for distance classes. ▌ = distance classes, — = 95% confidence interval; distance classes 1 and 2 are significantly positively autocorrelated, distance classes 4 and 5 are significantly negatively autocorrelated.

Table 1a. Cluster I – specialists for internal medicine/cardiology, general practitioners, PTCAs, indications, intervention rate (PTCA/ind), SMRs of indications and PTCA per district

District	Spec	Gen pract	Spec/10,000	Gen/10,000	Indications	PTCA	PTCA /indicat	SMR indicat	SMR PTCA
Waidhofen	2	9	1.7	7.8	181	9	4.97	1.29	1.6
Amstetten	4	53	0.4	5.2	976	66	6.76	1	1.51
Linz	28	114	3.1	12.7	2030	224	11.03	1.13	2.88
Steyr	7	26	1.4	5.1	602	57	9.47	1.24	2.6
Everding	0	15	0	5.1	236	21	8.9	0.83	1.65
Freistadt	1	34	0.1	4.7	402	51	12.69	0.67	1.86
Kirchdorf	1	31	0.2	6.0	467	31	6.64	0.92	1.33
Linz Land	7	62	0.6	5.2	1231	140	11.37	1.17	2.75
Perg	1	31	0.2	5.2	517	45	8.7	1.01	1.85
Rohrbach	3	32	0.5	5.6	356	40	11.24	0.69	1.69
Steyr Land	1	29	0.2	5.5	577	31	5.37	1.09	1.31
Uhrfahr-Umg	0	33	0	3.0	987	101	10.23	0.93	1.96
Wels	11	65	1.0	5.9	979	61	6.23	0.87	1.19
Total	66	534	0.7	5.8	9541	877	9.2	0.99	1.86

Table 1b. Cluster II – specialists for internal medicine/cardiology, general practitioners, PTCAs, indications, intervention rate (PTCA/ind), SMRs of indications and PTCA per district

District	Spec	Gen pract	Spec/10,000	Gen/10,000	Indications	PTCA	PTCA /indicat	SMR indicat	SMR PTCA
Güssing	2	14	0.7	5.0	288	8	2.78	0.89	0.55
Jennersdorf	1	14	0.6	7.8	253	2	0.79	1.19	0.21
Deutschlb	2	33	0.3	5.4	662	10	1.51	1.07	0.33
Feldbach	6	38	0.9	6.0	670	14	2.09	1.06	0.51
Fürstenfeld	2	19	0.9	8.3	291	7	2.41	1.14	0.55
Hartberg	4	41	0.6	6.3	564	12	2.13	0.94	0.41
Leibnitz	2	50	0.3	7.0	828	14	1.69	1.22	0.46
Mürzzuschl	3	26	0.7	5.8	380	6	1.58	0.69	0.25
Bad Radk	2	17	0.9	8.0	538	4	0.74	2.13	0.39
Voitsberg	2	30	0.4	5.4	1323	11	0.83	2.19	0.41
Weiz	3	47	0.4	5.8	664	22	3.31	0.83	0.59
Total	29	329	0.5	6.2	6461	110	1.7	1.2	0.42

(SMR range 0.21–0.59) (Table 1b) (Figure 2a, b). If the RSAC statistic was calculated for log-transformed SMRs, which led to a better approximation of the normal distribution, then cluster II was enlarged by two districts[3].

Intervention rates (PTCA/indications) and SMRs of PTCAs varied considerably within and between the clusters (Table 1a, b): within cluster I, the intervention rate varied between 4.97 and 12.69, within cluster II, it varied between 0.74 and 3.31. Mean intervention rate of cluster I (PTCA/indications: 8.7) was approximately fivefold higher than that of cluster II (PTCA/indications: 1.8). The same was true for mean SMRs for PTCA-applications (cluster I: mean SMR PTCA = 1.86, cluster II: mean SMR PTCA = 0.42) (Figure 3). For odds ratios of morbidity rate and intervention rate, see Table 2.

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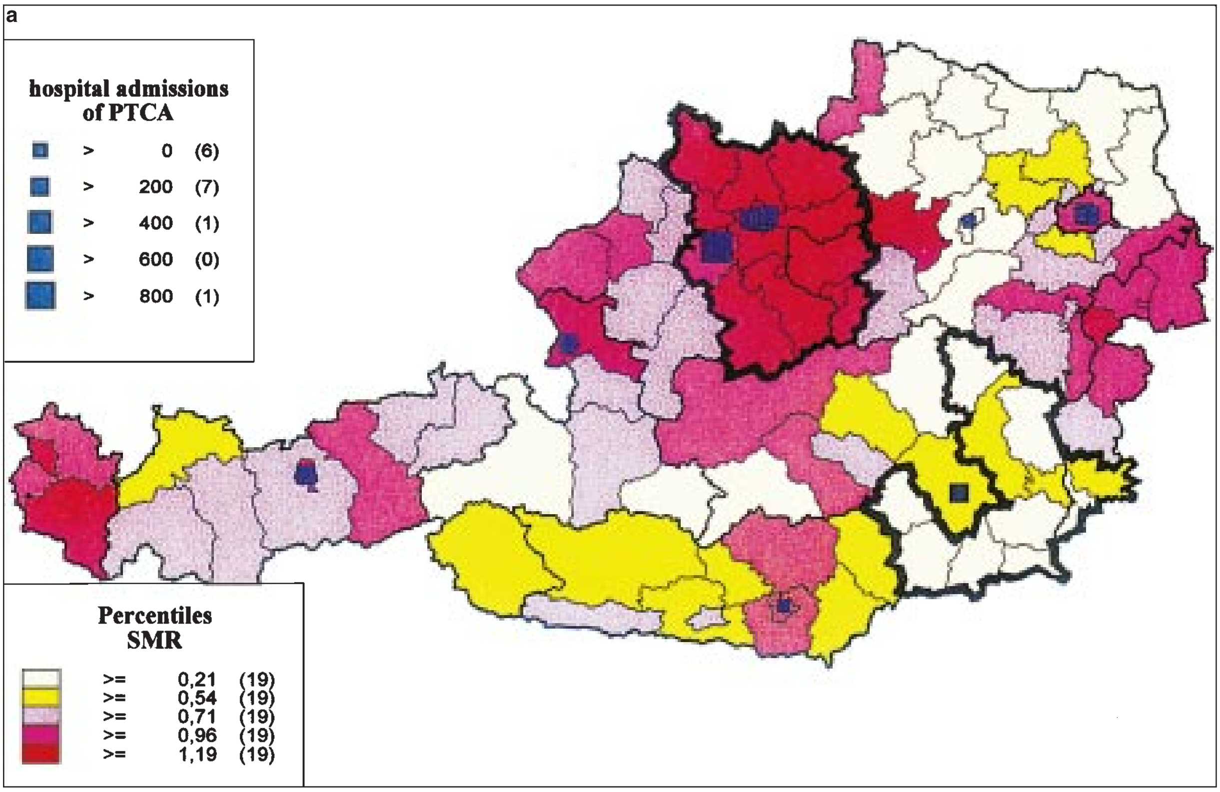
Demand factor morbidity

Austrianwide no overlap of PTCA-clusters with morbidity-clusters was observed by visual inspection. Moreover, in the area of cluster II, the 'negative' PTCA-cluster, a tendency for 'positive' clustering of districts with SMRs for indications $\geqslant 1.18$ was observed (Figure 2a, b). Nevertheless, there was no significant correlation between SMR of indications and SMR of PTCA both Austrianwide ($r = 0.94$, $p = 0.36$) and within the clusters (cluster I: $r = 0.37$, $p = 0.21$; cluster II: $r = -0.11$, $p = 0.75$) (Figure 4).

Supply factor number of specialists

In 1995, 1006 specialists for internal medicine/cardiology served the Austrian population of about 7.8 millions (1.4/10,000). On an average, one specialist served 14,663 persons in cluster I and 18,375 in cluster II (Table 1a, b). Although cluster I was better served than cluster II, the difference between the clusters was not significant (Table 2). The rate of



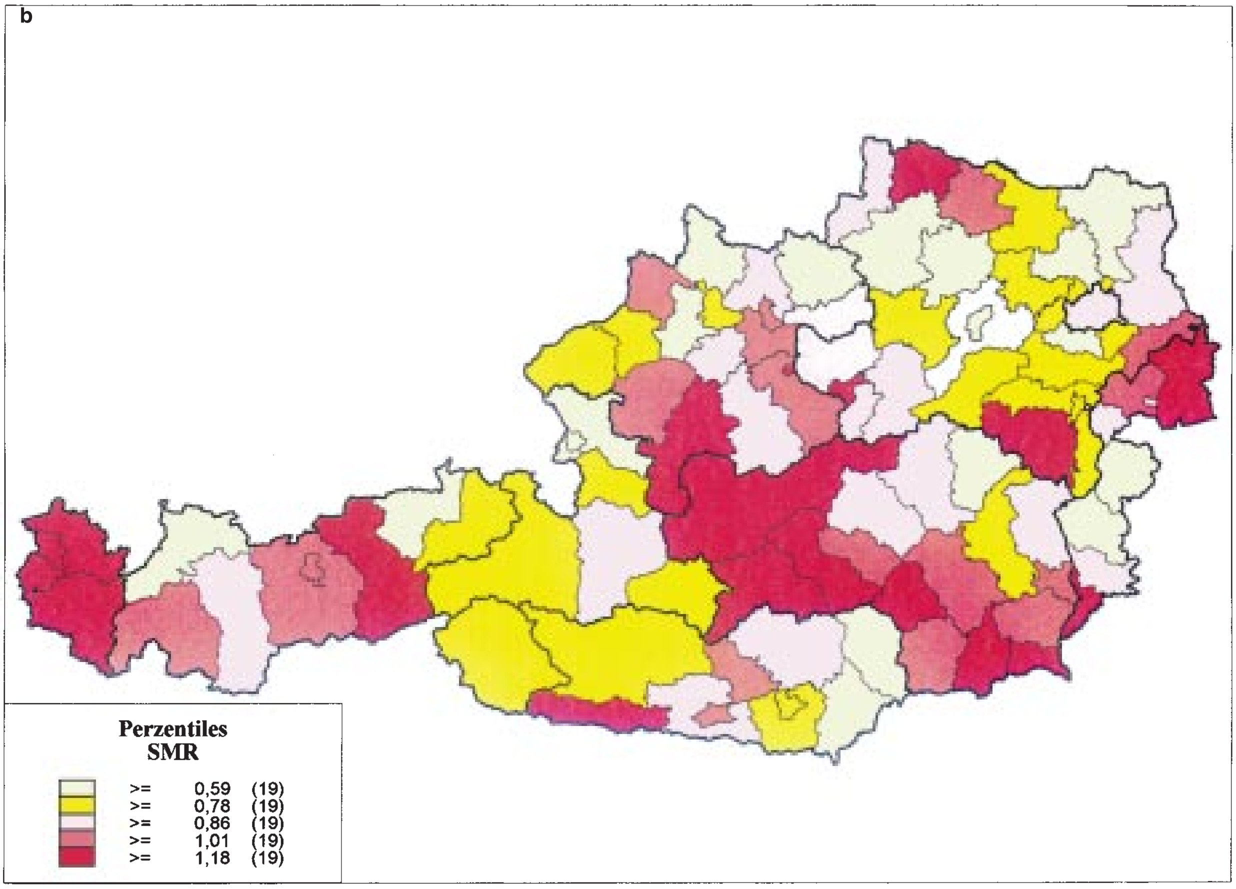
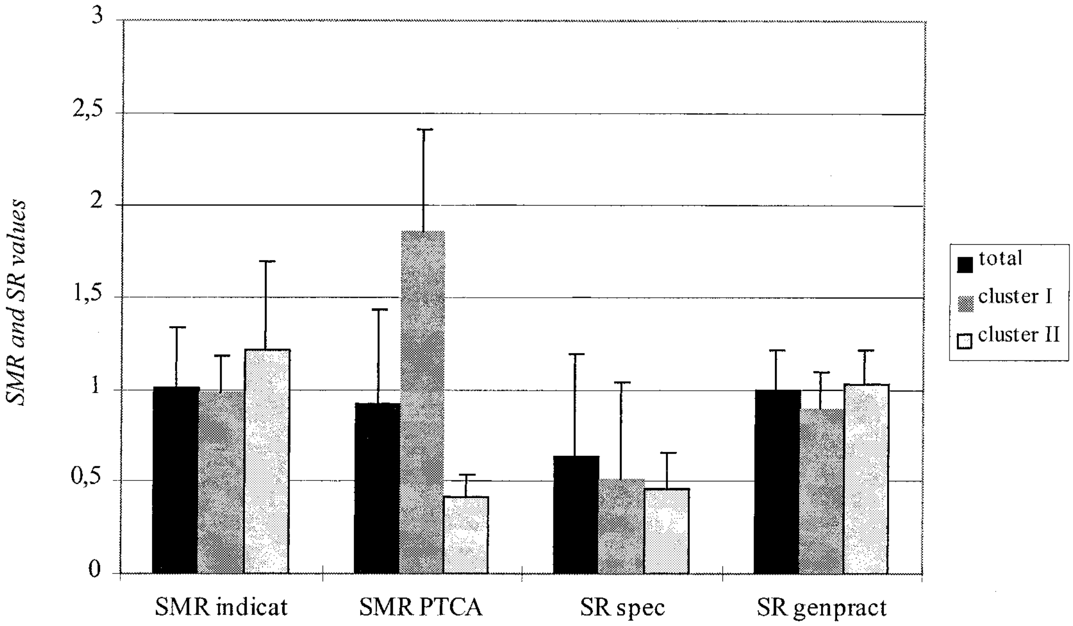


Figure 2. (a) SMR and hospital admissions of PTCA in Austria 1995. (b) SMR of indications for PTCA in Austria 1995.



SMR indicat: SMR of indications (angina pectoris and myocardial infarction)
SMR PTCA: SMR of PTCAs
SR spec: SR of specialists for internal medicine and cardiology
SR genpract: SR of general practitioners

Figure 3. Means and standard deviations of SMR of indications, SMR of PTCA, standardized rate (SR) of specialists and general practitioners.

specialists per persons lay in both clusters significantly under the Austrian average of one specialist per 7749 persons (cluster I: OR: 1.9, $p < 0.001$; cluster II: OR: 2.4, $p < 0.001$). The number of specialists Austrianwide and in the two clusters had neither significant influence on the intervention rate (Austria: $r = -0.03$, $p = 0.78$; cluster I: $r = -0.12$, $p = 0.69$; cluster II: $r = 0.03$, $p = 0.91$) nor on the SMR of PTCA (Austria: $r = 0.07$, $p = 0.5$; cluster I: $r = 0.41$, $p = 0.17$; cluster II: $r = 0.14$, $p = 0.68$). Significant influence of number of specialists on the SMR of indications was only observed in cluster I (Austria: $r = 0.09$, $p = 0.4$; cluster I: $r = 0.59$, $p = 0.03$; cluster II: $r = 0.02$, $p = 0.95$) (Figure 4).

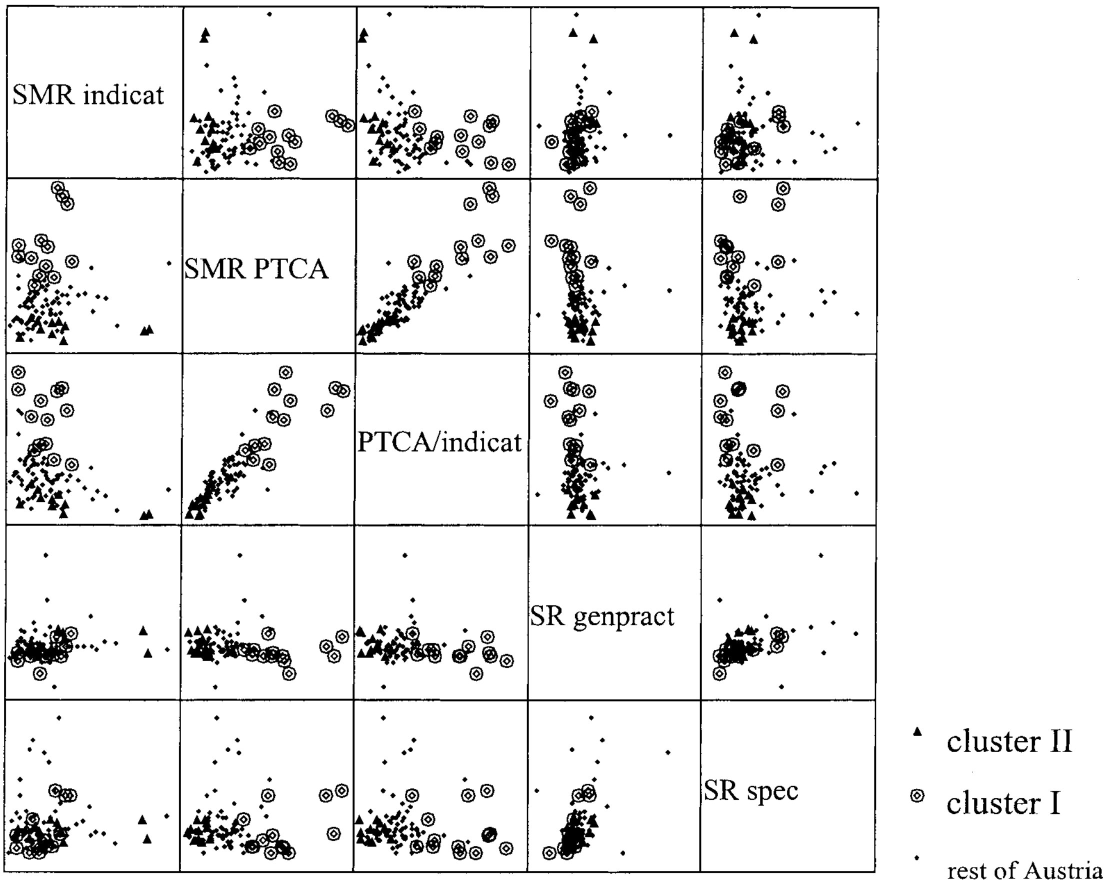
Table 2. Odds ratios of morbidity rate, intervention rate, general practitioners, specialists in private praxis, specialists working in intervention centres and beds in cluster I relative to cluster II

	OR	CI	p-value
Morbidity rate	0.9	0.63–0.89	< 0.001
Intervention rate	5.8	4.82–7.78	< 0.001
Genpract	0.9	0.78–1.03	0.1
Specialists[a]	1.2	0.79–1.99	0.3
Skilled specialists[b]	1.5	0.60–3.91	0.36
Beds	6.9	4.66–10.26	< 0.001

[a] Specialists for internal medicine and cardiology in private praxis.
[b] Specialists working in an intervention centre and skilled in PTCA.

Supply factor number of general practitioners
Austrianwide, 4858 general practitioners in private praxis were registered in 1995 (6.2/10,000). On an average, one general practitioner served 1815 persons in cluster I and 1619 in cluster II (Table 1a, b). Cluster II was slightly better served than cluster I but the difference was not significant (Table 2). The rate of general practitioners per persons lay in cluster I significantly under the Austrian average of one general practitioner per 1604 persons (cluster I: OR: 1.1, $p = 0.006$; cluster II: OR: 1.01, $p = 0.87$). The number of general practitioners Austrianwide and in the two clusters had neither significant influence on the intervention rate (Austria: $r = -0.13$, $p = 0.21$; cluster I: $r = -0.37$, $p = 0.2$; cluster II: $r = -0.33$, $p = 0.31$) nor on the SMR of indications (Austria: $r = 0.08$, $p = 0.41$; cluster I: $r = -0.47$, $p = 0.1$; cluster II: $r = 0.31$, $p = 0.35$) or the SMR of PTCA (Austria: $r = -0.06$, $p = 0.55$; cluster I: $r = 0.06$, $p = 0.85$; cluster II: $r = -0.07$, $p = 0.83$) (Figure 4).

In a multiple regression model, no significant influence of the factors morbidity ($p = 0.41$), number



SMR indicat: SMR of indications (angina pectoris and myocardial infarction)
SMR PTCA: SMR of PTCAs
PTCA/indicat: intervention rate
SR genpract: standardized rate of general practitioners
SR spec: standardized rate of specialists for internal medicine and cardiology

Figure 4. Correlations between SMRs of indications, SMRs of PTCA, intervention rate (PTCA/indications), standardized rate (SR) of general practitioners and specialists.

of general practitioners ($p = 0.32$) and specialists ($p = 0.25$) on PTCA utilization rates could be shown.

Intervention centres

Almost all patients of cluster I received PTCA in one of the four intervention centres within the cluster. 80% of patients of cluster II underwent PTCA in Graz, the capital of Styria. Almost 10% of patients of cluster II were referred to Wels (Upper Austria) and single cases were referred to further intervention centres outside the clusters. The intervention centre of Wels was the only one of over-regional importance with 67% of PTCA patients being residents of other Federal States than Upper Austria (Table 3). The total capacity of intervention centres within cluster I was higher than that of cluster II (cluster I: beds = 363, staffing: 19; cluster II: beds = 29, staffing = 7). The number of available cardiological beds differed significantly in the two clusters but not the number of cardiologists skilled in PTCA (Table 2). On an average, one cardiologist working in an intervention centre of cluster I performed 96 PTCAs per year whereas in cluster II one cardiologist performed 41 PTCAs per year.

Discussion

The demand of PTCA is determined mainly by the age–sex structure and the morbidity of the population [13]. Surprisingly, age–sex standardized PTCA rates were not significantly correlated with the SMR of indicational diagnoses and were in line with the findings of a survey done in 14 European countries [5]. This might be due to the preference of other types of interventions such as coronary bypass grafting and pharmacological therapy. A British survey on district level found even an inverse relation between morbidity and PTCA utilization [8]. The situation in cluster II, where low utilization rates contrasted with high morbidity, might support the thesis of 'inverse care law' which is defined as the tendency of an

Table 3. Intervention centres and served population per Federal state

	Burgenld	Carynthia	LA[a]	UA[a]	Salzburg	Styria	Tyrol	Vorarlbg	Vienna	Others[b]	Total
K416 Linz AKH	0	1	31	400	12	5	0	2	1	0	452
K418 Linz BSRVKH	0	0	70	169	0	1	0	0	1	4	245
K419 Linz Elisabethinen	1	2	18	199	0	2	1	0	0	0	223
K434 Wels	89	28	250	282	26	69	41	81	54	6	926
K612 Graz LKH	9	5	1	1	1	273	0	0	1	2	293

[a] Lower Austria and Upper Austria.
[b] European countries and states of former USSR.
K416, … = Hospital code.
All intervention centres are located in Upper Austria except Graz LKH (located in Styria).

inverse relationship of good medical care with the need of the population mainly due to heavier caseload of doctors and inherently by more ineffective traditions of consultations [21].

Austrianwide, the number of both specialists for internal medicine/cardiology and general practitioners had no significant influence on the number of diagnosed indications for PTCA and referred PTCA patients. This result was consistent with earlier findings of the European survey [5]. Nevertheless, the differences between the clusters concerning the number and capacity of intervention centres and the density of specialists pointed to supply factors as possible reasons for geographical disparity. As such, those results supported the British findings of differences in supply of services as the main factor of influence [8]. Furthermore, the Global Utilization of Streptokinase and Tissue Plasminogen Activator for Occluded Coronary Arteries (GUSTO) trial identified the availability of catheterization facilities as one of the main predictors of the decision by US physicians to use coronary angiography instead of conservative methods [22].

Differences in referral practice could partly explain the differences in performed PTCAs. Both patients' and physicians' attitude towards PTCA have considerable impact on referral practice: patients' request for PTCA leads to higher numbers of referrals [23] and cardiologists are more likely to refer patients than primary care physicians [24–26]. However, no data are currently available which describe the Austrian situation in this respect.

Earlier findings showed that cardiologists skilled in performing PTCAs are more likely to recommend this procedure than those who are not [22, 27]. Consequently, case load per interventional cardiologist might differ according to the individual level of experience and explain the difference of SMRs for PTCAs throughout Austria. However, data on individual case load are currently not available but studies are in progress.

Over the last decade, the number of PTCA has increased steadily due to the establishment of new intervention centres and expansion of existing ones. Given those continued developments, a reduction in the variation between the districts might be expected as the availability of services increases. This will be true if the current health system which provides the same quality of health services, regardless of factors such as socio-economic status or age, will be practised further on. Another scenario regarding the health care system will be more likely in the future: since considerable financing problems have occurred during the last decade, economic principles as the basis of insurance systems are in discussion. Economic factors like socio-economic status will probably replace supply factors as reasons for geographic variation [21].

Limitations

Since only hospitals which received financial aid from the Ministry for Social Affairs were obliged to perform the MBDS, we missed the data of 3 private intervention centres out of a total of 26. Consequently, the Austrianwide calculations were based on a lower number of cases. Nevertheless, for cluster investigation we dealt with a complete data set. Coding in the MBDS was based on the ICD-9 catalogue, which allows no classification of severity of disease. Therefore, our morbidity rates might not reflect the real demand for interventions. SMRs of indications for PTCA were calculated by using the case definition of the Austrian guidelines for Coronary Angiography Referrals. Although we consider this case definition as the most appropriate, case definitions including other indications might lead to different results.

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