Treatment quality indicators predict short-term outcomes in patients with diabetes: a prospective cohort study using the GIANTT database

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ABSTRACT

Objective To assess whether quality indicators for treatment of cardiovascular and renal risk factors are associated with short-term outcomes in patients with diabetes.

Design A prospective cohort study using linear regression adjusting for confounders.

Setting The GIANTT database (Groningen Initiative to Analyse Type 2 Diabetes Treatment) containing data from primary care medical records from The Netherlands.

Participants 15 453 patients with type 2 diabetes mellitus diagnosed before 1 January 2008. Mean age 66.5 years, 47.5% men.

Exposure Quality indicators assessing current treatment (CT) status or treatment intensification (TI) for patients with diabetes with elevated cardiovascular or renal risk factors.

Main outcome measures Low-density lipoprotein cholesterol (LDL-C), systolic blood pressure (SBP), and albumin:creatinine ratio (ACR) before and after assessment of treatment quality.

Results Use of lipid-lowering drugs was associated with better LDL-C levels (−0.41 mmol/litre; 95% CI −0.48 to −0.34). Use of blood pressure-lowering drugs and use of renin–angiotensin system inhibitors in patients with elevated risk factor levels was not associated with better SBP and ACR outcomes, respectively. TI was also associated with better LDL-C (−0.82 mmol/litre; CI −0.93 to −0.71) in patients with elevated LDL-C levels, and with better SBP (−1.26 mm Hg; CI −2.28 to −0.24) in patients with two elevated SBP levels. Intensification of albuminuria-lowering treatment showed a tendency towards better ACR (−2.47 mmol/mg; CI −5.32 to 0.39) in patients with elevated ACR levels.

Conclusions Quality indicators of TI were predictive of better short-term cardiovascular and renal outcomes, whereas indicators assessing CT status showed association only with better LDL-C outcome.

INTRODUCTION

Treatment quality indicators are part of indicator sets for measuring and improving quality of care.[1–3] Treatment indicators are often defined as the percentage of patients with a certain indication being treated with medication, such as patients with coronary heart disease who are treated with a β blocker or patients with albuminuria treated with angiotensin-converting enzyme (ACE) inhibitors.[3] These indicators measure treatment status in a cross-sectional manner. For cardiovascular risk factor control, particularly in patients with diabetes, clinical action indicators have been proposed as alternative indicators of treatment quality.[4–7] Such indicators assess whether treatment is started or intensified when indicated, for example, intensification of antihypertensive treatment in patients with elevated blood pressure levels. They target patients with an inadequately controlled condition, and may be more appropriate for capturing therapeutic inertia than indicators of treatment status.[8]

Treatment quality indicators are process-based measures which are used on the assumption that higher performance scores predict better patient outcomes.[7 9 10] This has yet to be proven for indicators of treatment status.[11 12] For action indicators, positive associations have been reported between indicators assessing intensification of glucose-lowering treatment and glycaemic control.[6 12–14] Evidence concerning indicators which assess treatment intensification (TI) for other cardiovascular risk

factors, however, is scarce.[15] Moreover, little is known about the sensitivity of treatment indicators to differences in population characteristics. Quality assessment may be affected by differences in patient case mix among providers, but adjusting for these differences is challenging.[7 16 17]

Previously, we investigated the predictive value of quality indicators of glucose-lowering treatment on glycaemic control in primary care patients with diabetes.[12] In this study, we assess whether quality indicators for treatment of other cardiovascular and renal risk factors, specifically high cholesterol, blood pressure and albuminuria, predict improvements in short-term outcomes of patients with type 2 diabetes. In addition, we assessed to what extent this relationship is sensitive to differences in patient characteristics.

METHODS

A prospective cohort study was conducted using data from 2008 to 2009 for patients with diabetes registered within 150 general practices (GPs) in the province of Groningen, The Netherlands. Associations were assessed between adequate performance according to 10 treatment quality indicators as binary independent variables and short-term outcomes, adjusting for baseline values and other confounders at patient level. Data from all patients with a diagnosis of type 2 diabetes before 1 January 2008 and managed by their general practitioner were included in this study. GPs were asked to confirm the documented diagnosis and date of diagnosis for all patients.

The data were collected from the Groningen Initiative to Analyse Type 2 Diabetes Treatment (GIANTT) database. This regional longitudinal database includes data for almost all primary care patients with type 2 diabetes (<1% opted out) managed by GPs who are contracted by a regional GP association to get reimbursed for diabetes care. In 2008, this association had contracted around 75% of all GPs in the region, who thereby consented to provide anonymised data related to their diabetes care. Routinely registered data are extracted from electronic medical records (EMRs) using validated procedures.[18] The data include prescription data, comorbidity and event data, routine laboratory test results, and physical examinations. All the GPs prescribe electronically using the EMR system. In The Netherlands, each patient is registered with a single GP who is gatekeeper, and obliged to keep adequate medical records regarding all relevant diagnostic and prescription information, including out-of-hours prescriptions made by other practitioners. Prescription data include information on the drugs' dosages, daily use and prescribed quantity, enabling the assessment of dosage increases and decreases, and switches between drugs and drug classes. Comorbidity and clinical events are documented on so-called 'problem lists' in the medical records by means of International Classification of Primary Care (ICPC) codes[19] or short text descriptions which were manually coded.

In The Netherlands, according to the Code of Conduct for the use of data in Health Research ('Gedragscode gezondheidsonderzoek' approved in 2004 by the Dutch College for Protection of Personal Data, taking into account Article 25 of the Dutch Act on the Protection of Personal Data) no ethics committee approval was needed for this research using data from anonymous medical records.

Quality indicators

We selected currently used or recommended quality indicators for the treatment of cardiovascular and renal risk factors in patients with diabetes from national indicator sets[1–3] and previous studies.[4 11] This included three measures of current treatment (CT) status and seven measures of TI (table 1). We evaluated the quality of treatment for the year 2008.

The indicators of CT status assess whether patients with diabetes are treated with lipid-lowering drugs, patients with elevated blood pressure levels are treated with blood pressure-lowering drugs, and patients with elevated albuminuria are treated with albuminuria-lowering drugs.[1–3] A patient was considered as receiving treatment when a prescription or refill for drug treatment was recorded within the last 3 months of the measurement year,[1] since a single prescription or refill can be issued for a maximum period of 3 months in The Netherlands.

For indicators of TI, various definitions and thresholds have been used.[11 14] We included thresholds as recommended in the Dutch guideline, that is, TI is recommended for patients with levels of low density lipoprotein cholesterol (LDL-C)>2.5 mmol/litre; systolic blood pressure (SBP)≥140 mm Hg; and albumin: creatinine ratio (ACR)≥2.5 mg/mmol (men) and ≥3.5 mg/mmol (women).[20] Since quality of care might be more at stake at higher thresholds,[7 21] we also included treatment indicators focusing on patients with more elevated risk factor levels of LDL-C >3.5 mmol/litre and SBP≥160 mm Hg. Finally, for blood pressure treatment indicators we included assessment of whether patients received TI after one or two elevated blood pressure levels.

We specified TI as starting a new drug class, addition of a new drug class, or dosage increase within 120 days after the initial elevated risk factor test in 2008. This grace period of 120 days was used to allow for the scenario when providers may give priority to one condition and postpone the decision regarding another until the next regular visit, which is conducted every 3 months for patients with diabetes in The Netherlands.

For lipid-lowering treatment, we included the classes statins, fibrates, bile acid sequestrants, nicotinic acid and derivatives, and other lipid-modifying drugs (omacor, ezitimib, ezetrol). The following five

Table 1 Definition of quality indicators

Quality indicators	Baseline factor	Definition of quality	Definition of short-term patient outcome
LDL-C			
Patients with diabetes who are treated with lipid-lowering drugs	First LDL-C test in 2008	Lipid-lowering drug prescription within last 3 months of 2008	First value of the LDL-C test in the period 21–120 days after the prescription date
Patients with diabetes with LDL-C>2.5 mmol/litre not on maximum treatment receiving lipid-lowering treatment intensification	First LDL-C test in 2008 if value>2.5 mmol/litre	Lipid-lowering drug start or dosage increase within 120 days after baseline test	First value of the LDL-C test in the period 21–120 days after the intensification date
Patients with diabetes with LDL-C>3.5 mmol/litre not on maximum treatment receiving lipid-lowering treatment intensification	First LDL-C test in 2008 if value>3.5 mmol/litre		
SBP			
Patients with diabetes with SBP≥140 mm Hg who are treated with blood pressure-lowering drug(s)	First SBP test in 2008 if value≥140 mm Hg	Blood pressure-lowering drug prescription within last 3 months of 2008	First value of SBP test in the period 14–120 days after the drug prescription date
Patients with diabetes with SBP≥140 mm Hg not on maximum treatment receiving blood pressure-lowering treatment intensification	First SBP test in 2008 if value≥140 mm Hg	Blood pressure-lowering drug start or dosage increase within 120 days after baseline test	First value of SBP test in the period 14–120 days after the intensification date
Patients with diabetes with SBP≥160 mm Hg not on maximum treatment receiving blood pressure-lowering treatment intensification	First SBP test in 2008 if value≥160 mm Hg		
Patients with diabetes with 2 sequential SBP≥140 mm Hg receiving blood pressure-lowering treatment intensification	First SBP test in 2008 with value≥140 mm Hg	Blood pressure-lowering drug start or dose increase within 120 days after baseline test	First value of SBP test in the period 14–120 days after the intensification date
Patients with diabetes with 2 sequential SBP≥160 mm Hg receiving blood pressure-lowering treatment intensification	First SBP test in 2008 with value≥160 mm Hg		
ACR			
Patients with diabetes with ≥2.5 mg/mmol (men) or ≥3.5 mg/mmol (women) treated with ACE inhibitors or ARBs	First ACR test in 2008 if value≥2.5 mg/mmol (men) or ≥3.5 mg/mmol (women)	ACE inhibitor or ARB drug prescription within last 3 months of 2008	First value of the ACR test in the 365-day period after the prescription date
Patients with ACR≥2.5 mg/mmol (men) or ≥3.5 mg/mmol (women) receiving ACE inhibitor or ARB treatment intensification	First ACR test in 2008 if value≥2.5 mg/mmol (men) or ≥3.5 mg/mmol (women)	ACE inhibitor or ARB start or dosage increase within 120 days after baseline test	First value of the ACR test in the 365-day period after the intensification date

ACE, angiotensin-converting enzyme; ACR, albumin:creatinine ratio; ARB, angiotensin II receptor blocker; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure.

treatment classes were included for blood pressure-lowering treatment: centrally acting antihypertensives, diuretics, β blockers, calcium channel blockers, drugs acting on the renin–angiotensin system. For albuminuria-lowering treatment, we specified intensification as the start or a dosage increase of an ACE inhibitor or an angiotensin II receptor blocker (ARB). The addition of a new drug class was not considered TI when there was a discontinuation in this or another class within 7 days, since this indicates a switch rather than intensification. Furthermore, a dosage increase was not considered TI when a discontinuation or dosage decrease occurred within 7 days in this or another class. Patients on maximum treatment were excluded from the intensification indicators, since there is no room for further intensification of drug treatment in such patients in the primary care setting. We defined maximum treatment according to the Dutch guideline for primary care.[20] For lipid-lowering treatment, the use of one or more drugs at maximum dosage was considered maximum treatment. For blood pressure-lowering treatment, the use of three or more drugs from different classes at maximum maintenance dosage was considered maximum treatment. For albuminuria-lowering treatment, prescribing of either an ACE inhibitor or an ARB at maximum dosage was considered maximum treatment. Dosage recommendations were obtained from the Dutch Pharmacotherapy Compendium.[22]

Outcomes

Outcomes were the levels of LDL-C, SBP and ACR, respectively, after the assessed provision of treatment. For this, we used the first value of LDL-C, the mean value of all available SBP values and the first value of ACR within predefined periods (table 1). The time windows for outcome assessment were based on a previous study assessing when effects from treatment can be observed in this population.[23] Thus, we assessed LDL-C within 21–120 days, SBP within 14–120 days and ACR within 365 days after the last prescription in 2008 or after the date of TI. The SBP

outcome was measured using the mean of the SBP values instead of a single SBP value, because blood pressure has a high intrapersonal variability. For the patients who had no treatment or TI, the outcome was assessed after a randomly generated date which was computed according to the observed distribution of treatment prescription dates of patients with treatment or TI. As baseline values we used the initial values of LDL-C, SBP and ACR in 2008.

Patient characteristics

Patient characteristics associated with the quality indicators can affect the relationship between these indicators and patient outcomes. The following characteristics were included as possible confounders and effect modifiers in our study:[17 24 25] general patient characteristics, that is, age, gender and duration of diabetes at baseline; comorbidity, including diabetes-related macrovascular, microvascular and mental comorbidity. Macrovascular comorbidity included transient cerebral ischaemia (K89), heart failure (K77), stroke (K90), atherosclerosis (K91), myocardial infarction (K75, K76), angina (K74), coronary artery bypass grafting, percutaneous transluminal coronary angioplasty and left ventricular hypertrophy. Microvascular comorbidity included diabetes neuropathy (N94.2), retinopathy (F83), renal failure (U99.1), renal hyperplasia/hydronephrosis (U99.2,3), terminal dialysis, kidney transplantation, diabetes foot and related amputations. Mental comorbidity was identified by any of the ICPC codes for mental disorders ranging from dementia (P70) to other mental disorders (P99).[19] Comorbidity was scored as the presence or absence in the 10 years preceding 1 January 2008.

Statistical analysis

Using independent t tests, we compared characteristics of patients receiving treatment according to a quality indicator with those not receiving the recommended treatment. We conducted multilevel linear regression with a random intercept to estimate the impact of the GP cluster level on the associations between each of the 10 quality indicators and short-term outcomes. The proportion of variance that was accounted for by the GP level was calculated for each model through intra-class correlation coefficients (ICCs). Since the ICC was less than 0.01 for all the tested associations, we present results based on multiple linear regression analysis that includes the risk factor outcome as a continuous dependent variable and the provision of treatment or TI (quality indicator) as binary independent variable at patient level. Patients with missing baseline or outcome values (loss to follow-up) were excluded from the analysis per quality indicator. Three models were built for each indicator to adjust for confounding. The first was the crude model, which only adjusts for the baseline risk factor level. The second was a model adjusted for general patient characteristics (gender, age, duration of disease). The third was a model also adjusting for different types of comorbidity (microvascular, macrovascular and mental comorbidity).

We examined confounding and effect modification of the patient characteristics on the tested associations. Confounding was investigated by looking at F-ratio changes and relative changes in estimated effect size of the associations after adding variables in the model. Effect modification was examined by testing for interactions between the quality indicator and other variables in the fully adjusted models.

We conducted several sensitivity analyses. We first tested whether using a single blood pressure outcome instead of the mean value in the outcome period would change our findings. Second, we checked whether excluding patients with an outcome value within the first month after treatment or TI would change the results. Furthermore, we adjusted the ACR models also for baseline haemoglobin A1c (HbA1c) level to take possible confounding of ACR measurement by high HbA1c levels into account. Finally, we included switching from one drug class to another for the indicators of lipid and blood pressure lowering TI, since in some of these cases switches might be made in reaction to poor risk factor control.

RESULTS

A total of 15 453 patients with diabetes were eligible for the study (table 2), after excluding 42 patients who did not have a confirmed date of diagnosis. Percentages of patients who did not have a baseline risk factor test in 2008 were 27.4% for LDL-C, 16.1% for SBP and 43.5% for ACR. These patients received less treatment in comparison to those with risk factor tests (figure 1, left panel). For uncontrolled patients, CT rates ranged from 43% to 79% whereas

Table 2 Patient characteristics at baseline

Patient characteristics	Number of patients with observation (%)	Mean±SD
Age (years)	15453	66.5±12.2
Male gender	7308 (47.5)	
Diabetes duration (years)	15453	2 (4; 8)*
HbA1c (%)	13608	7.0±1.0
LDL-C (mmol/litre)	11212	2.5±0.9
SBP (mm Hg)	12968	143±20.3
ACR (mg/mmol)	8734	4.8±14.2
Macrovascular comorbidity	2967 (19.2)	
Microvascular comorbidity	777 (5)	
Mental comorbidity	784 (5.1)	

*Median (25th and 75th percentiles).
ACR, albumin:creatinine ratio; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure.

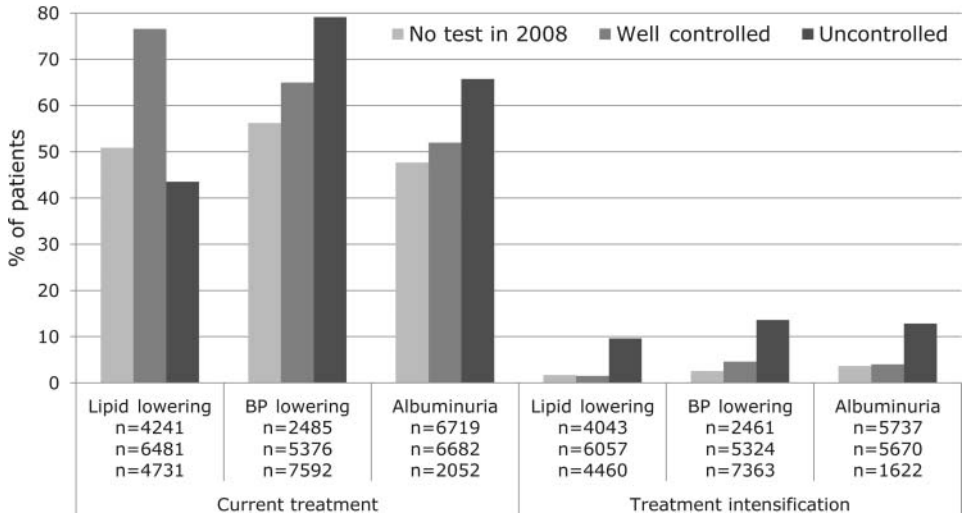

Figure 1 Percentage of patients who received current treatment and treatment intensification (TI) among those without a risk factor test, with well controlled baseline levels and uncontrolled baseline levels (numbers are given below the graphs), excluding patients already on maximum treatment for TI.

rates of TI within 120 days did not exceed 14% (figure 1, right panel). The numbers of patients with available baseline and outcome tests ranged from 539 for the indicator of TI in patients with highly uncontrolled LDL-C to 5815 for the indicator of treatments intensification in patients with uncontrolled SBP (table 3). The numbers of patients excluded for TI because of maximum treatment amounted to 5–6% of patients with elevated LDL levels, <2% of patients with elevated SBP levels and 23% of patients with elevated ACR levels. The numbers of patients with treatment switches were low, and including switching as TI did not change any of our findings (see online supplementary appendix A).

Patients receiving TI often had worse related baseline values in comparison to patients for whom intensification was indicated but not performed (table 3). There were no large differences in other clinical characteristics, but patients who received TI were on average 1–3 years younger than those not receiving intensification (see online supplementary appendix B).

Quality indicators related to LDL-C

Receiving any lipid-lowering treatment and receiving intensification of treatment when there was an LDL-C level>2.5 mmol/litre or >3.5 mmol/litre were significantly associated with improvement in LDL-C (table 3). Adjustment of the association between TI and LDL-C outcome for comorbidity explained significantly more variance in the LDL-C outcome ($p<0.05$), but had a negligible effect on the effect sizes of the observed associations (figure 2). No interactions were seen with baseline patient characteristics.

Quality indicators related to SBP

Receiving any blood pressure-lowering treatment and receiving intensification of such treatment when there was a single elevated SBP were not significantly associated with better SBP outcomes. Intensification of treatment after two SBP tests above 140 mm Hg was associated with the mean SBP outcome (table 3) but this association was lost when using a single SBP test or SBP mean within the period 31–120 days after date of TI as outcome (see online supplementary appendix A). The estimated change in SBP was greater when there was TI after two SBP tests above 160 mm Hg. Adjustment for patient characteristics explained significantly more variance ($p<0.01$) and changed the predictive effects of TI after two SBP tests above 140 and two SBP tests above 160 mm Hg on SBP outcomes from −1.26 to −0.95 and from −3.81 to −3.15 mm Hg, respectively (figure 2). No interactions were seen with baseline patient characteristics.

Quality indicators related to ACR

Receiving albuminuria-lowering treatment was not associated with an improvement in ACR but an interaction with baseline levels was observed. This interaction showed that in patients with a baseline ACR greater than 30 mg/mmol, receiving albuminuria-lowering treatment was associated with deterioration in ACR. For instance, current albuminuria-lowering treatment in a patient with a baseline ACR of 10 mg/mmol was not associated with a change in ACR (−2.6 mg/mmol; 95% CI −6.4 to 1.3), while in patients with a baseline ACR of 40 mg/mmol CT was associated with a significant deterioration in ACR (7.1 mg/mmol; 95% CI 2.2 to 12.0). Receiving TI showed a tendency towards an improvement in ACR (table 3). Adjustment for patient characteristics explained significantly more variance in ACR outcome ($p<0.01$) and decreased the predictive effect from the TI from −2.47 to −2.02 mg/mmol (figure 2). Adjusting for baseline HbA1c values did not change the findings (see online supplementary appendix A).

Table 3 Numbers of patients with and without the recommended current treatment (CT) and treatment intensification (TI), their mean baseline and outcome levels, and the effect sizes (with 95% CIs) of the associations between quality indicators and patient outcomes

Label of indicator	Quality indicators (unit of baseline and outcome measure)	Treated according to quality indicator (yes/no)	Number of patients (with/without measured treatment)	Mean baseline level	Mean outcome level	Estimated change in risk factor level‡ (95% CI)
LDL CT	Treated with lipid-lowering drugs (mmol/litre)	Yes No	2070 365	2.4* 2.6*	2.3† 2.8†	**−0.41 (−0.48 to −0.34)**
TI if LDL-C>2.5	Treatment intensification in patients with LDL-C>2.5 (mmol/litre)	Yes No	192 1230	3.9* 3.4*	2.6† 3.2†	**−0.82 (−0.93 to −0.71)**
TI if LDL-C>3.5	Treatment intensification in patients with LDL-C>3.5 (mmol/litre)	Yes No	117 422	4.4 4.3	2.8† 3.7†	**−0.93 (−1.11 to −0.76)**
CT if SBP≥140	Treated with blood pressure-lowering drugs in patients with SBP≥140 (mm Hg)	Yes No	4610 282	157 157	152 151	1.25 (−0.81 to 3.32)
TI if SBP≥140	Treatment intensification in patients with SBP≥140 (mm Hg)	Yes No	868 4947	165* 154*	153† 148†	−0.04 (−1.19 to 1.11)
TI if 2xSBP≥140	Treatment intensification in patients with 2 sequential SBP≥140 (mmHg)	Yes No	932 4698	165* 155*	154† 152†	**−1.26 (−2.28 to −0.24)**
TI if SBP≥160	Treatment intensification in patients with SBP≥160 (mm Hg)	Yes No	524 1675	176* 170*	158 156	−0.58 (−2.20 to 1.13)
TI if 2xSBP≥160	Treatment intensification in patients with 2 sequential SBP≥160 (mm Hg)	Yes No	580 1042	177* 171*	161 163	**−3.81 (−5.36 to −2.27)**
CT if ACR is elevated	Treated with ACE inhibitor or ARB in patients with ACR≥2.5 (men) or ≥3.5 (women) (mg/mmol)	Yes No	1027 120	16.9 16.4	15.8 15.7	−0.36 (−4.11 to 3.40)
TI if ACR is elevated	Treatment intensification in patients with ACR≥2.5 (men) or ≥3.5 (women) (mg/mmol)	Yes No	140 964	15.8 14.8	11.8 13.6	−2.47 (−5.32 to 0.39)

Bold text indicates significant associations (linear regression).
*Significant baseline differences (independent t test).
†Significant outcome differences (independent t test).
‡Estimated changes in risk factor level for the associations not adjusted for patient characteristics and comorbidity.
ACE, angiotensin-converting enzyme; ACR, albumin:creatinine ratio; ARB, angiotensin II receptor blocker; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure.

DISCUSSION

Our study showed that quality indicators of TI were predictive of better short-term clinical outcomes in patients with diabetes. For blood pressure treatment, this was only the case for intensification in patients with repeatedly elevated SBP levels. However, quality indicators assessing CT status showed only a predictive association for lipid-lowering drugs. For blood pressure-lowering treatment and albuminuria-lowering treatment, no associations were found with better short-term outcomes. Adjustment for general patient characteristics and comorbidity had little effect on the observed associations.

We specifically focused on treatment quality indicators of cardiovascular and renal risk factors in patients with diabetes. Such indicators are included in several quality indicator sets and the treatment quality of these risk factors needs attention. Lower treatment quality has been observed for patients with diabetes with elevated blood pressure, cholesterol or ACR levels than for patients with poor glycaemic control.[23 26] We included a large unrestricted cohort of primary care patients with diabetes from the north of The Netherlands. These patients are relatively well controlled regarding their HbA1c level, which is consistent with findings from another large Dutch cohort of patients with diabetes.[27] These patients belong mostly to the European Continental Ancestry Group which might influence the response to drug treatment and thus the strength of the studied associations. For some indicators, only a limited number of patients were included, which decreased the power to detect significant associations. When assessing TI, we excluded patients already on maximum treatment at baseline. Inclusion of such patients would classify them as being not intensified whereas other actions may have been conducted in these patients which were not assessed with the quality indicators, thereby falsely decreasing the associations observed. We observed differences in baseline risk factor levels and age of patients with and without CT and TI for several indicators. Our conclusions are therefore based on the models adjusting for these factors. Due

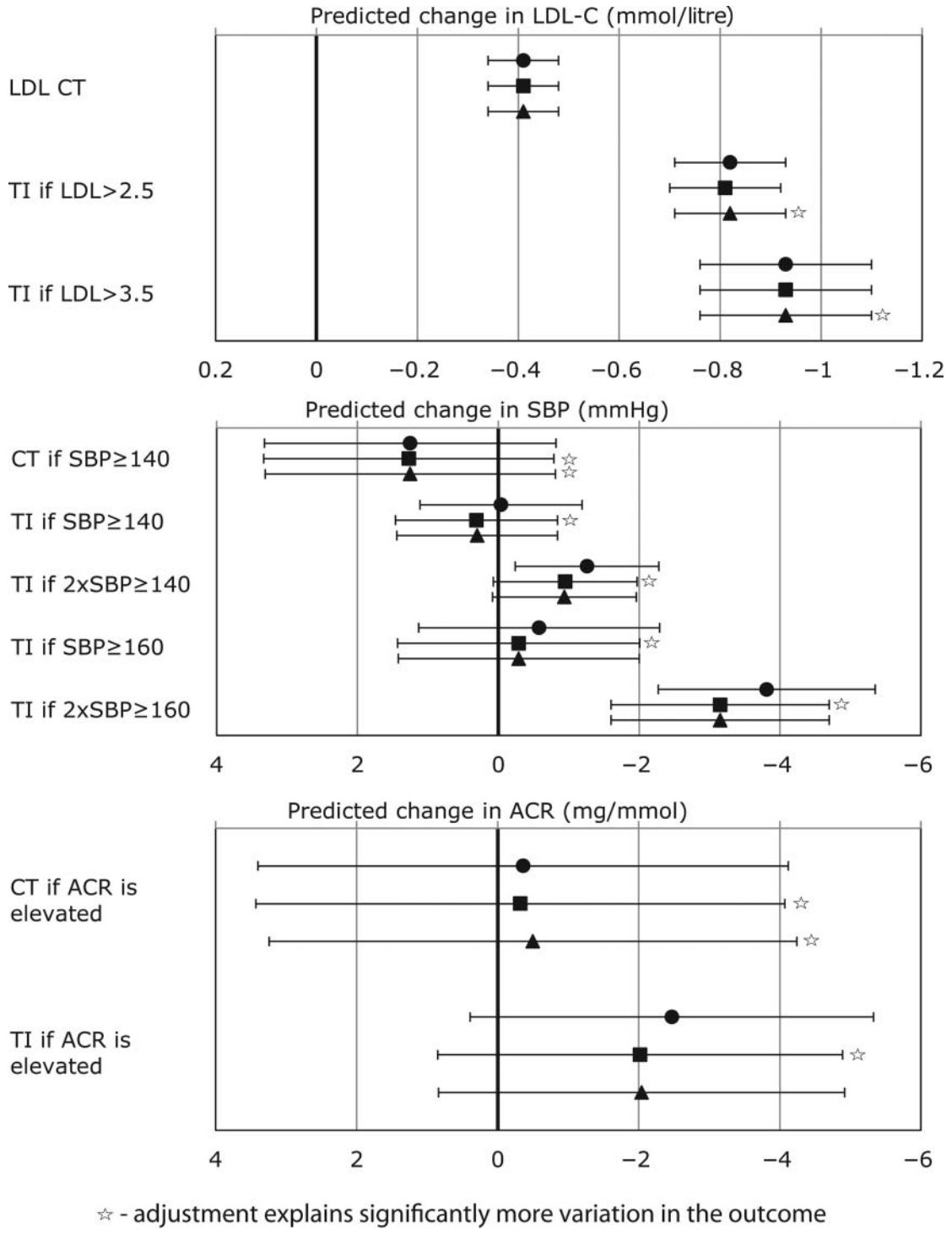

Figure 2 Estimated changes (with 95% CIs) in risk factor levels observed per quality indicator, where for each indicator the crude estimate is presented (●), the one adjusted for general characteristics (■), and the change adjusted also for comorbidity (▲). The indicator labels correspond with table 3. ACR, albumin:creatinine ratio; CT, current treatment; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TI, treatment intensification.

to differences in regression towards the mean effects, however, differences in risk factor levels of patients receiving the recommended care could be larger than in those not receiving such care. This implies that the associations for these quality indicators might be over-estimated. However, we did not have information about patients' non-adherence. This may lead to underestimations of the association between treatment quality indicators and risk factor levels. The data were obtained from EMR using validated procedures.[18] Although these records commonly contain all test results and prescriptions issued in GPs, occasional

tests or drugs prescribed by specialists might have been missed. Because we included only patients who were primarily managed by their general practitioner, this would be uncommon in our study population.

Our study showed that indicators of CT status have limited predictive value for short-term patient outcomes. These indicators assess CT in a cross-sectional manner, that is, whether patients with a specific indication receive treatment during or at the end of the measurement period. These indicators are relatively easy to calculate and are included in several quality indicator sets.[1–3] For glucose-lowering treatment, it was found that such an indicator of treatment status was not associated with better glycaemic control.[12] The predictive value for treatment indicators of other risk factors, however, was previously not known.[11] In our study, only lipid-lowering treatment assessed by means of such a simple treatment indicator was associated with better cholesterol outcomes. The absence of an association between blood pressure-lowering or albuminuria-lowering treatment status and clinical outcomes may seem surprising, but is the result of including patients without further TI and who may deteriorate. The deterioration in albuminuria observed among treated patients with highly elevated baseline albuminuria levels might indicate a more progressive nature of these advanced cases that are less responsive to treatment.

Our findings regarding indicators of TI are consistent with previous studies, showing predictive association for cholesterol-lowering[14] but not for blood pressure-lowering TI, when assessed after a single elevated SBP value.[28] Previously, it was also observed that TI indicators for glucose control predicted better glycaemic outcomes.[12] What our study adds is that we also evaluated TI in patients with repeated and highly elevated risk factor levels, and found that these did predict improvements in blood pressure and cholesterol control, respectively. Furthermore, we observed a trend in predicting better outcomes for intensifying albuminuria-lowering treatment. Of note is our finding that patients with and without TI after an elevated blood pressure level improved to similar outcome values. Thus, the change in blood pressure and possibly the clinical need appears to be larger for those receiving TI. This difference in clinical need is not fully captured when using indicators with cutoff levels.

Our findings demonstrate that there is a need to reconsider some of the currently used treatment indicators, as has been proposed by others.[7] Generally, the value of indicators that look at treatment status in a cross-sectional manner appeared to be limited. For assessing the quality of lipid-lowering treatment a simple treatment indicator may suffice. However, treatment indicators assessing 'patients with albuminuria treated with ACE-inhibitors'[3] or 'patients with elevated blood pressure receiving treatment' were not predictive of better short-term patient outcomes. They could be more indicative of disease severity in the assessed patient population than of better quality of care. We have shown that quality assessment using indicators of TI was more meaningful than the simple treatment indicators in terms of estimated patient outcomes. These clinical action indicators are not yet common for quality assessment since they require detailed prescription and clinical data and may be difficult to calculate. The growing use of EMR, however, presents the opportunity to perform this kind of assessment in the near future.[7] For blood pressure-lowering treatment there is an additional requirement, that is, one should focus on assessing TI in patients with repeated, not single, elevated levels.

In this study, we only looked at short-term patient outcomes. Although they are considered as predictors of morbidity and mortality, testing the direct relationship of treatment quality indicators to hard outcomes is needed.

Contributors GS researched data, contributed to the discussion and wrote the manuscript. JV researched data, contributed to the discussion and reviewed/edited the manuscript. DZ contributed to the discussion and reviewed/edited the manuscript. FHR contributed to the discussion and reviewed/edited the manuscript. PD researched data, contributed to the discussion and reviewed/edited the manuscript.

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Competing interests There were no financial relationships with any organisations that might have had an interest in the submitted work in the previous 3 years, and no other relationships or activities that could appear to have influenced the submitted work.

Ethics approval In The Netherlands, according to the Code of Conduct for the use of data in Health Research ('Gedragscode gezondheidsonderzoek' approved in 2004 by the Dutch College for Protection of Personal Data, taking into account Article 25 of the Dutch Act on the Protection of Personal Data), no ethics committee approval was needed for this research using data from anonymous medical records.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The data are stored within GIANTT database at the University Medical Center Groningen, and are available to the research team members who have been granted access to the required data by the GIANTT steering committee, including representatives from the data suppliers and patient organisation. No consent for data sharing with

other parties was obtained but the corresponding author may be contacted to forward requests for data sharing.

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