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The rational treatment of diabetes mellitus in older adults: The adequacy of treatment decisions based on individualized glycemic targets in primary and tertiary care

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ABSTRACT

Objectives: To access the adequacy of treatment decisions in accordance with current recommendations for individualizing glycemic targets in primary and tertiary care.
Methods: This multicenter cross-sectional study was conducted with a cohort of older type 2 diabetes patients from southern Brazil. Inclusion criteria were age over 65 years, having a previous diagnosis of type 2 diabetes (according to ADA criteria) and having at least two consultations registered in the medical records within one year. The primary outcome was the adequacy of treatment decisions according to pre-established HbA1c targets, which was compared with the complexity of care. The ideal HbA1c targets were: (1) 7–7.5% for an estimated life expectancy >10 years; (2) 7.5–8% for a life expectancy of 5–10 years; (3) 8–8.5% for a life expectancy <5 years. For analysis, the chi-square test was used for categorical variables and the *t*-test was used for continuous variables.
Results: Overall, 49.1% and 50.3% of the patients in the primary and tertiary care groups, respectively, received inadequate management. In patients whose HbA1c level was over target, the treatment was intensified in 46.3% and 51.2% of the primary and tertiary care groups, respectively ($p = 0.57$). In patients whose HbA1c level was under target, treatment was de-intensified in 5.9% and 26.2% in the primary and tertiary care groups, respectively ($p < 0.01$).
Conclusion: Treatment changes based on individualized glycemic targets do occur in a minority of patients, which reflects the need for new strategies to facilitate individualized treatment targets and optimize the treatment adequacy in older adults.

1. Introduction

Managing diabetes mellitus in older patients is particularly challenging since it requires special care and extra attention. It is estimated that about a fifth of the general population will be over 65 years of age by the year 2050.[1] The diabetes prevalence in individuals in this age group is up to 19%, and Brazil has the fifth highest prevalence worldwide of older adults with diabetes.[2] In addition to being susceptible to all the usual complications of diabetes, this group is more likely to suffer from adverse treatment effects, considering their frailty and decreased homeostatic capacity.[3,4] Hypoglycemia, which is responsible for 40% more hospitalizations than hyperglycemia, increases the risk of falling and is related to cognitive deterioration, morbidity and mortality in this group of patients.[5–8] Among adults over 65 years of age, insulin and oral antidiabetic agents are second only to warfarin and antiplatelet agents as iatrogenic causes of hospital admission.[9]

Several studies have attempted to determine the ideal hemoglobin A1c (HbA1c) target for patients with diabetes.[10–13] These results are difficult to extrapolate to older adults, considering that their life expectancy may be shorter than the time necessary to benefit from more rigorous glycemic control. Thus, beginning in 2014 the American Diabetes Association (ADA) made therapeutic targets more flexible, and current guidelines recommend that the HbA1c target for these patients should be individualized, accepting HbA1c values up to 8.0–8.5% for patients with multiple chronic illnesses, a greater risk of hypoglycemia and a shorter life expectancy.[14,15] Although other societies also recommend flexible therapeutic targets, there is no consensus on an adequate target for older patients. The American College of Physicians recommends HbA1c levels between 7.0 and 8.0% for all patients with type 2 diabetes, including more flexible targets for patients with a life

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expectancy <10 years.[16] The Diabetes Task Force of the European Society of Cardiology and the European Association for the Study of Diabetes, on the other hand, consider <8.0 or ≤9.0% adequate targets for older patients who are more frail and have multiple comorbidities.[17] Nevertheless, a recent study showed that in practice, older patients with worse health receive insulin more often and their treatment is less de-intensified when their HbA1c level falls below 8.4%.[18]

Establishing the appropriate glycemic target for each patient is always a difficult task. Apart from complications, the guidelines recommend that the treatment strategy should be modified (intensified or de-intensified) based on individualized targets according to the patient's clinical characteristics and life expectancy.[15–17] However, identifying patients who could benefit from more flexible glycemic control depends on the physician's experience and his capacity to see the patient as a whole, considering clinical performance, the risks of current treatment and social support. Until now, no studies have assessed whether the guidelines for individualizing treatment in older patients according to estimated life expectancy have been appropriately followed at different levels of health care. This study aims to assess the adequacy of treatment decisions in older patients in accordance with current recommendations in primary and tertiary care.

2. Methods

2.1. Study design and setting

This multicenter cross-sectional study was conducted to evaluate the adequacy of treatment decisions in a cohort of older patients with type 2 diabetes mellitus. Data from the electronic or paper medical records were used to select older patients with diabetes who were under regular follow-up at the endocrinology service of two university hospitals and two primary health care units in southern Brazil. All included participants received outpatient care, and there were no care/nursing homes representatives. We selected patients aged 65 years or older who had medical consultations at these services between January 19, 2015 and March 18, 2020. This period was chosen to coincide with the new flexible glycemic targets suggested by the ADA beginning in 2014. For the selection, an initial identification of patients diagnosed with type 2 diabetes who met the inclusion criteria in each unit was performed. Afterwards, the list of participants to be included in the study was selected, in a simple random way, by the number on the medical record. The initial identification was generated electronically based on the records of each institution.

After selecting the patients, a review of the electronic and paper medical records was performed to collect personal information, clinical data and laboratory tests from each consultation. All information collected from tertiary care was obtained from electronic medical record. For primary care services, electronic records systems were implemented more recently, starting in 2017. Data on medical appointments, personal information, and laboratory tests were obtained from paper records (manually written) when consultations were carried out between 2015 and 2017 in primary care. Two independent researchers (J.A and J. S) were responsible for collecting the data and preparing the database. For patients who made multiple visits, the treatment decision reported at the second consultation after January 2015 was defined as the criterion for analysis. The second consultation was selected due to the fact that most guidelines recommend modifying the treatment strategy when the target HbA1c is not reached after three months of treatment, which is the average interval between the first and second visit in one year.

In Brazil, the level of care where each patient will be followed up is stratified based on the severity of the disease and the need for resources. Thus, most patients, who are considered to be "low complexity", remain in primary care during the management of their disease. In primary care centers, patients are seen by general practitioners and family doctors, mainly. Tertiary care, on the other hand, represents more complex care, represented mainly by large hospitals. In Brazil, outpatient specialist care is usually organized in association with hospital care. Facilities vary in scope and organization, ranging from stand-alone specialized ambulatory care facilities to polyclinics with several ambulatory specialities. In our study, we included outpatient care from two endocrinology services linked to university hospitals in southern Brazil (representative from tertiary care). The services provided at those centers are performed mainly by endocrinology and metabolism residents and endocrinologists. The protocol that guides the referral of primary care to specialized care suggests that patients using insulin in a dose higher than one unit per kilogram of weight, patients with the presence of chronic diabetic complications (especially chronic kidney disease in stages 4 and 5) or patients who use insulin as their main medication before the age of 40 (suspected type 1 diabetes) should be referred.[19]

2.2. Participants

Patients with type 2 diabetes who were followed up for at least one year in a tertiary hospital or a primary health care unit were selected to participate in this study. Inclusion criteria were age over 65 years, having a previous diagnosis of type 2 diabetes (according to ADA criteria) and having at least two consultations registered in the medical records within one year between January 19, 2015 and March 18, 2020. Patients whose diabetes type was not well established or whose primary reason for follow-up was an endocrine disease other than diabetes were excluded.

2.3. Variables and data sources

The primary outcome assessed in this study was the adequacy of the treatment decision (optimizing treatment by increasing the dose of current medications or adding a new drug vs. maintaining treatment vs. de-intensifying treatment by reducing the dose of current medications or withdrawing drugs) according to different pre-established HbA1c targets, and the treatment was compared with the complexity of care.

The ideal HbA1c target and the treatment goal defined for each patient were determined according to Lipska et al.,[20] which included the following steps:

First step: determining the individualized glycemic control target according to the following definition: for older adults with an estimated life expectancy >10 years, an HbA1c between 7 and 7.5% was considered ideal; for older adults with an estimated life expectancy of 5–10 years, an HbA1c between 7.5 and 8% was considered ideal; for older adults with an estimated life expectancy of <5 years, an HbA1c between 8 and 8.5% was considered ideal.[21] Based on Kiistler et al.,[22] we adapted the strategy and estimated the life expectancy of each patient according to age and Deyo-Charlson comorbidity index score (CCIS).[23] This score categorizes patients into three subgroups based on the score for each comorbidity and age: life expectancy >10 years: younger and healthier patients (age between 65 and 79 years and CCIS 1); life expectancy of 5–10 years: younger patients who are slightly ill (age between 65 and 79 years and CCIS 2–3); life expectancy < 5 years: sicker and older patients (age between 65 and 79 years and CCIS ≥ 4 or age ≥80 years and CCIS ≥ 1).

Second step: Comparing the patient's current HbA1c level and the target level established according to estimated life expectancy.

Third step: Defining the recommended approach according to the glycemic target: if the current HbA1c level was over target, the treatment should be optimized (increasing the dose or adding medications); if the HbA1c level was on target, the current treatment should be maintained; if the HbA1c level was under target, the treatment should be de-intensified (reducing the dose or discontinuing the medication). For patients who were currently using only non-hypoglycemic oral medications, maintaining the current regimen when their HbA1c level was under target was also considered adequate.

Fourth step: Analyzing the adequacy of the plan according to the recommended treatment decision.

Fifth step: Comparing the treatment decisions in primary and tertiary care centers.

Clinical and demographic data were collected from the electronic and paper medical records. The information recorded in the medical record was used to assess hypoglycemia and treatment adherence, and information bias could have occurred. To describe comorbidities, any record of stroke, heart failure, ischemic heart disease or peripheral obstructive arterial disease was considered cardiovascular disease. Any record of chronic hepatitis, cirrhosis or hepatic steatosis was considered chronic liver disease. A glomerular filtration rate <90 ml/min or a glomerular filtration rate >90 ml/min with changes in urinary sediment was considered chronic kidney disease. Diabetes complications in the medical records, such as neuropathy or retinopathy, were also considered. High albuminuria or chronic kidney disease in which the etiology was attributed to diabetes in the medical records was considered diabetic kidney disease.

This study was approved by the research ethics committee of all involved centers in accordance with the Standard Guidelines and Regulatory Research Involving Human Beings (protocol number 25591819.9.0000.5336). It was also approved by the National Health Council (resolution 466/12) and the Porto Alegre Municipal Health Office. All authors signed a confidentiality agreement regarding data usage. The present study was described according to the STROBE protocol.

2.4. Sample size

The sample size was calculated based on the rate of treatment de-intensification in patients with type 2 diabetes, as described by Sussman et al.,[24] as well as on a comparison of the glycemic goals in patients of a primary care unit vs. a specialist outpatient clinic.[25] A total of 320 patients (160 in primary care and 160 in tertiary care) were needed to find significant differences in the proposed outcomes, with a power of 80% and a significance level of 0.05.

2.5. Statistical analysis

The statistical analysis was performed in SPSS® 20.0. For the presentation of the participants' characteristics, data are presented as mean ± standard deviation (SD) for those in which the assumption of normal distribution did not seem violated, frequencies and percentages, with 95% confidence intervals (CI). Differences between groups for baseline data were evaluated by the chi-square test for categorical variables and by the unpaired *t*-test for continuous variables.

Subgroup analyses were performed to assess the inadequacy of treatment decision and the relationship between the current and target HbA1c levels in the subgroups of interest. For the analyses, crosstabs for descriptive statistics were used to identify the measures of effect and their CI. For this, the variables of the subgroups of interest were assigned as column and the relation of HbA1c for the targets as row in the crosstabs. The results reflect the risk estimates and are presented as

Table 1
Demographics and clinical characteristics of the study participants.

	Total ($n = 322$)	Primary Care ($n = 160$)	Tertiary Care ($n = 162$)	*P-value*
Age (years)	75.0 ± 6.9	76.4 ± 7.2	73.7 ± 6.3	0.04
Age range				
Age ≥ 80 years	87 (27.0)	55 (34.4)	32 (19.8)	<0.01
Age between 70 and 79 years	160 (49.7)	74 (46.2)	86 (53.1)	0.22
Age < 70 years	75 (23.3)	31 (19.4)	44 (27.2)	0.10
Sex (female)	186 (57.8)	101 (63.1)	85 (52.5)	0.06
Race/ethnicity (white)	285 (88.5)	148 (92.5)	137 (84.6)	0.08
HbA1c (%)	8.1 ± 1.7	7.9 ± 1.8	8.3 ± 1.6	0.15
Diabetes complications				
Retinopathy	75 (23.3)	5 (3.1)	70 (43.2)	<0.001
Neuropathy	42 (13.0)	3 (1.9)	39 (24.1)	<0.001
Nephropathy	89 (27.6)	28 (17.5)	61 (37.7)	<0.001
Macrovascular	65 (20.2)	21 (13.1)	44 (27.2)	<0.01
Insulin use	164 (50.9)	33 (20.6)	131 (80.9)	<0.001
Metformin use	263 (81.7)	140 (87.5)	123 (75.9)	<0.01
Sulfonylurea use	79 (24.5)	48 (30.0)	31 (19.1)	0.02
SGLT2 inhibitor use	4 (1.2)	0 (0.0)	4 (2.5)	0.05
ACE inhibitor or ARB use	197 (61.2)	76 (47.5)	121 (74.7)	<0.001
Statin use	246 (76.4)	114 (71.3)	132 (81.5)	0.03
AAS use	129 (40.1)	53 (33.1)	76 (46.9)	0.01
Poor medication adherence*	95 (29.5)	58 (36.9)	37 (22.8)	<0.001
Capillary blood glucose monitoring	126 (39.1)	19 (11.9)	107 (66.0)	<0.001
Hypoglycemia**	38 (11.8)	0 (0.0)	38 (23.5)	<0.001
Smoking	27 (13.0)	15 (30.6)	12 (7.6)	<0.001
Charlson comorbidity index (%)				
1 point	137 (42.5)	108 (67.5)	29 (17.9)	<0.001
2 points	83 (25.8)	32 (20.0)	51 (31.5)	
3 points	61 (18.9)	16 (10.0)	45 (27.8)	
≥4 points	41 (12.7)	4 (2.5)	37 (22.8)	
Estimated life expectancy*** (%)				
>10 years	99 (30.7)	74 (46.3)	25 (15.4)	<0.001
5–10 years	104 (32.3)	29 (18.1)	75 (46.3)	
<5 years	119 (37.0)	57 (35.6)	62 (38.3)	

Data are mean ± standard deviation or n and (%). An α ≤0.05 indicates a significant difference. P-values indicate comparison between the primary and tertiary care groups. HbA1c: hemoglobin A1c; ACE: Angiotensin-converting enzyme; ARB: Angiotensin II receptor blockers. *Poor medication adherence recorded in medical records. **Hypoglycemia was based on the medical records, and may have been underestimated. ***Estimated life expectancy was calculated according to the age-adjusted Charlson comorbidity index. Life expectancy in Brazil is 76.6 years, according to data from the Brazilian Institute of Geography and Statistics.

odds ratio (OR) and their respective CI. *P*-values <0.05 were considered statistically significant.

3. Results

3.1. Participant characteristics

Initial participant selection was carried out by identifying patients who were followed up in the endocrinology service of tertiary centers and primary centers between January 2015 and October 2016 and between July 2019 and December 2019 (the collection in two moments was carried out with the objective of complementing the initial collection to reach the necessary sample size). A total of 322 patients who met the inclusion criteria were randomly selected for the study, 160 from primary care and 162 from tertiary care centers (sample selection is explained in detail in Supplementary Fig. 1). Overall ($n = 322$), the participants had a mean age of 75.0 ± 6.9 years old, 57.8% were female, and 88.5% were white. The mean HbA1c level was 8.1% ± 1.7, 50.9% of the patients used insulin, 39.1% performed capillary blood glucose monitoring, and 11.8% had a record of hypoglycemia. The medication adherence of approximately 30% of the participants was reported as poor in the electronic or paper medical records (see Table 1).

There were no significant differences in gender, race or mean HbAc1 level at the first evaluation in the primary and tertiary care groups. The primary care group was older (76.4 ± 7.2 vs. 73.7 ± 6.3; $p = 0.04$) and had a higher smoking prevalence (30.6% vs. 7.6%, $p < 0.001$). The tertiary care group had a higher prevalence of insulin use (80.9% vs. 20.6%; $p < 0.001$), performed capillary blood glucose monitoring more frequently (66.0% vs. 11.9%; $p < 0.001$) and reported hypoglycemia episodes more frequently than the primary care group (23.5% vs. 0.0%; $p < 0.001$). As expected, the tertiary care group had a higher prevalence of chronic complications of diabetes, such as retinopathy (43.2% vs. 3.1%; $p < 0.001$), neuropathy (24.1% vs. 1.9%; $p < 0.001$), diabetic kidney disease (37.7% vs. 17.5%; $p < 0.01$), and macrovascular complications (27.2% vs. 13.1%; $p < 0.01$). According to the medical records, the primary care group center had lower adherence (36.9% vs. 22.8%; $p < 0.001$).

Regarding comorbidities, the tertiary care group had a higher prevalence of cardiovascular disease (43.2% vs. 15.6%; $p < 0.001$), chronic liver disease (5.6% vs. 0.0%, $p < 0.01$) and neoplasia (11.1% vs. 2.5%, $p < 0.01$) (see Supplementary Table 1). This is reflected in significantly higher CCIS and fewer patients with a life expectancy >10 years in this group (15.4% vs. 46.3% in primary care centers; $p < 0.001$).

3.2. Outcomes

Overall, 49.1% and 50.3% of the primary and tertiary care groups, respectively, received inadequate treatment management, with no significant difference between the groups ($p = 0.82$). At the time of HbA1c assessment, 42.2% of the participants were over the target level for estimated life expectancy, 28.9% were on target, and 28.9% were under target (see Fig. 1).

3.3. HbA1c over target

In patients over the target level, the appropriate action (i.e. intensifying treatment) occurred in 46.3% and 51.2% of the primary and tertiary groups, respectively ($p = 0.57$). In the primary care group, the treatment of 51.9% of the patients was maintained, while in 1.9% it was de-intensified. In the tertiary care group, the treatment of 34.1% of the patients was maintained, while in 14.6% it was de-intensified ($p = 0.02$) (see Fig. 2).

Subgroup analyses were performed to identify groups at higher risk of over-target HbA1c levels. The tertiary care group had a greater chance of over-target HbA1c levels than the primary care group (OR 1.35; 95% CI, 1.09 to 1.68). Non-white patients (OR 1.87; 95 CI, 1.01 to 3.44), those under the age of 75 (OR 1.23; 95% CI, 1.01 to 1.50), those with a record of poor adherence (OR 2.55; 95% CI, 1.79 to 3.64), and those who used insulin (OR 1.82; 95% CI, 1.47 to 2.25) also had a greater chance of over-target HbA1c. Regarding life expectancy, patients with a life expectancy >10 years had a higher risk of an over-target HbA1c level (OR 1.51; 95% CI, 1.09 to 2.09) (see Table 2).

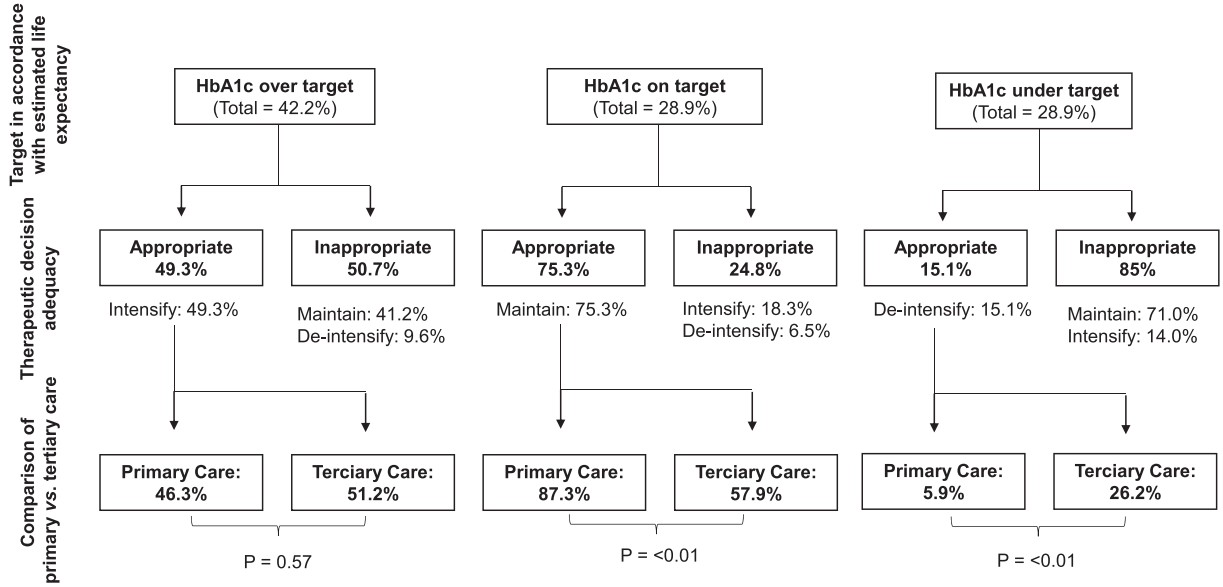

Fig. 1. The adequacy of treatment decisions according to the therapeutic target for estimated life expectancy. Legend: The first line shows the relationship between patient HbA1c level at the medical consultation and the target value for their estimated life expectancy. The second line shows the proportions of adequate or inadequate treatment decisions. For patients whose current HbA1c level was over target, treatment intensification was considered appropriate, while maintenance or de-intensification was considered inadequate. For patients whose current HbA1c was on target, treatment maintenance was considered appropriate, while intensification or de-intensification was considered inappropriate. For patients whose HbA1c level was under target, treatment de-intensification was considered appropriate, while maintenance or intensification was considered inappropriate. The third line compares the proportion of adequate decisions in primary care vs. tertiary care.

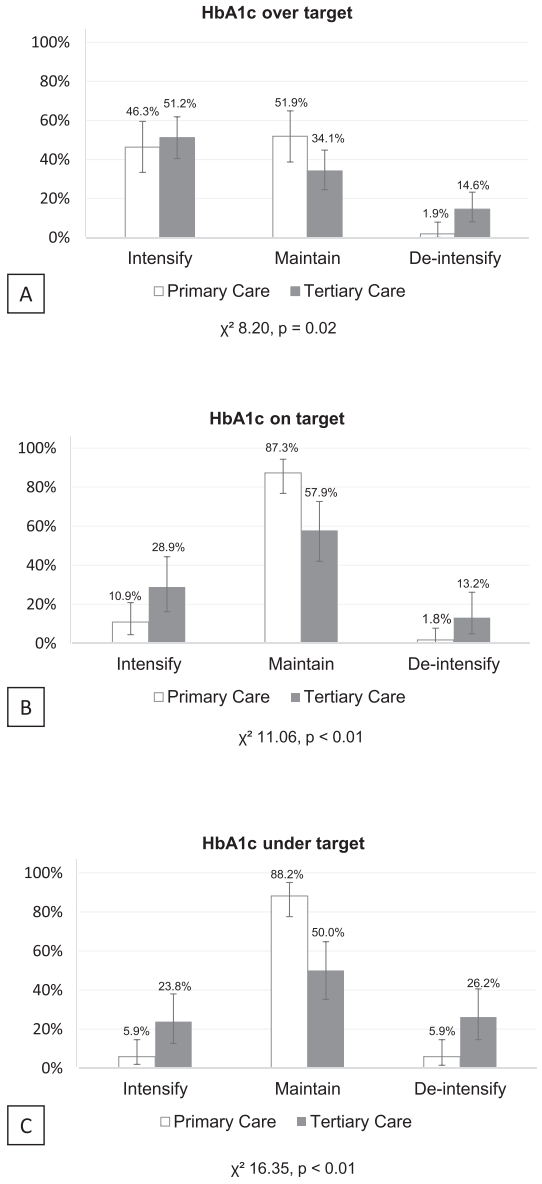

Fig. 2. Treatment decisions according to the therapeutic target for estimated life expectancy. Legend: The data are median and 95% confidence intervals and are based on the likelihood ratio test. (A) Treatment decisions for patients whose current HbA1c level was over target. Treatment intensification was considered appropriate, while maintenance or de-intensification was considered inadequate. (B) Treatment decisions for patients whose current HbA1c level was on target. Treatment maintenance was considered appropriate, while intensification or de-intensification was considered inappropriate. (C) Treatment decisions for patients whose current HbA1c level was under target. Treatment de-intensification was considered appropriate, while maintenance or intensification was considered inappropriate.

3.4. HbA1c on target

In patients whose HbA1c level was on target, the appropriate decision (i.e., maintaining treatment) was made in 87.3% and 57.9% in the primary and tertiary patients, respectively ($p < 0.01$). In the primary care group, the treatment of 10.9% of the patients was intensified, while in 1.8% it was de-intensified. In the tertiary care group, the treatment of 28.9% of the patients was intensified, while in 13.2% it was de-intensified ($p < 0.01$) (see Fig. 2).

Subgroup analyses show that the primary care group's HbA1c levels were more likely to be on target than those of the tertiary care group (OR 1.29; 95% CI, 1.04 to 1.61). In addition, white patients (OR 1.10; 95% CI, 1.02 to 1.18), those who do not use insulin (OR 1.68; 95% CI, 1.36 to 2.06), and those with no record of hypoglycemia (OR 1.11; 95% CI, 1.03 to 1.19) were more likely to have on-target HbA1c levels. There was no difference regarding comorbidities or life expectancy in relation to the risk of on-target HbA1c levels (see Table 2).

3.5. HbA1c under target

In patients whose HbA1c level was under the target, the appropriate treatment decision (i.e. de-intensifying treatment) was made in 5.9% and 26.2% of the primary and tertiary care patients, respectively ($p < 0.01$). In the primary care group, the treatment of 5.9% of the patients was intensified, while in 88.2% it was maintained. In the tertiary care group, the treatment of 23.8% of the patients was intensified, while in 50.0% it was maintained ($p < 0.01$) (see Fig. 2).

Subgroup analyses identified a greater risk of under-target HbA1c levels in patients over the age of 75 (OR 1.31; 95% CI, 1.03 to 1.66) and in those with no record of poor adherence (OR 1.31; 95% CI, 1.16 to 1.50). Regarding clinical status, there was a greater chance of under-target HbA1c levels in patients with a life expectancy <5 years (OR 1.67; 95% CI, 1.26 to 2.19) (see Table 2).

3.6. Differences in inadequacy

Due to the clinical differences between the groups (presented in Table 1), we performed a subgroup analysis to assess the adequacy of the therapeutic approach in subgroups of interest. There was no difference in the chance of appropriate or inappropriate treatment decisions among the evaluated subgroups. Subgroup analyses were also carried out for medical consultations before and after January 2018 to identify late differences in treatment adequacy, but no difference was found between the groups (see Table 2).

4. Discussion

In this study, we sought to investigate the adequacy of treatment decisions based on recommended HbA1c levels according to estimated life expectancy in older patients followed at primary and tertiary care centers in southern Brazil. We found a high prevalence of inadequate treatment, with approximately 50% of the patients receiving inappropriate treatment in both the primary and tertiary care groups. The worst rate of inappropriate treatment decisions occurred in patients whose HbA1c level was under target: the treatment of <30% of the tertiary care group and <6% of the primary care group was de-intensified when appropriate. For patients whose HbA1c level was over target, approximately half of the plans were appropriate, including treatment optimization. Most of the inappropriate plans were due to maintaining the current treatment regimen. For patients with on-target HbA1c levels, the treatment decisions were more adequate in the primary care group than in the tertiary care group. In the tertiary care group, patients under the age of 75 and those with a life expectancy >10 years were more likely to have an over-target HbA1c level. Patients over the age of 75 and those with a life expectancy <5 years had a greater risk of under-target HbA1c.

It is well known that de-intensifying diabetes treatment is uncommon among older patients.[18,20–26] A study by Weiner et al. showed that, over four years, insulin treatment was discontinued in only a third of patients over 75 years of age.[18] Another study showed that among older patients with episodes of hypoglycemia, the treatment of only 37% was de-intensified.[27] These results, similar to those found in our tertiary care group, represent a very low de-intensification rate, despite the recommendations of current guidelines. In primary care centers, our data showed an even more alarming situation, reflecting a culture of medicalization and overtreatment in older adults, which significantly increases the risk of treatment-associated adverse events and negative outcomes.[5–8] Another possible explanation is that current

Table 2
Subgroup analyses to assess inadequate treatment decisions in subgroups of interest.

Subgroup	Inadequacy n (%)	Inadequacy OR (95% CI)	HbA1c over target OR (95% CI)	HbA1c on target OR (95% CI)	HbA1c under target OR (95% CI)
Complexity					
Primary care	84 (49.1)	0.98 (0.78–1.22)	**0.73 (0.57–0.92)**	**1.29 (1.04–1.61)**	1.15 (0.92–1.45)
Tertiary care	76 (50.3)	1.02 (0.82–1.27)	**1.35 (1.09–1.68)**	**0.76 (0.58–0.99)**	0.86 (0.67–1.11)
Race/ ethnicity					
White	147 (86.0)	0.94 (0.87–1.02)	0.92 (0.85–1.00)	**1.10 (1.02–1.18)**	1.01 (0.93–1.10)
Non-white	24 (14.0)	1.63 (0.86–3.09)	**1.87 (1.01–3.44)**	**0.39 (0.16–0.96)**	0.91 (0.46–1.81)
Sex					
Female	96 (56.1)	0.94 (0.78–1.14)	0.98 (0.81–1.19)	1.12 (0.92–1.36)	0.88 (0.71–1.10)
Male	75 (49.3)	1.08 (0.84–1.41)	1.03 (0.79–1.33)	0.85 (0.63–1.15)	1.18 (0.90–1.54)
Age					
< 75 years	88 (51.5)	0.89 (0.73–1.09)	**1.23 (1.01–1.50)**	0.96 (0.76–1.20)	0.78 (0.61–1.00)
≥ 75 years	83 (48.5)	1.15 (0.90–1.46)	0.78 (0.60–1.00)	1.05 (0.81–1.36)	**1.31 (1.03–1.66)**
< 85 years	157 (91.8)	1.01 (0.95–1.08)	1.07 (1.00–1.14)	0.94 (0.86–1.02)	0.99 (0.91–1.06)
≥ 85 years	14 (8.2)	0.88 (0.43–1.79)	0.47 (0.21–1.08)	1.85 (0.91–3.75)	1.17 (0.55–2.48)
Complications					
No	115 (67.3)	(0.87–1.19)	0.95 (0.81–1.11)	1.16 (0.99–1.36)	0.93 (0.78–1.11)
Microvascular	56 (32.7)	0.97 (0.71–1.32)	1.11 (0.82–1.52)	0.71 (0.48–1.05)	1.15 (0.83–1.59)
Macrovascular	40 (24.4)	1.41 (0.90–2.21)	1.22 (0.79–1.88)	**0.50 (0.28–0.92)**	1.44 (0.93–2.24)
Poor medication adherence					
Yes	50 (29.2)	0.94 (0.67–1.31)	**2.55 (1.79–3.64)**	0.58 (0.37–0.91)	**0.43 (0.26–0.71)**
No	88 (51.5)	1.02 (0.89–1.18)	**0.66 (0.56–0.78)**	1.22 (1.06–0.94)	**1.31 (1.16–1.50)**
Insulin Use					
Yes	91 (53.2)	1.10 (0.89–1.37)	**1.82 (1.47–2.25)**	**0.53 (0.38–0.73)**	0.82 (0.63–1.06)
No	80 (46.8)	0.90 (0.73–1.13)	**0.50 (0.38–0.66**)	**1.68 (1.36–2.06**)	1.21 (0.96–1.52)
Hypoglycemia*					
Yes	20 (11.7)	0.98 (0.54–1.78)	1.28 (0.70–2.32)	**0.37 (0.15–0.93)**	1.60 (0.88–2.94)
No	151 (88.3)	1.00 (0.93–1.08)	0.97 (0.89–1.05)	**1.11 (1.03–1.19)**	0.93 (0.84–1.03)
Charlson comorbidity index					
1	70 (40.9)	0.92 (0.72–1.19)	0.98 (0.76–1.27)	1.13 (0.86–1.47)	0.95 (0.71–1.26)
2	42 (24.6)	0.91 (0.63–1.31)	1.09 (0.75–1.58)	1.19 (0.80–1.76)	0.73 (0.47–1.15)
3	35 (20.5)	1.19 (0.75–1.88)	0.92 (0.58–1.47)	0.88 (0.52–1.47)	1.20 (0.75–1.94)
≥4	24 (14.0)	1.25 (0.70–2.23)	1.01 (0.56–1.80)	0.51 (0.23–1.10)	1.58 (0.88–2.81)
Estimated life expectancy**					
≥10 years	52 (30.4)	0.98 (0.70–1.36)	**1.51 (1.09–2.09)**	0.79 (0.53–1.17)	0.79 (0.53–1.17)
5–10 years	49 (28.7)	0.79 (0.57–1.08)	1.22 (0.89–1.67)	1.14 (0.82–1.60)	**0.63 (0.41–0.94)**
≤ 5 years	70 (40.9)	1.26 (0.94–1.69)	**0.57 (0.41–0.79)**	1.06 (0.79–1.45)	**1.67 (1.26–2.19)**
Consultation date appointment					
Before Jan. 2018	113 (66.1)	0.96 (0.82–1.12)	0.97 (0.83–1.13)	1.05 (0.90–1.24)	0.96 (0.81–1.14)
After Jan. 2018	58 (33.9)	1.09 (0.79–1.49)	1.07 (0.78–1.46)	0.90 (0.63–1.28)	1.08 (0.77–1.51)

Inadequacy data are n and (%) and odds ratio (OR) and their respective 95% confidence intervals (CI). Subgroup analyses were performed using contingency tables to assess the inadequacy of the treatment decision and the relationship between current and target HbA1c levels in subgroups of interest. *Hypoglycemia was based on the medical records. **Estimated life expectancy was calculated according to the age-adjusted Charlson comorbidity index.

guidelines may not have been incorporated in hospital protocols. Moreover, even if the protocols had been updated, they may not have been followed, as other authors also have reported (e.g. a lack of standardized glucose management policies and a lack of standardized staff training for inpatient diabetes management).[28]

Although more and more medications are available for diabetes, the proportion of diabetes patients with poor glycemic control is still high. In older patients, this delay is often justified by the complexity of the patient's clinical condition, which delays the decision to optimize treatment. Our results are similar to those of Ajmera et al., who found that the treatment of approximately half of older patients with inadequately controlled diabetes was intensified. This study, which sought to understand the impact of different factors in the decision to intensify treatment, found that, contrary to expectations, specific complexities in older patients were not associated with time until treatment intensification.[27] Regarding complexity level, our study found that appropriate treatment intensification was independent of the prescribing physician's specialty, as has been found in previous studies.[25] However, primary care patients were more likely to have on-target HbA1c levels than tertiary care patients.

In our study, tertiary care patients were more likely to have over-target HbA1c levels. In addition, among patients with over-target HbA1c levels, approximately 15% of the treatment decisions in the tertiary care group were to de-intensify treatment, the opposite of what was expected. We believe that this can be explained by differences in the baseline characteristics. Tertiary care patients generally have more comorbidities, a shorter life expectancy, and a higher prevalence of diabetes complications. These factors alone may reflect poor patient adherence to long-term treatment, explaining the higher glycemic levels and difficulty reaching therapeutic targets. Although not evaluated in this study, the de-intensification rate among patients with over-target HbA1c levels might be explained by the greater frequency of hypoglycemia in this group. Lipksa et al. found that patients with an HbA1c level over 9% have a 16% higher risk of hypoglycemia episodes than patients with an HbA1c level between 7 and 7.9%.[29] Treatment de-intensification, under these conditions, can be used to encourage improvement in treatment adherence and reduce the incidence of potentially serious complications related to hypoglycemia episodes.

Overall, there was a greater tendency to maintain the current treatment in both groups. This tendency probably reflects the concept of clinical inertia, defined as the failure to establish appropriate targets and escalate treatment to achieve treatment goals in patients with diabetes. The causes of clinical inertia are multifactorial. Regarding physicians, one major hurdle is a limited awareness of clinical inertia, resulting in overestimating the quality of care and adherence to guidelines.[30] The decision to maintain treatment is frequently justified by the "first do no harm" principle, i.e. intervention is avoided due to the possible risks of treatment change. Moreover, physicians tend to

set HbA1c targets based on the strategies they are most familiar with, including conventional targets of approximately 7% for all patients.[31] Another obstacle could be pharmaceutical industry pressure to reach lower treatment targets and, thus, increase medication use. Organizing events, providing free samples and offering gifts are some industry strategies to create expectations and obligations, thus interfering with decision making.[32] This compounds the difficulty of caring for older patients with diabetes, considering that this group is even more vulnerable to adverse treatment effects and that their treatment targets must be individualized.

It is important to point out that inadequate treatment decision making in our country is associated with lower diabetes care quality. A study by Schneiders et al. in 2019 sought to evaluate care quality indicators in type 2 diabetes patients treated in the Brazilian public health system and compared the results between primary and tertiary health care. These authors found that <30% of tertiary care patients and <5% of primary care patients had the minimally acceptable level of indicators. HbA1c levels were not measured twice in one year in approximately 50% and 20% of the diabetes patients in primary care and tertiary care, respectively.[33] Thus, besides demonstrating that diabetes care is still suboptimal, it shows that health professionals require further education and that treatment strategies at different complexities of care must be reformulated, including a patient-centered focus guided by goals and indicators.[34] This need is even greater for older patients, considering the particularities involved in their care. Another limitation in our country is the difficulty in using medications such as GLP-1 analogs and/or SGLT2 inhibitors, which are potential alternatives for elderly patients and a lower risk of hypoglycemia. In Brazil, medication is dispensed free of charge to the population through the "Unified Health System (SUS)". The list of medications offered free of charge to patients with type 2 diabetes includes metformin, sulfonylureas (glyburide and gliclazide) and insulins (NPH and regular). The vast majority of patients who are seen in the public system have low income and are unable to purchase other treatment options. For this reason, these medications are not routinely part of the treatments used in patients seen in the public health care.

We must highlight some limitations of this study. Since this was a retrospective observational study, cause and effect relationships could not be determined in the associations. Data on comorbidities, medical adherence and hypoglycemia were extracted from electronic or paper medical records and were not checked directly with the patients, and thus were subject to error or incompleteness. One flaw is the absence of information in medical records about frailty, mobility and dementia, which would provide important information about the patient's performance. In addition, differences in the presence of chronic complications of diabetes and in the registration of hypoglycemia may occur due to the lack of specific medical evaluation for them in primary care centers. In some cases, especially in the primary care group, HbA1c values were extracted from electronic medical records with no laboratory report available for confirmation. Another important point is our use of the CCIS to rank patients and estimate their life expectancy, given that this scale has not been specifically tested or validated in subjects with diabetes. The use of alternative strategies, as proposed by the "Global Guideline for Managing Older People with Type 2 Diabetes", was not possible in our sample due to the lack of description about aspects related to cognition, fragility and mobility in medical records.[35] Furthermore, the objective of the present study was to assess treatment decision making after the ADA's reassessment of glycemic targets, including new consultations beginning in January 2015. It must be considered that the changes observed in practice are not always immediate. However, we found no difference in the adequacy of treatment decisions before and after January 2018, although specific studies should be carried out for this purpose. In addition, patients were selected from primary and tertiary care centers from the same region in Brazil, which could limit external validity.

Despite these limitations, this study found a high prevalence of inadequate treatment planning according to the estimated life expectancy of older patients. Despite the more flexible glycemic targets and recommendations for individualized therapeutic targets in older patients with different life expectancies, treatment was not de-intensified in more than two thirds of the patients. Likewise, treatment was not intensified when necessary in almost half of the patients. These results show that, although widely available and easily accessible, guidelines still fail to modify physician attitudes towards diabetes care. Physician adherence is critical in translating recommendations into improved outcomes. Despite adequate knowledge, external barriers can affect a physician's ability to comply with recommendations. Lack of familiarity, lack of agreement, outcome expectancy, and inertia from previous practice are potential barriers. Improvement strategies must account for differences between clinical targets and consider tailored rather than 'one size fits all' approaches. Although training about the new targets is necessary, it is not enough to bring about major change; interventions to improve diabetes care must outline specific roles and responsibilities, as well as address the clinician's skills and feelings.[36,37]

Our study showed that primary care patients usually receive more appropriate plans when their HbA1c level is on target, while tertiary care patients generally receive more appropriate plans when their HbA1c level is under target. Nevertheless, the differences in treatment inadequacy between the groups were minor when evaluated from a more general perspective, which shows that the problem is not limited to the complexity of care. However, treatment changes based on individualized glycemic targets do occur in a minority of patients, which reflects the need for further studies and strategies to facilitate individualized treatment targets and optimize the treatment adequacy in older adults.

Declaration of competing interest

No potential conflicts of interest relevant to this article were reported.

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CRediT authorship contribution statement

Janine Alessi: conceptualization, methodology, data curation, preparing the original draft of the manuscript. Gabriela H. Telo: conceptualization, data curation, preparing the original draft of the manuscript, supervision. Giovana B. de Oliveira: methodology, investigation. Josiane Schneiders: methodology, investigation. Maria José B. Zanella: reviewing and editing the manuscript. Beatriz D. Schaan: conceptualization, supervision, reviewing and editing the manuscript.

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Availability of data and materials

The data collected for the study, including deidentified participant data, will be available for 1 year after publication of the article upon

justified request to the e-mail address of the main researcher and with a signed data access agreement.

Ethics approval

The study was approved by the Research Ethics Committee of Hospital de Clínicas de Porto Alegre (CEP).

Consent to participate

Not applicable.

Consent for publication

All authors have reviewed the final version of the manuscript and agree with the publication of the results presented.

Code availability

Not available.

JA is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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