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Associations between quality of care in informal provider networks and nursing home admissions in Germany: results of a retrospective cohort study using German health claims data

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Abstract

Background: High-quality outpatient medical care can prevent care-dependent people from having to move to a nursing home. Quality of care is determined by the behaviour and cooperation of providers, which, when sharing patient collectives, can be understood as functionally defined informal provider networks (PN). There is still a lack of knowledge about the relationship between the quality of care in the interaction among service providers as a structural characteristic of a PN and nursing home admissions (NHA). We therefore examined associations between treatment quality, compositional characteristics, such as the number of general practicioners in the PN and NHA.

Methods: German statutory health insurance claims data from 2006 to 2016 was used in a retrospective cohort study. The observation cohort comprised community-dwelling people ≥ 65 years of age who initially became care-dependent in 2006 (n = 117,942). PN were constructed using the Speaker-Listener Label Propagation Algorithm. The quality of care provided by such networks was assessed by further including all people ≥ 65 years of age who were cared for by service providers of the observation cohort. Quality of care in the PN was measured using 67 quality indicators (QI). Event-time series analyses in three proportional hazard models, taking into account random effects, determined the association of treatment quality characteristics and compositional characteristics of the PN with NHA.

Results: 35,540 admissions occurred in 406 PN. The majority of QI and individual predictors show significant associations with NHA, as well as a few compositional characteristics of the PN. Out of 67 QI, 37 were significant in two of three models, 19 of which were associated with a lower risk and 18 with an increased risk for NHA.

Conclusions: Associations between quality characteristics of the PN and the risk of NHA constitute a relevant influence as they remain significant when controlled for individual predictors. Most compositional characteristics had no influence on NHA. Aspects of treatment quality thus do play a role in determining how long care-dependent people continue to live at home after onset of care-dependency. The results contribute

to revealing informal relationships between service providers that constitute a special characteristic of the German health care system and to the identification of starting points for further education in high quality treatment of selected populations and in formalizing care collaborations by joining voluntary PN. Further, sensitising service providers to the evaluation of care processes and to reflecting on the relevance of their role in PN can improve quality development and outcomes.

Keywords: Health claims data, Patient-sharing network, Quality indicators, Nursing home admission, Quality of care

Background

Various individual and external factors contribute to people in need of long-term care moving into a nursing home (nursing home admission, NHA). In addition to illness-related physical and cognitive impairments and risks, social support as well as emotional and physical stress among relatives providing care advance or prevent NHA (Hajek et al. 2015; Gaugler et al. 2007; Runte 2017; Salminen et al. 2017; Brown et al. 2019). Under the assumption that cognitive and functional impairments can be prevented, reduced or delayed through medical treatment, health care providers could play a key role in supporting care dependents wishes to age in place (Toot et al. 2017; Luppa et al. 2010a). However, community-dwelling people in need of long-term care are considered vulnerable to deficits in the provision of health care funded by the German statutory health insurance (SHI) (SVR 2014; Schulz et al. 2020).

Outpatient primary medical care is a process shaped by the cooperation of a wide variety of health services providers, since the quality of care (QoC) in shared patient collectives is determined by the actions of all providers involved (cf. von Stillfried et al. 2017). This cooperation among providers defines them as care communities or provider networks (PN). PN can either be established formally (members of the network having knowledge of each other and are contractually organised within the PN, e.g. accountable care organisations (ACO)) or informally (opportunistic cooperation without contractual basis or emerging randomly due to geographical proximity or shared patient populations).

While formal PN are being implemented to promote evidence-based and improved health care worldwide (Brown et al. 2016), the strategic pooling and organization of clinical expertise in formal PN is not legally mandatory within the German health care system. The majority of over 54,000 primary care physicians registered with the German National Association of Statutory Health Insurance Physicians are not yet members of a formal PN (https://www.kbv.de/html/18491.php). Informal network structures with cooperation and collaboration in care provision arise primarily through shared patient collectives or by means of voluntary engagement for the advancement of quality and the profession, but for which there is usually no joint obligation for extensive quality assurance and improvement. From the patient's perspective, freedom of choice of health care providers is a predominant principle in the German health care system, allowing every insurant to claim services from all SHI-licensed physicians and hospitals without the need of referrals or approvals (Busse et al. 2017). Albeit the lack of formal PN in Germany, informal networks can be observed based on commonly treated patients (von Stillfried et al. 2017).

The QoC achieved by such an informal PN can be seen as a structural or encompassing underlying characteristic affecting all patients cared for by that PN, regardless of their individual health problems. Although on average the majority of community-dwelling care-dependents in Germany have contact with their general practitioner (GP) at least once a quarter (Schwinger et al. 2017), differences in the QoC between individuals with and without care-dependency can be observed (Seibert et al. 2020). Respective differences between informal PN are also known, and patient populations, that have been functionally defined by considering which actual providers had been participating in care delivery, show a higher variability in individual QoC indicators than populations defined by geographical administrative boundaries (von Stillfried and Czihal 2014).

In prior research we found up to 56% of the statistical variation of nursing home admissions between functionally defined populations in Germany being attributable to characteristics of care providers, especially in the outpatient sector (Domhoff et al. 2021). Beyond that, there is only little knowledge on the contribution of the quality of outpatient SHI care to an ongoing residency at home. Reported relationships between the number of emergency treatments or the quantities of prescribed drugs (Luppa et al. 2010a; Nuutinen et al. 2017) and NHA, in combination with the assumption that physical and cognitive impairments are results of underlying diseases and their treatment, indicate that aspects of the process quality of outpatient primary medical care in particular might also act as predictors of NHA.

It is still unknown, whether QoC in functionally defined informal PN is associated with NHA. Nationally and internationally established quality indicators (QI) that are primarily derived from routine data are used to map and monitor QoC in formal and informal PN (Seibert et al. 2019). The analysis of SHI claims data to identify potential for improvement in SHI care may stimulate the advancement of formal networking or performance monitoring as well as the development of targeted interventions in the outpatient sector to help care-dependent people live in their own homes as long as possible.

Against this background, this study pursues the question, whether QoC as a structural characteristic of PN and the compositional characteristics of PN influence the risk for NHA in people in need of long-term care. Therefore, we elaborate on the underlying data, the methods employed for processing SHI claims data, conducting network analysis and community detection and the statistical analyses. The results present the association between identified indicators for QoC and NHA as well as the differentials in NHA between PN. We discuss implications of the results, strengths and limitations of the study and further needs for research and discourse.

Methods

This retrospective cohort study is based on anonymised SHI claims data from individuals aged 65 years or older, insured with one of the 11 AOK SHI funds in Germany. Analysed data comprises the entire individual in- and outpatient health care history of the study participants, including all diagnoses, provided medications, medical procedures, rehabilitation services and physical, occupational, speech and language therapy, podology, level of care and place of residence (nursing home or community-dwelling) as well as personal data including age, sex, and federal state of residence.

While the collection of SHI claims data in Germany primarily serves the purpose of reimbursement, the data are being used in health services research as they enable estimates of morbidity and mapping of care utilization patterns, QoC, costs and resource use (Schubert et al. 2008). In connection with descriptive or explanatory analyses they also enable policy impact research, quality research, outcomes research (Schubert et al. 2008), and the investigation of health care concepts and population-based approaches in order to identify "(vulnerable) groups with high care needs or suspected care needs or suspected misuse" (Schubert et al. 2008). SHI claims data are free from recall bias or non-response bias and allow for the inclusion of vulnerable populations in the analysis, who are often difficult to include in primary data studies (Lepore et al. 2017). Known limitations of SHI claims data result from the lack of information on about 9 million people in the German private health insurance, limited representativity when data from a single insurance provider are being used, missing information on severity of symptoms, on patients quality of life or satisfaction (Swart et al. 2014). Also, poor coding quality and incentive-induced coding have been reported for specific diagnoses, which may lead to under- or overestimation of results. Therefore, the internal as well as the external validity of the data have to be carefully examined within the given research context (Laux et al. 2014).

We follow the STROSA 2 reporting standard (Swart et al. 2016), specifically developed for analyses of secondary data and their specific requirements for the German health care system. This includes, amongst others, a reference to the specific legal basis for the use of secondary data and data protection that is not made explicit in international reporting standards such as the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statetement (Benchimol et al. 2015) or the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement (Elm et al. 2008).

Study population and sample size

The observation cohort includes all insured individuals aged 65 years or older from the 11 AOK SHI funds who became long-term-care-dependent for the first time in 2006 in accordance with Book XI of the German Social Code, and did not live in a nursing home throughout that year ($N_{cohort} = 117{,}942$). As information on the receipt of benefits from the long-term care insurance is entailed in German SHI claims data, all individuals without respective benefits in 2005 were considered as initially care-dependend when receiving benefits from 2006 onwards. All individuals were included in the cohort until the quarter in which they moved to a nursing home or changed the insurance company or died, or with the end of the observation period on December 31st 2016. As available results on NHA rates vary (Luppa et al. 2010a, b, 2012; Schulze et al. 2015), an observation period of ten years was chosen in order to include a larger number of NHA events in the analyses.

In addition, all individuals from the respective SHI funds aged 65 years and above who received services from a provider who treated at least one person from the observation cohort were included in a second dataset (PN-dataset). This dataset was used to determine QoC as a context factor for the people treated by a respective PN. The differentiation of the service providers was based on their site identification number (BSNR).

The PN-dataset dynamically added individuals on a quarterly basis according to use of services, and covered between 5.8 and 6.6 million individuals per quarter. Due to the exploratory nature of the analyses and the lack of defined intervention groups, no ex-ante sample size calculation was conducted.

Data protection and ethics approval

Data was provided by the AOK Federal Association as the data holder on behalf of the AOK insurance funds as data owners. Datasets containing information on the observation cohort ($N_{cohort} = 117{,}942$) were made fully available to the study team. For the PN-dataset a sample was provided ($N_{PN\text{-}sample} = 150{,}000$) for the purpose of preparing statistical analysis programs. Analyses of the full PN-dataset were then conducted on the premises of the data holder on a total of 18 non-consecutive working days. Aggregated data on QoC of PN were retrieved and handed over to the study team for further analyses. Access to provided raw data and interim analysis datasets at the facilities of the data holder was ensured for at least one year after the funding period.

The data protection officer of the AOK Federal Association approved an operation procedure for data protection, restricting usage of the data for the study's purpose. All data provided were designated anonymised by the data holder. The need for an ethics approval and informed consent is waived by the German federal regulation in §§ 67b & 75 German Social Code, Book X. The German Social Code regulates the usage of social data for the purpose of research. Use of the data without the informed consent of the persons included in this study is permitted by German law, as only anonymous data were used.

Network construction

Informal PN were identified by constructing functionally defined populations using a patient sharing network (PSN) (Barnett et al. 2011). This is defined as a social network of health services providers connected by commonly treated patients. Therefore, two providers are connected, when one patient utilised both of them within a defined period. Given this, there is no ex-ante limitation of the number of providers any provider can exhibit ties with.

In a first step, a network linking all service providers was constructed according to the number of patients shared by the same provider. Thus, two service providers are linked if a patient used both services during the entire observation period. In this PSN (graph), all service providers (hospitals, GP, medical specialists, providers of physical, occupational, speech and language therapy, podology and rehabilitation facilities; $N_{nodes} = 333{,}859$) from the years 2006–2016 formed the nodes (actors in the PSN). Patients treated jointly during this period formed the edges ($N_{edges} = 24{,}836{,}924$, representing the relationship of the actors in the PSN to each other), weighted by the respective number of patients treated jointly by two service providers. Specialists such as anaesthesiologists, laboratory physicians, pathologists, radiologists/radiotherapists and nuclear medicine specialists were excluded as it was assumed that there is little patient contact and only limited freedom of choice of this specialist groups.

Due to the large dimensions of the graph we reduced complexity for further proceeding. The previously undirected graph was converted into a directed graph by duplicating

all edges. Of this, only the 20% of outgoing connections with the highest weights were retained for each service provider in order to obtain the most relevant connections for each service provider, taking into account the individual strengths of relationships with other providers. This is reported to be a common process in research employing PSN (DuGoff et al. 2018).

To determine QoC, PN had to be identified within the PSN using community detection. This process exposes groups of especially strongly connected actors within the network. Applied to the presented research, this corresponds to groups of providers, which provide the majority of health care services for a larger population. With a variety of algorithms for community detection available (Javed et al. 2018), we selected feasbile methods based on the theoretical and practical requirements: Primarily, the algorithm had to be able to detect overlapping communities, as it was highly expectable, that due to the heterogeneity of the included providers and the freedom of choice of health service providers in Germany nodes may exhibit strong ties to more than one PN (e.g. hospitals). Furthermore, the algorithm had to be able to work on weighted and directed graphs and we required it to have a working implementation in software available for application. These criteria were met by the Order Statistics Local Optimization Method (OSLOM) (Lancichinetti et al. 2011), the Community Overlap Propagation Algorithm (COPRA) (Xie et al. 2013) and the Speaker-Listener Label Propagation Algorithm (SLPA) (Xie et al. 2013). We applied all algorithms to the graph, including sensitivity analyses for algorithm parameters as well as for the proportion of edges to retain (5%, 10%, 15%, 25%, 30%). Consequently, patients from the PN-dataset were assigned on a yearly basis to a primary PN, which provided services for the majority of individual treatment cases in the respective year. Performance was assessed through several metrics: Primarily the average proportion of contacts of patients with their PN should be maximised. Secondary criteria were the size distribution of the PN according to providers and assigned patients and the presence of all sectors in a PN. In a consensus, the research team decided on proceeding with results from SLPA (parameters: $r = 0.4$, $minC = 2$, $maxC = 1500$, $ev = 1$, $T = 100$, $lf = 10$).

Variables

The unit of analysis in our study were the care dependents in the observation cohort, and the target event was the first occurrence of NHA. The exposure and control variables include individual characteristics, QoC and compositional characteristics of the PN, which were calculated quarterly with the help of the PN-dataset and assigned to the individuals of the observation cohort on the basis of their affiliation to a PN.

Additional file 1 contains all independent variables. The place of residence was determined by the data provider per quarter as being or not being a nursing home, thus indicating whether a NHA had occurred for individuals in the observation cohort. As the dependent variable is available on quarterly basis alone, all analysis employ this time unit.

Indivdual characteristics

Individual characteristics of the observation cohort, such as age, gender and level of care, as well as characteristics described in the literature as predictors of NHA (cf.

Stiefler et al. 2020) were taken into account for risk adjustment. Besides diagnoses of predominantly chronic diseases, predictors include the individual number of hospital stays and physician contacts, the number of prescribed drugs and the Charlson Comorbidity Index.

Compositional characteristics of the PN

As compositional characteristics of the PN, the number of service providers in total and the proportion of specific sectors or specialities of service providers in each PN, and the mean number of comorbidities of the individuals treated by the PN in question were included.

Quality of care of the PN

We followed Donabedians' model for QoC which contains three components: structure, process and outcome (Donabedian 1966). In this context, structural quality (such as the number of providers in a PN) is a factor influencing process quality (such as guideline-adherent medical treatment of chronic diseases or continuity of care) with which it jointly influences the quality of the outcome of care (such as an reduction in emergency hospital admissions or morbidity). QI are quantitative metrics that can be used for monitoring and evaluating health care and that are capable of indicating opportunities for improving care and to monitor conformity with existing best clinical practice in order to achieve better processes of care and outcomes of care (Campbell 2002; Ramalho et al. 2019). By determining a quotient that represents defined relative frequencies (Laux et al. 2014), the proportions of desirable or undesirable treatment events (such as guideline-adherent treatment), treatment outcomes (such as mortality or physiological measures), or structural criteria (such as physician training hours) are depicted (Campbell 2002).

In this study, QoC in each PN is assessed by means of 67 QI that were selected in a multi-step process. First, a systematic review of the literature to identify internationally established QI was conducted (Seibert et al. 2019). The resulting selection of 286 possible indicators was rated by four members of the study team with regard to the German health system by an assessment of their relevance, comprehensibility, measurability, and representability with SHI claims data and influenceability by health care providers. After determining the required numerator and denominator information, an evaluation and discussion of selected QI with an external medical expert from the German College of General Practitioners and Family Physicians with regard to their clinical relevance and coding quality in everyday medical practice further narrowed down the selection of QI.

Operationalisation of the QI was carried out by means of diagnoses (ICD-10-GM), operation and procedure codes, item numbers from the fee scale for German medical doctors and drug substance groups (according to the Anatomical Therapeutic Chemical Classification System). Distribution and trends of the QI were reviewed and values were compared to external reference values initially on the basis of the sample of the PN-dataset before applying the QI on the full PN-dataset and repeated on the final QI results to assess reliability and validity. After determining the indicator values for each PN and quarter, QI with low overall variance (standard deviation < 0.01) were excluded from further analyses.

The QI cover eleven main areas of care: ambulatory care sensitive hospital cases (ACS cases), arthrosis, asthma, chronic obstructive pulmonary disease (COPD), cardiovascular diseases, dementia, type 2 diabetes mellitus (T2D), medication for the elderly, osteoporosis, prevention and depression. In addition to nine structural indicators, which provide information on the proportion of individuals with certain target diseases in the PN, mainly process indicators were included. These express QoC as either desired or undesired events and are mostly aimed at guideline-adherent prescribing behaviour or diagnostics. Continuity of care measures (cf. Vogt et al. 2016) were included as process indicators for selected chronic diseases. Two QI on adverse events (inpatient emergency treatment of COPD in persons with COPD and proportion of ACS cases in a PN) were included as outcome indicators.

QI were calculated according to the definitions shown in Additional file 1 with the PN-dataset and aggregated by year, quarter and PN. A direct age and gender standardisation of the QI was carried out using the new standard population of Europe (1990) (http://www.gbe-bund.de). As QI could not be calculated for each single PN in every quarter (no individuals with the necessary denominator definition in a PN), missing values were imputed in 0.7% of all quarters and PN with the mean value of the QI in the corresponding quarter. As the distribution of the number of service providers in a PN was clearly left-skewed, it was logarithmically transformed for regression modelling. All variables that represent proportional values (including QI and compositional characteristics) were multiplied by 100 for the regression analyses in order to obtain descriptive regression coefficients. The coefficients for proportional values can thus be interpreted as a change in the risk of nursing home admission if the independent variable is increased by 1 percentage point.

Statistical methods

The earliest possible occurrence of NHA was in the first quarter of 2007 (baseline) and the observation period ended in the fourth quarter of 2016. In addition to descriptive analysis of the compositional characteristics and QI of the PN the characteristics of the observation cohort for the baseline and final quarter are reported. The influence of QoC and compositional factors on NHA was calculated by multivariate regression analysis. Due to the time-dependent nature of NHA as the outcome from the onset of care-dependency and the time-varying QI we employed survival analysis with Cox regression models (Cox 1972; Sargent 1998). Individual characteristics and QI were included in the models as time-varying variables, while the compositional characteristics of the PN remained constant over time. Since it can be assumed that the assumption of independence between the observation units is violated by belonging to the same PN, all models took random effects into account to ensure homogeneity of the observations. Four hierarchical models were estimated to assess the change in the coefficient of determination through inclusion of compositional characteristics and QoC. Model 1 determined hazard ratios (HR) for individual predictors as independent variables without consideration of composition or QoC characteristics. Model 2 determined HR for composition and QoC characteristics, adjusted for age, gender and level of care, but without any further individual predictors. Model 3 determined HR for composition and QoC characteristics, adjusted for age, gender, level of care and individual predictors. In addition, a null model

with random effects was calculated without any further independent variables. The comparison of HR as well as the parameters of model quality (coefficient of determination R^2, akaike information criterion (AIC), standard deviation (SD) of random effects) between the models allows a statement on the contribution and interaction of the levels of the variables (individual, composition, treatment quality) as well as on the explanatory power of the models for the variance of NHA events. Furthermore, the random effects of the single PN were obtained as HR. In addition, we conducted sensitivity analyses by determining HR for two models only containing QI that refer to care processes while excluding all outcome QI. In the first step of sensitivity analysis, we excluded all outcome QI, all individual predictors and all QI that depict prevalence rates of diseases in the network from the model. In a second step we included the individual predictors again. We adjusted both models for age, sex, level of care. The level of significance was alpha = 0.05. The data preparation was carried out using the SAS® version 9.4 programme package, the statistical analysis using R version 3.6.1 (R Core Team 2019) and the coxme package (Therneau 2019). Code review for all steps of data preparation and analysis was performed by at least two members of the study team before running the final analyses.

Results

The observation cohort consists of 117,942 individuals, 30.1% (n = 35,540) of whom were admitted to a nursing home during the 10-year follow-up. Table 1 shows characteristics of the observation cohort for people with and without an NHA event. On average, people with an NHA event moved into a nursing home after 9.3 quarters. People without an NHA event were observed for an average of 15.6 quarters before they either left the study due to a change of insurance, death, or termination of the observation period. The large values in standard deviation underline the variance in further life expectancy after onset of care-dependency (Rothgang et al. 2015).

Table 1 Description of study cohort according to 2007-Q1 (N_{cohort} = 117,942) and follow-up period 2007–2016

	Without admission to nursing home (n = 82,402)	**With admission to nursing home (n = 35,540)**
Sex		
Male	29,990 (36.4%)	8 771 (24.7%)
Female	52,412 (63.6%)	26,769 (75.3%)
Age		
Mean (SD)	81.1 (7.3)	83.0 (6.9)
Median (Q1; Q3)	81.0 (76.0; 86.0)	84.0 (79.0; 87.0)
Nursing care level		
I	59,162 (71.8%)	28,047 (78.9%)
II	19,406 (23.6%)	6569 (18.5%)
III	3134 (3.8%)	588 (1.7%)
None	700 (0.8%)	336 (0.9%)
Follow-up in quarters		
Mean (SD)	15.6 (12.8)	9.3 (8.6)
Median (Q1; Q3)	12.0 (5.0; 24.0)	6.0 (3.0; 13.0)

SD standard deviation, *Q1* threshold value lower quartile, *Q3* threshold value upper quartile

Description and characteristics of PN

Community detection using SLPA identified 419 PN in the PSN. On average, one PN comprised 805 service providers (Q1: 261; Q3: 806). Each service provider was allocated to an average of 1.01 and a maximum of 4 PN, so there is only a small overlap between the clusters. This process resulted in an allocation table of service providers to PN (1:n allocation). Subsequently, the insured persons in the study population were assigned year by year, on the basis of the reimbursed outpatient medical treatment cases, to the PN in which most treatment cases were initiated (1:1 assignment) per patient. According to this allocation the primary PN dealt on average with 90.3% of the treatment cases and 93.3% of contacts with service providers for the persons in the PN-dataset. The PN constructed in this way reflect the actual care of jointly shared patients, but not all cases of active cooperation between service providers.

In the baseline quarter, the individuals of the observation cohort were assigned to 406 PN, which were involved in the care of 16,334 persons ≥ 65 years of age on average (including an average of 9% of care-dependent people, of whom an average of 288 individuals belonged to the observation cohort). Table 2 shows the average values of the compositional characteristics and QI of the PN for the baseline quarter and the fourth quarter of 2016. In the baseline quarter, the average number of providers in the PN was 825, of which an average of 45% were providers of physical, occupational, speech or language therapy or podology, followed by general practitioners and other disciplines (13%), multidisciplinary practices (8%), psychologists and psychotherapists (7%) and internists (6%). Ophthalmological, surgical and orthopaedic practices contributed an average of 2% each to the composition of the PN, while urological practices, rehabilitation facilities and hospitals make up a 1% share. The mean prevalence rates of the diseases underlying the QI are higher in the final quarter than in the baseline quarter.

Results of Cox regression (Proportional hazard models)

Table 3 shows the effects of compositional characteristics and QI of the PN on the risk of NHA. Effect estimates for the influence of individual predictors are not fully reported in Table 3, as they were only used for adjustment purposes and are not at the centre of the research question. Additional file 2 shows all effect estimators.

Compositional characteristics of the PN and risk of NHA

With regard to the composition of the PN, we found that the average number of comorbidities had a significant effect (HR > 2.5), which remains when adjusting for individual predictors for NHA. In terms of proportions of medical specialists, hospitals or therapists in a PN, no association could be observed in Model 3. Moreover, we observed an association between the number of providers within a PN and a slightly higher risk of NHA when not adjusting for individual predictors.

QoC of the PN and risk of NHA

Of the 67 QI, about two thirds (40 QI) show significant correlations with the risk of NHA (37 QI with significant p-values in both Model 2 and Model 3). Of these 37 QI, 19 QI are associated with a lower risk and 18 with an increased risk of NHA. Just

Table 2 Characteristics of the Provider Networks according to 2007-Q1 and 2016-Q4

	2007-Q1 (n = 406)	**2016-Q4 (n = 336)**
	If not stated otherwise mean proportion (standard deviation)	
Composition		
Therapists	0.45 (0.11)	0.47 (0.07)
General practitioners	0.13 (0.06)	0.12 (0.03)
Other disciplines	0.13 (0.05)	0.12 (0.04)
Multidisciplinary practices	0.08 (0.04)	0.08 (0.04)
Psychologists and psychotherapists	0.07 (0.03)	0.06 (0.03)
Internists	0.06 (0.02)	0.06 (0.02)
Ophthalmologists	0.02 (0.01)	0.02 (0.01)
Surgeons	0.02 (0.01)	0.02 (0.01)
Orthopaedics	0.02 (0.01)	0.02 (0.01)
Urologists	0.01 (0.01)	0.01 (0.00)
Rehabilitation facilities	0.01 (0.01)	0.01 (0.01)
Hospitals	0.01 (0.01)	0.01 (0.00)
Proportion of care-dependent people in provider network (cluster)	0.09 (0.06)	0.14 (0.04)
Number of providers in cluster (Mean, SD)	825.05 (982.07)	918.60 (1044.78)
Number of patients in cluster (PN-dataset) (Mean, SD)	16,334.37 (17,981.95)	16,636.75 (18,631.82)
Number of patients in cluster (cohort dataset) (Mean, SD)	288.36 (358.91)	26.67 (37.52)
Number of comorbidities (Mean, SD)	1.83 (0.18)	2.29 (0.19)
Quality of care indicators		
COC Asthma (Mean, SD)	0.78 (0.05)	0.60 (0.10)
SECON Asthma (Mean, SD)	0.88 (0.03)	0.82 (0.07)
UPC Asthma (Mean, SD)	0.86 (0.04)	0.76 (0.06)
COC COPD (Mean, SD)	0.79 (0.04)	0.70 (0.06)
SECON COPD (Mean, SD)	0.89 (0.03)	0.79 (0.04)
UPC COPD (Mean, SD)	0.87 (0.03)	0.81 (0.04)
COC Dementia (Mean, SD)	0.85 (0.04)	0.78 (0.05)
SECON Dementia (Mean, SD)	0.93 (0.02)	0.85 (0.03)
UPC Dementia (Mean, SD)	0.91 (0.03)	0.86 (0.03)
COC Diabetes (Mean, SD)	0.82 (0.04)	0.73 (0.07)
SECON Diabetes (Mean, SD)	0.92 (0.02)	0.80 (0.06)
UPC Diabetes (Mean, SD)	0.88 (0.03)	0.82 (0.05)
COC Heart Failure (Mean, SD)	0.78 (0.05)	0.68 (0.06)
SECON Heart Failure (Mean, SD)	0.90 (0.03)	0.80 (0.04)
UPC Heart Failure (Mean, SD)	0.86 (0.04)	0.80 (0.05)
Asthma: Prevalence	0.04 (0.01)	0.06 (0.02)
Asthma: Spirometry	0.33 (0.14)	0.40 (0.17)
Asthma: Inhalative medication	0.46 (0.10)	0.47 (0.08)
Asthma: ICS	0.28 (0.09)	0.25 (0.08)
Medication: PRISCUS	0.20 (0.03)	0.15 (0.02)
Medication: Beta-Blocker after myocardial infarction	0.55 (0.06)	0.65 (0.04)
Medication: ACE-inhibitor upon hypertension and renal insufficiency	0.45 (0.06)	0.38 (0.04)
Medication: ACE-inhibitor upon heart failure	0.47 (0.07)	0.39 (0.04)
Medication: Beta-blocker upon asthma	0.20 (0.06)	0.31 (0.05)
Medication: Electrolyte check upon diuretics	0.24 (0.06)	0.27 (0.07)
Medication: Polypharmacy	0.32 (0.04)	0.40 (0.04)
Ambulatory care sensitive hospital cases	0.03 (0.01)	0.03 (0.01)

Table 2 (continued)

	2007-Q1 (n = 406)	2016-Q4 (n = 336)
	If not stated otherwise mean proportion (standard deviation)	
COPD: Prevalence	0.09 (0.02)	0.13 (0.03)
COPD: Inhalative medication	0.43 (0.05)	0.47 (0.04)
COPD: Acute inpatient treatment	0.03 (0.01)	0.02 (0.01)
COPD: Respiratory therapy	0.04 (0.03)	0.08 (0.03)
COPD: Influenza vaccination	0.01 (0.01)	0.30 (0.08)
COPD: Specific beta-blocker therapy	0.34 (0.05)	0.43 (0.05)
COPD: Specific anticholinergic therapy	0.20 (0.04)	0.27 (0.04)
COPD: Oral corticosteroids	0.12 (0.04)	0.10 (0.02)
CVD: Prevalence hypertension	0.61 (0.06)	0.72 (0.05)
CVD: Medication for hypertension	0.05 (0.02)	0.05 (0.02)
CVD: Prevalence heart failure	0.02 (0.01)	0.06 (0.03)
CVD: Echocardiography upon heart failure	0.05 (0.14)	0.08 (0.19)
CVD: 12-lead ECG upon heart failure	0.10 (0.18)	0.11 (0.22)
CVD: ACE-inhibiter upon heart failure	0.57 (0.08)	0.62 (0.04)
CVD: Beta-blocker upon heart failure	0.48 (0.08)	0.58 (0.05)
CVD: Anticoagulant upon atrial fibrillation and heart failure	0.41 (0.10)	0.32 (0.10)
CVD: Referral to cardiologist upon heart failure	0.01 (0.06)	0.27 (0.32)
CVD: Acute inpatient treatment of heart failure	0.14 (0.06)	0.06 (0.03)
CVD: Apoplexy treatment in stroke unit	0.02 (0.01)	0.03 (0.02)
CVD: Platelet aggregation inhibitor upon stable chronic coronary heart disease	0.21 (0.05)	0.27 (0.05)
CVD: Statins upon coronary heart disease	0.29 (0.05)	0.46 (0.05)
CVD: Anti-hypertensive therapy upon coronary heart disease and hypertension	0.85 (0.02)	0.89 (0.02)
Dementia: Prevalence	0.04 (0.02)	0.07 (0.02)
Dementia: B12 and TSH	0.01 (0.02)	0.04 (0.04)
T2D: Prevalence	0.22 (0.05)	0.30 (0.05)
T2D: HbA1c	0.61 (0.08)	0.61 (0.15)
T2D: Ophthalmological examination	0.26 (0.08)	0.28 (0.04)
T2D: Fundus examination	0.16 (0.04)	0.14 (0.04)
T2D: Triglycerides and cholesterol	0.19 (0.09)	0.20 (0.09)
T2D: Hypertension, nephropathy and ACE-inhibitor or AT1-blocker	0.62 (0.10)	0.67 (0.04)
T2D: Serum-creatinine	0.57 (0.08)	0.56 (0.12)
Osteoarthritis: Prevalence	0.26 (0.04)	0.35 (0.05)
Osteoporosis: Prevalence	0.10 (0.02)	0.12 (0.02)
Prevention: Influenza vaccination	0.01 (0.01)	0.25 (0.08)
Prevention: Mammography	0.01 (0.03)	0.03 (0.04)
Prevention: Faecal occult blood test	0.02 (0.01)	0.01 (0.00)
Prevention: Men's cancer screening	0.07 (0.02)	0.07 (0.02)
Prevention: Skin-cancer screening	0.00 (0.00)	0.01 (0.00)
Depression: Prevalence	0.12 (0.03)	0.18 (0.03)
Depression: Anti-depressive pharmacotherapy	0.35 (0.05)	0.34 (0.04)

SD, standard deviation; COC, Continuity of Care Index; UPC, Usual Provider Index; SECON, Sequential Continuity of Care Index; T2D, type 2 diabetes mellitus; ICS, Inhalative Corticosteroids; PRISCUS, List of potential inadequate medication for the elderly; CVD, Cardiovascular disease; COPD, chronic obstructive pulmonary disease; B12, Vitamin B12; TSH, Thyroid Stimulating Hormone

Table 3 Effects of compositional characteristics and quality indicators of provider networks on the risk of nursing home admission

	Model 1: individual predictors	**Model 2: composition and quality of care indicators**	**Model 3: individual predictors, composition and quality of care indicators**
	Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors	**Hazard ratio [95% CI] adjusted for age, sex, level of care**	**Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors**
Sex female (Reference male)	1.24* [1.21; 1.28]	1.21* [1.18; 1.24]	1.24* [1.21; 1.28]
Level of care none (Reference level of care 1)	0.19* [0.15; 0.23]	0.17* [0.13; 0.20]	0.19* [0.15; 0.23]
Level of care 2 (Reference level of care 1)	1.25* [1.22; 1.28]	1.99* [1.94; 2.03]	1.26* [1.23; 1.29]
Level of care 3 (Reference level of care 1)	0.86* [0.83; 0.90]	1.77* [1.71; 1.85]	0.86* [0.82; 0.89]
Age	1.06* [1.05; 1.06]	1.04* [1.04; 1.04]	1.06* [1.05; 1.06]
Composition of the provider network			
Composition: general practitioners		1.04 [0.91; 1.19]	1.01 [0.88; 1.16]
Composition: ophthalmologists		1.18* [1.00; 1.38]	1.14 [0.97; 1.34]
Composition: surgeons		1.14 [0.98; 1.32]	1.08 [0.94; 1.25]
Composition: multidisciplinary practices		1.07 [0.94; 1.22]	1.04 [0.91; 1.19]
Composition: therapists		1.08 [0.95; 1.24]	1.04 [0.91; 1.19]
Composition: internists		1.10 [0.96; 1.26]	1.06 [0.93; 1.21]
Composition: orthopaedics		1.06 [0.92; 1.24]	1.03 [0.89; 1.20]
Composition: psychologists and psychotherapists		1.08 [0.94; 1.24]	1.04 [0.90; 1.19]
Composition: other disciplines		1.08 [0.95; 1.24]	1.04 [0.91; 1.19]
Composition: urologists		1.11 [0.94; 1.30]	1.07 [0.91; 1.26]
Composition: rehabilitation facilities		0.97 [0.85; 1.12]	0.96 [0.83; 1.10]
Composition: hospitals		1.01 [0.88; 1.16]	0.98 [0.86; 1.13]
Composition: logarithm of number of providers in provider networks		1.06* [1.00; 1.13]	1.05 [0.99; 1.11]
Composition: number of comorbidities		3.08* [1.36; 6.97]	2.95* [1.30; 6.68]
Quality of care indicators			
COC asthma		1.01* [1.00; 1.02]	1.01* [1.00; 1.02]
SECON asthma		1.00 [0.99; 1.01]	1.00 [0.99; 1.00]
UPC asthma		0.98* [0.96; 0.99]	0.98* [0.97; 0.99]
COC COPD		0.88* [0.84; 0.93]	0.89* [0.84; 0.94]
SECON COPD		1.06* [1.03; 1.08]	1.06* [1.03; 1.08]
UPC COPD		1.12* [1.04; 1.20]	1.11* [1.03; 1.19]
COC dementia		0.93* [0.89; 0.97]	0.93* [0.89; 0.97]
SECON dementia		1.01 [0.99; 1.03]	1.01 [1.00; 1.03]
UPC dementia		1.10* [1.04; 1.16]	1.10* [1.04; 1.16]
COC T2D		1.18* [1.11; 1.25]	1.17* [1.11; 1.24]
SECON T2D		0.96* [0.94; 0.98]	0.96* [0.94; 0.98]
UPC T2D		0.84* [0.78; 0.89]	0.84* [0.78; 0.90]

Table 3 (continued)

	Model 1: individual predictors	**Model 2: composition and quality of care indicators**	**Model 3: individual predictors, composition and quality of care indicators**
	Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors	**Hazard ratio [95% CI] adjusted for age, sex, level of care**	**Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors**
COC heart failure		0.98 [0.95; 1.00]	0.97* [0.95; 0.99]
SECON heart failure		0.99 [0.98; 1.00]	0.99 [0.98; 1.00]
UPC heart failure		1.05* [1.02; 1.08]	1.06* [1.03; 1.10]
Asthma: prevalence		0.99 [0.95; 1.02]	0.99 [0.95; 1.02]
Asthma: spirometry		1.00 [1.00; 1.00]	1.00 [1.00; 1.00]
Asthma: inhalative medication		1.00 [1.00; 1.01]	1.00 [1.00; 1.01]
Asthma: ICS		1.00 [1.00; 1.01]	1.00 [1.00; 1.01]
Medication: PRISCUS		0.93* [0.91; 0.95]	0.92*[0.91; 0.94]
Medication: beta-blocker after myocardial infarction		1.00 [0.99; 1.00]	0.99 [0.99; 1.00]
Medication: ACE-inhibitor upon hypertension and renal insufficiency		1.00 [0.99; 1.01]	1.00 [0.99; 1.00]
Medication: ACE-inhibitor upon heart failure		1.01* [1.00; 1.01]	1.01 [1.00; 1.01]
Medication: beta-blocker upon asthma		1.01* [1.00; 1.02]	1.01* [1.00; 1.02]
Medication: electrolyte check upon diuretics		1.00 [0.99; 1.01]	1.00 [0.99; 1.00]
Medication: polypharmacy		1.01 [1.00; 1.03]	1.01 [0.99; 1.03]
Ambulatory care sensitive hospital cases		0.98 [0.94; 1.02]	0.96 [0.92; 1.00]
COPD: prevalence		0.99 [0.96; 1.01]	0.98 [0.96; 1.01]
COPD: inhalative medication		1.02* [1.01; 1.03]	1.02* [1.01; 1.03]
COPD: acute inpatient treatment		1.01 [0.99; 1.04]	1.01 [0.98; 1.03]
COPD: respiratory therapy		0.99 [0.98; 1.00]	0.99 [0.98; 1.00]
COPD: influenza vaccination		1.00 [0.99; 1.01]	1.00 [0.99; 1.01]
COPD: specific beta-blocker therapy		0.98* [0.97; 0.99]	0.98* [0.98; 0.99]
COPD: specific anticholinergic therapy		0.98* [0.97; 0.99]	0.98* [0.97; 0.99]
COPD: oral corticosteroids		1.01* [1.00; 1.03]	1.02* [1.00; 1.03]
CVD: prevalence hypertension		0.98 [0.97; 1.00]	0.99 [0.97; 1.00]
CVD: medication for hypertension		0.98 [0.96; 1.01]	0.97 [0.95; 1.00]
CVD: prevalence heart failure		1.04* [1.02; 1.06]	1.04* [1.02; 1.06]
CVD: echocardiography upon heart failure		1.00 [1.00; 1.00]	1.00 [1.00; 1.00]
CVD: 12-lead ECG upon heart failure		1.00 [1.00; 1.00]	1.00 [1.00; 1.00]
CVD: ACE-inhibitor upon heart failure		1.00 [0.99; 1.00]	1.00 [0.99; 1.01]

Table 3 (continued)

	Model 1: individual predictors	**Model 2: composition and quality of care indicators**	**Model 3: individual predictors, composition and quality of care indicators**
	Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors	**Hazard ratio [95% CI] adjusted for age, sex, level of care**	**Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors**
CVD: beta-blocker upon heart failure		1.00 [1.00; 1.01]	1.00 [1.00; 1.01]
CVD: anticoagulant upon atrial fibrillation and heart failure		1.00* [0.99; 1.00]	1.00* [0.99; 1.00]
CVD: referral to cardiologist upon heart failure		1.00* [1.00; 1.00]	1.00* [1.00; 1.00]
CVD: acute inpatient treatment of heart failure		1.00 [1.00; 1.01]	1.00 [1.00; 1.01]
CVD: apoplexy treatment in stroke unit		1.03* [1.01; 1.04]	1.03* [1.02; 1.05]
CVD: platelet aggregation inhibitor upon stable chronic coronary heart disease		0.96* [0.95; 0.96]	0.95* [0.94; 0.96]
CVD: statins upon coronary heart disease		1.01 [1.00; 1.02]	1.01 [1.00; 1.02]
CVD: anti-hypertensive therapy upon coronary heart disease and hypertension		1.02* [1.00; 1.03]	1.02* [1.01; 1.04]
Dementia: prevalence		0.93* [0.90; 0.95]	0.91* [0.88; 0.94]
Dementia: B12 and TSH		1.00 [0.99; 1.00]	1.00 [0.99; 1.01]
T2D: prevalence		0.96* [0.95; 0.97]	0.96* [0.95; 0.98]
T2D: control of HbA1c		0.97* [0.97; 0.98]	0.97* [0.97; 0.98]
T2D: ophthalmological examination		0.99* [0.98; 0.99]	0.99* [0.98; 0.99]
T2D: fundus examination		0.99* [0.98; 1.00]	0.99* [0.98; 1.00]
T2D: triglycerides and cholesterol		1.00* [1.00; 1.01]	1.00* [1.00; 1.01]
T2D: hypertension, nephropathy and ACE-inhibitor or AT1-blocker		1.00 [1.00; 1.00]	1.00 [1.00; 1.00]
T2D: control of serum-creatinine		1.03* [1.02; 1.03]	1.03* [1.02; 1.04]
Osteoarthritis: prevalence		1.02* [1.00; 1.03]	1.02* [1.00; 1.04]
Osteoporosis: prevalence		1.00 [0.98; 1.03]	1.01 [0.99; 1.03]
Prevention: influenza vaccination		0.99 [0.98; 1.01]	1.00 [0.98; 1.01]
Prevention: mammography		0.99* [0.99; 1.00]	0.99* [0.99; 1.00]
Prevention: faecal occult blood test		1.12* [1.08; 1.16]	1.12* [1.09; 1.17]
Prevention: men's cancer screening		0.98* [0.97; 0.99]	0.98* [0.97; 0.99]
Prevention: skin-cancer screening		0.91* [0.87; 0.94]	0.90* [0.87; 0.93]
Depression: prevalence		0.96* [0.94; 0.98]	0.96* [0.94; 0.98]
Depression: anti-depressive pharmacotherapy		1.01* [1.00; 1.02]	1.01* [1.01; 1.02]
Model parameters			

Table 3 (continued)

	Model 1: individual predictors	**Model 2: composition and quality of care indicators**	**Model 3: individual predictors, composition and quality of care indicators**
	Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors	**Hazard ratio [95% CI] adjusted for age, sex, level of care**	**Hazard ratio [95% CI] adjusted for age, sex, level of care, individual predictors**
R^2	0.084	0.020	0.086
AIC	733,624.5	774,180.5	732,212.3
Random effects SD	0.320	0.375	0.374
N (person-quarters under risk)	1,622,695	1,622,695	1,622,695
Events (Nursing home admissions)	35,540	35,540	35,540

*Significance level α = .05. CI, confidence interval; SD, standard deviation; COC, Continuity of Care Index; UPC, Usual Provider Index; SECON, Sequential Continuity of Care Index; T2D, type 2 diabetes mellitus; ICS, Inhalative Corticosteroids; PRISCUS, List of potential inadequate medication for the elderly; CVD, cardiovascular disease; COPD, chronic obstructive pulmonary disease; B12, Vitamin B12; TSH, Thyroid Stimulating Hormone; R^2, R-squared; AIC, akaike information criterion

under half (17) of the QI significant in both models have an HR minimally above or below 1 (0.98 to 1.02) and the confidence intervals of ten QI include a value of 1.00 while showing a significant HR. No trend could be found in the direction of the association of significant HR for QI with desirable high values and the risk of NHA. This also holds true for significant HR for QI with desirable low values, although there is a lower risk for the proportion of people with PRISCUS-listed prescriptions in the PN.

With regard to the prevalence rates of selected diseases there is a significant reduction in the risk of NHA for higher proportions of people with T2D, depression and dementia. By contrast, there is a slight but significant increase in the risk of NHA if there are higher proportions of people with heart failure and osteoarthritis in the PN. Continuity of care measures have a significant effect, with the exception of the SECON for asthma, dementia and heart failure. There is a risk reduction for six continuity measures, whereas another six continuity measures increase the risk of NHA in both Model 2 and Model 3 without a clear disease-related trend.

There is no clear trend for significant HR in the eleven main areas of care, indicating a one-way risk-reducing or risk-increasing contribution of QoC in a specific area. Rather, there are differences in the contribution of individual QI to both reducing and increasing the risk of NHA. The highest reduction of the risk of NHA is shown for the share of people within a PN who underwent preventive skin cancer screening in accordance with the German cancer screening guideline (HR = 0.9 in Model 3). The highest risk increase (HR = 1.12 in Model 3) was also found in the context of prevention for the proportion of people with faecal occult blood tests according to the German cancer screening guideline.

Lastly, QI with significant HR in Models 2 and 3 with confidence intervals that did not exceed 1.00 can be summarised as follows: An association could be found between the proportion of persons with COPD and specific beta-blocker or anticholinergic treatment in PN and a lower risk of NHA. The proportion of people with acute stroke and treatment in a stroke unit increases the risk of NHA, and the proportion of people with

antiplatelet therapy in chronic stable coronary heart disease is associated with a lower risk. For people with T2D, the proportion of people with control of the HbA1c-value as well as an ophthalmological examination is associated with a lower risk, and in the area of prevention, in addition to the above-mentioned cancer screening measures, the percentage of men screened for the early detection of cancer in men is associated with a lower risk of NHA for people in need of care in the PN. The additional sensitivity analysis showed no substantial changes to the values of HR for the quality indicators and values of model parameters when only process indicators where included in the model.

The range of effect estimators for significant HR in Models 2 and 3 is narrow. A comparison of the model parameters shows a coefficient of determination of 0.020 for Model 2, which is unadjusted for individual predictors, and 0.086 for Model 3 with the independent variables of all levels. Model 3 has a slightly lower AIC (732,212.3) and a lower standard deviation (0.374) than Model 2 (AIC 774,180.5, SD 0.375).

Individual risk of NHA by affiliation with a PN

Figure 1 shows the random effects observed in the PN, depicting the individual's elevation of risk of NHA through affiliation with a PN. The Null Modell represents the HR of the 419 PN for a person's NHA without control for other influencing factors. In the illustrations of Models 1–3, the covariates as shown in Additional file 2 have been taken into account. As expected, average and median HR in all models are around 1. The middle 50% of PN in the Null Model show a HR between 0.85 and 1.19, in Model 3 between 0.81 and 1.21. While only slight changes are observed for the majority of PN, some outliers with PN that have an HR of over 2.5 are particularly evident in Models 2 and 3. In Model 3, HR range from 0.32 to 2.78. Care-dependent community-dwelling people in these PN thus have a 0.32-fold to 2.78-fold risk of NHA than on average, even when adjusting for compositional characteristics and QoC of the PN and the individual predictors (Fig. 1). Consequently, these factors did not account for the disparities in NHA between PN.

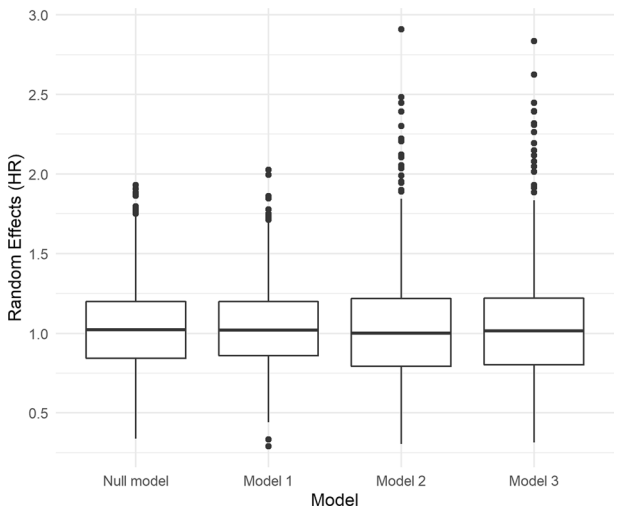

Fig. 1 Individual risk of nursing home admission by affiliation with a PN in the calculated models (N = 409)

Discussion

Key findings

The results of the proportional hazard models show considerable differentials in the risk for NHA in the identified PN. The majority of the quality characteristics of the PN, individual predictors as well as a few compositional characteristics of the PN show significant associations with the risk of NHA. Nevertheless, the direction of the effects is ambivalent, the coefficient of determination of all estimated models is low and the included independent variables do not attribute for the disparities in risk for NHA between PN.

To our knowledge, this study is the first to examine the contribution of the quality of outpatient primary medical care as an underlying determinant for aging in place of people in need of long-term care that includes functionally defined informal PN in the analyses. A direct comparison with empirical findings from other research is therefore not possible. The findings do not support the findings from a former population-level study (Domhoff et al. 2021) to be directly transferrable on the care-dependents individual risk for NHA. Rather, the results, as well as the methodological aspects of the study, should be critically reflected upon, especially with respect to their plausibility and practical relevance. In the following, we point out further implications for research and policy making.

Unexplained factors influencing the risk of NHA

The coefficient of determination is markedly low for all models, with the model including all variables (Model 3) only explaining 8.6% of the statistical variation in the risk for NHA. QoC in PN alone only contributing 2.0% towards this figure. This indicates that NHA are also explained by other factors not considered in this study. In addition to individual characteristics such as the presence of relatives providing care, the loss of a spouse or the individual nature of impairments to mobility (Hajek et al. 2015; Gaugler et al. 2009), further structural and compositional characteristics of the PN and QI must also be taken into account. For example, factors such as continuing education and staff training on age and care-specific issues can be assumed to have an influence on treatment decisions and access to care.

In our analysis, with the exception of the proportion of comorbidities in the PN, the compositional characteristics show no effect on NHA events. This suggests that the design of the care process itself is more important than the structure of the PN, as included in the presented study. At the same time, the associations between QoC of the PN and the risk of NHA remain, even when controlled for individual characteristics, indicating that they constitute a signficant influence. Subsequent research could also include further characteristics for the cooperation in PN, including the strength of ties between providers and preferably information on the actual cooperation between providers.

Size and structure of the PN

In Germany, there are basically no mandatory collaborations or networks in the health care system and the majority of GP are not part of any voluntary formal PN. In addition, the principle of freedom-of-treatment guides individual GP actions and the principle of

freedom-of-choice-of-provider guides patients' decisions to contact a specific provider. The average number of service providers per PN identified by the community detection in this study is higher (825 in the baseline quarter) than the average number of about 700 pyhsicians per cluster reported by von Stillfried et al. (2017) in their analysis of treatment patterns in GP-based PSN. This can be caused by the presented study also including other healthcare professionals such as physical, occupational, speech and language therapists, podologists, hospitals and rehabilitation facilities in the PN. On the one hand, this provides a more extensive representation of health services provider networks, but the degree and the arrangement of their actual cooperation remains unknown. Although the PN is larger than the direct care environment of specific individuals, it comprises their relevant care environment to a very high degree, as 80% of the medical services of the observation cohort came from their respective PN. On the other hand, the structure of the PN results from the patients' use of service providers and thus provides a demand-induced picture of real, but probably informal, and not necessarily intentional, cooperation in care. In contrast to analyses with regional demarcations, this method takes into account the actual radius of action or the utilisation behaviour, irrespective of whether relevant specialists are located in the same administrative areas.

Given the methodological decision in specifying PSN and performing community detection of the PN, different results for the compositional characteristics and QoC seem likely. With the high proportion of contacts patients obtained within their primary PN, a relevant question in this regard is whether PN may entail less providers to be able to reflect a scope, which would make actual knowledge of each other and resulting actual cooperation feasible.

Suitability of the included QI

The QI included do not represent an exhaustive set for mapping outpatient primary medical care quality for older people and people in need of long-term care. Available indicator sets that have been developed to assess QoC in elderly and care-dependent populations, such as the Assessing Care for Vulnerable Elders (ACOVE) set (Wenger et al. 2003), include other factors whose relation to NHA events is yet unknown, but which cannot be analysed by German SHI claims data, as information on the extent of specific symptoms or the content of medical consultations is not entailed in the data (cf. Neubauer et al. 2012). Nevertheless, the QI address age-typical diseases of relevance to the German health care system as reflected in their uptake in national treatment guidelines and disease management programmes. Methodologically, there was no aggregation of single QI towards a summarised QoC-score for a specific area of care. The procedure chosen for the joint presentation of diagnosis-specific QI in one area of care, such as diabetes care, is advantageous because it allows a clearer representation of the quality of treatment (Schrappe 2001) and, hence, the possibility of investigating the contribution of individual processes of the health care services to the NHA event. On the other hand, an overall QoC-score would provide an opportunity to both stratify or match PN and include fewer variables in the analysis in order to reduce the complexity of the model. While general rules of thumbs on the events per variable ratio such as a minimum of ten events per predictor variable (Vittinghoff and McCulloch 2007) or more are clearly satisfied by the more than 35,000 events during the observation period, the final Model

3 containing 133 variables is complex and the small-scale interpretation of single coefficients complicates the derivation of findings that are relevant to practice. Alternative approaches to variable selection in models aiming to include QoC as a structural or encompassing characteristic of PN should be evaluated by further research.

Implications for policy makers and practice

Considering implications for policy makers and practice that can be derived from the results, topics that are being discussed for formal PN in the context of quality evaluation, such as outcomes-based reimbursement (Vlaanderen et al. 2019), hardly provide suitable starting points when turning to QoC in informal PN. The detected differences in the risk for NHA between the PN rather point towards focusing on needs and QoC deficits of specific populations, such as community-dwelling elderly people in need of nursing care, from an individual service providers' perspective but also from the perspective of the general health care system.

This could be achieved by the development and application of evidence-based guidelines that also consider multimorbidity and patient-reported outcomes as well as by expanding population-specific monitoring activities based on SHI claims data to detect quality deficits and subsequently initiate quality improvement interventions. Considering the ambivalent results in regression analysis with theoretically favourable QI were associated with a higher risk of NHA, a discussion on the importance of single QI for care-dependent or multimorbid patients within the medical specialities should be encouraged. Reasons for favourable QI leading to adverse outcomes may as well lie in the omission of certain procedures for specific populations due to measures with higher priority or an assumed lack of neccessity (Davari et al. 2018; Faria et al. 2009).

Limitations to the internal and external validity of the results

It should be noted that the M2Q-criterion for identifying valid outpatient diagnoses (documentation of an assured outpatient diagnosis for at least two quarters of a year) was not applied to the assignment of persons to diagnosis groups for indicator calculation (Swart et al. 2014). However, a comparison of the diagnosis frequencies of selected variables with and without the application of the M2Q-criterion showed slight differences in the case numbers, so that it can be assumed that the results are not strongly distorted by the procedure chosen in the study. Similarly, SHI claims data naturally do not contain any information on other characteristics of people in need of long-term care associated with NHA, such as the composition of the individual social network and their specific housing situation (Hajek et al. 2015), so that these characteristics were not considered as individual predictors in the models. Lastly, as the receipt of benefits from German long-term care insurance or respectively the absence of benefits in 2005 was used to determine initial care-dependency in 2006, it cannot be ruled out that a small number of individuals in the observation cohort had been receiving benefits some time prior to 2005 and had lost the entitlement to benefit claims at some point in time but became eligible again in 2006. While it is known that the usage of data from a single SHI provider might prove a limitation to the representativeness of results of studies based on SHI claims data (Hoffmann and Icks 2012) this study used data from a SHI provider with a large share of the long-term care

dependent overall population. Among those insured by the AOK in 2020, there were 1.5 million people in need of long-term outpatient and day-care services. Which corresponds to 46.1% of all people in need of outpatient and day-care care in Germany (AOK-Bundesverband 2021).

Conclusion

Disparities in NHA between informal PN in Germany exist. Individual aspects and, to a lesser extent, the quality of outpatient primary medical care in informal PN play a role in how long people in need of long-term care can continue to live in their own homes. More research and interdisciplinary discourse is necessary regarding indicators for QoC for people in need of long-term care. Compared to countries where quality aspects of formal PN have been researched to a larger extent, this study contributes to revealing informal relationships between providers that constitute a special characteristic of the German health care system.

Furthermore, starting points for education of providers in a high quality treatment of selected populations and in formalizing care collaborations by joining voluntary provider networks for which the German legislation provides special measures and requirements on quality development and support, can be derived from the results. If the intrinsic motivation and professional self-image of service providers do not provide a sufficient incentive to participate in formal care collaborations, the participation in practice networks recognized by the German Association of SHI medical doctors in accordance with Section 87b (4) German Social Code, Book V which also provides for compensation adjustments, can pose an external incentive for participation in formal collaborations. Health care providers awareness should be raised for the evaluation of care processes in which they are involved and to emphasise the relevance of their role in networks of health care actors. If service providers are aware of the jointly achieved QoC, treatment processes for community-dwelling people in need of care can be strategically optimised.

It remains to be discussed, however, under which conditions the avoidance of a nursing home admission is not necessarily desirable, but rather the reasonable decision at that point in the care process and individual lifes of care-dependent people.

Abbreviations

ACO: Accountable care organisation; AIC: Akaike information criterion; BSNR: Site identification number; COPD: Chronic obstructive pulmonary disease; GP: General practitioner; HR: Hazard ratio; NHA: Nursing home admissions; PN: Provider network; PSN: Patient sharing network; Q1: Threshold value lower quartile; Q3: Threshold value upper quartile; QI: Quality indicator; QoC: Quality of care; SD: Standard deviation; SHI: Statutory health insurance; SLPA: Speaker-listener Label Propagation Algorithm; T2D: Type 2 diabetes mellitus.

Supplementary Information

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Additional file 1: Definition of the included indicators of health care quality.

Additional file 2: Effects of composition characteristics and quality indicators of provider networks on the risk of nursing home admission, including effect estimates for model 1.

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Author contributions
DP and KWO conceived the superordinate research project and applied for funding. DD and KS conceptualised this study, performed data processing, and conducted the statistical analyses. DD conducted the construction of the PSN. KS conducted the construction of the quality indicators included. SS conducted the construction of the individual predictors included. DP, DD, KS and SS worked together in selection of the included predictors and quality indicators and the preceding literature research. KS wrote the first draft of the manuscript and prepared the tables, DD was responsible for the revision of the manuscript and prepared the figure. All authors read and approved the final manuscript.

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Availability of data and materials
The data that support the findings of this study are available from the Scientific Institute of the AOK but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Scientific Institute of the AOK.

Declarations

Ethics approval and consent to participate
Informed consent is waived by the German federal regulation in §§ 67b & 75 German Social Code, Book X. The data protection officer of the AOK approved the use of the data for this study. The German Social Code regulates the usage of social data for the purpose of research. Use of the data without the informed consent of the persons included in this study is permitted by law, as only anonymous data were used. The authors declare that all methods were carried out in accordance with the Guideline for Good Practice in Secondary Data Analysis (GPS). This study follows the STROSA 2 reporting standard, specifically developed for analyses of secondary data and their specific requirements for the German health care system.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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