Journal of Pediatric Endocrinology & Metabolism, 16, 131-148 (2003)

Dietary Management for Children and Adolescents with Diabetes Mellitus: Personal Experience and Recommendations *

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ABSTRACT

Diet has traditionally played an important role in diabetic therapy. Over the years, various diets have been proposed, often without scientific evidence. One of the main errors was (is) to speculate that there exists a direct linear correlation between the injection of x units of insulin and the utilization of y grams of glucose. If this were true, one should give more insulin to practice physical activity. In reality, it is the reverse. Dietary recommendations issued over the last few years are the same for diabetic and non-diabetic individuals in order to avoid degenerative diseases. In many countries, the intake of fat is too high, and that of complex carbohydrates too low. The so-called 'Mediterranean diet', in combination with appropriate insulin therapy, may be optimal. This consists mainly of fiber-rich complex carbohydrates (grain), vegetables, fruits, fish, and olive oil. Explanations of this diet should focus on quality rather than quantity of foodstuffs, and should be given by a multidisciplinary team. Prescription of a highly rigid diet has proved ineffective in producing adequate metabolic control, and increases the risk of deviations from the diet. In our experience, the proper use of the two-injection regimen, in countries where the meal schedule allows correct allocation of diet, may lead to 'intensive conventional therapy' and good metabolic control. It is inadequate to systematically assign the multiple-insulin injection regimen to intensified insulin therapy, and the 'conventional' two-injection regimen to a non-intensified insulin therapy. The proper use of the basal-bolus regimen, with increased flexibility in daily life and dietary freedom, cannot always be applied successfully before adolescence. The adjustment of insulin dosage is more complicated than in the twice-daily injection regimen because dose alteration cannot be made only according to sliding scales based on the glycemia measured immediately before the insulin injection. The simplistic use of these non-physiological sliding scales is the main error in the multiple daily insulin injection regimen. The use of fast-acting insulin analogs in the basal-prandial regimen improves post-prandial glycemia at the expense of an increase in pre-prandial glucose levels, if the period between two meals, and therefore two injections, exceeds 3-4 hours, because of the short duration of action. If there are 4-6 or 7 hours between two meals, it is better to use a rapid-acting insulin. Avoid dogmatism - only objective results (good glycosylated hemoglobin and lipid levels, as well as good quality of life) are important.

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* Following is a review on the dietary management of young patients with diabetes mellitus written by a physician who has devoted many years to the treatment of this disease and whose achievements in maintaining metabolic control are remarkable[1]. Prof. Dorchy works in a country where gourmet food is part of life. Nutritional customs and advice to patients with DM differ from county to country[2], so we expect much discussion in our correspondence column.

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KEY WORDS

type 1 diabetes mellitus, children, diet, dietary intake, dietary allowances, insulin regimens, HbA_{1c}

HISTORICAL BACKGROUND

The age of dogmatic diets without scientific evidence

Diet has traditionally played an important role in the therapy of diabetes mellitus (DM). Before the discovery of insulin, a restrictive diet, yielding more or less positive results in 80% of patients with DM, was the only therapy available. Later, it became evident that diet, as such, is the ideal treatment for obese middle-aged individuals with DM (now called type 2 DM, that is beginning, however, to be encountered in children and adolescents with the rising rate of obesity[1]) since the problem is not based on a lack of insulin. In children and adolescents, DM is most often associated with a genetically determined predisposition, the presence of autoimmune markers, aggressive beta-cell destruction leading to severe insulin deficiency (type 1 DM), and the urgent need for insulin replacement therapy.

Over the years, various diets have been proposed, often without scientific evidence. Restriction in calories, carbohydrates, or lipids was advocated, but also a high intake of the same nutriments or of proteins. 'Free diet' as well as 'anarchic' eating habits as opposed to 'restricted' and 'weighed' diets (using scales or 'exchange lists') have all been proposed[2,3]. Total caloric restriction inhibits growth and, associated with a lack of insulin, leads to Mauriac syndrome[4].

One of the main errors was (and still is) to speculate that there exists a direct linear correlation between the injection of x units of insulin and the utilization of y grams of glucose[5]. If this were true, one should give more insulin to practice physical activity. In reality, it is the reverse. The reason is that the affinity of the muscular insulin receptors, as well as the activity of the glucose transporter GLUT4, is increased during (and even after) muscular work, but it is not the case for the hepatic insulin receptors. Moreover, the regulation of glucose is dependent on a number of factors, such as counter-regulatory hormones, gluconeogenesis, the relative use of glucose and non-esterified fatty acids as energy for muscular exercise, psychological factors (stress), and other mechanisms which are beyond our control[6,7]. Very recently, it was shown that a decrement in glucose *per se*, or a signal elicited by a moderate decrement in glucose, but largely independent of glucagon and hepatic catecholamine action, stimulates glucose release from the liver during exercise[8].

Evolution to a normal and flexible diet

In the 1970s, clinical studies by Henri Lestradet in France[9,10], and by our group in Belgium[11-14], demonstrated that children with DM, receiving an adequate and flexible dose of insulin according to self-monitoring of urine glucose at that time, benefited from a normal 'spontaneously balanced and adapted diet'. The best glycemic control was not obtained by totally free or rigid diets, but by appropriate daily adjustments of insulin and adequate distribution of normal food intake. Children with DM have no fixed energy requirements because they grow and participate in variable physical activities. Energy intake may fluctuate from day to day without mandatory changes in the need for insulin or in the degree of glycosuria[9,11,13]. To impose a weighed and measured diet is undesirable both for diabetic control and for psychological reasons. Moreover, the notion of 'measuring' leads to rejection of the entire therapeutic regimen and to emotional problems. A restricted diet that controls only carbohydrate intake and thus favors fat intake is potentially dangerous for the vascular system. On the other hand, even in the 1970s we observed a too high fat consumption in Belgian children with DM (42.2% of the total caloric intake) and we had to concentrate our efforts on emphasizing fat restriction rather than carbohydrate restriction[12]. We also noted a positive correlation between the blood levels of glycosylated hemoglobin (HbA_{1c}) and those of total cholesterol and triglycerides[14], which we confirmed later when measurements of LDL-cholesterol and apolipoprotein B were added[15]. There was no relationship between HbA_{1c} and HDL-cholesterol or its subfractions[16]. This was

confirmed by other studies[17,18]. This means that lipid abnormalities are not necessarily related to a diet high in saturated fat.

RELATIONSHIPS BETWEEN DIETARY ADVICE AND INSULIN REGIMENS: PERSONAL EXPERIENCE

The coupled insulin-diet

The practical strategy for the dietary education of our patients with DM was deduced from our four clinical studies[11-14] and published in 1983[19]. The major principles are still relevant today. For example, from the 1970s till now, the dietician never gave rigid meal plans or exchange lists. Diet has never been prescribed. The dietician builds up a picture of the family's and child's usual eating habits and life style. When possible, the family is encouraged to adopt a similar and normal eating pattern so that the child with DM does not have to eat specially prepared meals. Our practical dietary recommendations have been updated according to changes in the insulin regimens, mainly the basal-prandial insulin therapy and the introduction of insulin analogs[20-23]. Diet and insulin regimen cannot be separated.

Two-daily insulin injections in children under 15 years: easy and effective

In the 1970s, with the development of the twice-daily injection regimen (rapid-acting and intermediate-acting insulins), we had already shown that the allocation of carbohydrates throughout the day was essential, and must follow the cumulated insulin activities resulting from the superposition of action of the four insulins. The proportion of carbohydrates in the mid-morning snack must be more than that of breakfast[19,22]. Indeed, the peak activity of the so-called rapid-acting insulin occurs only 1.5-3.0 h after injection, and cumulates its effect with the one of the intermediate-acting insulins mixed in the same syringe (Fig. 1). Not to do this is the most common error made in the twice-daily injection regimen, even nowadays[22]. If the carbohydrate content of breakfast is higher than that of the snack taken at ~10.00 h, there is a risk of hyperglycemia after breakfast and of hypoglycemia at the end of the morning period. In order to allow eating more carbohydrates at breakfast, a solution is to replace a part of the rapid-acting insulin by a fast-acting insulin analog, but the adjustment of the dose needs a postprandial glycemia measurement, which is uncomfortable.

An individualized mixture of rapid-acting and intermediate-acting insulins in a syringe gives better results, in terms of HbA_{1c}, than the use of premixed insulins with a pen injector, as shown in an international comparison[24]. The reason is that with premixed insulins, one cannot adjust the two insulins of the mixture separately, and therefore cannot provide a made-to-measure adaptation.

In our experience, the proper use of the two-injection regimen, in countries in which the meal schedule allows correct allocation of diet, may lead to 'intensive conventional therapy' and good metabolic control[25-28]. It is inadequate to systematically assign the multiple-insulin injection regimen to intensified insulin therapy, and the 'conventional' two-injection regimen to non-intensified insulin therapy. Indeed, a multiple-injection regimen not associated with adequate education, as well as with the application of the knowledge gained, may have deleterious effects on HbA_{1c}, as shown by the Hvidøre Study Group on Childhood Diabetes[24,29-31].

Basal-bolus regimen in adolescents: more freedom but more complicated

The proper use of the basal-bolus regimen (Figs. 2 and 3), with increased flexibility in daily life and dietary freedom, cannot always be applied successfully before adolescence[22]. The adjustment of insulin dosage is more complicated than in the twice-daily injection regimen, because dose alteration cannot be made only according to sliding scales based on the glycemia measured immediately before the insulin injection. The simplistic use of these non-physiological sliding scales is the main error in the multiple daily insulin injection regimen. Insulin dose alteration must be triple: 1) retrospective, according to numerous previous experiences, in order to enjoy more freedom for meals, sports, etc; 2) prospective, according to programmed changes in meals and sports; 3) with only a 'touch' of compensatory adaptation according to the present glycemia. This needs psycho-

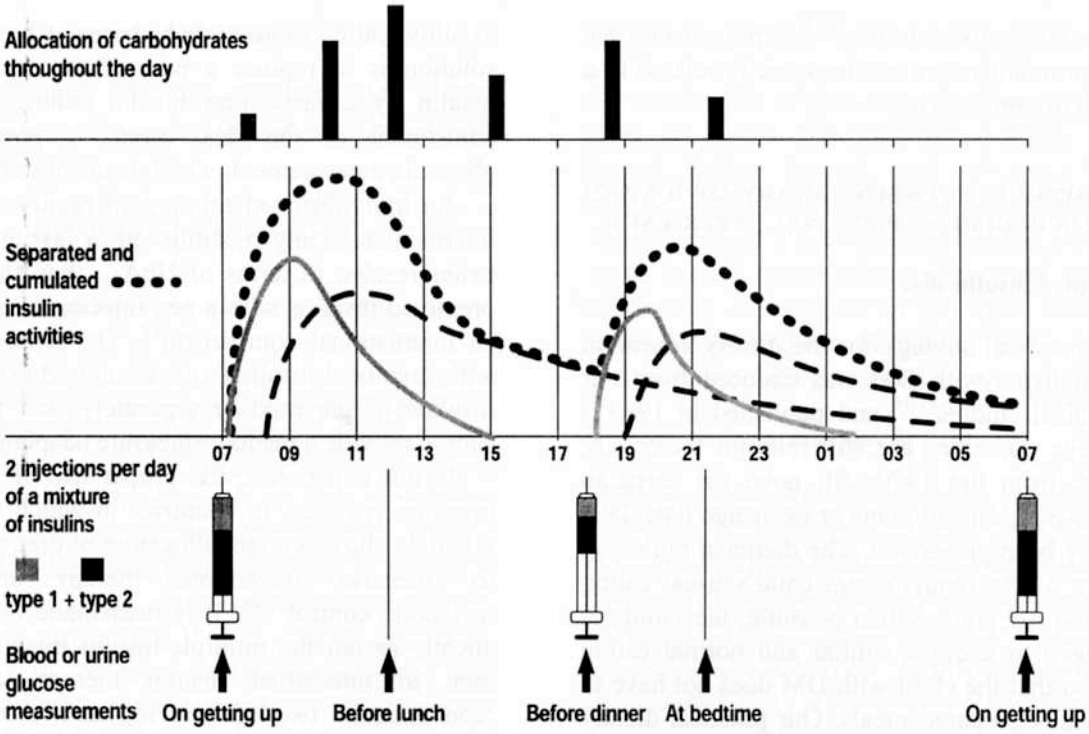

Fig. 1: Twice-daily injection regimen with a mixture of rapid- and intermediate-acting insulins (types 1 and 2). The allocation of carbohydrate throughout the day must be parallel to the profile of action of the cumulative insulin activities in blood. The mid-morning snack must be richer in carbohydrates than breakfast.

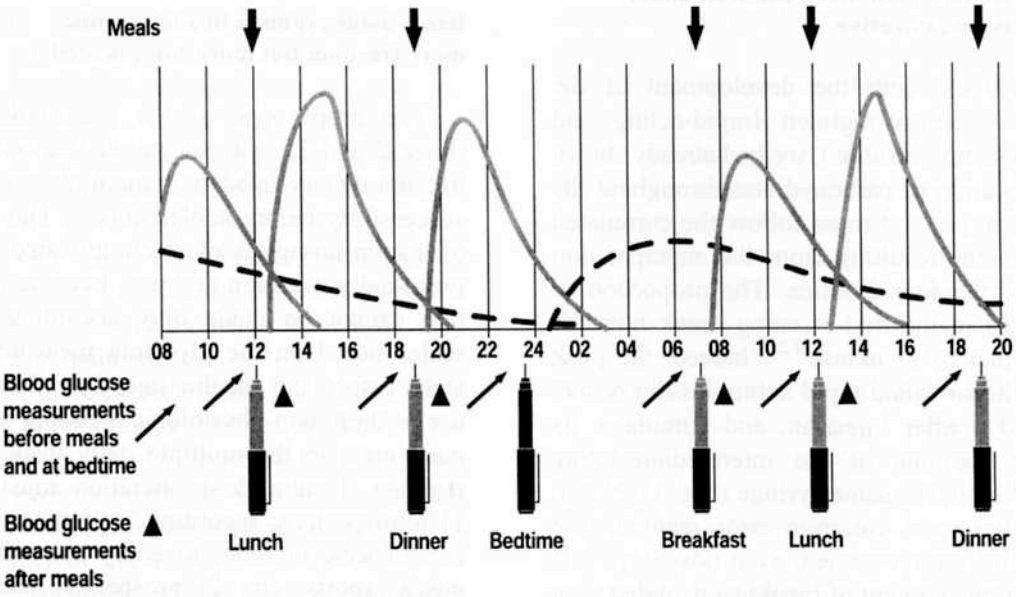

Fig. 2: Basal-prandial regimen with injection of an intermediate-acting insulin at bedtime, and three injections of rapid-acting insulin half an hour before the three daily meals. This is a good solution if the period between two injections lasts 4-7 hours; otherwise there is a risk of hyperglycemia before the next meal or injection.

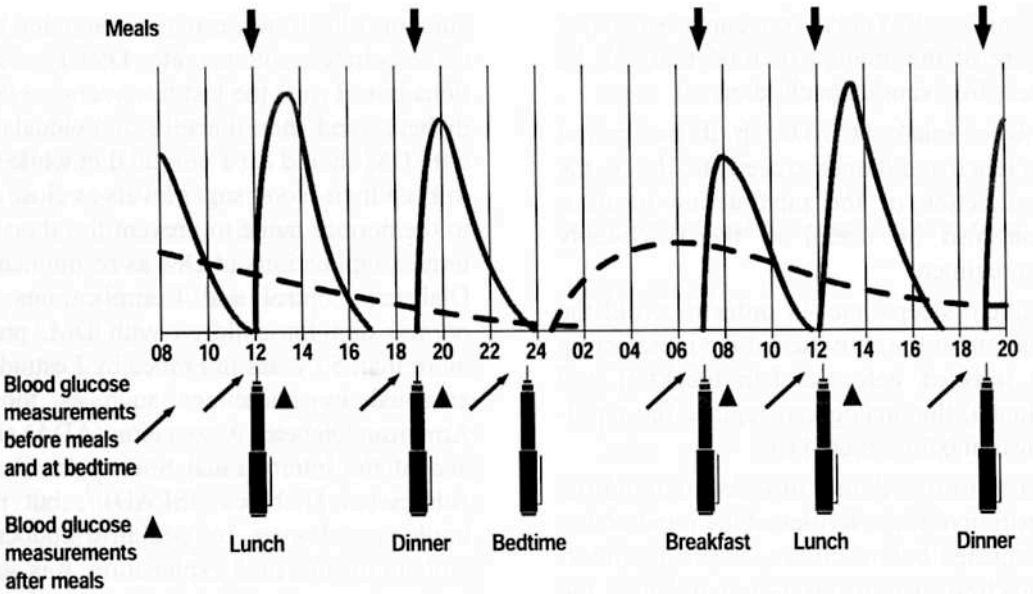

Fig. 3: Basal-prandial regimen with injection of an intermediate-acting insulin at bedtime, and three injections of a fast-acting insulin analog just before the three daily meals. This is a good choice if the period between two injections is less than 4 hours.

logical maturity; otherwise, the multiple injection system leads to anarchy and obesity, mainly in adolescent girls[20,29]. The number of daily insulin injections, *per se*, does not necessarily give better HbA_{1c} levels, both in our experience[27,28] and in the international comparison by the Hvidøre Study Group[24,29-31]. On the other hand, this more physiological regimen is the best choice in adolescents and adults who have learned to cope alone.

Indications for the use of fast-acting analogs

The use of fast-acting insulin analogs in the basal-prandial regimen improves post-prandial glycemia[32] at the expense of an increase in pre-prandial glucose levels, if the period between two meals, and therefore two injections, exceeds 3-4 hours, because of the short duration of action. If there are 4-6 or 7 hours between two meals, it is better to use a rapid-acting insulin[22]. Overall control is not necessarily improved by the systematic replacement of rapid-acting insulins by fast-acting analogs, as shown by many studies. Some authors have proposed an association of the fast-acting analogs with NPH insulin that is administered four times daily[33]. This means *seven* injections per day, and seven blood glucose measurements to adapt the seven insulins! Another solution is the use of premixed insulins (fast-acting and intermediate-acting) before meals. However, in this case, the patient is unable to adjust the two insulins of the mixture separately if he uses a pen injector. Moreover, postprandial glycemia measurements are always necessary. In my experience, the best results are given by an injection of a protamine insulin at bedtime (zinc insulins are too unstable) and by the prandial injection of a fast-acting analog if there are less than 3 or 4 hours between two injections, or by a preprandial injection of a rapid-acting insulin if there are 4-6 or 7 hours between two injections[22]. The fast-acting analogs are also recommended in well-defined circumstances:

- To correct hyperglycemia rapidly, which is also valuable in the twice-daily injection regimen.
- To allow eating something between the main meals, which is also valuable in the twice-daily injection regimen. The injection may even be

done after a snack. This is convenient when one is unaware of the amount of food that will be consumed, for example in children.

- To allow a snack at 16.00 h if the period between lunch and dinner exceeds 6-7 h, i.e. the length of action of the rapid-acting insulins. This can also be useful in the twice-daily injection regimen.
- If the patient sleeps late, in order to avoid the superposition of the activities of the rapid-acting insulins injected before a late breakfast and before lunch, the analog can replace the rapid-acting insulin before breakfast.
- If dinner is near bedtime, in order to avoid the superposition of the activities of the rapid-acting insulin injected before dinner, and of the intermediate-acting insulin injected at bedtime, the analog can replace the rapid-acting insulin before a late dinner. This reduces the risk of nocturnal hypoglycemia.

Recent clinical research on the fast-acting insulin analogs demonstrates the difficulties of translating the theoretical benefits into relevant clinical advantages. This might happen to other (long-acting) insulin analogs. Safety issues should also be carefully monitored[34]. The two fast-acting analogs, lispro and aspart, have no mitogenic potency. On the other hand, glargine insulin, which is a peakless long-acting analog, binds to IGF-I receptors with up to 8-fold greater affinity than human insulin, raising concerns about possible mitogenicity and angiogenic activity of the peptide[35,36]. In contrast, detemir insulin is less potent than human insulin in binding to the IGF-I receptor[35].

GUIDELINES FOR NUTRITION IN CHILDREN AND ADOLESCENTS WITH DIABETES MELLITUS

Normal 'Mediterranean diet' without rigid 'prescription'

A close association has been demonstrated between a number of degenerative diseases (atherosclerosis, cardiovascular disease, hypertension, obesity, etc.) and the unbalanced diet in industrialized countries characterized by excessive amounts of calories, proteins, saturated fats, simple carbohydrates, sodium, etc. Dietary recommendations issued over the last few years are the same for diabetic and non-diabetic individuals. Children with DM should eat a normal diet while taking care to keep their blood sugar levels as close as possible to the normal range to prevent the short- and long-term complications of DM as recommended by the Diabetes Control and Complications Trial[37]. A normal diet for children with DM, proposed for more than 50 years in France by Lestradet[2], is now accepted by guidelines such as those of the American Diabetes Association (ADA) since 1986[38] and of the International Society for Pediatric and Adolescent Diabetes (ISPAD)[39], but not always implemented even by pediatric endocrinologists, without documented explanation. It is surprising to notice, in a recent publication by the ADA, the promotion of 'carbohydrate counting' or of exchange lists and of the insulin-to-carbohydrate ratio of 1 U insulin per 15-20 g carbohydrate[5]. A prospective, stratified, randomized study in children with DM has proven that flexible dietary instruction based on the food pyramid[39], as compared with a measured carbohydrate exchange diet, improves HbA_{1c} levels and quality of life[40], confirming with better methodology our findings and those of Lestradet in the 1970s[9,11].

Concerning the quantification of carbohydrates, the ISPAD guidelines are: "*There is danger that such dietary "prescriptions" will lead to carbohydrate constraint as the child grows, and may lead to disordered eating behavior (including eating disorders). However, some practical quantification of carbohydrate is necessary as part of intensification of management. Parents and young people should be able to visualize amounts of and types of carbohydrate using educational tools such as the "plate model" or "size in hand model". In this way it may be possible to estimate the glycemic impact of various types of food. The insulin dose and action profile needs to be balanced against the expected carbohydrate intake*"[39]. Eating disorders in young women with DM have been studied by Rydall *et al.*[41]; they found binge eating, omission or underdosing of insulin for weight loss, self-induced vomiting, laxative use, dieting for weight loss. These are

associated with impaired metabolic control and a higher risk of diabetic retinopathy. Screening for subclinical complications (retinopathy, neuropathy, nephropathy) should be performed annually from puberty and after 3 years of DM by sensitive methods with the goal of detecting early abnormalities responsible for functional disorders that can be reversed by improved metabolic control, before the development of definitive lesions[27,42-46].

Evidence-based nutritional principles and recommendations for the treatment of all forms of DM and its complications have recently been extensively reviewed[47]. For young patients with DM, the so-called 'Mediterranean diet' seems to be optimal[48,49]. It consists mainly of fiber-rich complex carbohydrates (grain), vegetables, fruits, yogurt, fish, and olive oil. Explanations of this diet should focus on quality rather than quantity of foodstuffs, and should be given by a multidisciplinary team including an experienced dietician. The Consensus Guidelines from ISPAD[39] are in agreement with the Mediterranean diet, taking into account that nutritional advice must be adapted to cultural, ethnic and family traditions, and to the individual requirements of the child. The psychological significance of feeding patterns, appetite and tastes of the child must not be underestimated. Modern dietary recommendations for young people with DM are essentially healthy eating recommendations suitable for the general population, and should therefore be applicable to the whole family. Several of the recommendations are associated more with reducing cardiovascular risk than specifically helping to improve glycemic control.

Goals of nutritional management

The goals of nutritional management are[39]:

- To provide sufficient and appropriate energy intake and nutrients for optimal growth, development and good health;
- To encourage healthy lifelong eating habits whilst preserving social, cultural and psychological well-being;
- To achieve and maintain the best possible glycemic control;
- To achieve and maintain ideal body weight;
- To prevent and treat acute complications of DM, such as hypoglycemia, hyperglycemic crises, illness and exercise-related problems;
- To help to prevent micro- and macrovascular complications.

Main nutritional recommendations from ISPAD[39]

Energy intake

- Total energy needs to be sufficient for growth but to avoid obesity, and flexible according to physical activity. It is interesting to note that, other than duration of DM and metabolic control, BMI seems to be a significant predictive risk factor for developing proliferative retinopathy[50].
- Total daily energy intake should be distributed approximately as follows:
  - ✓ *Carbohydrates* >50% (athletes: 60-70%)
    - Encourage complex unrefined higher fiber carbohydrate
    - Moderate sucrose intake
  - ✓ *Fat* 30-35%
    - Less than 10% saturated fat
    - Less than 10% polyunsaturated fat
    - More than 10% monounsaturated fat
  - ✓ *Protein* 10-15%
    - Decreasing with age.

Carbohydrates (Table 1[47])

- Meals containing *complex carbohydrates* from sources such as whole grains (wheat, corn, maize), potatoes, rice or pasta are particularly recommended.
- Carbohydrate sources containing *soluble fiber* should be strongly encouraged:
  - ✓ Soluble fiber found mainly in vegetables, legumes, oats and fruits may be particularly useful because it reduces the speed of carbohydrate absorption and may improve lipid metabolism.
  - ✓ Insoluble fiber found in grains and cereals promotes healthy bowel function.
- *Sucrose*

TABLE 1

Carbohydrate classification and US terminology (adapted from [47])

Subgroups	Components	Food labeling
Sugars (1-2 molecules)		
Monosaccharides	glucose, galactose, fructose	sugars
Disaccharides	sucrose, lactose	sugars
Polyols	sorbitol, mannitol, xylitol, isomalt, maltitol, lactitol, etc.	sugar alcohol
Oligosaccharides (3-9 molecules)		
Malto-oligosaccharides	maltodextrins	other CHO
Other oligosaccharides	raffinose, stachyose, fructo-oligosaccharides	other CHO
Polysaccharides (>9 molecules)		
Starch	amylose, amylopectin	other CHO
Fiber	cellulose, hemicellulose, pectins, hydrocolloids	dietary fiber

- ✓ Can provide up to 10% of total energy intake;
- ✓ Moderate amounts can be included as part of mixed meals without causing hyperglycemia;
- ✓ Denial of sucrose-containing foods may have important psychological implications;
- ✓ May be used to prevent or treat hypoglycemia before and during physical exercise;
- ✓ Sucrose-sweetened drinks or sweets eaten at inappropriate times may cause significant hyperglycemia and obesity.

- *Fructose*
  - ✓ The major fruit sugar, does not greatly elevate blood glucose;
  - ✓ In excess may elevate triglyceride level;
  - ✓ Is not recommended as a sweetening agent;
  - ✓ Naturally occurring sources, fruits and vegetables, are recommended.

Fats (Table 2[47])

- A diet low in total fat with emphasis on decreasing saturated and transunsaturated fatty acids is recommended.
  - ✓ Saturated fats are found in animal produce, such as whole milk, cheese, butter and red meats.
  - ✓ Transunsaturated fatty acids are found in manufacturated confectionary such as biscuits, cakes and chocolates.

- *Polyunsaturated fatty acids (PUFA)* derived from vegetable origin, such as corn, sunflower, safflower, soybean, seeds and oils, or from oily marine fish, may reduce lipid cardiovascular risk factors.
  - ✓ Unsaturated fatty acids of the ω-3 variety found in oily fish and certain vegetable oils are thought to be particularly beneficial.
  - ✓ The ratio between ω-6 and ω-3 PUFA should be near 6[48].
- *Monounsaturated fatty acids (particularly cis-configuration)* found in olive, sesame, rapeseed and some nut oils may be beneficial in controlling lipid levels and convey some protection against cardiovascular disease. The proportion of saturated fatty acids in vegetable oils is given in Table 3.

TABLE 2

Composition of some dietary fatty acids and food sources (adapted from [47])

Fatty acids	Chemical notation	Food sources
Polyunsaturated		
Linoleic acid	18:2, ω-6	Vegetable oil, nuts, seeds
α-Linoleic acid	18:3, ω-3	Flaxseed, canola, soybean oils, walnuts
Eicosapentaenoic acid	20:5, ω-3	Fish and fish oil
Docosahexaenoic acid	22:6, ω-3	Fish and fish oil
Monounsaturated		
Oleic acid	18:1, ω-9 (*cis* form)	Olive, soybean, canola, safflower, peanut oil, almonds, cashews, pecans, avocado, peanuts
Elaidic acid	18:1, ω-9 (*trans* form)	Solid margarines, salad dressing
Saturated		
Lauric acid	12:0	Meats, poultry, butter, milk, cheese, ice cream, egg yolks
Myristic acid	14:0	Dairy products, coconut oil
Palmitic acid	16:0	Dairy products, meat
Stearic acid	18:0	Dairy products, meat, chocolate

TABLE 3

Fatty acid composition of common vegetable oils

Fatty acids (%)	Saturated	Poly-unsaturated ω-6	Poly-unsaturated ω-3	Mono-unsaturated
Sunflower	12	65		23
Maize/corn	13	57		30
Soya bean	15	53	7	25
Rapeseed	8	20	10	62
Groundnut	20	30		50
Olive	15	12		73

Protein

- Decrease intake during childhood from approximately 2 g/kg per day in early infancy to 1 g/kg per day for a 10 year old, and to 0.8-0.9 g/kg per day in later adolescence.
- Sources of *vegetable protein,* such as beans, legumes and lentils, which are lower in saturated fat and higher in fiber and complex carbohydrates, should be encouraged as 50% of the total protein requirement.

- When persistent microalbuminuria, raised blood pressure or established nephropathy occurs, excessive protein intake may be detrimental.

Vitamins, minerals and antioxidants

- Supplements of vitamins, minerals or trace elements are not usually recommended unless nutritional assessment confirms deficiencies. However, decreased magnesium levels may be found in sera and erythrocytes of children and adolescents with DM[51]. Lower plasma vitamin C levels may be found in young patients with DM with microalbuminuria[52,53].
- Many fresh fruits and vegetables are naturally rich in antioxidants (tocopherol, carotenoids, vitamin C, flavonoids) and should be strongly encouraged in young people with DM.
- In adults, less than 6 g/day of salt is recommended (except in very hot countries) but evidence is not available for children.
  - ✓ In many countries, salt intake is in excess of recommendations.
  - ✓ Sodium chloride is added to many processed and 'fast foods'.

Alcohol

- Alcohol is dangerous in children.
- Excess alcohol intake may induce a prolonged hypoglycemic effect.
- Carbohydrate should be eaten before, during and after alcohol intake.

Special labeled 'diabetic' foods

- These are not recommended or necessary because they are expensive, calorie-dense, high in fat, and may contain sweeteners with laxative effects.
- Low-sugar or sugar-free products are more suitable (however, in some countries, 'sugar-free' means only 'without saccharose', but other sugars may be present).

'Bulk' sweeteners

- Sweeteners such as dextrins or sugar alcohols (e.g. sorbitol, mannitol, xylitol, maltitol, isomalt) are added to commercial foods to improve sweetness and palatability (in some countries even in the so-called 'sugar-free' products).
- These are all energy-containing, and affect the level of blood glucose.
- They may also produce a laxative effect and are not recommended as sweeteners.

Artificial or intense sweeteners

- Saccharin, aspartame, acesulfame K, cyclamates, alitame and sucralose are used in low-sugar or sugar-free products to improve sweetness and palatability.
- Acceptable daily intakes have been established in some countries.

Other advice

Glycemic index

- The glycemic index represents the blood glucose area above the fasting glucose concentration following the ingestion of 50-g carbohydrate portions of food compared with the blood glucose area obtained with a 50-g carbohydrate portion of white bread as an index food in the same subjects: the glucose area response to the index food is considered to be 100%. The response to other foods is given as a percentage of that obtained with the index food[54]. Some examples are shown in Table 4.
- The reproducibility of the glucose response is low even in the same subject.
- The glycemic index is influenced by the type and amount of the sugar, the nature of the starch, gastric motility, the presence of substances slowing digestion (lectins, phytates, tannins, etc.), the physical structure of foods which may be modified by cooking, the mixture of various foods, etc.[47,48,55].
- In the literature, the usefulness of low glycemic index diets in individuals with type 1 DM is controversial[47].

Non-nutritive sweeteners

- The acceptable daily intake[47] in mg/kg body wt is:

TABLE 4

Glycemic index of some food items

Food item	GI (%)
Potatoes	118
Bread	100
Sucrose	90
Bananas	84
Rice	80
Gnocchi	70
Oranges	66
Spaghetti	54
Apples	54
Milk	50
Beans	45
Lentils	40

- ✓ acesulfame K: 15
- ✓ aspartame: 50
- ✓ saccharin: 5
- ✓ sucralose: 5.

- The sugar-free colas with non-nutritive sweeteners may contain large quantities of phosphorus, adding to the already excessive phosphorus intake in the modern diet. The possible consequences of this phosphate and acid load on blood calcium levels and on calcium accretion in bone during childhood and adolescence have not yet been fully evaluated[56].

Soft drinks

- Soft drinks are ready-to-use drinks presented in bottles or cans, carbonated or not, sweetened with sucrose, high fructose, corn syrup or intense sweeteners, and containing neither milk nor alcohol. Consumption is increasing in all countries of the world. They contain large amounts of sugars, for example, in g/l:
  - ✓ Classic cola: sucrose: 40; glucose: 35; fructose: 35.
  - ✓ Regular iced tea: sucrose: 40; glucose: 25; fructose: 25.
  - ✓ Regular lemonade: sucrose: 30; glucose: 15; fructose: 15.
- The nutritional consequences are mainly the result of the high content of carbohydrate:
  - ✓ Obesity;
  - ✓ Dental caries;
  - ✓ Hyperlipidemia because of fructose;
  - ✓ Diarrhea because of fructose or sorbitol.

Transunsaturated fatty acids

- These increase LDL-cholesterol and lower HDL-cholesterol.
- They are formed when vegetable oils are processed and made more solid (hydrogenation).
- They are found in some margarines and in food fried in hydrogenated vegetable oils[47].

Lipid oxidation products

- Lipid oxidation products and cholesterol oxide products are considered more health damaging than native cholesterol.
- The main sources are oil deep fried food, powdered eggs, and industrial bakery products containing butter, milk and eggs.
- In our patients we have not observed abnormal levels of serum oxidized LDL[57].

Stanols/sterols

- Plant stanols are found in very small amounts in food from plants such as corn and soy. Within plant tissue they are derived from plant phytosterols.
- They block the intestinal absorption of cholesterol. In the amount of 2 g/day, LDL-cholesterol is lowered by 14%[47].

Celiac disease

- Unrecognized celiac disease may be found in 3-5% of children with DM when screened with the IgA anti-endomysium antibody test.

- Indications to prescribe a gluten-free diet must be discussed with the gastroenterologist[58-59]. It seems that in children with DM, untreated celiac disease results in lower BMI SDS and increased HbA_{1c} levels[60].

DIETARY STUDIES DURING THE LAST DECADE

Comparison of mean daily nutrient intake

In 2001, Virtanen *et al.*[61] reviewed studies on the diet of children and adolescents with type 1 DM published during the last decade (Table 5)[62-69]. Because of differences in the dietary assessment methods and nutrient databases used, only rough comparisons between studies from different countries are meaningful. The protein intake was unnecessarily high in all of the studies (17-18%) except among Italian children (13%). The intake of fat comprised between 30 and 38%, being highest in Belgium. The intake of carbohydrate ranged from 44-55%, being lowest in Belgium, and highest in Italy. Sucrose intake was very low in the recent Austrian and Finnish studies. The Italian children, with their moderate intake of protein and saturated fatty acids, and high intake of mono-unsaturated fatty acids and carbohydrate, seemed to be closest to the recommended diet[67]. Their diet consisted of a high intake of starchy foods and vegetables and a restricted amount of animal products. The prevalence of obesity (body weight >120% of ideal body weight for height, age and gender) was low (5.7%). One must be cautious when comparing tiny differences in percentages of nutrients, because every dietary inquiry is marred by large errors. Moreover, the Italian dietary assessment method by interviews is less precise than our 7-day records.

Even if the food habits of Belgian children are poor as compared with Italian children, the mean level of HbA_{1c} is very close and good (± 7%) in the two populations[27,28,67]. The fact that the mean

TABLE 5

Mean daily nutrient intake of children with diabetes mellitus according to studies published during the last decade

Study	Virtanen *et al.*[62]	Pietiläinen *et al.*[63]	Randecker *et al.*[64]	Dorchy *et al.*[65,66]	Pinelli *et al.*[67]	Schober *et al.*[68]	Virtanen *et al.*[69]
Dietary survey method	48 h recall	48 h recall	3 x 24 h recall	7-d food record	*	2-d food record	5-d food record
No. of children	74	48	66	33	194	63	33
Age (yr)	15-20	10-19	4-9	7-14	1-23	10-14	2-7
Protein %E	17	17	17	18	13	18	18
Fat %E	36	34	31	38	32	34	30
SFA	16	14	11	15	8	–	11
MUFA	13	12	–	16	21	–	11
PUFA	7	6	–	7	4	–	7
Carbohydrate %E	47	50	53	44	55	48	52
Sucrose	3	9	–	16	10	3	3
Fiber (g)	32	21	17	12	18	30	23

* Interview with mothers and children by a dietician.
SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.
Table reproduced from Virtanen *et al.*[61] with permission.

HbA_{1c} levels of our children with DM are among the lowest in a comparison of major studies of glycemic control in children with DM[70] (Fig. 4), and in international comparisons by the Hvidøre Study Group[24,28-31], seems to prove that insulin adjustment is essential in order to obtain good glycemic control[22]. We have demonstrated in homozygous twins the major importance of metabolic control on the development of diabetic retinopathy, by suppressing the differential genetic influence on diabetic retinopathy evolution and reducing to a minimum external and individual differences[71]. Nevertheless, a balanced normal diet helps to reduce atherosclerosis, cardiovascular disease, hypertension, obesity, etc., as in the non-diabetic population.

Nutritional intake of Belgian children with DM

Our dietary inquiry, conducted in 1996, was a very detailed study on the nutritional intake of 33 children with DM who were 7-14 years of age, with duration of DM of 1-11years. It was published *in toto* in French[65] and as a letter in English[66]. Patients were followed at our diabetology clinic and their mean HbA_{1c} was 7.2%, which does not differ greatly from the mean HbA_{1c} of the total population of our children with DM under 18 years of age[28]. Dietary intake was calculated from 7-day records, and compared with recommendations for a normal population of the same age as well as with the results of a dietary inquiry in a non-diabetic population of children of the same age. The records were kept by the parents with the help of the children in determining food eaten away from home. The forms for recording nutritional intake contained food lists and were illustrated. Their use was explained by the same specialized dietician in the diabetology clinic, and if necessary afterwards by phone. The dietician herself collected the forms at the homes of the patients to check the dietary records with the family and to exclude ambiguous information. Portion estimation of food eaten was facilitated by standard household measuring cups, spoons, etc., and by food pictures from a specific

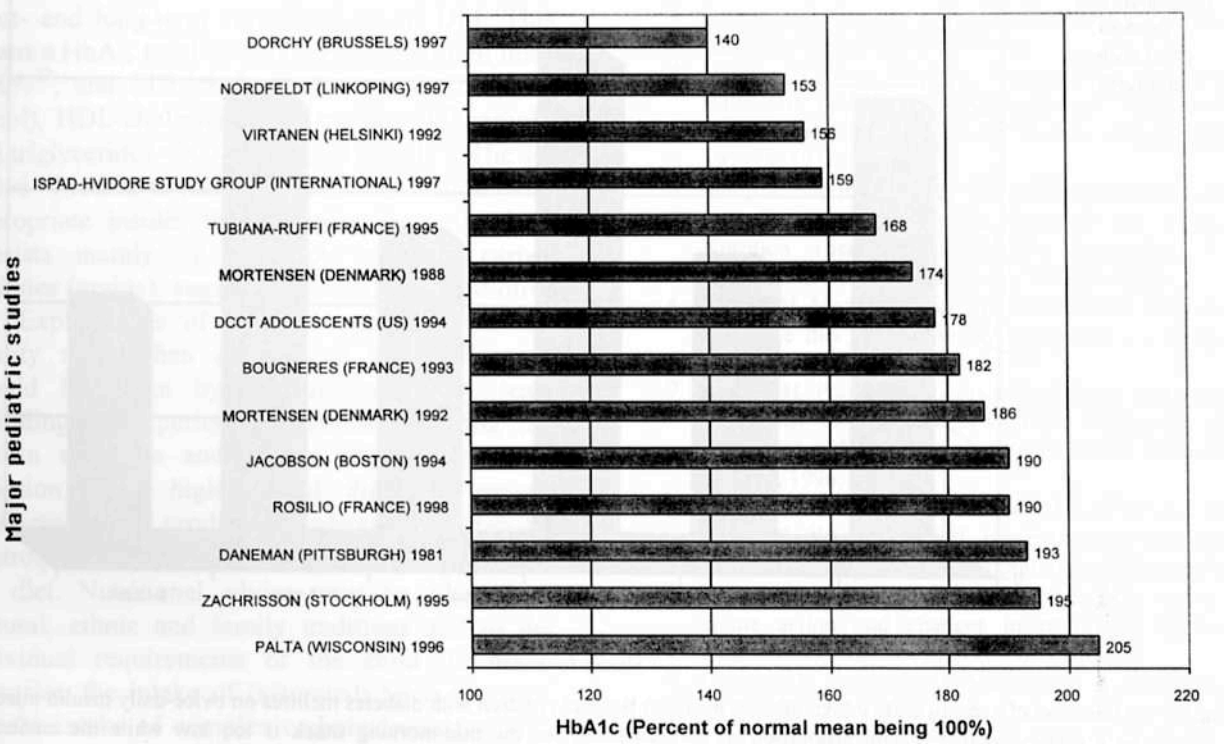

Fig. 4: Comparison of HbA_{1c} levels in major pediatric studies, expressed as a percentage above the normal mean (100%) (data from Rosilio *et al.*[70]).

book. Dietary intake was assessed by a computerized database based on the 'Souci' and 'Nevo' tables which are in accordance with our dietary habits[65,66]. The average protein (18% of total energy) and fat (38%) intakes were too high and very similar to what was observed 15 years ago[14]. In the non-diabetic children, the intake of protein and fat was 13% (lower than in children with DM) and 39% (similar to children with DM), respectively. The animal-to-vegetable protein ratio stood above the recommendations (i.e. 1) by more than 200%. The polyunsaturated-to-saturated fat ratio was too low at 0.45, but better than in our previous study[14]. The average cholesterol intake, at 220 mg/day, corresponded to the recommended amounts. Carbohydrate intake was too low (44%) and not really better than that 15 years ago[14]. In non-diabetic children, the proportion of carbohydrate was better: 48%. In children with DM, the allocation of carbohydrate intake into six meals shows a too low proportion for the mid-morning snack, and a too high amount for breakfast (Fig. 5), so that the profile of allocation of carbohydrates is not parallel to the cumulative insulin activities in blood (Fig. 1). The mean fiber consumption was less than 12 g/day, i.e. more than 50% below the recommendation (too low intake of fruits, vegetables, wholemeal bread and whole cereals). Sodium (cooked pork meats, cheese, chips, added salt, etc.), potassium (potatoes, meat, milk, fruit juice, etc.) and phosphorus intake (meat, eggs, cola drinks, etc.) were largely higher than the recommendations, while the intake of magnesium (lack of whole cereals) and calcium (lack of half-skimmed milk) were too low. Iron intake corresponded to the recommended amount. For vitamins, only vitamin D intake was insufficient. Even if one proposes a normal diet, the fear of sugar persists in children with DM, and they reduce their consumption together with an increased protein intake, which is not observed in non-diabetic children, while the fat intake is similar in diabetic and non-diabetic

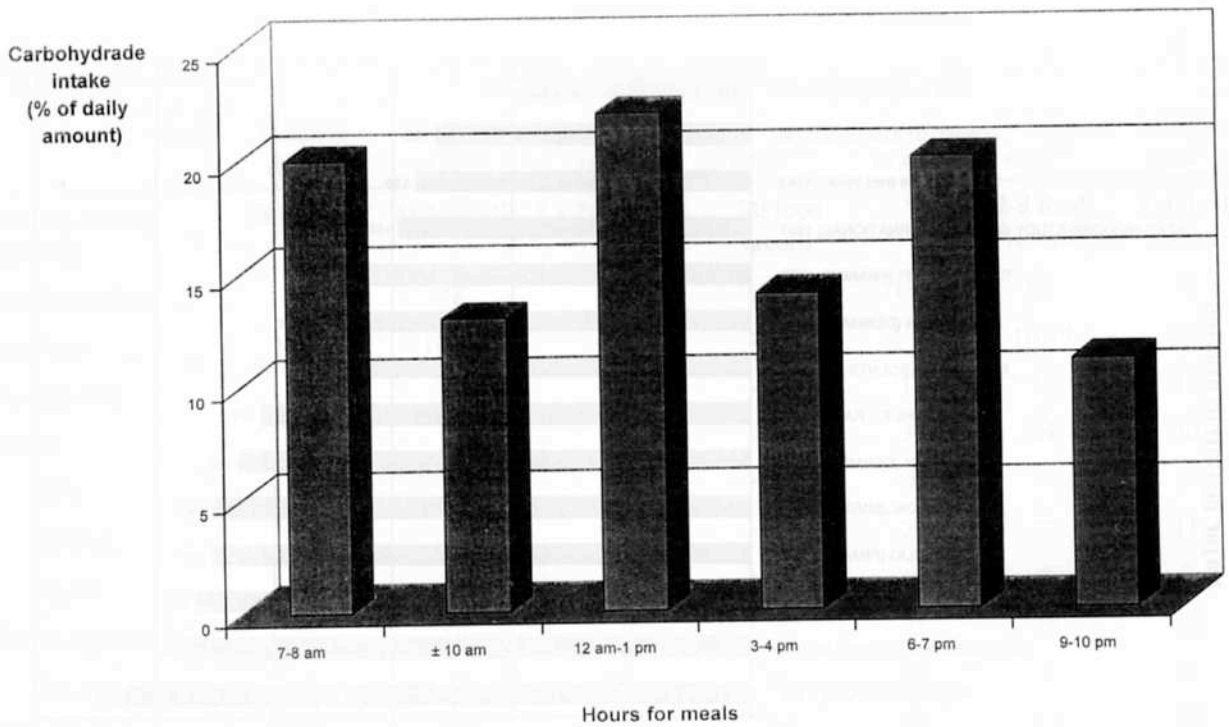

Fig. 5: Allocation of carbohydrate intake into six meals in Belgian children with diabetes mellitus on twice-daily insulin injection in a dietary inquiry[65]. The proportion of carbohydrates for the mid-morning snack is too low while the amount of carbohydrates for breakfast is too high, so that the profile of allocation of carbohydrates is not parallel to the cumulated insulin activities in blood (see Fig. 1).

children. In conclusion, our children with DM do not meet present dietary recommendations, fortunately without hampering a good mean HbA_{1c} level[27,28]. Their dietary consumption habits are almost unchanged over the past 15 years. However, they were better than those of other Belgian children with DM[12], which may reflect some influence of our education programs, even though improvement is still needed.

TREATMENT RECOMMENDATIONS

Close association has been demonstrated between a number of degenerative diseases (atherosclerosis, cardiovascular disease, hypertension, obesity, etc.) and the unbalanced diet in industrialized countries characterized by excessive amounts of calories, proteins, saturated fats, simple carbohydrates, sodium, etc. Dietary recommendations issued over the past few years are the same for diabetic and non-diabetic individuals. Children with DM should eat a normal diet while taking care to keep their blood sugar and lipid levels as close as possible to the normal range to prevent the short- and long-term complications of DM. This means a HbA_{1c} level <7% if the upper normal limit is 6%[72], and LDL-cholesterol <100 mg/dl (<2.6 mmol), HDL-cholesterol >45 mg/dl (>1.2 mmol), and triglycerides <200 mg/dl (2.3 mmol)[73]. The so-called 'Mediterranean diet', in combination with appropriate insulin therapy, may be optimal. It consists mainly of fiber-rich complex carbohydrates (grains), vegetables, fruits, fish, and olive oil. Explanations of this diet should focus on quality rather than quantity of foodstuffs, and should be given by a multidisciplinary team including an experienced dietician knowing the insulin regimens and insulin adjustments. Prescription of a highly rigid diet has proved ineffective in producing adequate metabolic control, and increases the risk of deviations from the diet. Nutritional advice must be adapted to cultural, ethnic and family traditions and to the individual requirements of the child. In many countries, the intake of (saturated) fat is too high and the intake of complex carbohydrates too low. In the twice-daily injection regimen, the daily intake of carbohydrate must be divided into six meals, and the proportion of carbohydrate of the mid-morning snack must be more important than that of breakfast. The proper use of the basal-prandial regimen, with a bolus of insulin for each meal, increases flexibility in daily life and dietary freedom, but is more complicated and is seldom applied successfully before adolescence. The selective use of fast-acting insulin analogs allows eating something sweet at any time, and the injection may even be done after eating, which is convenient when one is unaware of the amount of food that will be consumed. Dogmatism should be avoided - only objective results (good glycosylated hemoglobin and lipid levels, as well as good quality of life) are important.

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