Evaluating Methods for Intersectoral Comparison of Quality of Care: A Routine Data Analysis of Elective Percutaneous Coronary Interventions

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Summary

Objectives: To compare the quality of care regarding the use of elective percutaneous coronary interventions (PCIs) in the inpatient and outpatient setting and to evaluate different methods of confounder control in this context.

Methods: Based on data of three statutory health insurances including more than nine million insurance members, a retrospective cohort study between 2005 and 2009 was conducted. The occurrence of myocardial infarction, stroke, further coronary intervention and death was ascertained following the first PCI in the study period, which was preceded by a one-year period without a PCI. A Cox proportional hazard model was used to assess the influence of the setting of the elective PCI on the risk for complications after the PCI for each outcome separately. Age, sex, the number of diseases of the Elixhauser comorbidity measure, past acute coronary syndrome, coronary artery disease, dyslipidemia, past stroke, past coronary artery bypass surgery and the year of the PCI were included as covariables. The analyses were repeated in a propensity score matched cohort as well as in inverse probability of treatment weighted analyses.

Results: The cohort comprised 4,269 patients with an outpatient PCI and 26,044 patients with an inpatient PCI. The majority of the analyses revealed no statistically significant effect of the setting of the PCI on the risk of myocardial infarction, stroke and further coronary interventions, whereas a reduced mortality risk was observed for outpatient PCIs. Similar results were obtained in the propensity score analyses.

Conclusions: The analysis revealed that the adjusted risk for complications following an elective PCI is similar between the inpatient and the outpatient setting. For mortality the risk differed but this might be explained by residual or unmeasured confounding. The different methods applied in this study revealed mostly similar results. Since our study only covered one aspect of quality of care in the field of PCI and did not consider drug treatment in hospital or in the outpatient setting, further studies are needed which include these aspects.

Keywords: Percutaneous Coronary Intervention, Quality of Health Care, Outpatient and Inpatient Care, Methods for Confounder Control

Introduction

Cardiovascular diseases (CVDs) are the leading cause of death worldwide. According to the World Health Organization (WHO) more than 17 million died from CVDs in 2008, accounting for more than 30% of all deaths (1). In Europe more than 40% of all deaths are due to CVDs (2). The prevalence of CVDs such as coronary artery disease (CAD) is high and increases with advancing age. In people aged 65 years or older the lifetime prevalence of CAD is greater than 15% in Germany. Furthermore, CAD is observed more frequently in men than in women (3). Therapeutic innovations such as percutaneous coronary interventions (PCIs), which are carried out to open blocked or narrowed coronary arteries in coronary heart disease and to restore arterial blood flow to the heart tissue without open heart surgery, are increasingly being used in the therapy of CAD (4;5). In the last two decades the use of PCIs, increased from 44,030 PCIs in 1991 to 328,654 PCIs in 2011 in Germany (5). A stent, a tiny, expandable metal coil, is now often inserted into the newly-opened area of the artery to help keep the artery from narrowing or closing again. Given the increasing specialization in the outpatient setting, shifts in service from the hospital to the outpatient setting can be assumed (6). Although quality assurance measures exist for both settings (7-10), different methods complicate a direct comparison of the quality of care. Further, one might assume that high numbers of cases and thus a high degree of standardisation in the inpatient setting might lead to a lower complication rate than in the outpatient setting. Since routine data of statutory health insurances (SHI) comprise individual information on diagnoses and procedures in both settings, they allow an intersectoral comparison of the quality of care.

The decision for the treatment in the in- or outpatient setting strongly depends on the severity of the underlying disease and the risk factor profile, thus leading to a more severely diseased population in the inpatient setting. Therefore adequate controlling for confounders is of crucial importance. Propensity score (PS) methods such as PS matching and inverse probability of treatment (IPT) weighting using the PS can improve the homogenization of the populations and thus the confounder adjustment (11).

Objectives

The aim of this study was to compare the quality of care regarding the use of elective PCIs in the in- and outpatient setting in Germany and to evaluate different methods of controlling for confounders in this context.

Methods

Data base

This study was based on data from the German Pharmacoepidemiological Research Database (GePaRD). GePaRD comprises claims data from four SHIs including more than 17 million insurants. The database was described elsewhere (12;13). Besides demographic variables such as age, sex and region of residence of the insurance members, GePaRD contains information on outpatient physician visits, hospital admissions and outpatient prescriptions. The outpatient data comprises information on outpatient diagnoses, for which only the quarter of the year is specified, and treatments and procedures (e.g. PCIs) with their exact dates. Outpatient diagnoses are distinguishable into confirmed diagnoses, suspected diagnoses, diagnoses ruled out and status post diagnoses. The hospital data include information on admission diagnoses, main hospital discharge diagnoses, a maximum of 40 secondary hospital discharge diagnoses and procedures with their respective dates. The admission diagnosis represents the assumed reason for the hospital admission, whereas the main hospital discharge diagnosis represents the true reason for the hospital admission diagnosed during the hospital stay. Inpatient and outpatient diagnoses are coded according to the German Modification of the International Classification of Diseases 10th Revision (ICD-10-GM) (14). Three SHIs approved the use of their data for this study, so that we were able to include more than nine million insurance members during the study period

Use of the data for research purposes needs to be approved by the SHIs contributing the data and by local or federal government authorities responsible according to data protection legislation. In accordance with § 75 of Volume 10 of the Social Insurance Code, informed consent of involved insurance members was not required. Since the study was based on routinely collected pseudonymized data delivered by the SHIs, a vote of the ethics committee was not required.

Study design

For the evaluation of the quality of care regarding the use of PCIs, a retrospective cohort study was conducted, in which the occurrence of relevant complications (myocardial infarction, stroke, further coronary intervention and death from any cause) after an elective PCI was studied.

Study population

Inclusion criteria

Patients, in whom at least one PCI was carried out between 2005 and 2009 preceded by a continuous one-year insurance period without PCIs, were eligible for inclusion in the study population.

Exclusion criteria

Patients without valid information on sex, year of birth, and region of residence were excluded from the study population. Since only elective PCIs were considered in this study, patients who received an admission diagnosis of "acute coronary syndrome" or "recurrent myocardial infarction" during the hospitalization in which the first PCI (index-PCI) was carried out, were also excluded from the cohort.

Cohort entry and cohort exit

Cohort entry was at the date of the index-PCI between 2005 and 2009. Patients remained in the cohort until the end of the insurance period, end of follow-up (31.12.2009) or the occurrence of the myocardial infarction, stroke, further coronary intervention or death. Each outcome was studied in a separate analysis.

Ascertainment of exposure, outcomes and comorbidity

Occurrence of unfavourable outcomes after an elective PCI was considered as quality indicators in our study and was ascertained by using the ICD-10-GM codes I21 and I22 for myocardial infarction and I63 and I64 for stroke. For the identification of these outcomes, only main hospital discharge diagnoses were considered. Further coronary interventions were ascertained using the following codes for the reimbursement of inpatient procedures (OPS-codes) (15) and the reimbursement of outpatient procedures (EBM-codes) (16):

- OPS-code 8837 (for an inpatient PCI).
- EBM-codes 5120 and 5122 (until 31.03.2005) or 34291 and 34292 (from 01.04.2005), which had both to be coded at the same date (for an outpatient PCI)[1]

Patients were identified as having died, if the cause for the end of the insurance period was "death". The corresponding date of insurance exit was defined as the date of death.

For the identification of the comorbidity of the patients, the 30 diseases of the Elixhauser comorbidity measure (ECM), a comorbidity measure which was developed for the prediction of the inpatient mortality (17), were ascertained. Since the ECM comprises many non-cardiovascular

1 In the association of the SHI physicians in Bremen (Kassenärztliche Vereinigung Bremen) different codes for the identification of outpatient PCIs were used (**supplementary material**).

diseases, five other relevant cardiovascular risk factors or diseases (past stroke, recurrent myocardial infarction, past acute coronary syndrome, other coronary artery disease, dyslipidemia) were additionally considered. For this purpose, confirmed outpatient diagnoses and main and secondary hospital discharge diagnoses in the year preceding the cohort entry were considered. A list of the considered diseases can be found in the **supplementary material**.

Statistical Analysis

Primary Analysis

The incidence rates of the outcomes after elective PCI were calculated by dividing the number of incident cases by the accumulated person time in the respective follow-up period. Confidence intervals (CI) for incidence rates were calculated using the substitution method (18). To assess the influence of the setting of the elective PCI on the risk of complications after the PCI, a multivariable Cox proportional hazard model was used. The following independent variables were included in the full model: year of cohort entry, age at cohort entry (continuous), sex, number of diseases of the ECM (19), past acute coronary syndrome, CAD, dyslipidemia, past stroke, and past coronary artery bypass surgery. The year of the index PCI was included in the final model, in case the respective effect estimate was significantly different from 1 (Wald test p-value < 0.05). All statistical analyses were conducted using SAS 9.2 (SAS Institute Inc.).

Propensity Score Analyses

The effect of the setting on complications was subsequently studied using the PS matched cohort. The PS was defined as the probability of an elective PCI in the outpatient setting given a set of variables likely influencing this probability. It was estimated by a logistic regression model including age, sex, region of residence, year of cohort entry, diseases of the ECM and other comorbidities and interventions as explanatory variables (**supplementary material**). A Greedy 6->1 Digit Matching strategy was used to perform a 1:1 matching of patients with respect to the setting of the PCI (20). The balance of all variables in the PS matched cohort was examined with the standardized difference. For continuous variables, the standardized difference was defined as

$$SD = \frac{\left| \acute{x}_{amb} - \acute{x}_{stat} \right|}{\sqrt{\frac{s^2_{amb} - s^2_{stat}}{2}}}$$

and for binary variables, it was defined as

$$SD = \frac{\left| \acute{x}_{amb} - \acute{x}_{stat} \right|}{\sqrt{\frac{\acute{x}_{amb}(1-\acute{x}_{amb}) - \acute{x}_{stat}(1-\acute{x}_{stat})}{2}}}$$

where $\acute{x}_{amb}$ and $\acute{x}_{stat}$ denote the mean of the respective variable in patients with an outpatient PCI and inpatient PCI, respectively, and s^2_{amb} and s^2_{stat} denote the sample variance of the respective variable in patients with an outpatient PCI and inpatient PCI, respectively. The standardized difference was calculated in the full cohort and the matched cohort. A standardized difference of greater than 0.1 indicated an important imbalance (21).

We also used the PS to perform an inverse probability of treatment (IPT) weighted analysis. Therefore, the primary analysis was repeated and the contribution of each patient to the log-likelihood of the Cox model was weighted by the inverse of the probability of receiving a PCI in the respective setting. In particular, the weights were 1/PS for patients with an outpatient PCI and 1/(1-PS) for patients with an inpatient PCI. The analysis was further repeated with stabilized IPT weights. Here, the weights for patients in the outpatient and inpatient setting were multiplied by the proportion of patients in the outpatient and inpatient setting, respectively (22). In addition, to examine the impact of extremely low and high stabilized IPT weights on the effect estimate, we performed three analyses with stabilized weights where the lowest and highest 1%/5%/10% of the weights were truncated to the 1%/5%/90% and 99%/95%/90% quantile of the weight distribution, respectively (23).

Results

The influence of the in- and exclusion criteria on the size of the study population is shown in the sample flow chart (**Figure 1).** The cohort comprised 30,313 patients with an elective PCI between 2005 and 2009, of which 4,269 (14.1%) were conducted in the outpatient setting (**Table 1**). The mean age at cohort entry and the mean number of diseases of the ECM were similar between the in- and outpatient setting. Patients with an outpatient PCI had more frequently diagnoses of CAD and dyslipidemia in the year prior to the PCI. Past strokes were more common in patients with an inpatient PCI. Furthermore, the prevalence of heart failure, cardiac arrhythmias, complicated hypertension and complicated diabetes mellitus, all diseases which are part of the ECM, was also somewhat higher for patients in the inpatient setting (**Table 1**). The mean follow up time was 2.1 years (standard deviation (SD): 1.4) for the outcome “myocardial infarction”, 2.2 years (SD: 1.4) for

the outcome “stroke”, 1.7 years (SD: 1.5) for the outcome “further coronary intervention” and 2.2 years (SD: 1.4) for the outcome “death”, respectively.

Primary Analysis

The age- and setting-specific incidence rates of complications after an elective PCI are shown in **table 2**. The multivariable Cox regression showed that higher age was associated with an increased risk in all four outcomes (**Table 3**). An ECM of ≥5 was associated with an increased risk concerning the outcomes “stroke” and “death”, but showed no association with the outcome “further coronary intervention” or “myocardial infarction”. A reduced mortality risk and a reduced risk of further coronary interventions were observed for women compared to men. The setting of the PCI had no influence on the occurrence of myocardial infarction and stroke. Regarding the outcome “death” and “further coronary intervention”, a reduced HR was seen for outpatient PCIs.

Propensity Score Analyses

The matched cohort comprised 4,007 patients of all patients with an elective PCI in the outpatient setting (93.9%) and 4,007 of all patients with an elective PCI in the inpatient setting (13.2%). The standardized difference for each of the variables in the full cohort and the matched cohort is displayed in Figure 2. In the full cohort, many variables had a standardized difference of more than 0.1 indicating important imbalance, e.g. for the region of residence, dyslipidemia and CAD. After the matching, none of the variables showed an important imbalance between the outpatient and the inpatient setting.

The results of the Cox regression in the PS matched cohort and in the full cohort with IPT weights are presented in **Table 4**. The results were largely similar to those of the primary analysis, however, the protective effect of outpatient PCIs on further coronary interventions that was observed in the primary analysis was no longer significant. Estimates of the IPT weighted analysis and the stabilized IPT weighted analyses were almost identical. The stabilized IPT weights ranged from 0.14 to 21.00 with a mean of 1.00 (SD=0.39). After a 5% truncation, the stabilized IPT weights were close to 1 (range: 0.69 - 1.24, mean=0.99, SD=0.11).

Discussion

Based on German health insurance data, we investigated the risk of complications after an elective PCI in relation to the setting of the PCI. The majority of the analyses revealed no statistically significant effect of the setting of the PCI on the risk of myocardial infarction, stroke and further coronary interventions, whereas a reduced mortality risk was observed for outpatient PCIs. The different methods for confounder control applied in this study mostly revealed similar results.

Due to an increasing specialisation in the outpatient setting, PCIs are now also performed outside the hospital. Stent insertion is commonly carried out in PCIs to prevent restenosis or closure of the artery. In 20-30% of the cases, an in-stent-restenosis, that is a renewed narrowing of the coronary artery due to cell proliferation occurs after stent placement, which can lead to a myocardial infarction, unless a further PCI is performed (24). Without stent placement, restenosis occurs in 30-50% of all patients solely undergoing a dilatation of the narrowed coronary artery (25) Furthermore, stroke represents an important complication after a PCI, although strokes occur less often compared to the other complications (26). With respect to these possible complications, we chose myocardial infarction, stroke, death and further coronary interventions as outcomes and possible quality indicators in our study.

Since the decision whether to conduct the PCI in the inpatient or outpatient setting likely depends on the severity of the underlying disease and the patient's comorbidities, adequate confounder control is of great importance when comparing the complication risk between both settings. In a first step, we excluded in-hospital PCIs due to acute coronary syndrome to restrict the PCIs to elective PCIs, since PCIs carried out in the outpatient setting are assumed to be overall elective. With consideration of the ECM and further cardiovascular risk factors, we also considered a large number of possible confounders in the analyses. Despite this extensive confounder adjustment in the conventional Cox regression model, a statistically significantly reduced risk of death and further coronary interventions in the outpatient setting was observed. Most of the PS analyses did not confirm this significantly reduced risk of further coronary interventions. The matched PS cohort analysis showed a statistically significantly reduced risk of myocardial infarction which was not seen in the conventional regression analysis and in the IPT-weighted PS analyses. Since the matched PS analysis excluded 22,299 patients (73.6%) with PCI, the differing result might be due to the exclusion of this large number of patients. Overall, the PS analyses, especially the IPT weighted analyses, yielded similar results to the conventional confounder-adjusted regression analysis. This is in line with a review of Stürmer et al., who similarly found that PS analyses did not yield substantially different estimates compared with conventional multivariable methods (27).

One advantage of PS analyses is that additional covariables may be considered in the statistical analysis in case of a limited number of outcomes, since all covariables are combined into the PS and therefore consideration of a large number of covariables will not lead to unstable statistical results. In our study, the region of residence and each individual disease of the ECM were considered in the calculation of the PS, whereas in the primary analysis, the ECM was included aggregated and the region of residence was not further considered. Nevertheless, the PS analyses can only account for covariables that are available in the data. Thus, unmeasured confounding due to lack of information

on relevant confounders such as nutrition, physical activity, smoking behaviour and alcohol consumption cannot be resolved by the PS analyses. Another approach to overcome possible confounding in the risk estimate for mortality might be to analyse the data by use of the high-dimensional PS approach. This automated search for confounders is thought to make use of proxy information for unmeasured confounders and might thereby be able to partly adjust for the unmeasured confounders (28).

Another theoretical advantage of a PS matched analysis is that the matching excludes patients in which the effect of the setting cannot be estimated. When considering the distribution of the PS in the outpatient and inpatient setting, it could happen that for very low and very high values of the PS, the distribution of the PS in both settings will not overlap (29). These patients will not be included in the matched population, since no matching patient with a similar PS exists. However, in our study, there was an overlap of the PS distributions for all values of the PS.

A weakness of a PS matched analysis is that patients without a matching partner are excluded from the analysis. Highly differing population sizes, as it was the case in our study, lead to a considerable fraction of unmatched patients in the larger subpopulation whereas almost all patients of the smaller subpopulation are included in the matched sample. This would imply two consequences. First, the exclusion of unmatched patients would lead to a somewhat reduced efficiency in the effect estimates compared to the analysis including all patients. A fixed ratio of controls (e.g. 1:2 or 1:3 matching) might have led to the exclusion of patients from the already small subpopulation of outpatient PCIs, due to an insufficient number of matching partners. This would have also reduced the efficiency of the effect estimates. Second, the smaller matched population might be different from the original population which can influence the results obtained in a PS matched analysis as e.g. we observed for the risk of myocardial infarction in our analysis. This should be considered when interpreting the effect estimates (30). The validity of the PS matched analysis critically relies on the balance of the covariables in the matched cohort which might not be given in all situations. In our study, the standardized difference revealed no imbalance in any of the covariables after the matching. However, lack of imbalance does not necessarily imply validity, if important confounder information is missing.

In an IPT weighted analysis all study subjects are considered, since the PS is only used for weighting each patient's contribution to the likelihood of the Cox model. As a consequence, the effect estimate of an IPT weighted analysis corresponds to the whole study population (30). However, a violation of the positivity assumption might be present (31). The positivity assumption states that there is a nonzero probability of receiving each treatment at each level of the confounding factors (23). High IPT weights indicate a practical violation of the positivity assumption that could lead to bias and variance inflation of the effect estimates (23;31). To address this problem, stabilized IPT weights are

recommended, which are less variable than unstabilized weights (22). To further explore the impact of the high stabilized IPT weights on the effect estimates, a truncation of high weights at different levels can be performed (23). In our study, the analysis with the stabilized version of the IPT weights and a truncation of the stabilised IPT weights yielded only slightly smaller CIs than the IPT weighted analysis, indicating that there is no violation of the positivity assumption in the IPT weighted analysis.

Strengths and Limitations

The major strength of this study is the large and supraregional population on which the analyses were based. In addition, it could be shown that the age- and sex-distribution of patients included in GePaRD is similar to that of Germany (13), suggesting external validity of the results. However, these analyses were conducted on the basis of four SHIs. For this study, three SHIs approved the use of their data. Furthermore, we directly compared the quality of care regarding the use of elective PCIs between the inpatient and outpatient setting. Previous studies evaluated the quality of care in both settings separately and on the basis of different methods (8;9).

However, there are also several limitations. German SHI data do not comprise information on lifestyle factors such as nutrition, physical activity, smoking behaviour and alcohol consumption. Furthermore, information on disease severity is not contained for most diseases in the ICD 10 classification and thus lacking in German SHI routine data. While we adjusted for a large number of diseases in the statistical analyses, we were not able to account for the severity of these diseases. The severity might have been higher for patients treated in the inpatient setting, contributing to residual confounding by comorbidities in the analyses. Although we restricted our analyses to elective PCIs, the exclusion of inpatient PCIs due to an acute coronary syndrome might not have been successful in all cases, if this diagnosis was not sufficiently coded. Exclusion of emergency PCIs may also not have been complete, if the admission diagnosis was not confirmed during the hospital stay, e.g. if a patient was admitted to the hospital for an elective PCI due to a stable angina pectoris (admission diagnosis), but the stable angina pectoris turned out to be an acute coronary syndrome (main discharge diagnosis), for which reason an emergency PCI was done.

Conclusion

This study showed that the adjusted risk for complications following an elective PCI is similar between the inpatient and the outpatient setting. For mortality the risk differed but this might be explained by residual or unmeasured confounding. The different methods for confounder control, which were applied in this study, mostly revealed similar results. In the context of an aging society and therefore

increasing numbers of patients with CAD, this represents an important finding for care planning. Our study only covered one aspect of quality of care in the field of PCI. Other aspects, such as antithrombotic drug therapy following a PCI should be considered in further studies. In the end, the decision for an inpatient or outpatient PCI also depends on the patient preference, independently from potential differences in the quality of care.

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Conflict of interest

This study was funded by the Central Research Institute of Ambulatory Health Care. The authors had complete autonomy for the process of establishing the protocol, carrying out the analyses and interpreting the results. This also includes the full right to publish the results without limitation. CO, DE, AT, RM and EG are working/worked for an institute that occasionally performs studies for pharmaceutical industries. These companies include Bayer, Celgene, GlaxoSmithKline, Mundipharma, Novartis, Sanofi-Aventis, Sanofi Pasteur MDS, and STADA. EG has been a consultant to Bayer-Schering, Nycomed, Teva, GlaxoSmithKline, Schwabe and Novartis and is a member of the German Standing Vaccination Committee (Ständige Impfkommission, STIKO). The present work is unrelated to these grants or relationships. RL and DHS are working for the Scientific Institute of TK for Benefit and Efficiency in Health Care. The mission of the Scientific Institute of TK for Benefit and Efficiency in Health Care (Wissenschaftliches Institut der TK für Nutzen und Effizienz im Gesundheitswesen, WINEG) is to investigate the value of innovations and new programmatic approaches within the statutory health insurance framework. The authors declare that because they belong to the Techniker Krankenkasse, a potential conflict of interest exists according to the guidelines of the International Committee of Medical Journal Editors. WH has received honoraria and research funding from several pharmaceutical companies. However, the present work is unrelated to any of his grants and relationships.

References

(1) World Health Organization (WHO) [Internet]. Cardiovascular Diseases (CVDs). [cited 2014 May 05]. Available from: http://www.who.int/mediacentre/factsheets/fs317/en/index.html

(2) EUGLOREH. Non-communicable diseases and related time trends: Prevalence, incidence and mortality; the status of health in the European Union: towards a healthier Europe. 2009.

(3) Gosswald A, Schienkiewitz A, Nowossadeck E, Busch MA. Prevalence of myocardial infarction and coronary heart disease in adults aged 40-79 years in Germany: results of the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2013 May;56(5-6):650-5.

(4) Czwikla J, Ohlmeier C, Enders D, N'Diaye I, Timmer A, Mikolajczyk R, et al. Häufigkeit koronarer Interventionen zwischen 2004 und 2009 in Deutschland. Proceedings of the 8th annual Conference of the German Association of Epidemiology; 2013 Sep 24-27; Leipzig; Germany.

(5) Deutsche Herzstiftung. Deutscher Herzbericht 2011. Frankfurt am Main; 2012.

(6) Robra B-P, Swart E, Vogt T. Veränderungen des Umfangs der vertragsärztlichen Leistungen durch Leistungsverlagerungen zwischen dem stationären und dem ambulanten Sektor. Magdeburg; 2010.

(7) Albrecht A, Levenson B, Gohring S, Haerer W, Reifart N, Ringwald G, et al. The QuIK-Registry of the German Society of Cardiologists in private practice: countrywide and benchmarking quality assurance in invasive cardiology. Dtsch Med Wochenschr 2009 Oct;134 (Suppl 6):S211-S213.

(8) AQUA-Institut. Qualitätsreport 2009. Göttingen; 2010.

(9) Boy O, Hahn S, Kociemba E, BQS-Fachgruppe Kardiologie. Koronarangiographie und Perkutane Koronarintervention (PCI). Düsseldorf; 2008.

(10) Jeschke E, Baberg HT, Dirschedl P, Heyde K, Levenson B, Malzahn J, et al. Complication rates and secondary interventions after coronary procedures in clinical routine: 1-year follow-up based on routine data of a German health insurance company. Dtsch Med Wochenschr 2013 Mar;138(12):570-5.

(11) Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. Multivariate Behav Res 2011 May;46(3):399-424..

(12) Mikolajczyk RT, Kraut AA, Garbe E. Evaluation of pregnancy outcome records in the German Pharmacoepidemiological Research Database (GePaRD). Pharmacoepidemiol Drug Saf 2013 Aug;22(8):873-80.

(13) Pigeot I, Ahrens W. Establishment of a pharmacoepidemiological database in Germany: methodological potential, scientific value and practical limitations. Pharmacoepidemiol Drug Saf 2008 Mar;17(3):215-23.

(14) DIMDI Deutsches Institut für Medizinische Dokumentation und Information [Internet]. Internationale Statistische Klassifikation der Krankheiten und verwandter

Gesundheitsprobleme: 10. Revision: Version 2008. [cited 2014 May 05]. Available from: http://www.dimdi.de/static/de/klassi/icd-10-gm/kodesuche/onlinefassungen/htmlgm2008/index.htm

(15) DIMDI Deutsches Institut für Medizinische Dokumentation und Information [Internet]. Operationen- und Prozedurenschlüssel (OPS) Version 2008. [cited 2014 May 05]. Available from: http://www.dimdi.de/static/de/klassi/ops/kodesuche/onlinefassungen/opshtml2008/

(16) Kassenärztliche Bundesvereinigung [Internet]. Einheitlicher Bewertungsmaßstab (EBM). [cited 2014 May 05]. Available from: http://www.kbv.de/html/ebm.php

(17) Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care 2005 Nov;43(11):1130-9.

(18) Daly LE. Confidence limits made easy: interval estimation using a substitution method. Am J Epidemiol 1998 Apr 15;147(8):783-90.

(19) Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care 1998 Jan;36(1):8-27.

(20) Parsons L. Reducing bias in a propensity score matched-pair sample using greedy matching techniques. SUGI 26 2010.

(21) Normand ST, Landrum MB, Guadagnoli E, Ayanian JZ, Ryan TJ, Cleary PD, et al. Validating recommendations for coronary angiography following acute myocardial infarction in the elderly: a matched analysis using propensity scores. J Clin Epidemiol 2001 Apr;54(4):387-98.

(22) Robins JM, Hernan MA, Brumback B. Marginal structural models and causal inference in epidemiology. Epidemiology 2000 Sep;11(5):550-60.

(23) Cole SR, Hernan MA. Constructing inverse probability weights for marginal structural models. Am J Epidemiol 2008 Sep 15;168(6):656-64.

(24) Simard T, Hibbert B, Ramirez FD, Froeschl M, Chen YX, O'Brien ER. The evolution of coronary stents: a brief review. Can J Cardiol 2014 Jan;30(1):35-45.

(25) Mack MJ, Head SJ, Holmes DR, Jr., Stahle E, Feldman TE, Colombo A, et al. Analysis of stroke occurring in the SYNTAX trial comparing coronary artery bypass surgery and percutaneous coronary intervention in the treatment of complex coronary artery disease. JACC Cardiovasc Interv 2013 Apr;6(4):344-54.

(26) Weintraub WS. The pathophysiology and burden of restenosis. Am J Cardiol 2007 Sep 3;100(5A):3K-9K.

(27) Sturmer T, Joshi M, Glynn RJ, Avorn J, Rothman KJ, Schneeweiss S. A review of the application of propensity score methods yielded increasing use, advantages in specific settings, but not substantially different estimates compared with conventional multivariable methods. J Clin Epidemiol 2006 May;59(5):437-47.

(28) Schneeweiss S, Rassen JA, Glynn RJ, Avorn J, Mogun H, Brookhart MA. High-dimensional propensity score adjustment in studies of treatment effects using health care claims data. Epidemiology 2009 Jul;20(4):512-22.

(29) Glynn RJ, Schneeweiss S, Sturmer T. Indications for propensity scores and review of their use in pharmacoepidemiology. Basic Clin Pharmacol Toxicol 2006 Mar;98(3):253-9.

(30) Kurth T, Walker AM, Glynn RJ, Chan KA, Gaziano JM, Berger K, et al. Results of multivariable logistic regression, propensity matching, propensity adjustment, and propensity-based weighting under conditions of nonuniform effect. Am J Epidemiol 2006 Feb 1;163(3):262-70.

(31) Petersen ML, Porter KE, Gruber S, Wang Y, van der Laan MJ. Diagnosing and responding to violations in the positivity assumption. Stat Methods Med Res 2012 Feb;21(1):31-54.