Investigating practice variation in a changing primary care

A multilevel perspective on The Skaraborg Primary Care Database

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ISBN 978-91-86871-33-8
ISSN 1652-8220
Lund University, Faculty of Medicine Doctoral Dissertation Series 2011:83
Department of Clinical Sciences Malmö, Unit of Social Epidemiology
Printed in Sweden by Media-Tryck, Lund University
Lund 2011

Abstract

Background and Aims: Differences in the clinical care of patients have been explained through the concept of practice variation, that is, the occurrence of established local medical procedures that varies between geographic areas. The primary measures introduced to eliminate undesirable differences in medical care are the introduction of medical guidelines and economical incentives that rewards the desired behaviour.

Practice variation in primary care can be seen on different hierarchically organised levels (e.g. patient, physician, health care center (HCC)) and Multilevel Regression analysis techniques (MLRA) offer a suitable tool to analyse these kinds of data. Data extracted from computerised medical records are ideal for studying practice variation as they often comprise information from several levels. In the region of Skaraborg in Sweden a new database, the Skaraborg Primary care database (SPCD), comprising information extracted form the computerised medical records of all public health care centres has recently been established.

The overall aims of this thesis were to examine the usefulness and quality of the SPCD database for research and to study practice variation in some important areas such as diagnosis registration, laboratory analysis ordering and prescriptions. Furthermore, the influence of changes in the economic incentives on physician's clinical behaviour was investigated.

Material and Methods: In all studies data from the SPCD comprising data on individual patients from all public health care centres was used. The registration of diagnoses in the SPCD was validated by comparing the occurrence of recorded diagnosis in the diagnosis register of the database with the free text part of the patient medical records for a randomly selected sample of patients. Multilevel logistic regression analysis was used to investigate practice variation in prescribing and laboratory test ordering, focusing on measures of both frequency and variance. The effects of changes in economic incentives for diagnosis coding and prescribing were examined by comparing multilevel analysis results before and after implementation of the economic incentives.

Results and Conclusions: The frequency of registration of ICD codes varied between diagnoses but also between physicians and HCCs. Different diagnoses need to be validated separately.

The occurrence of practice variation was demonstrated both in laboratory test ordering where the physician level was the most important level and in prescribing where physician and HCC levels were equally important in explaining the observed variation.

A positive effect in adherence to prescribing guidelines was demonstrated after the introduction of a decentralised drug budget.

The introduction of a strong economic incentive for ICD coding showed the expected rise in coding rates and decline in variation, directly affecting the diagnoses register of the research database.

Changes in the healthcare process will have a direct impact on the research database. Knowledge about the local health care processes is essential when interpreting database data.

The SPCD seems as a good complement to previously established databases and quality registers, offering new possibilities when studying primary care.

List of publications included in this thesis

I. **Hjerpe P**, Merlo J, Ohlsson H, Bengtsson Bostrom K, Lindblad U: Validity of registration of ICD codes and prescriptions in a research database in Swedish primary care: a cross-sectional study in Skaraborg primary care database. *BMC Med Inform Decis Mak*, 2010. **10**: p. 23.

II. Dalemo S, **Hjerpe P**, Ohlsson H, Eggertsen R, Merlo J, Bostrom KB: Variation in plasma calcium analysis in primary care in Sweden--a multilevel analysis. *BMC Fam Pract*, 2010. **11**: p. 43.

III. **Hjerpe P**, Ohlsson H, Lindblad U, Bostrom KB, Merlo J: Understanding adherence to therapeutic guidelines: a multilevel analysis of statin prescription in the Skaraborg Primary Care Database. *Eur J Clin Pharmacol*, 2011. **67**(4): p. 415-23.

IV. **Hjerpe P**, Boström KB, Lindblad U, Merlo J: Increased registration of hypertension and cancer diagnoses after the introduction of a new reimbursement system: a study in the Skaraborg Primary Care Database, Sweden

Submitted

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Abbreviations

ACG	Adjusted clinical group
ATC	Anatomical therapeutical chemical classification
CHF	Congestive heart failure
CI	Credible interval
CoI	Confidence interval
CV	Change in variance
DIC	Deviance information criterion
GP	General practitioner
GPRD	General Practitioners Research Database
HCC	Health care centre
ICC	Intra class correlation
ICD	International Classification of Disease
IHD	Ischemic heart disease
MLRA	Multi level regression analysis
MOR	Median odds ratio
OR	Odds ratio
PCV	Proportional change in variance
P-Ca	Plasma calcium
PDIII	ProfDoc Journal III
pHPT	Primary hyperparathyroidism
PPV	Positive predictive value
SPCD	Skaraborg Primary Care Database
VAR	Variance
VGPV	Västra Götaland Primary Care

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1. Introduction

1.1 Practice variation

In the clinical everyday practice one often notes differences in clinical and administrative procedures between doctors but also between higher levels in the health care hierarchy (Health care centres (HCCs), regions and countries). There is often a striking variation in for example prescribing patterns, laboratory test ordering, hospitalisation rates and diagnosing [1-4].

Differences in the clinical care of patients, without underlying clinically relevant factors such as differences in co-morbidity or risk factors, have been explained with the concept of practice variation, that is, the occurrence of established local medical procedures that varies between different geographic areas, HCCs and physicians. The occurrence of differences in patient care that cannot be explained by medical factors invokes questions of both over and under treatment as well as questions regarding equity in health. For example, the observed variation in prescription of antibiotics, both between [5, 6] and within countries [7], is important to address in order to stop the spread of antibiotic resistance.

The first observation of practice variation has been attributed to Glover in 1938 [8] who identified unexplained variation in tonsillectomy rates. Thereafter, the phenomenon of practice variation has been studied in a wide range of settings [9-14]. While practice variation is an important determinant of differences in expenditure [15], it can also be a positive sign of quality when dealing with multifactorial problems with multiple solutions in primary care [16] .

Several theories have been proposed to explain practice variation. Wennberg and co workers, in their work on “small area variation” [14, 17], focus on the “preference theory”. That is, practice variation depends on the individual physician’s preferences and uses the term “practice style”. The practice style is determined by the individual physicians education, experience and attitudes [16]. The degree of variation differs between diagnoses and conditions. This difference in variation between diverse conditions is often explained by different levels of professional uncertainty [17, 18].

In 1999 Westert and Groenwegen [19] introduced their constraint and incentive orientated theory. It emphasises the role of the physician’s local circumstances and

conditions in explaining practice variation. Physicians sharing the same work environment develop local standards depending on these circumstances [19,20]. In her thesis [11], Judith de Jong further examines Westert and Groenwegen's theory which is supported by her studies. However, other authors emphasise that practice variation depends of the interaction between an array of different factors acting on different health care hierarchy levels [21,22].

The practice variation that depends on practice styles or "therapeutic traditions" is based on a combination of scientific knowledge, the individual doctors' clinical experience and influences from the context in which the physicians work. Further, on the organisational level factors such as availability of resources, reimbursement system, practice size and staffing play an important role. Also patient's clinical (e.g. comorbidities) as well as non clinical conditions (e.g. preferences, health beliefs, and traditions) may affect the physician's decisions [5, 23]. When studying practice variation, this complex structure needs to be accounted for.

1.2 Changing clinical performance

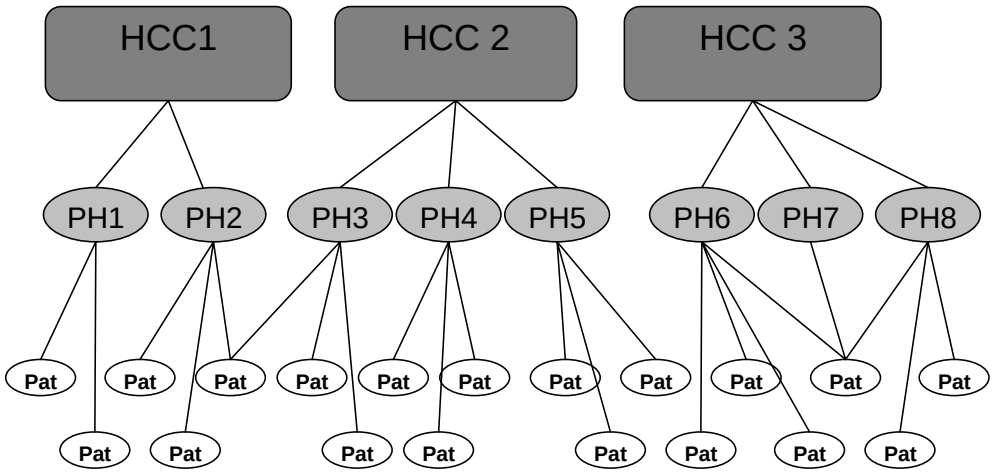
One of the major approaches to eliminate undesirable differences in medical care is the widespread introduction of medical guidelines and protocols [24] promoting evidence based medicine. These guidelines are often the work of an expert committee (local, national or international) that summarises the current scientific knowledge into recommendations useful in the everyday clinical work [25]. The Cochrane Collaboration is an international not-for-profit organisation [26] producing systematic reviews of the effect of health care and one of the main advocates of evidence based medicine in the world. In Sweden, Statens beredning för medicinsk utvärdering (SBU, Swedish Council on Health Technology Assessment), has the mandate of the Swedish Government to assess healthcare technology from medical, economic, ethical, and social standpoints [27]. These assessments are often used as foundations when producing guidelines nationally and locally. The need for guidelines arises from a general understanding that promoting evidence based and efficient medical care may reduce unnecessary medical practice variation and improve quality [28]. Moreover guidelines may also be an aid for physicians who are hardly able to assimilate the increasing volume of new scientific information [24, 25, 29, 30]. Even though the investigation of adherence to guidelines is attracting increasing interest, it is still not sufficiently well understood how factors at different levels of the health care organization influence adherence to guidelines [31-34].

In Sweden, every county council has a drug therapeutic committee responsible for issuing of evidence-based guidelines on the prescription of medicines [35, 36]. Despite these recommendations several studies have demonstrated substantial and unexplained differences in the adherence to guidelines among physicians and among HCCs [33, 34, 37, 38]. These differences might express themselves as a clustering of similar prescription behaviour among physicians at the same HCC and suggest the existence of local therapeutic traditions. Quantifying and understanding this variation is relevant for the planning of interventions aimed to improve the quality of clinical care.

There is a growing awareness that the mere existence of guidelines is not enough [39, 40] to promote evidence based health care. Implementation strategies such as information, education and incentives are necessary to encourage guideline use [41, 42]. Recently, the introduction of an educational program in primary care, promoting evidence based use of lipid lowering drug treatment, not only demonstrated a decrease in cholesterol levels but also reduced mortality in patients with coronary heart disease [43, 44]. Furthermore, economical incentives that promote the desired behaviour seem to support changes in clinical care.

1.3 The Multilevel data structure

The primary health care process can be conceptualised as a complex multilevel structure with patients visiting physicians who in turn attends different HCCs. Level specific characteristics can be seen on all levels (figure 1). As shown in the figure patients often visit different physicians in the same HCC. This has implications for the analysis which is further discussed in the limitation section 5.3.1.



Levels	**Examples of level specific characteristics**
HCC – Health Care Centre	Finance form (Public/Private)
PH – Physician	Sex, title
Pat – Patient	Sex, age, co morbidities

Figure 1. The multilevel structure of primary health care

The fact that practice variation can be seen on any of these different levels makes the analysis complicated. Differences in clinical practice can be observed between HCCs but also between physicians within the same HCC. To get an understanding of the processes that influence practice variation it is relevant to study the amount of variation around the mean of the studied outcome. But, because of the multilevel data structure we need to partition the observed variation at each relevant level. In later years the introduction of Multilevel Regression analysis techniques (MLRA) offer a suitable tool to analyse these kinds of hierarchically organised data [45, 46].

Prior to the introduction of MLRA, the standard analytical approach was the application of single level statistical models with information aggregated at the level of interest but without consideration of the multilevel structure of the information.

Aggregating information from a lower level (i.e. the patient) to higher hierarchical level (e.g. HCC) is not appropriate. Among others, a main peril of using aggregated information is the so called "ecological fallacy" [46, 47] i.e. drawing inferences to the individual level based on aggregated data. For example, even if increased per capita income is shown to be associated with increasing traffic accident mortality on the country level, it is not certain that an increase of personal income on the individual level is associated in the same way [47]. However, even when we are only interested in the HCC level and we do not aim to draw conclusions on the patient level, the aggregated analysis is not appropriate and can lead to misinterpretations. For example, when comparing health outcome between hospitals, neglecting factors as patient characteristics might threaten the validity of the study [48, 49]. On the other hand, disaggregating data from the higher HCC level to a the lower patient level will lead to "the miraculous multiplication of numbers of units" with an exaggerated sample size and the risk of type I errors (finding an association where there in fact is none) [46].

Moreover, the use of single level techniques where in fact a multilevel data structure exists denies us the opportunity to make comparisons of variation between levels. MLRA enables us to include variables from both individual and higher levels in the same analysis and thus calculate the amount of the total variation that can be attributed to each level. Thus, when planning an intervention to reduce practice variation, the appropriate level to target can in this way be determined.

When studying practice variation in primary care with MLRA we need both individual patient data and information on the higher levels (physician, HCC). Data extracted from computerised medical records are ideal for this purpose as they often comprises information on several levels (i.e. health care visits, patients, physicians, HCCs). Nowadays this kind of information is accessible from primary care databases in several countries.

1.4 Primary care research databases

An increasing number of databases that record information from computerised medical records from HCCs are being established in many countries. These databases include information such as clinical diagnoses, laboratory analyses and medical treatments including prescribed medication.

Among the largest and most well known is the General Practitioners Research Database (GPRD) [50, 51] in the United Kingdom with over 4 million active patients from around 500 primary care practices throughout the UK. Data from the GPRD has been used in over 750 peer reviewed publications for epidemiological, pharmaco epidemiological, disease management and outcomes research. Patient records are checked for appropriate quality and completeness before a new caregiver is accepted to deliver data into the database.

In The Netherlands the Integrated Primary Care Information (IPCI) [52] database contains computerised medical record information from a selected group of GPs who voluntarily agreed to supply data to the database.

Pharmaco epidemiological studies are the main focus of the BIFAP database [53] in Spain, which in 2006 contained clinical and prescription data from about 2.2 million patients.

The Health Search Database (HSD) [54-56], which was set up by the Italian College of General Practitioners, contained in 2003 medical records of over 800 000 primary care patients. The participating family physicians are selected to be representative of the whole Italian population.

1.5 The foundations for the Skaraborg Primary Care Database (SPCD)

The patient records in Swedish primary care were gradually computerised during the 1990s. One of the main motives for this change was the prospect of easy, fast and reliable access to clinical data for research and development. Rather soon, however, it became clear that the tools for this were missing. The follow up procedures of most medical record software's were rudimentary and the user's knowledge of the importance of structured data registration was missing.

In the former county of Skaraborg, primary care records were computerised during the 1990s, mainly by local initiative, resulting in different systems in different HCCs. However, in the late 1990s a single software system, ProfDoc Journal III, became mandatory for all HCCs. At the same time registration procedures were standardised. Quite soon, the work with creating a research database, Skaraborg Primary Care Database (SPCD), with data on individual level from the patient medical records was initiated. The public primary care, which is the dominating form of primary care in Skaraborg, has constituted an administratively cohesive unit facilitating standardisation of data entry procedures throughout the entire organisation. However, to be useful for research purposes, quality assessment and

auditing of health care, the registration must be of high quality. This may be difficult to attain when the information is routinely generated in every day practice.

1.6 Skaraborg Primary Care

The “Skaraborg model”

The importance of a well functioning primary care for an effective health care system was early acknowledged in the former county of Skaraborg. In the seventies and eighties the “Skaraborg model” [57] was developed, where a comprehensive primary care emphasised in order to promote cost effectiveness and relieve pressure on residential care. In the Skaraborg model the HCC had medical responsibility for its geographical area and worked in cooperation with the social welfare offices and local pharmacies. Teams including GPs, nurses, physiotherapists, dieticians and other health care professionals were supported, especially for geriatric care and occupational rehabilitation. Many HCCs even had possibilities for geriatric residential care. Nurse based practices, not only for maternity and infant care, but also for the care of patients with hypertension, diabetes and asthma were developed at most HCCs.

“Ädelreformen (Reform of care of elderly)” and the Västra Götaland Region

In 1992 responsibility for geriatric care was moved from the county administrated primary care to the local municipality authorities because of the implementation of new national regulations, “Ädelreformen” [58], leaving the GP in more of a consultant role. Another major change to primary care in Skaraborg took place in 1999 when the county was incorporated in the newly formed Västra Götaland Region (VGR) which supply health care for approximately 1.5 million citizens in the south west of Sweden. Skaraborg became on out of five primary care areas in VGR. The political aims of this reorganisation were to improve the democratic process, enhance efficiency and increase competitiveness within the whole region [59].

Further development: the “Västra Götaland Primary Care”(VGPV)

In 2009 a new organisation and reimbursement system, “Västra Götaland Primary Care” [60], was introduced in order to increase freedom of choice for the citizens. The HCC responsibility moved from geographic area to listed patients and the reimbursement from grant to capitation. Both privately and publicly run HCCs are allowed on equal terms in the new organisation, and all HCCs have to comply with the regulations expressed in a protocol decided by the region administration [60].

This has lead to a standardisation of the conditions for primary care in the whole region including Skaraborg.

Economic reimbursement system of the Skaraborg Primary care

During the last decade, primary care in Skaraborg has seen a dramatic change in the budgetary system. Previously, tax financed care in Sweden has been grant funded, administrated by the county authorities. In the last decade the financial responsibility has gradually been decentralised from the county authorities to the local caregivers. On the contrary, the political and administrative power making decisions regarding the financial limits has been centralised.

In 2003 the drug budget was decentralised to The HCCs. At the same time a rapid incline in drug costs was seen, which led to a pressure on the HCCs to adopt a more cost effective prescribing.

Further, the introduction of VGPV in 2009 involved a drastic change in HCC reimbursement and also opened up possibilities for new HCCs to establish. The reimbursement system became primarily dependent on capitation funding with age, gender and morbidity of each of the individual patient determining the level of HCC reimbursement. A case mix system with morbidity measured by a modified Adjusted Clinical Group (ACG) index [61] calculated from registered diagnosis codes of each patient was introduced. Codes for chronic disease (e.g. diabetes, hypertension) weigh more heavily than codes for minor problems (e.g. tonsillitis). In this radical change the ICD coding has come into focus as one of the major components when determining each HCCs level of reimbursement. Previously ICD coding was primarily done in order to enhance quality assessment but now a strong economic incitement for coding was introduced. Previous studies have shown that the method of payment of the physicians affects their clinical behaviour [62]. Even though the physician´s salary did not change, the introduction of VGPV may have led to a greater awareness among the physicians of how their behaviour in terms of diagnosis coding can influence the HCC budgets.

The changing conditions for primary care in Skaraborg in later years have the potential to radically alter the clinical performance of the health care professionals. As the contents of the new research database SPCD is a direct representation of the everyday clinical work in the HCCs it offers great possibilities to study practice variation, but also changes in care over time. On this background the studies included in this thesis were performed.

2. Aims

2.1 General aims

The overall aims of this thesis were to examine the usefulness and quality of the SPCD database for research and to study practice variation in some important areas such as diagnosis registration, laboratory analysis ordering and prescriptions. Furthermore, the influence of changes in the economic incentives on physician's clinical behaviour was investigated.

2.2 Specific aims

To achieve the overall aims, four specific studies were conducted:

Study I: Validation of diagnosis registration and variation in diagnosis coding

This study was designed to assess the quality of chronic disease registration in the SPCD by examining the frequency and sensitivity of visit ICD coding and recorded prescriptions in the database for four different diagnoses; hypertension, diabetes mellitus, congestive heart failure (CHF) and ischemic heart disease (IHD). Furthermore, a multilevel logistic regression analysis was performed to quantify the relative importance of different levels (visit, physician, HCC) for understanding variations in ICD-coding.

Study II: Variation in test ordering.

This study was designed to investigate determinants of, and practice variation in plasma calcium (P-Ca) laboratory test ordering. The SPCD was used to elucidate the relative importance of the different levels in the health care organisation for the ordering of P-Ca analyses. From the perspective of the National Recommendation [63], the identification of factors explaining this variation, is of relevance for planning interventions towards an optimal frequency of P-Ca laboratory test ordering.

Study III: Variation in adherence to prescribing guidelines

This study was designed to investigate practice variation in prescription patterns. By using multilevel regression analyses, and data from the SPCD the effect of the decentralised drug budget on the adherence to guidelines was evaluated regarding statin (HMG-CoA reductase inhibitors) prescription. The relevance of different levels (i.e. patients, physicians, HCCs) for understanding variation in adherence with guidelines was also assessed. Based on previous studies [34] the hypothesis was that the decentralised budget would result in an increased prevalence and a decreased variance between physicians and between HCCs, concerning prescription of recommended statins.

Study IV: The effect of a new reimbursement system on diagnosis registration

This study was designed to investigate the impact on ICD-coding of a new reimbursement system, introducing economic incentives for coding. With multi-level techniques the coding was assessed in terms of quantity and variation on different levels before and after the implementation of the new reimbursement system. The hypothesis was that the introduction of a strong economic incentive based on patient morbidity on the HCC level would increase the coding of chronic diseases.

3. Populations and Methods

3.1 The Skaraborg Population

Skaraborg was a Swedish county until 1999 when it became one of the administrative areas of the region of Västra Götaland in the southwest of Sweden (figure 2). Skaraborg is mostly rural and it is inhabited by approximately 250,000 individuals within 15 municipalities.

Inpatient care is offered by three public hospitals. Before the introduction of VGPV in 2009, primary care in Skaraborg was supplied by one private and 24 public HCCs, as well as by a few independent private GPs. In 2005 the public HCCs were staffed with 124 GPs handling 57 % of the patient visits. 119 physicians under education (interns and residents) handled 24 % of the visits. The remaining visits (19 %) were handled by locum doctors attending the HCCs for shorter or longer stays. Before 2009 about 250,000 office visits were registered in the public HCCs every year. In 2007, 75 % of all drug prescriptions were issued by the primary health care, and 85 % of these prescriptions were made at the public HCCs.

The introduction of VGPV in 2009 has change the composition of primary care in Skaraborg and in Mars 2011 there were 22 public HCCs with approximately 210,000 listed persons and 11 Private HCCs with 45,500 listed persons.

Figure 2. Skaraborg, one of five primary care areas in Västra Götaland

3.2 The PDIII record software

Since year 2000, all public HCCs in Skaraborg primary care share the same computerised medical record system, Profdoc Journal III 1.82 (Profdoc AB, Uppsala, Sweden, PDIII). Primarily, this computerised medical record was intended for clinical purposes and therefore all HCCs have a separate electronic record database with local accessibility.

The PDIII contains records generated by all medical staff on the HCC, including doctors, nurses, physiotherapists, occupational therapists and dieticians depending on the organisation of the HCC. Registration is done by the caregiver or by a secretary from dictation.

The structure of the record system comprises several different components.

The text module

The main module, the free text part of the patient record, which includes all visit notes, is normally written by the secretary from the physician's dictation. The text is linked to a standardised set of keywords, (e.g. "blood pressure") making it possible to extract part of the free text material in a standardised way.

The document module

External communication, such as referral letters and letters to the patient are stored in the document module. Part of the information in this module is standardised. Incoming communication are scanned into the document module and no information is stored in paper form.

The laboratory module

Laboratory results are recorded partly automatically and partly manually by the laboratory staff in the laboratory module. The design of this module is highly standardised making it easy to access information electronically. Because of this standardisation and the advantages it conveys, other parameters, apart from laboratory results, are also stored here (e.g. smoking habits yes/no, patient weight/height, spirometry parameters).

The diagnosis module

The ICD codes for diagnoses are stored in the diagnosis module. The codes are selected from a pick list included in the PDIII medical record software and coded according to the Swedish version of the 10th version of the International Classification of Diseases (ICD-10) adapted for primary care [64]. They are assigned by the physician at the time of the visit and should reflect all health problems addressed during the visit. The ICD codes are registered by the physician during the patient's visits or later by the secretary from the physician's dictation.

The drug module

When prescribing pharmaceuticals, the prescribing information is automatically recorded in the drug module at the same time as the prescription is written. To keep the drug list in the medical record up to date, changes in dosage and drug terminations should also be recorded.

Medication prescribed to patients cared for in municipal home care is often handled via the ApoDos drug delivery system (individual drug packages supplied to the patient directly by the district nurse) [65]. This system is managed by the pharmacies and the prescribing is done electronically one the web, outside the record software. Therefore prescription information for patients in municipal home care is often missing in PDIII.

For cardiovascular drugs, the proportion of drugs prescribed via the ApoDos system, and therefore not included in the PDIII database, varies by age, being approximately 5 % in patients less than 80 years of age and about 35 % in patients aged 80 years and more.

The sick leave module

When issuing a sick leave certificate, which is done by the doctor in the PDIII software at the visit, the entered information is stored in the sick leave module.

The procedures module

Information about therapeutic procedures is stored in the procedures module. This is done in the same way as the diagnosis registration by picking a code form a pick list in the software and coded according to “Klassifikation av vårdåtgärder” (KVÅ, Classification of health care procedures) [66] or the specific code list decided regionally. The codes are used by the nurses when performing ordered assignments but it is also a part of the VGPV reimbursement system requiring procedure coding of patient visits under specific circumstances (e.g. use of interpreter).

3.3 The SPCD

3.3.1 The SPCD compilation process

Selected record information from the local PDIII journal in the HCCs are regularly extracted to produce the research database SPCD. The extraction is done by a specific purpose-built software. The retrieval of data is done automatically without direct involvement of the individual physician. During the extraction procedure, which is initiated by an administrator at the local computer department, nine separate dBase files containing laboratory data, drug prescriptions, ICD codes, contact information, documents, part of the free text (e.g. blood pressure),

therapeutic procedures, information on sick leave and postal codes are retrieved from each HCC (figure 3). A variable list is included in appendix A.

In the extraction process patient and staff identities are blinded and are assigned specific unique dummy identification numbers to allow the linkage of the information within the database and over time.

SPCD now contains longitudinal journal data from all publicly run health care centres from years 2000 and forward. These 9 dBase files from each of the 22 HCCs that constitutes the SPCD are located and managed by the Research and Development centre, Skaraborg Primary Care, Skövde. The data in SPCD can be further processed by different data base engines to produce datasets for statistical analysis. In this work mainly Access (Microsoft® Office Access 2003, Microsoft Corporation) and EpiInfo (Epi Info 6.04d, Centers for Disease Control and Prevention, Atlanta, Georgia USA) has been used.

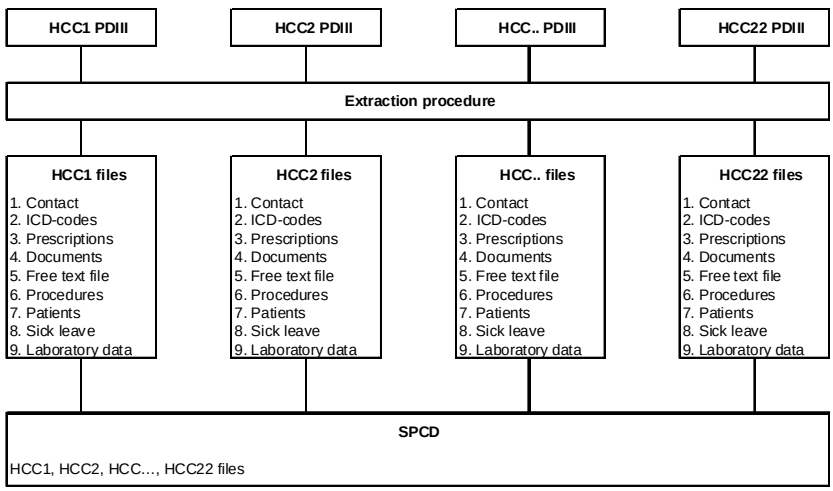


Figure 3. The extraction procedure of the SPCD

3.3.2 Ethical considerations

The demands for confidentiality are fundamental in medical records. Therefore, when extracting this type of information it is crucial to secure confidentiality in all

the parts of the process including the research database. In the database, confidentiality does not exclusively apply to the patients but also to the caregivers and the HCCs. To minimise the risk of integrity problems, all data is anonymised during the extraction of data into the SPCD.

After application to, and approval from the Regional Ethical committee it is however possible to extract personal identification numbers from a separate file extracted at the same time as the SPCD file. This is necessary mainly when there is a need for linkage on the individual level with other data sources. The SPCD does not contain any information on the identity of the caregivers. If this information is needed it must be obtained by special measures from each HCC after approval from the director. It is however possible to identify the HCC in SPCD. This could pose a problem mainly for the staff at small HCCs with for example only one physician. These issues need to be considered by all researchers using data from SPCD.

3.4 Statistical and Epidemiological methods

3.4.1 Multilevel Models

The information in the database has a multilevel structure. Therefore in the investigations, multilevel regression analyses (MLRA) [45, 46] that consider the structure of the information (e.g. patients nested within physicians in turn nested within HCCs) was used.

The different levels (HCC, Physician, patient) with their attached level specific variables are defined and entered in the analysis according to their position in the multilevel health care structure (figure 1). The MLRA provides measures of degree of associations of the level specific variables (i.e. fixed effects) as any other regression analysis but also information of the amount of variance (i.e. random effects) that can be attributed to each level. In this thesis, determining how variance is partitioned at different levels is essential for both obtaining correct estimation of standard errors around the regression coefficients of the contextual variables and obtaining measures of clustering that can be used to quantifying practice variation.

As the outcome variables in all studies were binary, logistic regression was used. The MLRA estimations were made by using Markov chain Monte Carlo (MCMC) methods [67] with the MLwiN software (MLwiN 2.20, Centre for Multilevel Modelling, University of Bristol). The parameters and their 95 % credible intervals (95 % CIs) were obtained from the posterior distribution of the regression coefficients and residual variances. The credible intervals obtained from the MCMC analysis were used equivalently to confidence intervals.

Measures of associations, fixed effects

To study associations in the fixed effects part of the multilevel logistic regressions odds ratio (ORs) and their 95 % credible intervals (95 % CIs) obtained from the posterior distribution of the regression coefficient were calculated

Measures of variance, random effects

This variance can be expressed in different ways. In these studies the *Median Odds ration* (MOR) [68-70] which is a measure differences or the *Intra Class Correlation* (ICC) [46, 68,71] which is a measure of clustering was used.

Medians Odds ratio

The aim of the MOR is to translate the area level variance into the widely used odds ratio scale, which has a consistent and intuitive interpretation and can be compared with other OR (associations) in the model. The MOR is defined as the median value of the odds ratio between the area at highest risk and the area at lowest risk. The MOR is exemplified in figure 4 by the 22 HCCs in Skaraborg with different odds for a specific outcome.

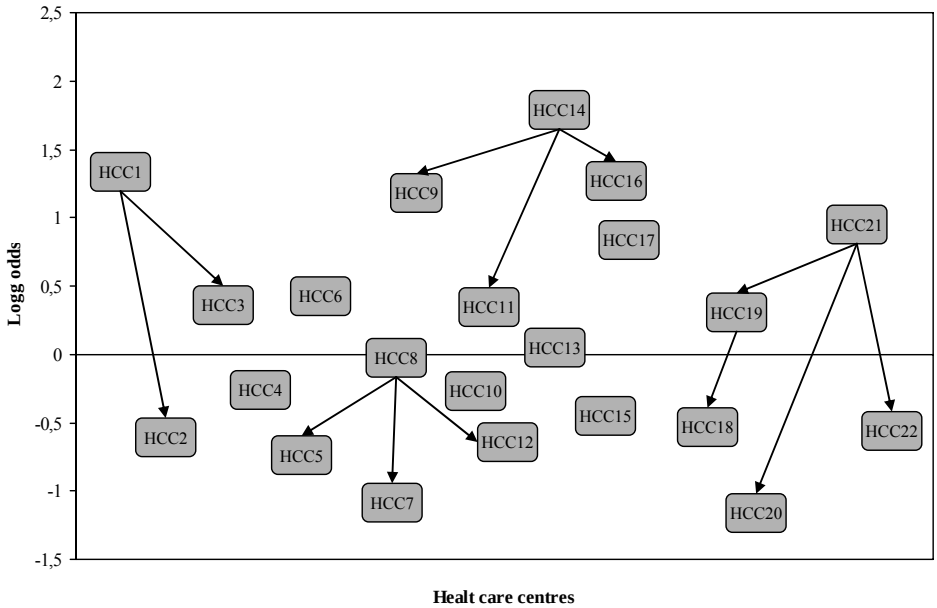


Figure 4. The MOR exemplified by the 22 HCCs in Skaraborg with different odds for a specific outcome. Some of the odds ratios are illustrated by arrows.

The odds ratio between a HCC with higher odds and a HCC with lower odds is computed for each pair of HCCs. The MOR is defined as the median value of the distribution of these odds ratios and is always equal to 1 or above.

When randomly picking out two HCCs the MOR can be conceptualised as the increased odds that (in median) a person would have if moving to another HCC with a higher odds. If the MOR was equal to one, there would be no differences between HCCs in the probability of the outcome. If there were strong HCC level differences the MOR would be large and the HCC level would be relevant for understanding variations of the individual probability of the outcome [68].

Intra Class Correlation

The ICC informs us on the proportion of total variance in the outcome that is attributable to the area level. In multilevel linear regression both the individual level and the area level variances are expressed on the same scale. Therefore, partition of variance between different levels is easy to perform for detecting contextual phenomena. In multilevel logistic regression, however, the individual level variance and the area level variance are not directly comparable. Whereas the

area level residual variance is on the logistic scale, the individual level residual variance is on the probability scale [68].

There are different ways to calculate the ICC in logistic regression. However, they provide similar information on clustering and in **study IV** the "The linear threshold model" [46, 68] was used to convert the individual level variance to the logistic scale before calculating the ICC.

In order to determine to what degree the level specific variables explain the variance, multiple models were constructed including variables from different levels step by step. This procedure is exemplified in table 1 constituting a dummy table composed of four consecutive models. The first model A (empty model) just includes the different levels as random effects. The additional three models includes the level specific characteristics as fixed effects (patient: sex – model C, physician: sex – model D and HCC: public/private – model D).

The importance of the variables added in explaining the variance was expressed by calculating the proportion of change in magnitude of variance (PCV) between the initial (reference) model ($Var_{initial}$) and the extended model (Var_{more}):

$$\text{Proportion of change (PCV)} = ((Var_{initial} - Var_{more})/(Var_{initial}))x100$$

The Deviance Information Criteria (DIC) obtained in the analysis was used as a measure of goodness of the fit. For each model a lower DIC indicates a better model fit and accordingly a better representation of the data.

Prevalence

In this thesis the term "prevalence" is used not only to describe the proportion of people with a specific disease but also the frequency of other characteristics of a population [72] (e.g. frequency of prescription of recommended statins, frequency of registered hypertension diagnoses).

Table 1. Dummy table with an example of a three level Multi level regression analysis with one empty model (A) and three models (B,C,D) including level specific variables as fixed effects. The Random effects are expressed as the Median Odds Ratio (MOR)

	Model A	Model B	Model C	Model D
Fixed effects	OR (95 % CI)	OR (95 % CI)	OR (95 % CI)	OR (95 % CI)
Patient				
Female	-	REF	REF	REF
Male	-	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)
Doctor				
Female	-	-	REF	REF
Male	-	-	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)
HCC				
Finance form				
Public	-	-	-	REF
Private	-	-	-	x.xx (x.xx-x.xx)
Random effects	Variance (95 % CI)	Variance (95 % CI)	Variance (95 % CI)	Variance (95 % CI)
HCC	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)
MOR_{HCC}	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)
Physician	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)
$MOR_{Physician}$	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)	x.xx (x.xx-x.xx)
HCC and Physician	x.xx	x.xx	x.xx	x.xx
$MOR_{HCC+\ Physician}$	x.xx	x.xx	x.xx	x.xx
DIC	xx xxx	xx xxx	xx xxx	xx xxx

3.5 Design of the individual studies

The compositions of the different datasets used in the four studies are shown in table 2a, 2b and 2c. Table 2a defines the datasets and their time periods. Table 2b shows the inclusion criteria and the included levels with number of units on each level. In table 2c outcome variables and included fixed effects are defined.

Table 2a. The different datasets and their time periods of inclusion

Paper	Dataset	Study period
I	Ia	1st May 2002 to 31st October 2003
	Ib	1st May 2002 to 31st October 2003
II	II	1st January 2005 to 31st December 2005
III	IIIa	May 2002 to October 2003
	IIIb	July 2004 to December 2005
IV	IVa	1st October 2005 to 30th September 2006
	IVb	1st October 2006 to 30th September 2007
	IVc	1st October 2007 to 30th September 2008
	IVd	1st October 2008 to 30th September 2009
	IVe	1st October 2009 to 30th September 2010

Table 2b: The inclusion criteria of each dataset and the number of units in the included levels

Dataset	Inclusion criteria	Levels, number of units
Ia	A random sample of all patients with at least one prescription for cardiovascular drugs. 50 patients per HCC	Patients: 50x24
Ib	All patient visits	HCC:s 24 Physicians: 858 Visits: 348,776
II	All individuals that attended any of the HCCs	HCCs: 24 Physicians: 457 Patients: 154,629
IIIa	All patients with at least one prescription of statin with all his/her cardiovascular drugs issued by the same physician	HCCs: 24 Physicians: 425 Patients: 6,205
IIIb		HCCs: 24 Physicians: 402 Patients: 7,979
IVa	All patients, fifty years of age and older, visiting a HCC	HCCs: 23 Physicians: 554 Patients: 76,546
IVb		HCCs: 23 Physicians: 489 Patients: 78,350
IVc		HCCs: 23 Physicians: 589 Patients: 79,007
IVd		HCCs: 23 Physicians: 627 Patients: 79,826
IVe		HCCs: 23 Physicians: 468 Patients: 77,805

Table 2c: Outcome variable and level specific variables included in the multi level analysis

Dataset	Outcome variable	Level 1 variables: (Visits/Patients)	Level 2 variables: (physicians)	Level 3 variables: (HCCs)
Ia	-			
Ib	Visit ICD code: Y/N	Patient sex, age Visit: planned/not planned		
II	Calcium Analysis: Y/N	Sex P-Ca test 2004 Riskscore	Occupational status Sex Age	Number of laboratory test groups including calcium
IIIa	Recommended Statin: Y/N	Sex Age		
IIIb	Recommended Statin: Y/N	Sex Age	Occupational status Sex Age	
IVa	Patient with hypertension or cancer diagnosis: Y/N	Sex Age (centred 68)		
IVb	Patient with hypertension or cancer diagnosis: Y/N	Sex Age (centred 68)		
IVc	Patient with hypertension or cancer diagnosis: Y/N	Sex Age (centred 68)		
IVd	Patient with hypertension or cancer diagnosis: Y/N	Sex Age (centred 68)		
IVe	Patient with hypertension or cancer diagnosis: Y/N	Sex Age (centred 68)		

3.5.1 Study I: Validation of diagnosis registration

In the validation part of **study I** (dataset Ia), all patients in the SCPD with at least one prescription for cardiovascular drugs (appendix B), from 1st May 2002 to 31st October 2003 was selected.

In these patients all the ICD-10 codes for diabetes mellitus (E118P, E119, E108P, E14-P, E109), hypertension (I10-, I13-P), ischemic heart disease (I25-P, I209P, I21-P, I200-) and congestive heart failure (I50-) in the SPCD were identified. A random sample of 50 patients from each of the 24 HCCs was drawn from the selected patients and the information on diagnoses and prescribed drugs in the free text part of the electronic PDIII journal was used as gold standard for assessing the validity of the ICD codes and prescribed drugs found in the SPCD. The free text includes all notes from visits, telephone contacts, and any other situation of relevance for the care of the patient. The free text part of the electronic journal also includes an automatically written text that is generated when diagnoses codes or medications are registered. Therefore, all diagnoses and medications registered in the designated code field of the electronic journal are automatically recorded as free text as well. On the contrary, diagnoses or medications noted only in the free text section of the journal do not generate an ICD code or a registration in the prescription register. Therefore, since the database is constructed with information from the specific code fields of the electronic medical records, any diagnosis or prescription that only appears in the free text part of the journal will be missed.

To evaluate the validity of the SPCD the information in the files extracted into the SPCD were compared with the information in the free text sections of the electronic medical records. All text from the computerised patient records were transferred to a spreadsheet (Microsoft Excel) and in a first step a macro was used to highlight relevant words or text fragments (e.g. diabetes, metoprolol) to facilitate the second step where the complete texts were visually reviewed to identify relevant diagnoses and prescriptions. The sensitivity of the ICD coding and prescription in the SPCD was calculated as the percentage of patients with relevant diagnoses or prescriptions in the free text section of the medical records that had a matching ICD or ATC code in the SPCD (figure 5).

		Free text (sample) Registered ICD/Prescription	
		Present	Absent
SPCD (sample) Registered ICD/Prescription	Present	A	B
	Absent	C	D

Sensitivity=A/(A+C)

A = patients with specific ICD codes/prescriptions in the SPCD
A+C = patients with specific diseases/prescription in the free text
Sensitivity = A/(A+C) * 100

Figure 5. Calculation of the sensitivity of ICD coding and prescription in the SPCD

The frequency of visits with ICD codification in the SPCD was computed by dividing the number of visits with a registered ICD code by the total number of visits in each HCC during the study period.

To determine the strength of linear dependency between frequency of ICD coded visits and the sensitivity of ICD coding and registration of medication the Pearson correlation coefficient (r) was calculated.

3.5.2 Study I: Variation in diagnosis coding

To study practice variation in ICD coding information on coding performed by the 858 physicians (approximately 130 employed General practitioners and the rest

Interns, Residents or Locums) at the 24 HCCs at all patient visits (n = 348,776) during the study period was extracted. A MLRA was performed with patient visits nested within physicians that in turn were nested within HCCs.

Individual level variables

The outcome was a dichotomous variable indicating if a visit had an ICD coding or not. The patients' sex (with women as reference) and age (categorised by quartiles with the youngest age group as reference) were identified as independent variables at visit level. Type of visit was defined as planned or unplanned with planned visit as reference.

Two consecutive models were developed. The first empty model (A) only included physicians and HCCs as random effects. The second model (B) added the characteristics of the visit as fixed effects, which allowed the investigation of whether these characteristics explained residual variation at the physicians and HCCs levels by calculating the PCV. The MOR was calculated in order to quantify the importance of the different levels for ICD coding.

3.5.3 Study II: Variation in test ordering.

To study practice variation in test ordering, examining variation in P-Ca was chosen. Primary hyperparathyroidism (pHPT) is a common disease that often remains undetected and causes severe disturbance especially in postmenopausal women [73-75]. Therefore, national recommendations promoting early pHPT detection by P-Ca have been issued in Sweden [63].

Individual level variables

All 154,629 individuals that attended any of the 24 HCCs during 2005 in the study was included. The outcome variable was P-Ca analyses during 2005 (yes/no). Sex of the patient and P-Ca analyses during 2004, were included as fixed effects. ICD-10 coded diagnoses and symptoms associated with pHPT was also selected [76]. A risk score for a P-Ca analysis was created with stepwise logistic regression [77] based on age, concomitant diagnosis and drug treatment, in order to control for confounding factors. The risk score was divided in quintiles. Patients with the lowest risk of P-Ca analyses were used as reference.

Physician and HCC level variables

The physicians were categorised according to sex and title. GP and locum were also dichotomised at 46 year. GPs, 46 years or older, were used as reference in the analysis. As only six doctors among interns and residents were above 45 years, they were not dichotomised. The HCCs had different standardised group analyses, for instance analyses of electrolytes, hypertension checkups and diagnosing dementia, in which P-Ca was included. HCCs were categorised as having none, 1–2, and ≥ 3 standardised groups including P-Ca. The HCCs having no group analyses were used as reference.

MLRA was used to estimate the odds of patients being ordered a P-Ca analysis. As one patient could attend several physicians and several HCCs, a multiple membership model was used [78]. The weights were constructed according to number of visits to a certain physician/HCC during the study period.

Four consecutive models were developed. The empty model A included the random parameters (physicians and HCCs), model B included the patient characteristics, model C the patient and physician characteristics and model D the patient, physician and HCC characteristics. In order to quantify the importance of the different levels in the analysis the MOR was calculated.

3.5.4 Study III: Variation in adherence to prescribing guidelines

To study practice variation in prescribing, statin prescriptions was used as this group of cholesterol lowering drugs has very homogeneous indications and similar efficacy which nearly eliminates the possibility of confounding by indication and patient mix when comparing different practices and physicians [79].

From the SPCD, all patients with at least one prescription of statin defined according to the Anatomical Therapeutical Chemical (ATC) classification system code C10AA were identified. In order to examine the effect of the decentralised drug budget on prescribing, one dataset with all patients from all 24 HCCs with at least one statin prescription prior to, (i) during May 2002 to October 2003 (i.e. 2003 dataset, n=7,460), and one after, (ii) during July 2004 to December 2005 (i.e. 2005 dataset, n=9,643) the budget decentralisation was selected. If a patient received more than one statin prescription during each time period, the last one was selected. Prescriptions for other cardiovascular drugs (appendix B) were also extracted. In order to identify homogeneous physician–patient relations, only

patients with all his/her cardiovascular drugs issued by the same physician were included. This resulted in 6,205 patients, treated by 425 physicians in the 2003 dataset and 7,979 patients treated by 402 physicians in the 2005 dataset.

To get an estimate of the consistency of the results over time, the frequency of recommended statin prescriptions in the time period from July 2008 to December 2009 was calculated. In this analysis all patients with a statin prescription in this time period was included, resulting in 11,540 patients.

Individual level variables

The outcome variable was prescription of recommended statin (yes vs. no). In the 2003 dataset, these drugs were Simvastatin (Zocord® or generic simvastatin) and Pravastatin (Pravachol®) and in the 2005 dataset only Simvastatin (Zocord® or generic simvastatin). The age of the patients were categorised into four age groups: -54 years, 55–64, 65–74, and 75-, and used the youngest group as reference. The sex of the patients was included as a dummy variable using women as reference in the analysis.

Physician level variables

Physician's occupational status was included, categorised as Intern, Resident, General practitioner or Locum. Each category was split into two groups according to the median age of the specific group. Of the eight different groups older GPs were used as reference in the analysis. Sex of the physician was included as a dummy variable using women as reference. However, information on physician's characteristics was only available for the 2005 dataset.

Multilevel models

MLRA was used to estimate the probability of prescribing a recommended statin. Three consecutive models (A, B, C) were developed for data set 2003 and 4 models (A, B, C and D) for data set 2005. Model A was an empty two level model including only patients and HCCs as random effects. Model B was a three-level model in which patients were nested within physicians that were in turn nested within HCCs. Model C and model D added the patient characteristics respectively patient and physician characteristics. In the random-effects part of the MLRA, the MOR and 95 % credible intervals and the PCV was calculated.

The absolute change in variance (CV) between the two time periods (2003 and 2005) was also calculated and a t-test was performed to calculate their 95 % confidence intervals (CoI).

Change in variance (CV) = Var_{2005} - Var_{2003}

3.5.5 Study IV: The effect of a new reimbursement system on diagnosis registration

When investigating the effect of a new reimbursement system on diagnosis coding, datasets from five consecutive time periods were extracted, containing all patients, 50 years of age or older, attending any of the 23 public HCCs.

The first three periods represent the baseline (figure 6). During the fourth period the forthcoming change in reimbursement system became known but it was officially introduced at the start of the last period in 1st October 2009. The number of patients were approximately the same in all periods (n=76,546 to n=79,826).

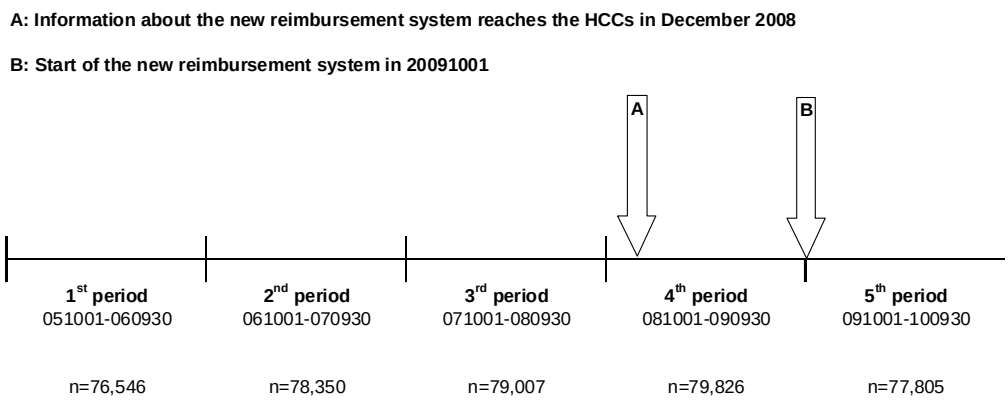


Figure 6. Time periods included in the analysis

The diagnosis of *hypertension* (ICD I10-, I13-P, I15-) was chosen for the study, since it is a well-defined chronic disease, and *cancer* (C00-C96-P) that represents a group of diagnosis with low registration rates in primary care.

Individual level variables

The outcome was a dichotomous variable indicating if a patient had a hypertension/cancer code registration in the diagnosis register during each time period or not. The patients' sex (with women as reference) and age (centred at the mean of 68 years) was also included.

MLRA, with patients nested within physicians who in turn were nested within HCCs was performed. For each patient, the physician with the majority of patient contacts was determined. In order to observe changes in prevalence and variance over time separate analyses for each time period and disease under investigation was performed. In the random part of the model, the variance (VAR) was used to calculate the Intra Class Correlation (ICC). It was calculated as follows:

$$ICC_{PHYSICIAN}=(VAR_{HCC}+VAR_{PHYSICIAN})/(VAR_{HCC}+VAR_{PHYSICIAN}+VAR_{PATIENT})$$

$$ICC_{HCC}=(VAR_{HCC})/(VAR_{HCC}+VAR_{PHYSICIAN}+VAR_{PATIENT})$$

In the hypertension datasets the variances were calculated with the logit link where the $VAR_{PATIENT}$ is defined as 3.29. However, because of the low prevalences in the cancer datasets the probit link was used to calculate the variances, and the $VAR_{PATIENT}$ is defined as 1 [46].

4. Results

4.1 Study I: Validation of diagnosis registration

In the SPCD, 32,846 individual patients with prescriptions of drugs for cardiovascular diseases during the study period were identified. Of these patients, 58 % (18,928/32,846) had hypertension, 19 % (6,082/32,846) presented ischemic heart disease (IHD), 8.2 % (2,687/32,846) congestive heart failure (CHF), and 16 % (5,373/32,846) diabetes in the SPCD diagnosis register. In order to get a rough estimate of the completeness of ICD coding, the information from the SPCD was used and a prevalence in the population (n = 250,000) of 7.6 % (18,928/250,000) for hypertension, 2.4 % (6,082/250,000) for IHD and 1.1 % (2,687/250,000) for CHF was found. The prevalence of diabetes could not be estimated as only patients with cardiovascular drugs were included in the study, excluding patients with diabetes but no cardiovascular medication.

The random sample of 1,200 patient records (50 from each of the 24 HCCs) showed that sensitivity of ICD codes in the SPCD varied between HCCs. For diabetes the sensitivity varied between 67 and 100 % (mean 89 % (95 % CoI: 85–93)), for hypertension between 50 and 97 % (mean 83 % (95 % CoI: 80–86)), for IHD between 36 and 92 % (mean 77 % (95 % CoI: 72–81)), and for CHF between 25 and 100 % (mean 66 % (95 % CoI: 58–73)). A correlation between the frequency of ICD coded visits and sensitivity of the ICD files in the SPCD was found for hypertension (r = 0.466) and CHF (r = 0.458) but not for diabetes or IHD (figure 7).

A correlation was also found between the number of patients with a completely correct ICD code combination and the frequency of coded visits (r = 0.584). The variation of sensitivity in medication registration between HCCs was 60–98 % (mean 88 % (95 % CoI: 86–90)). There was no significant correlation between frequency of ICD coding and sensitivity of prescription registration.

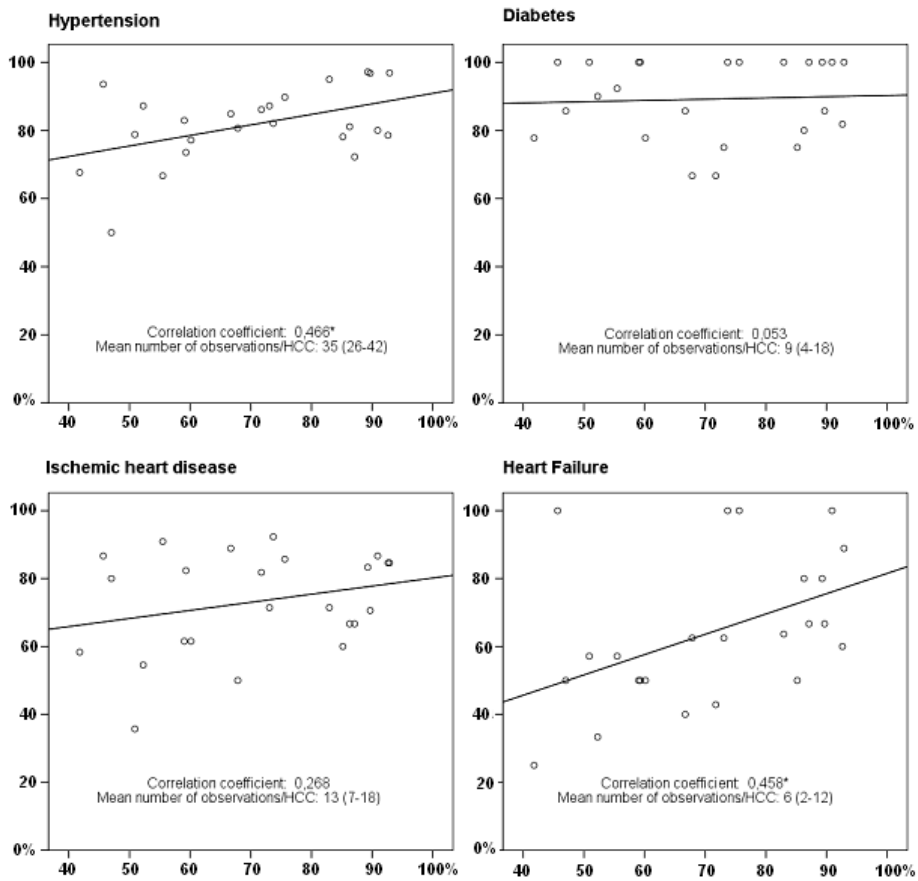


Figure 7: Correlation between percentage of patients with correct registration for the different diagnoses (y-axis) and percentage of coded visits (x-axis) for each of the 24 HCCs. * Significant at < 0.05 level.

4.2 Study I: Variation in diagnosis coding

The frequency of visits with ICD coding varied among the 24 HCCs from 42 % to 93 % with a median of 72 %. The multilevel logistic regression (table 3) showed that there was a high clustering of similar behaviour among physicians from the same HCC ($MOR_{HCC\text{-}PHYSICIAN}$ = 5.23). In other words, if a patient moved to a new physician working in a different HCC that had a higher propensity for ICD coding, the odds of registration will, in median, increase 5.23 times. Analysing the independent role of the physician and the HCC, the larger component of variance was found at the physician level ($MOR_{PHYSICIAN}$ = 4.22; 95 % CI 3.92–4.58).

Compared to planned visits, unplanned visits resulted more frequently in an ICD coding (OR 1.44; 95 % CI 1.41–1.47). Moreover, compared to the youngest age group, older patients were less likely to get their visits ICD coded (OR 0.75; 95 % CI 0.73–0.77). The inclusion of individual characteristics at the visit level (model B) explained only a very small part of the higher level variance ($PCV_{HCC\text{-}PHYSICIAN}$ = 0.9 %). The DIC statistics showed that model B had a better model fit than model A.

Table 3. Multilevel logistic regression analysis of frequency of ICD coded visits

	Model A	Model B
Fixed effects		OR (95 % CI)
Patient age group		
1 (-28)	-	REF
2 (29-49)	-	0.86 (0.84–0.89)
3 (50-67)	-	0.84 (0.82–0.87)
4 (68-)	-	0.75 (0.73–0.77)
Patient sex		
Female	-	REF
Male	-	0.98 (0.96–1.00)
Type of visit		
Planned	-	REF
Not planned	-	1.44 (1.41–1.47)
Random effects		
HCC Variance (95% CI)	0.76 (0.40–1.54)	0.76 (0.41–1.50)
MOR (95% CI)	2.30 (1.82–3.26)	2.29 (1.84–3.22)
Physician Variance (95% CI)	2.28 (2.05–2.55)	2.25 (2.02–2.53)
MOR(95% CI)	4.22 (3.92–4.58)	4.19 (3.88–4.56)
HCC+Physician Variance	3.04	3.01
MOR	5.23	5.28
PCV		
HCC	-	0.3 %
Physician	-	1.3 %
HCC+Physician	-	0.9 %
DIC	303170.55	301079.69

OR = odds ratio, CI = credible interval, MOR = median odds ratio, DIC = Deviance Information Criterion, PCV=proportional change in variance, HCC=health care centre

4.3 Study II: Variation in test ordering

Overall 5.8 % of the inhabitants in Skaraborg and 9 % of the patients (11 % of the women and 8 % of the men) attending the HCCs had a P-Ca analysis. The mean age of the patients with P-Ca analysis was 62 years compared to 45 years for patients with no P-Ca analyses. At the different HCCs the number of standardised group analyses including P-Ca analyses varied from zero to seven. The locums were most numerous but had short periods of attendance.

There was a substantial variation in number of P-Ca analyses between HCCs and physicians.

The multilevel model

In the empty model A the $MOR_{physician+HCC}$ indicated that for a patient changing both GP and HCC, to a GP and HCC with higher odds for a P-Ca analysis, the odds would in median increase by 2.31. The physician level, $MOR_{physician}$ = 1.95 (95 % CI: 1.85–2.08) contributed more than the HCC level, MOR_{HCC} = 1.65 (95 % CI: 1.44–2.07).

Model B, C and D

After the inclusion of patient variables in model B male sex was associated with lower propensity of a P-Ca analysis (OR 0.80; 95 % CI 0.77–0.83). The inclusion of physician variables in model C illustrates that interns (OR 1.48; 95 % CI 1.00–2.00), residents (OR 1.69; 95 % CI 1.35–2.24) and younger GPs (OR 1.30; 95 % CI 1.02–1.76) ordered more P-Ca analysis compared to older GPs. Locums ordered fewer P-Ca analyses (locums >=46 years, OR 0.73; 95 % CI 0.57–0.94). There were no differences between male and female physicians. After adding the HCC variable, model D illustrates that a high number of standardised group analyses were associated with a high number of P-Ca analyses (3 or more group analysis compared to none, OR 2.79; 95 % CI 1.25–5.09). Including all explanatory variables and controlling for confounders, a patient changing both GP and HCC, from low to high odds for P-Ca analysis, the odds for a P-Ca analysis would in median increase by 2.5 times, $MOR_{physician+HCC}$ 2.45. However, even if some of the included variables on the patient, physician or HCC levels were associated with the frequency of P-Ca analysis, they did not explain the variance at the higher levels.

4.4 Study III: Variation in adherence to prescribing guidelines

The overall prevalence of adherence with guidelines for prescription of statins increased from 77 % in 2003 to 84 % in 2005 (Relative Ratio: 1.09 (95 % CoI, 1.01–1.19)). In 2003 adherence to guidelines was better for older patients, but this age difference disappeared in 2005. Men were prescribed statins more often than women, but there were no gender related differences in the prescription of recommended drugs. In 2005, 68 % of all the statins were prescribed by male physicians who also showed a slightly lower guideline adherence compared with female colleagues. Young intern physicians showed the highest (90 %) and older locums the lowest (77 %) adherence to guidelines.

In the 2009 dataset 89 % of the patients were prescribed a recommended statin.

Figure 8 shows that although there were some HCCs with rather low adherence to guidelines in 2003 all HCCs had approximately 80 % adherence in 2005.

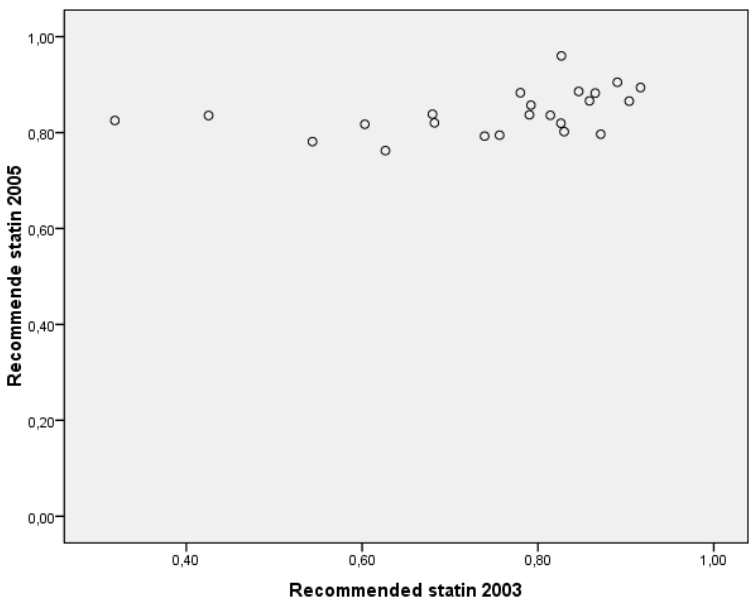


Figure 8. Adherence to guidelines on statin prescription for each of the 24 HCCs in 2005 related to adherence in 2003.

It is also clear that the HCCs with the poorest adherence in 2003 showed the largest improvement in 2005 (figure 9).

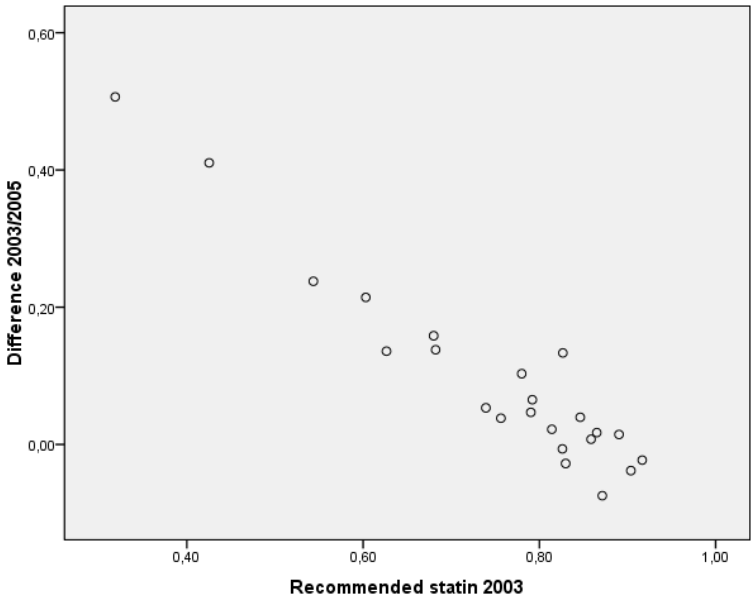


Figure 9. Change in adherence to guidelines on statin prescription for each of the 24 HCCs between 2003 and 2005 related to adherence in 2003.

Multi-level regression analysis

In 2003 adherence to guidelines increased with age of the patients; 65–74 years (OR 1.32, 1.08–1.62) and over 75 years (OR 1.51, 1.20–1.89) in comparison to the youngest age group (less than 54 years). In contrast, in 2005 there were no differences between age groups. Older locum physicians presented a lower probability of prescribing a recommended statin than older GP (OR 0.56, 0.38–0.82). There were no differences between the other physician categories including sex of physicians.

Model A in table 4, only includes two levels (i.e. patients and HCCs) and shows that in median a randomly selected patient's odds of receiving a recommended statin would increase 2.14 times in 2003 ($MOR_{HCC2003}$ = 2.14) and 1.37 times in 2005 ($MOR_{HCC2005}$ = 1.37) if he/she moved to an HCC with higher adherence to guidelines.

Model B in table 4 includes three levels and shows that the HCC and physician levels accounted each for approximately 50 % each of the variation at the higher levels in 2003 ($MOR_{HCC2003}$ = 1.89 vs. $MOR_{PHYSICIAN2003}$ = 1.88). In 2005 the variance among HCCs and physicians was lower ($MOR_{HCC2005}$ = 1.30 vs. $MOR_{PHYSICIAN2003}$ = 1.52). From 2003 to 2005 the variance between physicians and between HCCs decreased by 55 % and 82 % respectively.

The inclusion of patient and physician characteristics (models C and D) did not explain any significant part of the variance at the different levels.

Table 4. Analysis of variance of prescription of recommended statins obtained from the multilevel regression analysis in the Skaraborg Primary Health Care Database (SPCD) in the years 2003 and 2005.

	Model A		**Model B**		**Model C**		**Model D**
	2003	2005	2003	2005	2003	2005	2005
Variance							
HCC (Intercept)							
Variance (95 % CI)	0.64 (0.33–1.16)	0.11 (0.04–0.23)	0.44 (0.20–0.88)	0.08 (0.02–0.20)	0.46 (0.20–0.91)	0.07 (0.01–0.19)	0.06 (0.00–0.16)
MOR	2.14 (1.73–2.80)	1.37 (1.22–1.58)	1.89 (1.53–2.44)	1.30 (1.12–1.52)	1.92 (1.54–2.49)	1.29 (1.10–1.51)	1.26 (1.07–1.47)
Physician (Intercept)							
Variance (95 % CI)	-	-	0.44 (0.30–0.60)	0.20 (0.12–0.30)	0.44 (0.31–0.62)	0.20 (0.12–0.30)	0.21 (0.13–0.31)
MOR	-	-	1.88 (1.68–2.10)	1.52 (1.40–1.68)	1.89 (1.70–2.12)	1.53 (1.39–1.69)	1.54 (1.40–1.70)
HCC & Physician (Intercept)							
Variance (95 % CI)	-	-	0.88	0.28	0.90	0.27	0.27
MOR	-	-	2.45	1.66	2.47	1.64	1.64
Proportional Change in variance (PCV)							
Between models			From model A		From model B		From model B
HCC	-	-	-31 %	-27 %	-4.5 %	12.5 %	25 %
Physician	-	-	-	-	0 %	0 %	-5 %

Change in variance (CV)							
Between years							
HCC (95 % CoI, %)	-0.53 (-0.88– -0.18) -83 %		-0.36 (-0.65– -0.07) -82 %		-0.39 (-0.68– -0.10) -85 %		-
Physician (95 % CoI, %)	-		-0.24 (-0.32– -0.16) -55 %		-0.24 (-0.32– -0.16) -55 %		-
Goodness of the fit							
DIC (MCMC)	6157.85	6898.25	5947.56	6803.07	5936.96	6806.30	6805.55

HCC: Health Care Centre, MOR: Median Odds Ratio, DIC: Diagnostic Information Criteria, MCMC: Marcov Chain Montecarlo

Model A is a two level analysis (patients and HCCs) that includes only HCC as a random intercept. **Model B** is a three level (patients, physicians and HCCs) analysis including HCC and physician as random intercepts. **Model C** is analogous to model B but includes patient characteristics as fixed effects. **Model D** develops model C by also including physician characteristics.

4.5 Study IV: The effect of a new reimbursement system on diagnosis registration

The number of patients in each dataset was approximately the same (i.e. between 76,546 and 79,826) with an overall mean age of 68 years. The raw prevalence of ICD codes of hypertension increased from 17 % in the first time period, to 33 % in the last, equally distributed between sexes. The raw prevalence of patients with registered cancer diagnosis also increased from 1.4 % to 3.9 % but with higher rates for males. Figure 10 illustrates the crude prevalences according to sex and time period.

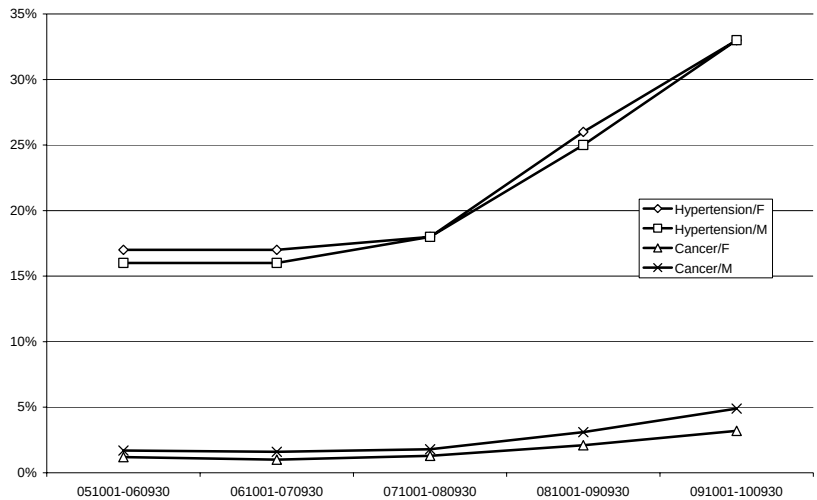


Figure 10. Crude prevalence of hypertension and cancer diagnosis registration for patients 50 years of age and older according to sex (Female/Male) and time period

Multilevel regression analysis

Table 5 shows that the adjusted prevalence of hypertension increased from 17.2 % to 32.2 % between the first and the last time period with no evident difference between sexes. The adjusted prevalence for cancer diagnoses also shows an increasing trend from 0.79 % to 2.32 %. Here a clear and stable difference over time between sexes with ORs around 1.6 for men can be observed.

Figure 11 shows the rise in adjusted prevalence of ICD codes for hypertension, but also the simultaneous decline in ICC on both HCC and physician level in the last two periods. For cancer diagnosis figure 12 shows a rise in prevalence and a decline ICC on physician level, but not on the HCC level.

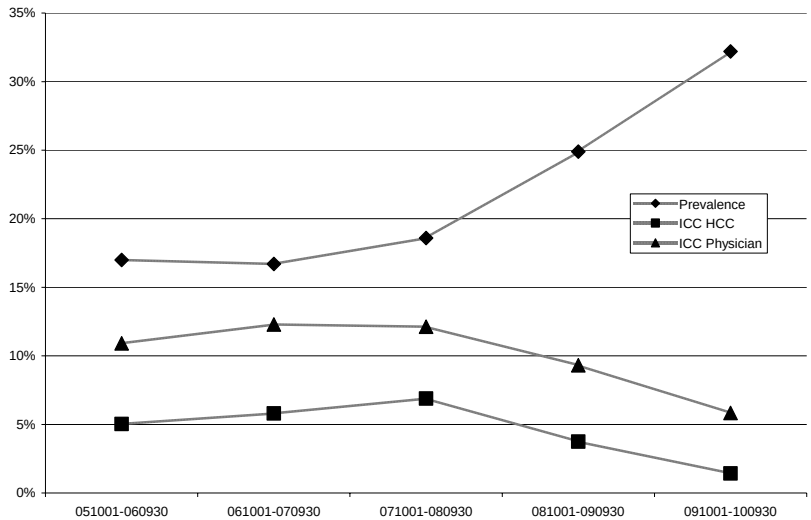


Figure 11. Adjusted prevalences and ICCs for patients with registered hypertension diagnosis

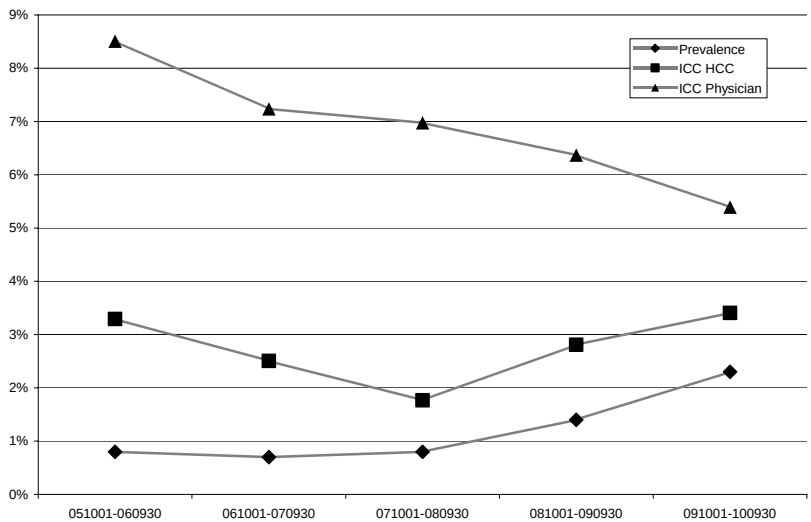


Figure 12. Adjusted prevalences and ICCs for patients with registered cancer diagnosis

Table 5. Adjusted prevalences of hypertension and cancer diagnoses, association between patient sex and these diagnoses as well as analysis of variances obtained from the multilevel regression analysis in the Skaraborg Primary care database for the five time periods.

Time period		**051001-060930**	**061001-070930**	**071001-080930**	**081001-090930**	**091001-100930**
Diagnosis						
Cancer						
	Fixed effects					
	Adjusted prevalence, % (95 % CI)	0.79 (0.6–1.02)	0.74 (0.58–0.93)	0.84 (0.67–1.03)	1.43 (1.18–1.78)	2.32 (1.92–2.74)
	Patient sex, OR (95 % CI)					
	– Female	REF	REF	REF	REF	REF
	– Male	1.6 (1.46–1.81)	1.63 (1.43–1.85)	1.56 (1.38–1.74)	1.64 (1.5–1.79)	1.71 (1.59–1.84)
	Random effects					
	HCC variance (95 % CI)	0.036 (0.014–0.088)	0.027 (0.011–0.064)	0.019 (0.06–0.049)	0.03 (0.014–0.065)	0.036 (0.019–0.076)
	ICC	3.3	2.5	1.8	2.8	3.4
	Physician variance (95 % CI)	0.057 (0.039–0.081)	0.051 (0.034–0.074)	0.056 (0.038–0.08)	0.038 (0.027–0.054)	0.021 (0.014–0.03)
	ICC	8.5	7.2	7.0	6.4	5.4
Hypertension						
	Fixed effects					
	Adjusted prevalence, % (95 %CI)	17.0 (14.8–19.7)	16.7 (14.4–19.2)	18.6 (16.1–22.0)	24.9 (21.6–28.9)	32.2 (29.8–35.4)
	Patient sex, OR (95 % CI)					
	– Female	REF	REF	REF	REF	REF
	– Male	0.91 (0.88-0.95)	0.93 (0.89-0.96)	0.96 (0.92-0.99)	0.97 (0.93-1.0)	1.01 (0.98-1.05)

Random effects					
HCC variance (95 % CI)	0.19 (0.1–0.4)	0.22 (0.11–0.46)	0.26 (0.14–0.52)	0.14 (0.07–0.28)	0.05 (0.02–0.12)
ICC	5.0	5.8	6.9	3.7	1.4
Physician variance (95 % CI)	0.22 (0.17–0.28)	0.24 (0.19–0.31)	0.20 (0.16–0.25)	0.20 (0.16–0.25)	0.15 (0.12–0.20)
ICC	10.9	12.3	12.1	9.3	5.8

OR: odds ratio. CI: credible interval. HCC: health care center, ICC: intra-class correlation

5. Discussion

The aims of this thesis were to examine the usefulness and quality of the SPCD database for research and to study practice variation in some important areas such as diagnosis registration, laboratory analysis ordering and prescriptions. Furthermore, the influence of changes in the economic incentives on physician's clinical behaviour was investigated.

5.1 Quality of the SPCD for research purpose

The SPCD is one of the first primary care databases describing Swedish primary care. As this is a new database we found it crucial to evaluate the quality of the registration before the data in the database were used for further research.

When validating ICD code registration in **study I** it was found that that the sensitivity of ICD code registration varied between diagnoses, being highest for diabetes mellitus (89 %) and hypertension (83 %) and lowest for CHF (66 %). The observed variation in sensitivity between different diagnoses is in line with previous studies [80, 81]. A reason for the high sensitivity found for diabetes might be that diabetes has clearly defined and well known diagnostic criteria and is therefore more readily coded than other diagnoses with more complex diagnostic criteria, for which the physician may choose to record a note as free text but not select any specific ICD code. In addition, a registered diabetes ICD code is mandatory for a patient to be included in the structured nurse based diabetes team care, which probably further enhance the coding of diabetes. Thus, it is likely that nearly all diabetic patients attending an HCC can be identified in the database.

Hypertension also had a high ICD coding frequency in the SPCD. The explanation for this finding could be that in Skaraborg primary care, a large research project with a standardised protocol for screening and treatment of hypertension was inaugurated in the 70s [82, 83], and most of the physicians therefore have a long tradition of diagnosing and managing hypertensive patients. Still the prevalence for hypertension was about half of what would be expected from earlier studies of the Skaraborg population aged 40–69 years [84]. Similarly, the prevalence of CHF was also half of that expected from the Treatment guidelines from the Swedish Medical Products Agency in 2006 [85] but on the same level as that reported in another study of computerised patient records in Swedish primary care [86].

Even though there are several possible sources of error in the prescription register, such as failure to register when medication is terminated, the overall quality of the information on prescriptions seems to be better than for the ICD coding. This is probably due to the fact that medication is automatically registered when the prescription is printed. There was 88 % mean registration sensitivity for prescriptions, even for rather complex medications.

The frequency of coded visits is the most frequently used quality measure for ICD coding and theoretically it should be correlated to the coding of specific diagnoses. This was true for some of the diagnoses but not for others. Thus, the coding frequency of patient visits is not always a useful measure of completeness of ICD code registration in chronic diseases which means that different types of diagnoses need to be validated separately.

It is ultimately the individual physician who is responsible for selecting and entering an ICD code, and since there were no external incentives for coding at the time of **study I** it was expected to show a variation in coding practice among physicians. This was also demonstrated in the study. The lack of external incentives for coding during this time period give us no reason to believe that other than purely medical considerations would affect the coding. This fact minimises the risk of coding bias due to economical considerations, but also results in low coding rates. However, in 2009, such incentives were introduced by making HCC reimbursement to a large extent dependent on ICD coding.

In **study IV** these new incentives were evaluated and a nearly two fold rise in registration of both hypertension and cancer diagnoses was demonstrated. The enhanced diagnosis registration is probably due to a shift in registration practice as increased coding of indirect patient contacts, such as renewed prescriptions over a telephone consultation. Therefore the rise in diagnosis prevalence rather reflects the changing incentives for coding than a true change in morbidity.

The rise in diagnosis prevalence could be attributed to upcoding, that is miscoding to receive higher reimbursement, which could threaten the validity of the research database. Upcoding is a well-known phenomena in other casemix reimbursement systems, especially the US Medicare system [87, 88] where 7.5 % of the fees were estimated to depend on upcoding in 2009 [89]. In a comparison of three casemix systems Steinbusch et al [90] concludes that fewer opportunities for upcoding occurs in systems where the coders' salary do not depend on the outcome of the

coding process. In this setting the VGPV system should be less disposed to upcoding.

The observed adjusted prevalence of hypertension of 33 % in the last period in **study IV** is similar to that found in previous prevalence studies [91]. This indicates that the observed prevalence presumably reflects the burden of hypertension in the population. However, in order to exclude possible upcoding, a future study validating the registered ICD codes is required. This risk will probably differ between diagnoses, with lower risks for diagnoses with more clear diagnostic criteria [18].

As the new reimbursement system was introduced rather recently and the impact on the HCC budget is delayed, further changes in coding patterns may occur. The decline in variation in coding between physicians and HCCs can be expected to continue when the budget effects becomes apparent. However, it can not be excluded that over time, initially high coding rates will gradually fall with increased variation as a consequence.

Changes in reimbursement system have been demonstrated to have direct impact on research databases such as SPCD. A more complete coding will enhance the possibilities to use the databases for identification of patients with chronic disease. Furthermore, other factors such as new administrative or clinical procedures might also influence the registration. Thus, knowledge about the local health care processes is essential when interpreting information from register databases.

When composing the SPCD the main model was the GPRD in Great Britain. The GPRD is a well established database with an impressive size and publication list describing primary care in the UK. The GPRD has been validated extensively [92, 93] with different approaches and reports good validity of diagnosis. As in the SPCD the prescriptions are well documented because of the automatic recording when prescribing [93]. In the GPRD the prevalence of diabetes is however shown to be underestimated [94]. The reason for this could be that chronic disease just needs to be reported at first presentation in GPRD [93]. The SPCD database, however presents high registration rates for diabetes, presumably because of the habit with repeated code registration.

In order to secure good quality, many international databases only include care givers who reach certain standards in documentation. However, including only

care givers with a special interest leads to the risk of creating a database that is not representative of primary care as a whole. As the SPCD includes all patients, physicians and HCCs in public care in Skaraborg the risk of selection bias is minimised. The disadvantage of not checking and excluding HCCs with low registration rates is data of inconsistent quality. However the Skaraborg primary care has a long tradition of participating in research, starting with the hypertension project mentioned earlier. Around the same time a structured nurse based care of patients with diabetes was inaugurated resulting in a local register [95]. The hypertension project is still running and is the basis for several academic dissertations [96, 97, 98]. These previous research experiences and the homogeneity of the Skaraborg primary care provide a good foundation for the creation of a population based research database.

As the SPCD comprises records from all publicly administrated HCCs in Skaraborg, the individual HCC participation in the database is not optional but required by the local health care authorities. Therefore, when designing the SPCD it was found crucial not to interfere with the daily clinical work and avoid introducing complicated requirements for adapting data registration, in order to get a widespread acceptance of the database project. The main purpose of the PDIII record software is purely clinical. Therefore the data registration techniques are not always optimised for research purpose. In some of the modules (diagnoses, laboratory, contacts, sick leave and therapeutic procedures) the data is stored in such a way that the information can be easily extracted. The information in modules with a high degree of free text registration (journal text, documents) is however more unreliable, making it possible only to extract certain parts. When building the SPCD it was chosen to extract only the information in PDIII that was recorded in a standardised way omitting most of the free text parts.

As shown in **study I** the registration rate in the diagnosis register of the SPCD differ between diagnoses with good registration for some diagnoses but poorer for others. As the diagnosis register is the main source of information used to identify cohorts of patients with a specific morbidity, high registration rates are crucial. It seems that one side effect of the economic incentive that was introduced in 2009 is an improved diagnosis registration. However, there are sometimes alternative ways of identifying specific patient cohorts apart from using the diagnosis. The observed high registration in the prescribing register and the accurate and reliable registration in the laboratory module can in some instances be useful. When identifying diabetes patients in a database, inclusion of the parameters diabetes specific prescriptions and raised blood glucose levels has been shown to increase the completeness of the search [99]. When identifying patients with asthma or chronic obstructive lung disorder, search strategies combining diagnosis and

prescription can be used [100]. In the same way the combination of different search techniques might be useful when finding patients with for example depressive disorders (diagnosis and prescriptions) or renal failure (diagnosis and laboratory analysis) and hypertension (diagnosis and blood pressures values).

5.2 Studying practice variation

In the study of practice variation presented here, the focus has been on both changes in variance and changes in mean measures of the outcome [101]. When trying to change undesired practice habits, observing a mean increase in the desired behaviour in a primary care area does not necessarily imply a clinically relevant improvement since the variation between physicians and HCCs could be very high [102, 103]. The desired outcome is obviously not only to increase the mean performance but also to eliminate unnecessary practice variation. In this light, the combined study of mean centric measures (prevalences) and measures of variance seems appropriate when estimating changes in practice habits.

When studying variation in prescribing in **study III**, transferring the economical responsibility from the central health care authorities at the County Council to the local HCCs seems to have improved adherence to statin prescription guidelines. The use of recommended statins increased from 77 % in 2003 to 84 % in 2005 and the variance between HCCs and between physicians decreased by 82 and 55 % respectively. This suggests that the new prescribing habits were adopted by most HCCs and physicians.

In **study IV**, after the introduction of the new HCC reimbursement system promoting coding of chronic disease a clear rise in diagnosis prevalence, for both hypertension and cancer registration was demonstrated. A simultaneous decline in variation expressed as ICC, especially at the physician level was also observed. This indicates that, as expected, the change of reimbursement system increased the diagnosis coding. This new practice behaviour was rather general since the variation in practices habits (expressed by the size of the ICC) was less important at the end of the study period.

5.2.1 Level specific characteristics (Fixed effects)

In **study I-III** several variables from different levels showed a conclusive association with the outcome under investigation according to their ORs. Lower ICD coding rates in planned visits demonstrated in **study I** might be explained by the greater complexity of the medical problems addressed during the planned visits in comparison with the unplanned visits. In the same way lower coding rates among the elderly could be attributed to their more complicated and time consuming medical conditions.

In **study II** female patients and patients with previous P-Ca analysis were more likely to have a P-Ca analysis, which could be explained by women's greater risk of pHPT and recurrent check-ups of patients with chronic diseases. The sex of the physician had no influence on P-Ca test ordering, in contrast to a study from Israel where female physicians ordered more test [104]. Older and more experienced physicians were less likely to order a P-Ca-test, which is in line with previous studies indicating that test ordering behaviour of GPs was influenced by years of experience [105]. P-Ca analyses done as part of group analyses used in surveillance of different chronic conditions may inflate the number of P-Ca analyses [106].

In **study III**, older locum physician was shown to have a lower adherence to prescription guidelines than older GPs, which may reflect intrinsic characteristics of this personal category. Locum physicians share the common work environment and the same constraints as other physicians at the HCC but only for a limited period of time and therefore might be less affected by the therapeutic traditions acting at the HCC.

To explain the observed variances, a system of multiple analyses was used, including the explaining variables from different levels in new models step by step [107]. A reduction of the variance between models would suggest that these variables are important in explaining the observed practice variation. However, even though the multilevel approach identified factors, at all levels, which are important to consider when explaining the outcome (according to their ORs), none of the included variables (not even the highly associated risk score included in **study II**) could explain a significant part of the variation at the higher levels.

In the studies in this theses only variables available in the SPCD database were included. In previous studies, other characteristics of the physician, such as attitude to risk taking and involvement in development of guidelines, explained parts of the higher level variance [108]. When the presence of unwanted variation is established other research techniques might be useful to determine the cause of the variation. Opinions, attitudes and professional preferences of physicians can be investigated, using such methods as questionnaires, focus groups or interviews. Since differences in subjective and ideological beliefs like attitudes towards the pharmaceutical industry are shown to influence GPs prescribing of new drugs [109], including variables related to GP attitudes in the analysis would add strength to studies of adherence. The identification of yet unidentified factors that contribute to the variation is needed in future studies for monitoring practice variation and quality assessment but also when designing interventions to reduce unwanted variation.

5.2.2 Targeting the preferred level for an effective intervention

One of the major features of MLRA in the study of practice variation is the partitioning of the variance between the different levels. In theory it would be most effective to direct an intervention designed to decrease unwanted variation to the level that corresponds to the greatest proportion of the total variance.

In **study I** a large variation between physicians and between HCCs in the frequency of ICD coding was demonstrated with the largest difference being between physicians. **Study II** also showed that the ordering of P-Ca analyses was influenced by factors both at the physician and at the HCC level, with the physician level being more important than the HCC level. This indicates that in both studies the physicians may be a more effective target than HCCs for interventions intended to improve ICD code registration and P-Ca test ordering.

Furthermore, two interventions were studied comprising two different changes in budget systems, both affecting the HCC and the physician level simultaneously. Even though the primary goal of neither was to change practice habits, this effect was demonstrated.

When studying adherence to guidelines on prescriptions in **study III** it was shown that the variance at the higher levels was rather large before the decentralised budget and equally distributed among HCCs and physicians, indicating that any

intervention aimed to improve adherence with guidelines should be focused on both levels simultaneously. The decentralised budget, that was implemented, was a general intervention towards all HCCs and all physicians that was disseminated through the HCCs and it appeared to effectively decrease the variance at both levels. After the decentralised budget the higher level variance was very small which suggests that any further intervention directed towards specific HCCs or physicians would be less effective.

In **study IV**, the new HCC reimbursement system that promotes ICD coding of chronic disease seems to have a mixed influence on the variation in coding habits. The variation in hypertension registration decreased on both HCC and physician levels but for cancer registration the reduction in variation was limited to the physician level. This suggests that changing registration patterns regarding cancer diagnoses are not adopted equally by all HCCs.

As shown in **study III** and **IV**, introducing economic incentives seem powerful when trying to change both clinical performance and administrative procedures. However, because of its potency new economic incentive needs to be thoroughly assessed before implementation in order to avoid unexpected and unwanted effects. In **study IV** economic incentives promotes ICD code registration but on the other hand it enhances the risk of upcoding, making further validation of the diagnosis necessary

5.3 Limitations of the studies

5.3.1 Methodological limitations

The result of a validation study is usually expressed by sensitivity and positive predictive value (PPV) [80, 110]. When coding in the PDIII patient records, the assigned ICD codes are stored in the diagnosis register of the medical record database. However, at the selection of an ICD code, the software automatically records a notation in the text section, which was used as gold standard in this study. Therefore in **study I** it was found inappropriate to distinguish between true and false positive cases as the former, per definition, amounts to 100 %. This could be overcome by discarding the automated text notations from the review but in this study it was chosen to include everything. With this approach it was not possible to calculate PPV.

Further, since the assigned codes reflect the opinion of the physician, a more thorough and objective validation of the quality of coding would have to include comparison of the medical outcomes of the individual patients with the diagnostic criteria for the relevant diagnoses. This was not done in **study I**, and therefore only the registration performance of the physicians, but not their diagnostic capabilities can be reflected on. Using the SPCD in the future to study for example prescription of antibiotics in infectious diseases highlight this problem of choosing the appropriate ICD code as it might be suspected that the registered code depends on the physician's treatment decision. ICD codes of viral infections might be avoided in order to motivate an inappropriate antibiotic prescription.

When examining the effect of the decentralised drug budget in **study III** it can not be excluded that unmeasured factors besides the change in budget system might have influenced the observed results (i.e. increase in prevalence and reduction in variance). In addition, the expiration of the Zocord patent in 2003, with the following decline in price for generic simvastatin and increase in cost difference with other statins, might have contributed in choosing the recommended statin. Information campaigns issued by the local therapeutic committee and the growing awareness of rising costs for medication are other possible contributing factors.

Further the period of analyses was relatively short so it can not be excluded that an immediate positive response is followed by a later gradual return to the pre intervention situation. Therefore, in order to obtain some information on the effect of the intervention beyond 2005, the prevalence of recommended statins in the time period from July 2008 to December 2009 was analysed. Because at the moment of the analyses this data was not complete (i.e. it included only 23 out of 24 HCCs and there was not information on prescribers) it was not included in the main multilevel analysis. This analysis indicated that the overall prevalence of recommended statin prescriptions in 2008–2009 was 89 %, which suggest that the effects of the intervention were stable.

Observational epidemiological studies are often the only option for investigating questions that for practical, economical, or ethical reasons cannot be analysed by randomised trials [111-114]. However, confounding and selection bias may threaten the validity of the studies. In **study II** the risk for confounding by indication was minimised by including the previously described risk score. In this case, however, the outcome seems not to be confounded by indication as the inclusion of the risk score did not effect the variance to any higher degree.

When investigating adherence to guidelines on prescriptions in **study III**, statins was chosen as an ideal medication group for investigating prescribing behaviour. Because of similar indications and efficacy [79], there is in this case no rationale for considering patient characteristics as confounding factors when investigating practice variation

When building a multilevel model with patients nested within physicians, in turn nested within HCCs it is often difficult to determine which physician is responsible for the individual patient. In real life one patient is not assigned to a specific physician bur rather sees several physicians as illustrated in figure 1. In the four studies this problem was addressed in different ways.

In **study I**, when examining if a patients visits are coded or not, a part of the observed variation could actually be at the patient level as a patient could have several visits. However, as the residuals at the patient level were not normally distributed this level was excluded from the analysis. A complementary analysis using generalised estimation equations and alternating logistic regression [37] also showed that the clustering at this level was small (pair wise odds ratio of 1.15) and the exclusion of this level in the analysis will affect the variance at the higher levels only to a small degree.

An alternative approach to solve this problem is to build a multiple membership multilevel model [78]. In this model all physicians are partitioned their responsibility for the patient according to what extent he/she is involved in the patient care (e.g. proportion of visits, prescriptions, test ordering). This proportion is entered in the analysis as a weight for each physician. In **study II**, this model was used when studying variation in test ordering.

In **study IV**, when studying coding prevalence two types of models when establishing the patient/physician relationship were tested, one simpler where the most frequently visited physician was chosen (i), and one more elaborate multiple membership model (ii) where all doctors participating in the care of the single patient were partitioned their responsibility for the ICD coding according to the their number of contacts with the patient. When comparing variances for the two models (i and ii) in one of the five time periods only small differences were found, $VAR_{DR}(i)=0.243$ resp $VAR_{DR}(ii)=2.66$ and $VAR_{HCC}(i)=0.218$ and $VAR_{HCC}(ii)=0.254$). Therefore it was decided to use the simpler model (i) in the analysis.

When studying variation in prescriptions in **study III**, patients with more than one prescribing physician was excluded in order to identify homogeneous physician–patient relations, including about 80 % of the patients with a relevant prescription.

As shown it s possible to treat the problem of multiple physicians caring for one patient in different ways. The circumstances in each case have to be considered when determining which model to use.

5.3.2 Limitations of the SPCD

A drawback of the SPCD database is the problem to identify physicians and patients attending more than one HCC. Due to demands for confidentiality the database is blinded with regards to patient and physician identity. The internal identification number of patient and physician from the local journal databases can be used to link data within HCCs, but because all HCCs journal databases has their own identification numbers, they cannot be used to link between HCCs. This means that it is impossible to determine if a patient or physician occurs in several HCCs.

Regarding patient, this poses just minor problems as the number of patients changing HCC are rather low (e.g. 3.4 % of all patients with hypertension in Skaraborg visited more than one HCC during a 10 year period). On the physician level this might lead to underestimation of the variance when studying variation in performance. In special cases (as in the 2005 dataset of **study III**) the identity and characteristics of physicians can be established but in a very time consuming way. This problem needs to be addressed in the further development of the SPCD. Possibilities to extract personal identification numbers on patients have recently been established solving the linkage problem on the patient level. However, the personal identification number file is not incorporated in to the SPCD and can only be accessed after approval from the Regional Ethical committee.

Further, as prescription information for patients included in the ApoDos system [65] is missing in the SPCD, studies focusing on prescriptions among elderly are hard to perform. However since 2005, this problem can be solved by linking prescription information via the Swedish Prescribed Drug Register at the Swedish National Board of Health and Welfare [115].

Another limitation of SPCD is the incomplete registration of variables such as smoking, physical activity, diet habits and adverse drug reactions often needed when evaluating cardiovascular diseases. These variables are usually registered in the unstructured free text part of the records and are therefore difficult to retrieve. Improvement of this registration is essential in the further development of the database.

5.4 Future perspectives of the SPCD

Development of new databases and quality registries

The introduction of the VGPV system has led to the establishment of several new privately run HCCs in Skaraborg. This has caused a decrease in the number of patients cared for by the public HCCs and subsequently included in the SPCD. In order to preserve the completeness of the database, all new HCCs, irrespective of business form, are invited to participate in the database. However, at present only HCCs using the PDIII patient journal are able to produce data suitable for the SPCD and so far none of the new HCCs has been incorporated. Moreover the regional authority has decided on the implementation of a new computerised journal system for the whole Västra Götaland region. This opens up the possibility to create a research database for primary care in the entire region. In this process the experiences from the SPCD will be useful.

In Sweden several national quality registers have been established in later years [116]. At present (May 2011) about 70 registries receive central funding [117]. These registries compose selected information for separate diagnoses registered and reported specifically for this purpose with good validity. They pose a great source for research and quality assessment for the specific diagnosis. One of the drawbacks, however, is the often time consuming registration procedures hampering implementation in the everyday clinical work. In this light, despite the quality problems, data from computerised medical records (like SPCD) might be an alternative when constructing new registries, especially in primary care.

The use of SPCD in future research

One strength of SPCD is the newly incorporated possibility to extract personal identification numbers and subsequent linkage with other health care registries. The complete registration of prescriptions in SPCD facilitates compliance studies by comparing prescribed medications in SPCD with dispensed drugs in the Swedish Prescribed Drug Register. Furthermore, linkage with national registries

containing socio economic, mortality and morbidity data enables studies in these fields.

As continuity of care has come into focus in order to enhance quality in health care, the kind of data that SPCD contains also has the advantage of being longitudinal. This enables studies of the importance of continuity for quality of care and patient outcomes.

6. Conclusions

In this thesis the quality of the SPCD database has been investigated. It was shown that the registration of ICD codes varied between diagnoses but also between physicians and HCCs indicating that different diagnoses needs to be validated separately. It was also demonstrated that changes in the health care process might influence the registration in the patient medical journals and subsequently have a direct impact on the contents of the research database. Therefore knowledge about the local health care processes is essential when interpreting database data. However, bearing this in mind, the Skaraborg Primary Care Database seems as a good complement to previously established databases and quality registers, offering new possibilities when studying primary care.

Furthermore, multi level analyses demonstrated the occurrence of practice variation both in laboratory test ordering and in adherence to prescription guidelines while simultaneously determining the levels of importance in explaining the observed variation. A positive effect on the adherence to prescription guidelines was demonstrated after the introduction of a decentralised drug budget, and the introduction of a strong economic incentive for ICD coding showed an expected rise in coding rates and decline in variation between physicians and HCCs. Analysing data from computerised patient record using multilevel regression techniques seem appropriate for further studies of practice variation.

7. Sammanfattning på svenska

”Practice variation”

I den kliniska vardagen ser man ofta slående variationer i handläggningsrutiner mellan läkare och vårdcentraler utan att detta kan förklaras av skillnader i sjuklighet hos patienterna. Dessa oförklarade skillnader benämns ”practice variation” och beror på lokalt förankrade rutiner ofta etablerade sedan länge. De är sällan vetenskapligt underbyggda utan kan snarare ses som ett uttryck för enskilda doktorers skiftande kliniska erfarenheter eller som orsakade av att yttre faktorer såsom varierande ersättningssystem, bemanning eller resurser. Ofta är denna variation oönskad och kan finnas på olika nivåer i sjukvårdshierarkin (sjukvårdsområden, vårdcentraler eller doktorer). Förekomst av variation i handläggning väcker frågor om över- och underbehandling men även om brister i jämställdhet i vården.

Ett sätt att minska oönskad ”practice variation” är införandet av medicinska styrdokument såsom vårdprogram och läkemedelskommittéernas förskrivnings-rekommendationer. Det har dock visat sig att det ofta krävs mer än riktlinjer för att åstadkomma förändringar inom sjukvården. Ett effektivt styrmedel i dessa fall är införandet av olika ekonomiska incitament.

Flernivåanalyser

En gängse metod för jämförelser av kvalitet i vården är att t.ex. jämföra antal vårddagar, frekvenser av förskrivna läkemedel eller olika typer av behandlingar mellan vårdinrättningar (Öppna jämförelser). Slutsatserna av sådana jämförelser kan bli felaktiga eftersom man inte tar hänsyn till att bakomliggande faktorer kan påverka resultatet. Ett alternativt sätt att göra jämförelserna på är att använda flernivåanalyser (Multilevel regression analysis, MLRA). Denna teknik möjliggör att faktorer från olika nivåer (t.ex. vårdcentral (bemanning), läkare (kön, ålder, erfarenhet) eller patient (kön, ålder sjuklighet) kan inkluderas i samma analys. Dessa analyser möjliggör också att den variation som finns kan fördelas på de olika nivåerna. Man kan på så sätt avgöra vilken nivå som bäst lämpar sig för påverkan för att minska oönskad variationen.

Data från datoriserade patientjournaler lämpar sig mycket väl för att studera denna variation. Den avspeglar direkt vad som gjorts i det kliniska mötet mellan patient och vårdgivare på individnivå och innehåller ofta data på såväl vårdcentral- och läkarnivå som patientnivå.

Skaraborg och Skaraborgs primärvårds databas (SPCD)

Skaraborg, som tidigare var ett eget län, är sedan 1999 en del av Västra Götalandsregionen och har ungefär 250 000 invånare. Inom primärvården i Skaraborg har den offentliga vården varit klart dominerande, och sedan slutet av 1990-talet använder alla 22 offentliga vårdcentraler samma journalsystem, ProfDoc Journal III som gjort det möjligt att konstruera en forskningsdatabas, The Skaraborg Primary Care Database (SPCD). SPCD består av separata datafiler från varje vårdcentral med information om registrerade diagnoser, läkemedelsförskrivningar, laboratorieprover, åtgärder, sjukskrivningar, remisser och patientkontakter på individnivå. Vid extrahering av data från vårdcentralernas datajournaler sker en avidentifiering av patient och vårdgivare men specifika löpnummer möjliggör kopplingar inom databasen.

En primärvård i förändring

Det har skett flera förändringar av organisatorisk och ekonomisk natur inom primärvården i Skaraborg under senaste decenniet. Vårdcentralsbudgeten decentraliserades år 2003 och 2009 infördes vårdvalssystemet ”Västra Götalands Primärvård” (VGPV) vilket bl.a. innebar ett ersättningssystem byggt på antal listade patienter och deras vårdtyngd beräknat på diagnoser registrerade i patientjournalen.

Eftersom SPCD är en databas som tar data från den kliniska verksamheten och innehåller data från samtliga offentliga vårdcentraler i Skaraborg utan selektion, finns ett särskilt intresse att använda dessa data för studier för att öka vårdkvaliteten.

Syftet med denna avhandling är att:

Studera SPCD:s kvalitet för forskningsändamål och hur dess innehåll påverkas av förändringar i sjukvårdsorganisationen.

Studera “practice variation” i diagnosregistrering, beställning av plasma kalcium (P-Ca) analyser och läkemedelsförskrivning.

Studera lämplig nivå (vårdcentral, läkare, patient) att påverka för att minska en oönskad variation i handläggning.

Till de fyra delprojekt i denna avhandling har datamängder från SPCD använts. I **studie I** kontrollerades registreringen av diagnoser och läkemedel för diagnosgrupperna högt blodtryck, diabetes, kranskärlssjukdom och hjärtsvikt genom att jämföra innehållet i SPCD:s diagnosregister med journaltexten från 1 200 slumpvis utvalda patienter (validering). I de övriga studierna användes MLRA-teknik för att studera ”practice variation” i beställning av laboratorieanalyser (**studie II**), förändring i förskrivning av blodfettssänkande läkemedel efter den decentraliserade budgeten (**studie III**) och förändring av diagnosregistrering efter införande av VGPV (**studie IV**).

Resultat

Diagnosregistreringsfrekvensen visade sig variera mellan diagnoser, med höga frekvenser för diabetes och hypertoni, men även mellan läkare och vårdcentraler. Detta medför att olika diagnoser måste valideras och värderas var för sig. Registreringen av förskrivna läkemedel visade sig vara god (**studie I**).

De ekonomiska incitament som infördes 2009 visade sig höja frekvensen patienter med registrerad hypertoni och cancerdiagnos till det dubbla. Detta beror sannolikt på ändrade registreringsrutiner. Detta har haft en direkt effekt på innehållet i SPCD, vilket gör att kunskap om förhållandena i det lokala sjukvårdsområdet krävs när man studerar denna typ av data (**studie IV**).

Vidare påvisades ”practice variation” vid beställning av P-Ca analyser, där läkarnivån var viktigast (**studie II**), och vid förskrivning av blodfettssänkande läkemedel där läkar- och vårdcentralsnivåerna var lika viktiga för att förklara de observerade skillnaderna och att de förändrade ekonomiska villkoren ökade följsamheten till rekommendationerna (**studie III**).

Konklusion och framtidperspektiv

De två budgetförändringar som studerades visade sig påverka doktorernas beteende. Ekonomiska styrsystem förefaller således potenta när det gäller att åstadkomma förändringar inom sjukvården. De måste därför vara väl genomtänkta före införandet, för att undvika oönskade bieffekter. SPCD förefaller utgöra ett bra komplement till tidigare kvalitetsregister och internationella databaser för forskningsändamål. Den kan dessutom på grund av individdata länkas till nationella databaser såsom läkemedelsregistret, SCB och Socialstyrelsens vårddataregister.

8. Acknowledgements

I would like to thank everyone who supported me during the completion of this thesis. In particular, I want to express my gratitude to:

My head supervisor, professor Juan Merlo for all support, interesting discussions and good company during my time in Malmö. Your good ideas and enthusiasm never seems to stop.

My co-supervisor professor Ulf Lindblad for your deep knowledge of primary care research, and for supporting and encouraging me to start my PhD studies.

My co-supervisor associate professor Kristina Boström for her incredible enthusiasm and never ending helpfulness. You gave me the encouragement needed to finish this project.

My fellow researchers, Henrik Ohlsson for his invaluable statistical advice and Sofia Dalemo for her cheerfulness and enthusiasm.

Sven Fornwall for much appreciated discussions, not only related to research, and for being my friend.

Johanna Låstberg, Ann Segerblom, Paolina Weidinger, Mikael Åberg, Birgitta Ahlström, Anna-Lena Östberg and Bo Rylander at the Skaraborg Primary Care R&D Centre in Skövde for their support and good company. Special thanks to Johanna for her excellent help and assistance with the layout of this thesis.

Sara Ellmark for her advice on language and structure of this thesis.

Joseph Moosman and Kickan Abrahamsson for excellent cooperation when constructing the SPCD

Micael Elmerson, head of Norrmalm health care centre, for supporting me and supplying time needed for this project.

All Colleagues and personal at the Norrmalm health care centre for their support and participation in creating a research friendly atmosphere.

Finally I would like to thank my wife Ewa, and my children Carl and Anna for their patience with me, when I was sometimes absent both in mind and person, during this project.

This thesis was supported by grants from the Skaraborg Institute, the R&D centre Skaraborg Primary Care, the Skaraborg Research and Development Council, the Swedish Council for working life and social research, the Swedish Research Council and an ALF Governmental grant.

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10. Appendix

10.1 Appendix A

Composition of the 9 database files in the SPCD

1. Contact file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
IDDAT	ID+DATKON
DOCID1	Care provider identification number 1
DATKON	Date of contact
TIMEKON	Time of contact
KONTYP	Type of contact (name)
KONTYPKOD	Type of contact (code)
GRPID	Code of Care provider group
GRPNAME	Name of Care provider group
SITEID	HCC identification number

2. Diagnosis file (ICD-codes)

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
IDDAT	ID+DATDIAG
DOCID1	Care provider identification number 1
DATDIAG	Date of diagnosis registration
NR	Diagnosis code
DIAGN	Diagnosis
KRON	Chronic diagnosis
HB	Primary/secondary diagnosis
NKF	New/Control/Final diagnosis
BEV	Diagnosis linked to specifik problem
ENDDAT	Date of diagnosis termination
LISTA	Classification in use
SITEID	HCC identification number

3. Prescription file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
DATMED	Prescription date
DOCID1	Care provider identification number 1
IDDAT	ID+DATMED
ATCKOD	ATC code
PNMN	Prescribed drug (name)
BERF	Formulation
STRNUM	Strenght
STRENH	Unit
VARUID	Preparation code 1
RECO	
EXTORD	External prescription
APODOS	APODOS
SORTKOD	
PREPID	Preparation code 2
REGNR	Preparation code 3
VARUNR	Preparation code 4
KONTRKOD	
AUP	Pharmacy market price
AIP	Pharmacy purchase price
ORDTYP	Prescription type
ORDID	Prescription code
ITER	Iterations
ANTALFRP	Number of packages
INTERVAL	Interval between dispensation
FTYP	Prescription type
URSPRUNG	Origin
UTSATT	Termination date
USTATUS	Termination status
STATUS	Status
OUTPUT	
KORTDOS	Dosage
SITEID	HCC identification number

4. Document file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
IDDAT	ID+DATDOK
DOCID1	Care provider identification number 1
DATDOK	Date of document
DOKNAMN	Document type 1
RIKTNING	Direction of document (in/out)
DOKID	Document identification number
DOKORGID	Document code
SIDDAT	Date of doccument sheet
SIDNAMN	Name of document sheet
SIDID	Sheet identification number
TYPNAMN	Document type 2
DOKFORM	Document source
FORMNAMN	Name of document source
DOKTYP	Code of document type
ADRNAMN	Address
ADRAVD	Ward
ADRID	Address code
SITEID	HCC identification number

5. Free text file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
DOCID1	Care provider identification number 1
IDDAT	ID+DATJOUR
DATJOUR	Registration date
KEYWORD	Keyword
SUBKEYW	Subkeyword
TEXT	Text
ROW	Row
JOURNR	Type of journal registration
SITEID	HCC identification number

6. Procedure file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
IDDAT	ID+DATATG
DOCID1	Care provider identification number 1
DATATG	Date of procedure registration
ATGNUM	Procedure code
ATGTXT	Procedure
SITEID	HCC identification number

7. Patient file

Variables	Comment
ID	Patient identification number (internal)
ASTATUS	Patient status (deceased, left the HCC)
KOMMCODE	Municipality code
LANCODE	County code
POSTNR	Postal code
SYMBOL1	Symbol code 1
SYMBOL2	Symbol code 2
SYMBOL3	Symbol code 3
SYMBOL4	Symbol code 4
PATMARK	Patient code
KOD1	Code 1
KOD2	Code 2
FLEGE	Usual care providor
LISTSTAT	Usual care providor registration
DATLIST	Usual care providor registration date
SITEID	HCC identification number

8. Sick leave file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
IDDAT	ID+DATSS
DOCID1	Care provider identification number 1
DATSS	Date of sick leave registration
FORLANGD	Extention
SML	Contagious disease
DIAGNR	ATC code on sick leave certificate
PERSKONT	Personal contact with care provider
DTPERS	Date of contact with care provider
TELEKONT	Telephone contact
DTTELE	Date of telephone contact
JOURKONT	Journal information
DTJOUR	Date of journal information
ANNAKONT	Other contact type
DTANNAN	Date of other contact type
ORDINAX	Prescription (Yes/No)
ORDINATI	Text of prescription
POLIKLIX	Patient visit (Yes/No)
BELASTNX	Strain to be avoided (Yes/No)
BELASTNI	Text of strain
BESOKX	Visiting work place (Yes/No)
ATGARDX	Procedure ordered by care provider(Yes/No)
ATGARDSJV	Text of procedure
ANNANX	Other procedure (Yes/No)
ANNANATG	Text of other procedure
OVRIGTX	Other (Yes/No)
OVRIGT	Text of other
ARBREHAB	Rehabilitation code
MEDBE	Employed/Unemployed
START25	Start date of 25% sick leave
STOPP25	Last date of 25% sick leave
START50	Start date of 50% sick leave
STOPP50	Last date of 50% sick leave
START75	Start date of 75% sick leave
STOPP75	Last date of 75% sick leave
START100	Start date of 100% sick leave
STOPP100	Last date of 100% sick leave

Continues on the next page

HELT01	"Not in use"
HELT02	"Not in use"
HELT03	"Not in use"
HELT04	"Not in use"
HELT05	"Not in use"
HELT06	"Not in use"
PROGNOS	Prognosis of restored capacity
RESOR	Transport to/from work place restore capacity (Yes/No)
KONTFK	Contact with Social insurance office requested (Yes/No)
AVSTAMMN	Meeting with Social insurance office requested (Yes/No)
SSID	Sick leave certificat identification number
SITEID	HCC identification number

9. Laboratory file

Variables	Comment
ID	Patient identification number (internal)
AGE	Age
KJOENN	Sex
REQKEY	Contact number
IDDAT	ID+DATREQ
DOCID1	Care provider identification number 1
DATREQ	Date of test registration
TIMEREQ	Time of test registration
DATTAKEN	Date of test
TIMETAKE	Time of test
NAMESHORT	Name of test (code)
RESULTCHAR	Test result (character)
UNIT	Unit
PATHOL	Pathological
RANGE	Normal range
PRICE	Price
ADDRNAME	Name of laboratory
BEVNAME	
ADDRID	Name of laboratory (code)
BEVID	
SITEID	HCC identification number

10.2 Appendix B

Cardiovascular Drug groups and ATC codes

Drug groups	ATC codes
Long-acting nitrates	C01DA08, C01DA14
Loop diuretics	C03C
Potassium-sparing diuretics	C03D
Diuretic combinations	C03E
Thiazides	C03A, C03B
Beta blockers	C07
Calcium channel blockers	C08
ACE-inhibitors	C09A, C09B
Angiotensin receptor blockers	C09C, C09D
Statins	C10AA
Fibrates	C10AB
Resins	C10AC