Frequency of Blood Pressure and Estimated Glomerular Filtration Rate Testing in Type 2 Diabetes Mellitus: A Retrospective Study with 43,509 Patients

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ABSTRACT

Background The goal of this study was to analyze the frequency of blood pressure (BP) and estimated glomerular filtration rate (eGFR) testing in type 2 diabetes mellitus (T2DM) patients followed in general and diabetological practices in Germany.

Methods The study included individuals who had at least two concultations due to T2DM diagnosis (ICD-10: E11) between January and December 2016. Patients were followed in 557 general and diabetological practices. The primary outcome was the frequency of BP and eGFR testing in T2DM patients in 2016. The association between several demographic and clinical variables and the odds of receiving ≥ 2 BP and ≥ 1 eGFR tests in the year 2016 was analyzed using multivariate logistic regression models.

Results A total of 43,509 individuals were available for analysis. The mean age of the population was 68.6 years (SD = 12.4 years). The mean number of measurements was 2.9 (SD = 3.5) for BP and 0.4 (SD = 1.1) for eGFR. 52.3 % of patients were tested at least twice for BP and 15.3 % of them at least once for eGFR in 2016. Older patients, individuals followed in diabetological practices, people receiving antihyperglycemic medications, and those affected by chronic conditions (i. e. hypertension, renal complications, or neuropathy) displayed higher odds of receiving ≥ 2 BP and ≥ 1 eGFR tests, whereas patients with a diabetes duration of > 1 year displayed lower odds.

Conclusions The frequency of BP and eGFR testing was low in T2DM patients in Germany in 2016. Several demographic and clinical variables were associated with this frequency.

List of abbreviations

BP	blood pressure
eGFR	estimated glomerular filtration rate
GLP-1 RA	Glucagon-like peptide-1 receptor agonist
OAD	oral antidiabetic drug
T2DM	type 2 diabetes mellitus

Introduction

Approximately 10.6 % of the German population suffered from diabetes in 2015, the majority of them diagnosed with type 2 diabetes mellitus (T2DM) [1]. Diabetes-associated costs in Germany were estimated at USD 35 billion, and the country was ranked third in the world in terms of health expenditure related to this condition [1].

T2DM is a chronic disorder frequently associated with high blood pressure (BP) and an increased cardiovascular risk overall [2–4]. T2DM and its complications are also known to have a major impact on kidney function [5–7], which can be assessed by measuring the estimated glomerular filtration rate (eGFR) [8]. In 2012, Cederholm and colleagues showed that high BP increased the risk of coronary heart disease, stroke, and mortality [9]. Another study found that the incidence of end-stage renal disease was higher in individuals

with diabetes than in those without this chronic condition [5]. Thus, optimized and personalized T2DM management requires frequent measuring of BP and eGFR. Based on the recommendations published by the German Disease Management Program (DMP) for diabetes [10], BP should be tested at least twice yearly and eGFR once per year in people affected by T2DM. In recent years, several authors have focused on the management of hypertension and chronic kidney disease in people with T2DM in Germany [11–13]. The proportion of diabetes patients reaching targeted BP levels has recently increased, but the prevalence of chronic kidney disease has remained high in this population [12]. In line with the work of Du and colleagues [12], Laxy et al. found an increase in the share of patients reaching BP targets, but detected no improvement in patients' BP monitoring carried out by physicians or themselves, and furthermore observed a decrease in the likelihood of being monitored for proteinuria [13].

Although these results are of great interest, little is know about the exact frequency of BP and eGFR monitoring in primary care practices. Therefore, the goal of the present study was to analyze the frequency of BP and eGFR testing in T2DM patients followed in German general and diabetological practices.

Methods

Database

The present retrospective study was based on the nationwide Disease Analyzer database (QuintilesIMS). This database contains demographic, clinical, and pharmaceutical variables anonymously obtained by QuintilesIMS from a nationwide sample of general and specialist practices [14]. The quality of these data is assessed on a regular basis, and it was shown by Becher and colleagues that the Disease Analyzer database is representative of German practices [14]. Finally, several diabetes studies have already been conducted using this database [15–18].

Study population

The study included individuals who received at least two T2DM diagnoses (ICD-10: E11): at least one between January and June 2016, and at least one between July and December 2016. Patients were treated and followed in 557 general and diabetological practices for which BP and laboratory values were available (about 50 % of all practices).

Study outcome and independent variables

The primary outcome was the frequency of BP and eGFR testing in T2DM patients in 2016. Several demographic data were available for analysis: age, sex, and type of care (general care versus diabetological care). Diabetes duration, annual frequency of BP and eGFR monitoring, and mean annual values of HbA1c, BP, and eGFR, were also included as clinical variables. Using practice records for the time period 2012–2016, nine different disorders were further included: coronary heart disease (I24, I25), hypertension (I10), hyperlipidemia (E78), myocardial infarction (I21, I22, I23), stroke including transitory ischemic attacks (TIA) (I63, I64, G45), peripheral arterial disease (I73.9, E11.3), renal complications (N18, N19, E11.2), neuropathy (E11.4) and retinopathy (E11.3). Finally, these types of glucose-lowering therapies were available for 2016: oral antidiabetic drugs (OAD) or glucagon-like peptide-1 receptor agonists (GLP-1 RA) only (Ephmra Anatomical Therapeutic Chemical [ATC] Classification System: A10H, A10J, A10K, A10L, A10M, A10N, A10P and A10S), insulin only (A10C), and both OAD/GLP-1 RA and insulin.

Statistical analyses

Descriptive analyses were obtained for all demographic variables and mean ± SDs were calculated for continuous variables. The association between the previous independent variables and the odds of being tested at least twice for BP and once for eGFR in the year 2016 was analyzed using multivariate logistic regression models. A p-value of < 0.05 was considered statistically significant. All analyses were carried out using SAS 9.3 (SAS Institute, Cary, NC, USA).

Results

The baseline characteristics of patients included in this retrospective study are shown in ▶ **Table 1**. A total of 43,509 individuals were available for analysis. The mean age of the population was 68.6 years (SD = 12.4 years). The three most common disorders were hypertension (77.8 %), hyperlipidemia (53.9 %), and coronary heart disease (28.0 %). Diabetes duration was longer than five years in almost 55 % of the population, and around one out of two patients received OAD or GLP-1 RA only. Finally, 48.9 % of individuals had a mean systolic BP between 121 and 140 mmHg, 62.3 % had a mean diastolic BP equal to or lower than 80 mmHg, and 44.0 % had a mean eGFR between 61 and 90 mL/min/1.73 m^2.

▶ **Table 2** displays the frequency of BP and eGFR testing in T2DM patients in 2016. The mean number of measurements was 2.9 (SD = 3.5) for BP and 0.4 (SD = 1.1) for eGFR. 52.3 % of patients were tested at least twice for BP and 15.3 % at least once for eGFR in 2016.

Patients aged 71–80 years (odds ratio [OR] = 1.15, 95 % confidence interval [CI]: 1.09-1.22) or > 80 years (OR = 1.17, 95 % CI: 1.09-1.25) and individuals followed in diabetological practices (OR = 1.98, 95 % CI: 1.87-2.10) were more likely to receive at least two BP measures than those aged ≤ 60 years and those followed in general practices, respectively (▶ **Table 3**). All comorbidities except stroke were positively associated with the likelihood of receiving at least two BP measurements (OR ranging from 1.09 to 1.51). Furthermore, patients being prescribed antihyperglycemic treatments had a higher chance of having ≥ 2 BP measurements than those receiving no antihyperglycemic medication (OR ranging from 1.21 to 1.55). Finally, a diabetes duration of 1–5 years was found to be a risk factor when compared to a diabetes duration of ≤ 1 year (OR = 0.85, 95 % CI: 0.78-0.92).

Patients aged > 60 years (OR ranging from 1.19 to 1.28) and those treated by diabetologists (OR = 1.51, 95 % CI: 1.39-1.62) were further found to have a higher chance of receiving at least one eGFR test in 2016 compared to those aged ≤ 60 years or treated by general practitioners (▶ **Table 4**). Six comorbidities were positively associated with an increased likelihood of being prescribed ≥ 1 eGFR tests: hypertension, hyperlipidemia, myocardial infarction, stroke, renal complications, and neuropathy (OR ranging from 1.09 to 1.38). Finally, individuals treated for T2DM (OR ranging from 1.20

▶ **Table 1** Baseline characteristics of the study population (Disease Analyzer Database, QuintilesIMS).

Variable	Number of patients
N	43,509
Demographic variables	
Age (Mean, SD)	68.6 (12.4)
< 60 years (N, %)	11,191 (25.7)
61–70 years (N, %)	11,612 (26.7)
71–80 years (N, %)	13,317 (30.6)
> 80 years (N, %)	7,389 (17.0)
Men (N, %)	23,311 (53.6)
Women (N, %)	20,198 (46.4)
Diabetological care (N, %)	9,948 (22.6)
General care (N, %)	33,661 (77.4)
Co-diagnoses documented in 2012–2016	
Coronary heart disease	12,198 (28.0)
Hypertension	33,868 (77.8)
Hyperlipidemia	23,430 (53.9)
Myocardial infarction	2,025 (4.7)
Stroke incl. TIA	2,725 (6.3)
Peripheral arterial disease	7,062 (16.2)
Renal complications	8,486 (19.5)
Neuropathy	12,153 (27.9)
Retinopathy	3,095 (7.1)
Glucose-lowering therapy in 2016 *	
No medication	4,057 (9.3)
OAD/GLP-1 RA only	21,827 (50.2)
Insulin only	6,823 (15.7)
OAD/GLP-1 RA + Insulin	10,802 (24.8)
Diabetes duration	
≤ 1 year	3,159 (7.3)
> 1- ≤ 5 years	16,460 (37.8)
> 5 years	23,890 (54.9)
Mean values in 2016	
HbA1c (Mean, SD)	7.2 (1.2)
Systolic blood pressure (mmHg)	
≤ 120	3,846 (14.4)
121–140	13,099 (48.9)
141–160	7,560 (28.2)
> 160	2,282 (8.5)
Diastolic blood pressure (mmHg)	
≤ 80	16,686 (62.3)
81–90	7,460 (27.9)
> 90	2,38 (9.9)
eGFR (mL/min/1.73 m²)	
> 90	1,788 (26.8)
61–90	2,933 (44.0)
31–60	1,945 (29.2)

* Patient can receive more than one class of antihyperglycemic drugs

GLP-1 RA: Glucagon-like peptide-1 receptor agonist; OAD: oral antidiabetic drug; eGFR: estimated glomerular filtration rate

▶ **Table 2** Frequency of blood pressure and estimated glomerular filtration rate testing in type 2 diabetes mellitus patients in primary care practices in Germany in 2016.

Variable	Blood pressure	Estimated glomerular filtration rate
Mean number of measurements (SD)	2.9 (3.5)	0.4 (1.1)
Share of patients with no measurement (%)	38.4	84.7
Share of patients with at least one measurement (%)	61.6	15.3
Share of patients with one measurement (%)	9.3	5.6
Share of patients with two measurements (%)	8.9	3.2
Share of patients with three measurements (%)	9.8	2.6
Share of patients with more than three measurements (%)	33.6	3.9

to 1.52) were more likely to have been given at least one eGFR test in 2016 compared to those without any antihyperglycemic medication, whereas those with a diabetes duration of > 1 year (OR ranging from 0.72 to 0.80) were less likely to be prescribed ≥ 1 eGFR test than those with a diabetes duration of ≤ 1 year.

Discussion

This German retrospective analysis including more than 43,500 patients showed that only 52 % of the population received at least two BP tests and 15 % at least one eGFR test in 2016. Older patients, individuals followed in diabetological practices, and people receiving antihyperglycemic medication had higher odds of receiving ≥ 2 BP and ≥ 1 eGFR tests when compared to younger patients, individuals followed in general practices, and people who were not receiving any antihyperglycemic treatment. By contrast, patients with a diabetes duration of > 1 year were found to be at a higher risk for low frequencies of testing than those with a diabetes duration of ≤ 1 year. Finally, several comorbidities, in particular hypertension, renal complications and neuropathy, increased the chance of receiving at least two BP tests and one eGFR measurement in 2016.

The major finding of this study is that an important proportion of T2DM patients do not receive a sufficient number of BP and eGFR tests in Germany. Based on the recommendations of the German DMP for diabetes, BP and eGFR should be measured at least twice and once per year, respectively [10]. To date, few authors have focused on the management of high BP and chronic kidney disease in T2DM in this country. In 2015, Du et al. investigated changes in T2DM care indicators in Germany [12]. The study, which included more than 800 individuals, estimated that there was a significant improvement in BP levels between 1997–1999 (< 130/80 mmHg: 32.0 %) and 2008–2011 (47.2 %). This positive trend was associated with an overall increase in the proportion of people with HbA1c < 7 % (32.4 % versus 65.4 %). Nonetheless, there was no significant change in the prevalence of comorbid chronic kidney disease between 1997–1999 (44.8 %) and 2008–2011 (40.3 %). These

▶ **Table 3** Association between demographic/clinical variables and the frequency of blood pressure measurements in type 2 diabetes mellitus patients (multivariate logistic regression model).

	Odds Ratio for at least two measurements per year *	p-value
Demographic variables		
≤ 60 years	reference	
61–70 years	1.03 (0.98-1.09)	0.259
71–80 years	1.15 (1.09-1.22)	<0.001
>80 years	1.17 (1.09-1.25)	<0.001
Men (vs. women)	1.01 (0.97-1.05)	0.090
Diabetological care (vs. general care)	1.98 (1.87-2.10)	<0.001
Co-diagnoses documented in 2012–2016		
Coronary heart disease	1.09 (1.04-1.15)	<0.001
Hypertension	1.50 (1.41-1.58)	<0.001
Hyperlipidemia	1.30 (1.24-1.36)	<0.001
Myocardial infarction	1.26 (1.14-1.40)	<0.001
Stroke incl. TIA	1.07 (0.98-1.17)	0.109
Peripheral arterial disease	1.27 (1.20-1.35)	<0.001
Renal complications	1.51 (1.42-1.60)	<0.001
Neuropathy	1.27 (1.21-1.34)	<0.001
Retinopathy	1.15 (1.06-1.26)	0.004
Antihyperglycemic therapy in 2016		
No antihyperglycemic medication	reference	
OAD/GLP-1 RA only	1.23 (1.14-1.32)	<0.001
Insulin only	1.21 (1.10-1.32)	<0.001
OAD/GLP-1 RA + Insulin	1.55 (1.43-1.68)	<0.001
Diabetes duration		
≤ 1 year	reference	
>1-≤5 years	0.85 (0.78-0.92)	<0.001
>5 years	1.03 (0.94-1.13)	0.507

* Adjusted by age, sex, diabetes duration, co-diagnoses, and antihyperglycemic therapy

GLP-1 RA: Glucagon-like peptide-1 receptor agonist; OAD: oral antidiabetic drug

▶ **Table 4** Association between demographic/clinical variables and the frequency of glomerular filtration rate measurements in type 2 diabetes mellitus patients (multivariate logistic regression model).

	Odds Ratio for at least one measurement per year *	p-value
Demographic variables		
≤ 60 years	reference	
61–70 years	1.19 (1.09-1.30)	<0.001
71–80 years	1.21 (1.10-1.32)	<0.001
>80 years	1.28 (1.15-1.43)	<0.001
Men (vs. women)	0.96 (0.90-1.03)	0.189
Diabetological care (vs. general care)	1.51 (1.39-1.62)	<0.001
Co-diagnoses documented in 2012–2016		
Coronary heart disease	1.01 (0.93-1.09)	0.834
Hypertension	1.38 (1.25-1.51)	<0.001
Hyperlipidemia	1.09 (1.02-1.17)	0.015
Myocardial infarction	1.26 (1.09-1.46)	0.002
Stroke incl. TIA	1.18 (1.04-1.35)	0.012
Peripheral arterial disease	1.01 (0.92-1.10)	0.894
Renal complications	1.37 (1.26-1.48)	<0.001
Neuropathy	1.27 (1.18-1.37)	<0.001
Retinopathy	1.01 (0.90-1.14)	0.860
Antihyperglycemic therapy in 2016		
No antihyperglycemic medication	reference	
OAD/GLP-1 RA only	1.20 (1.05-1.36)	0.006
Insulin only	1.45 (1.30-1.67)	<0.001
OAD/GLP-1 RA + Insulin	1.52 (1.32-1.74)	<0.001
Diabetes duration		
≤ 1 year	reference	
>1-≤5 years	0.72 (0.62-0.83)	<0.001
>5 years	0.80 (0.69-0.92)	0.003

* Adjusted by age, sex, diabetes duration, co-diagnoses, and antihyperglycemic therapy

GLP-1 RA: Glucagon-like peptide-1 receptor agonist; OAD: oral antidiabetic drug

findings suggest that, although T2DM care has already improved in recent years in Germany, the management and treatment of diabetes patients need further improvement in the next decade.

More recently, in 2016, Laxy and colleagues conducted an analysis of time trends in T2DM care in Germany between 2000 and 2014 [13]. In a study including more than 150 participants, the authors showed that the proportion of individuals with BP levels < 140/80 mmHg and HbA1c < 7 % increased significantly (OR equal to 6.14 and 1.56, respectively). Moreover, oral antihyperglycemic medication, BP lowering molecules, and lipid lowering treatments were more frequently prescribed in 2014 than in 2000, whereas the use of insulin decreased significantly throughout the same period. By contrast, the proportion of T2DM patients with at least one self-administered BP measurement did not increase between 2000 and 2014. Finally, there was also a decrease over time in the percentage of people who were monitored for proteins in their urine in the year prior to the inclusion. These findings, which corroborate the work of Du and colleagues [12], are promising but also call for a better management of T2DM in Germany.

Another important finding is that people followed by diabetologists were more likely to receive ≥ 2 BP and ≥ 1 eGFR tests in 2016 than those followed by general practitioners. In 2004, de Berardis and colleagues prospectively evaluated the quality of care and outcomes in 3,437 T2DM patients followed in general practices and diabetes clinics in Italy [19]. The authors showed that there was a significant difference in favor of diabetes outpatient clinics for the majority of measurements. Furthermore, participants visiting these clinics displayed better cholesterol levels than those followed in general practices, although there was no significant difference in terms of metabolic control or BP levels. More recently, a study conducted by Renard et al., which included 21,068 T2DM patients from Luxembourg, found that patients consulting only a general practi-

tioner displayed a lower adherence to the guidelines than those consulting a diabetologist [20]. These two studies suggest that diabetologists are more likely to follow national and international diabetes guidelines than general practitioners, and patients treated by diabetologists are more likely to be adherent and compliant than those treated by general practitioners.

We further found that people receiving antihyperglycemic medications were more likely to receive at least two BP and one eGFR tests in 2016, compared to those receiving no antihyperglycemic medications. There are two hypotheses to explain this finding. The most likely one is that patients who are not being treated with any antidiabetic drugs display less advanced and severe forms of the disease than those being prescribed OAD, GLP-1 RA and/or insulin. Therefore, physicians tend to evaluate BP and to prescribe eGFR tests less frequently in this low-risk population than in T2DM patients who are at a higher risk for diabetes complications. It is also possible that patients without any T2DM treatment are less adherent and compliant than those with at least one T2DM molecule, and thus have a lower chance of undergoing frequent BP and eGFR monitoring. Finally, patients without any T2DM treatment and followed by general practitioners could potentially be simultaneously monitored by diabetologists as well as their GPs. In this case, the information regarding prescriptions and BP/eGFR measurements documented by diabetologists would not be available in the database.

This study also estimated that the likelihood of being administered ≥ 2 BP and ≥ 1 eGFR tests was higher in patients over the age of 70 than in those aged 70 years or under. In 2013, Chew and colleagues showed, in a study including 70,889 participants, that age ≥ 60 years was an independent risk factor for diabetes-related complications despite achievement of glycemic and lipid targets [21]. One year later, in 2014, a U.S. study including more than 72,000 diabetes patients estimated that diabetes morbidity and mortality were positively associated with age [22]. As the development of diabetes-related complications is common in old age, general practitioners and diabetologists should consider regularly assessing BP and eGFR in the elderly. Finally, several comorbidities, such as hypertension, renal complications, and neuropathy, had a positive impact on the chance of receiving ≥ 2 BP and ≥ 1 eGFR tests in the year 2016. Since most of these disorders are diabetes complications [23–25], the presence of one of these diseases might lead to an increase in the annual number of BP and eGFR measurements. In light of this hypothesis, patients with longer diabetes duration should be more frequently tested for these two parameters than those with shorter diabetes duration. Nonetheless, opposite findings were showed in the present work, suggesting that factors not included in the regression models might have biased this particular result.

This study displays major limitations which should be mentioned at this point. Data regarding BP and eGFR measurements were not available in all practices, thus introducing a potential bias in subsequent analyses. Furthermore, there was a lack of information about factors which could have had an impact on the frequency of BP and eGFR monitoring (i. e. social support, quality of the physician-patient relationship, or number of previous diabetes-related hospitalizations). Finally, each patient was observed retrospectively in only one practice. If patients observed by GP, visited diabetologist—which is common in Germany—this visit would not be documented in the database accordingly. It can cause the underestimation of BP and eGFR testing frequency. The strengths of this work are the high number of patients and practices available for analysis. Another strength is the fact that this analysis was based on a nationwide database, allowing an estimation of T2DM management and quality of care in German primary care practices.

Conclusions

The frequency of BP and eGFR testing was low in T2DM patients in Germany in 2016. Several demographic and clinical variables were associated with this low frequency. Therefore, an increase in the annual frequency of BP and eGFR monitoring is needed in the future. This increase is important in order to improve the management and treatment of people with diabetes.

Author Agreement/Declaration

All authors have seen and approved the final version of the manuscript. We warrant that the article is the authors' original work, hasn't received prior publication and isn't under consideration for publication elsewhere.

Author Contributions

KK contributed substantially to the conception and design of the study, as well as the analysis and interpretation of the data, revised the manuscript with a critical eye and gave the final approval of the version to be published. AL and LJ contributed substantially to the conception and the design of the study, drafted and revised the manuscript, and gave the final approval of the version to be published.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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