Upsala J Med Sci 110 (3): 267–273, 2005

A Low Carbohydrate Diet in Type 1 Diabetes: Clinical Experience – A Brief Report

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ABSTRACT

Due to failure to achieve control twenty-two patients with type 1 diabetes with symptomatic fluctuating blood glucose started on a diet limited to 70-90 g carbohydrates per day and were taught to match the insulin doses accordingly. The caloric requirements were covered by an increased intake of protein and fat. The purpose was to reduce the blood glucose fluctuations, the rate of hypoglycaemia and to improve HbA1c.

After three and 12 months the rate of hypoglycaemia was significantly lowered from 2.9 ± 2.0 to 0.2 ± 0.3 and 0.5 ± 0.5 episodes per week respectively. The HbA1c level was significantly lowered from 7.5 ± 0.9 % to 6.4 ± 0.7 % after three months and was still after 12 months 6.4 ± 0.8 %. The meal insulin requirements were reduced from 21.1 ± 6.7 I.U./day to 12.7 ± 3.5 I.U./day and 12.4 ± 2.6 I.U./day after three and 12 months respectively.

Furthermore the triglyceride level was significantly lowered whereas the levels for total cholesterol and HDL-cholesterol were unchanged.

Conclusion: the present report shows that a 70-90 g carbohydrate diet is a feasible long-term alternative in the treatment of type 1 diabetes and leads to improved glycaemic control.

INTRODUCTION

The Diabetes Control and Complication Trial (DCCT), in which conventional versus intensive insulin treatment was studied, showed that a reduction of the risk of microvascular complications in type 1 diabetes was directly linked to a lowered HbA1c level (1). The incidence of severe hypoglycaemia including coma and seizures, however, was threefold higher in the intensively treated patients, 61.2 versus 18.7 episodes per 100 patient-years (2). The dietary advice in the DCCT includ-

Received 25 April 2005
Accepted 7 June 2005

ed a carbohydrate proportion of 55 % of the calories. In a 2000 kcal diet this amount corresponds to about 275 g carbohydrates, mostly consumed as starches from potatoes, bread and pasta, that in the gut swiftly are broken down to glucose. This quantity of carbohydrates therefore corresponds to about the same amount of glucose within the body and behaves like ingested glucose.

Patients with type 1 diabetes commonly take fixed pre-meal doses of insulin. Some patients change the dose according to the pre-meal glucose level, but normally the dose is taken without regard to the carbohydrate content of the following meal. However, by way of education, patients can learn to estimate the carbohydrate content of a meal and to match the insulin accordingly. In this way patients with type 1 diabetes reduced mean HbA1c from 9.5 to 8.5 %. But the high rate of severe hypoglycaemia still persisted, 20 episodes per 100 patient-years (3).

The lesson from the DCCT is that normal glycaemic control is impossible unless the risk of severe hypoglycaemia can be reduced.

A mismatch between insulin and glucose causes unpredictable glucose swings. With large insulin doses this may lead to severe hypoglycaemia. The mismatching is an inherent problem, since first, the assessment of carbohydrates in a meal is hampered by a large error rate (4), and second, the absorption of insulin may vary by up to 30 % (5). The two major determinants of the blood glucose, therefore, cannot be determined with any accuracy. It thus becomes very problematical to match carbohydrates with insulin.

Large variations in the input -- carbohydrates and insulin -- may cause large variations in the output -- the glucose levels -- manifested as hypo- and hyperglycaemia. According to basic calculus a reduction in the size of the input reduces the degree of variation in the output.

Consequently, a reduction of both carbohydrates and given insulin ought to lead to a reduced degree of fluctuations and thus allow the patient to reduce the mean glucose level and the HbA1c safely.

For motivated patients this principle works well. A carbohydrate content of less than 40 g per day with accurately matched insulin doses seems to normalise the blood glucose levels and diminish the risk of hypoglycaemia in patients with type 1 diabetes who adhere to the program; the plasma lipids are normalised also(6-8).

The objection to the regimen is that a reduction of carbohydrates to less than 40 g per day probably is unrealistic in the general diabetes population. Such a radical reduction might limit the number of patients willing to try the method.

A reduction to 70-90 g per day, however, seems a feasible long-term choice (9). Since a reduced amount of carbohydrates with appropriate insulin doses as well as the ability to count carbohydrates are factors important in regulating the blood glucose, we have combined these two principles in the treatment of patients with poor glycaemic control, when treatment according to the guidelines has failed to stabilise the blood glucose. The purpose is to reduce the glucose fluctuation and HbA1c.

We have done this in the form of educational programs attended by 6-8 patients. The patients had all failed to achieve an – in their own opinion – satisfying glucose

control. All such patients have at our clinic for a couple of years received information on the theoretical background for the herein described treatment model. It is then up to the patients themselves to decide whether they wish to make any changes. All the patients in the present report have actively sought the presented treatment model.

A clinical chart review has been performed for the first 24 patients attending the program. It is a quality control, and its purpose is to evaluate to what degree initial positive changes are retained one year later even without close follow-up.

An approach using a carbohydrate quantity of 70-90 g per day has to our knowledge not been reported before. The purpose of the present report is to describe the method and the results after one year.

Table 1. Changes in the rate of hypoglycaemia, in HbA1c, insulin utilization, cholesterol, HDL-cholesterol and triglycerides in 22 patients with type 1 diabetes before, 3 and 12 months after a change to a diet restricted to 70-90 g of carbohydrates per day.

	Start	3 mo	P*	12 mo	P*
Hypoglycaemic episodes/week: §	2.9± 2.0	0.2± 0.3	<0.001	0.5± 0.4	0.004
HbA1c (%)	7.5 ± 0.9	6.4 ±0.7	<0.001	6.4 ± 0.8	<0.001
Meal-insulin(i.u./day)	21.1± 6.7	12.7± 3.5	<0.001	12.4± 2.6	<0.001
Total insulin (i.u./kg/24 hours)	0.5 ± 0.1	0.4 ± 0.1	<0.001	0.4± 0.1	<0.001
Tot-chol (mmol/l)	5.5 ± 1.0	5.7 ± 0.8	0.3	5.6 ± 0.7	0.3
HDL-chol.(mmol/l)	1.4 ± 0.2	1.5± 0.4	0.6	1.4 ± 0.3	0.8
Triglycerides(mmol/l)	0.8 ± 0.2	0.7 ± 0.2	<0.02	0.6± 0.3	<0.02

* P is for the difference within the group from base line. § n=15. HbA1c < 5.6 % in non-diabetic persons.

MATERIAL AND METHODS

The patients were outpatients with type 1 diabetes and episodes of hypo- and hyperglycaemia that had been treated at our clinic. The first 24 patients, 17 women and 7 men, who attended the program, constitute the present group.

The mean duration of diabetes was 18±13 years and the mean age was 51 ± 10 years. Seven patients were over-weight and had BMI > 27 kg/m^2 (range 27-38). Eleven patients administered insulin with an insulin pump. Another 13 patients used long acting insulin glargin (Lantus) twice or once a day; for meal-insulin they used insulin aspart in a pen device (NovoRapid) that enables delivery of half units.

All patients were requested to record the occurrence of hypo- and hyperglycaemia as well as other symptoms of poor diabetes control before they started on the new regime as well as 3 months later. About 12 months after the start the patients again in a letter were asked to record the occurrence of symptomatic hypoglycaemia, i.e. not severe but manageable by the patients themselves without help from others.

The program began with a 6-hour-meeting followed by, over the next two months, five follow-up meetings lasting approximately two hours. The main issues on the first day were the effect on the blood glucose by the different constituents of the food, the timing of insulin administered and the timing of blood glucose measurements. The patients received a flow sheet wherein they entered the blood glucose levels, the time of each meal and the amount of carbohydrates. Further, the time and amount of insulin units taken were entered together with any occurrence of hyper- and hypo-glycaemia. The number of glucose tablets needed to correct low blood glucose levels were recorded as well as the extra insulin units needed to correct a too high pre-meal and bedtime glucose level.

The regimen: A carbohydrate restricted diet (70-90 g per day) that excluded potatoes, rice, pasta, bread and cereals, but included hard bread and vegetables. Intensive glucose monitoring, > 4 times per day, was required; recording of the time of glucose levels, meals, insulin dosage, exercise and correction of too high or too low pre-meal and bed-time glucose levels with insulin or glucose tablets were also required. The target for pre-meal blood glucose was 5.6 mmol/l (plasma glucose 6.0 mmol/l).

The patients were instructed to eat three meals a day and abstain from any eating between the regular meals; the interval between meals should be at least four hours – the duration of one dose of aspart. To assist them the patients were given samples of menus and recipes showing the carbohydrate and protein content. The initial distribution of carbohydrate, protein and fat was 20%, 30% and 50 % respectively. Sugar or other fast acting carbohydrates were not permitted.

During this 2 months period the regimen for each patient was individually tailored.

Special attention was paid to the occurrence of gastroparesis. Even though this condition might be asymptomatic the effects on glucose control usually are obvious very soon. In such cases the autonomous nervous system was examined and the patient prescribed domperidone (Motilium) and if needed switched to insulin human (Actrapid).

After finishing the program the patients were able to handle their own treatment

without help. Only routine visits to the diabetes nurse every 3-4 months were continued or according to the individual patient's preferences.

HbA1c and insulin utilization were recorded at start and after three months. About 12 months later they were once more recorded from the chart. Since HbA1c vary we have calculated average HbA1c from the charts for the previous year before start for each individual. HbA1c <5.6 % in non-diabetic persons. (chromatography HPLC monoS column)

Total-cholesterol, HDL-cholesterol (HDL) and triglycerides (TG) were measured at start and after 3 months. It was then measured again about 12 months later.

The results are presented as means with Standard Deviation. Paired T-test is used for comparisons.

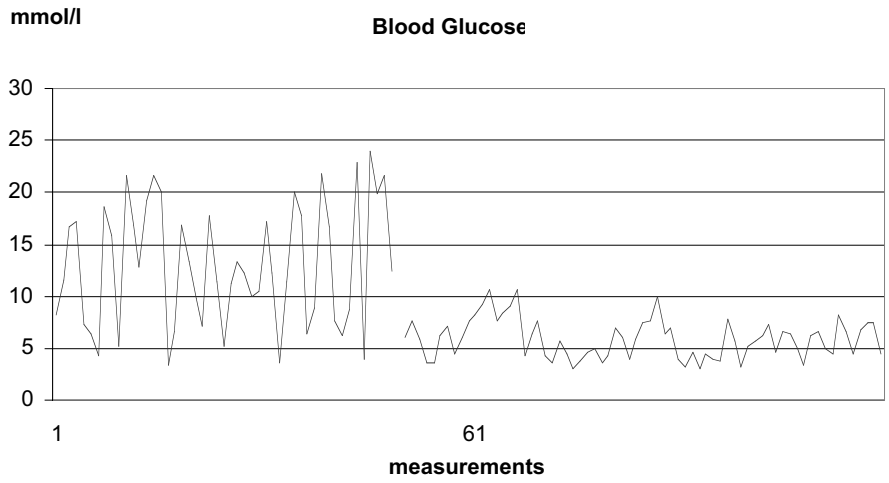

Figure 1. Blood glucose values in a patient with type 1 diabetes before and a few days after a change to a carbohydrate restricted diet (70-90 g daily) with adapted insulin doses. The measurements cover 12 days with 58 measurements before the change, and 10 days with 70 measurements after the change. The mean for the 58 measurements before the change was 12.9 ± 6 mmol/l. The mean for the 70 measurements after the change was 5.9 ± 2 mmol/l.

RESULTS

Two patients left the program after approximately 1 month for personal reasons.

Blood glucose: The effect of the diet on the glucose fluctuations is illustrated in Figure 1. The size of the fluctuations before the change clearly forbids any lowering of the mean glucose levels. For this patient average HbA1c the year prior to start was 7.5 %. One year later it was 4.7 %.

Hypoglycaemia: Nine patients had failed to record the occurrence of hypoglycaemia before start. The following figures are calculated from the records of 15 patients. The rate of symptomatic hypoglycaemia among these was reduced by 94 % after 3 months on the new regimen, and at twelve months by 82 % from base line. (see Table 1)

HbA1c and insulin: Table 1 shows that the effect on HbA1c and insulin administration was stable from 3 to 12 months in the group.

Lipids: There was no change except for a significant 16 % lowering of the triglycerides.

Two patients lost weight due to other illnesses. Otherwise, the bodyweight for the normal-weight patients remained stable, while all the overweight patients lost weight. Six patients were diagnosed with diabetic gastroparesis and were prescribed domperidon (Motilium).

DISCUSSION

By lowering the carbohydrate amount and corresponding insulin doses the blood glucose fluctuations diminished and a better HbA1c was achieved. The rate of hypoglycaemic episodes was reduced without any deterioration in the lipids. It is likely that the risk of severe hypoglycaemia has diminished also.

It is remarkable that the effect is retained without close follow-up. In the DCCT the patients visited the clinic in person once a month and were in contact by phone and fax once a week to get directions from the diabetes team [1]. This in order to maintain a tight control of HbA1c.

The group presented here achieved and maintained an HbA1c close to the one accomplished in the DCCT without close contact to the diabetes team. This suggests that the treatment method presented here is a more reliable tool for the patients. This might be due to the improved predictability of the blood glucose as illustrated in the reduced rate of hypoglycaemic episodes.

Most patients experience more freedom since they do not have to eat at a fixed time. With a correct dose of basal insulin a meal can be postponed or even cancelled without consequences for the glucose levels.

We did not study compliance to the diet, but since both HbA1c and insulin requirements stayed low, the findings for the whole group further suggest that the selected initial amount of carbohydrates is feasible in the long term in patients with type 1 diabetes. It was still possible for individual patients at their own discretion to pursue a stricter carbohydrate reduction in order to achieve an even better control, and two persons did so.

The high carbohydrate dietary advice in type 1 diabetes is based on avoidance of protein and fat in the food, especially saturated fat. The importance of this may however, with respect to the present findings, be reconsidered (10-12).

In summary: The approach to therapy reported here is feasible in type 1 diabetes for motivated patients. It improves HbA1c and appears to increase safety by lowering the rate of symptomatic hypoglycaemia, and the effect was retained one year later.

ACKNOWLEDGEMENTS

We are grateful to Peter Naeser, MD, PhD, for reading the manuscript and for valuable advice. We thank Kamma Willumsen, dietician, for help.

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