Acta Biomed 2005; 76; Suppl. 3: 44-48

Insulin therapy and carbohydrate counting

Gaia Chiesa, Maria Antonietta Piscopo, Andrea Rigamonti, Angela Azzinari, Sonia Bettini, Riccardo Bonfanti, Matteo Viscardi, Franco Meschi, Giuseppe Chiumello

Department of Pediatrics, Endocrine Unit, Scientific Institute Hospital San Raffaele, Vita-Salute University, Milan, Italy

Abstract. Nutritional management is one of the cornerstones of diabetes care. Many studies have been performed on the correlation between nature and amount of carbohydrate in meal intake and insulin delivery by artificial pancreas in Type 1 diabetic patients. In fact consistency in the amount and source of carbohydrate intake from day to day is associated with improved blood glucose control in people with Type 1 diabetes. Many methods of counting carbohydrate have been used and many are still commonly used in paediatric practice (exchange, portion/serving, grams, glycemic index, carbohydrate/insulin ratio). Carbohydrate counting is a meal planning approach with patients with Type 1 diabetes mellitus that focuses on carbohydrate as the primary nutrient affecting postprandial glycemic response. The aim of this paper is to review published data on the significance of carbohydrate counting on meeting outcome goals and allowing flexibility in food choices. (www.actabiomedica.it)

Key words: Type 1 diabetes mellitus, carbohydrate counting, glycemic index, diet

Nutritional management is one of the cornerstones of diabetes care and education. ISPAD Consensus Guidelines 2000 show the nutritional management aims: first of all, to provide sufficient and appropriate energy intake and nutrients for optimal growth, development and good health, secondary to encourage healthy lifelong eating habits, to achieve and maintain the best possible glycemic control and ideal body weight. Aim of nutritional management is also to prevent acute complications (such as hypoglycaemia, hyperglycaemic crisis and exercise-related problems) and micro and macrovascular complications.

ISPAD Consensus Guidelines also recommend that total energy intake should be distributed as follows: more than 50% of carbohydrate (CHO), encouraging complex unrefined higher fiber CHO and moderating sucrose intake; about 30-35% of fat (less than 10% saturated fat, less than 10% polyunsaturated fat, more than 10% monounsaturated fat); about 10-15% of protein. The proportion of CHO as a percentage of total energy intake varies enormously around the world, but there is agreement that CHO should not be restricted. Also in some countries where CHO represents 60-70% of intake, excellent glycemic control is achievable.

Many methods of counting carbohydrate have been used and many are still commonly used in paediatric practice, such as exchange, list portion/serving, grams, glycemic index (GI), carbohydrate/insulin ratio. The GI of a carbohydrate is defined as the incremental rise in plasma glucose (above baseline) relative to that induced by a standard, usually 50 g di glucose or a white bread challenge. Lower GI values indicate a lesser rise in glucose (Table 1). The GI appears to be substantially determined by rates of intestinal hydrolysis. Although exchanges and gram counting appear to have an educational value, there is little evidence that parents can understand or implement such

Table 1. Some food's glycaemic index

Food	Glycaemic index	Food	Glycaemic index
Sugar	138	Orange	59
Potatoes	118	Apple	53
Corn flakes	115	Ice cream	52
Pizza	106	Peas	49
BREAD	100	Pear	47
Grapes	88	Spaghetti	45
Banana	84	Beans	45
Rice	81	Lentils	37
Orange juice	67	Milk	32
Maccheroni	64	fructose	31

diet at long term. Unless rigorously reviewed, there is a danger that such dietary prescriptions will lead to carbohydrate constraint as the child grows, and may lead to disordered eating behaviour. However, some practical quantification of CHO is necessary as part of intensification of management. Parents and young people should be able to visualize amount and types of CHO using educational tools such as the "plate model" or "size of hand model". In this way it may be possible to estimate the glycemic impact of various types of food (1).

Consistency in the amount and source of carbohydrate intake from day to day is associated with improved blood glucose control in people with Type 1 diabetes. Diet variation was found to have a greater effect on HbA1c than body mass index and insulin dose. Some studies demonstrate that variation in glycemic index is helpful for the prediction of prandial insulin requirement (2) (Fig. 1).

More recent studies evidence that, for diabetes diet planning, the amount of CHO is more important than the source, in that the variation in starch intake is more closely related to HbA1c than variation in diet glycemic index, supporting the official position of the American Diabetes Association (ADA) (3).

Many studies have been conducted about correlation between the nature and amount of carbohydrate in meal intake and insulin delivery by artificial pancreas in Type 1 diabetic patients. Blood glucose variations were studied after ingestion of variable amount of CHO, either as complex carbohydrate in a mixed meal or as simple sugar dextrose. As observed in normal subjects, blood glucose increased to higher levels, but for a shorter period of time, after the dextrose load

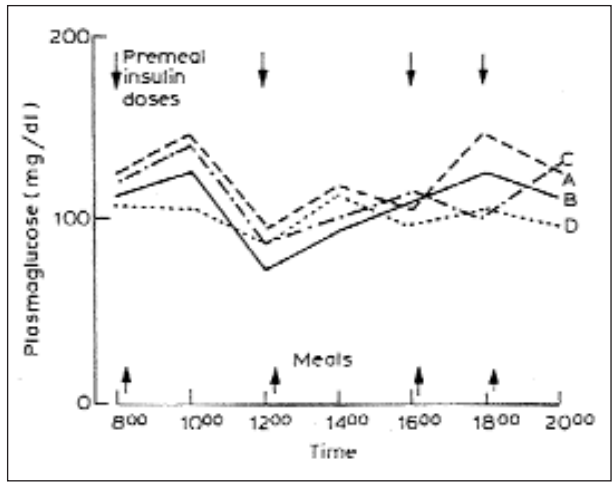

Figure 1. Diurnal plasma glucose profile (means) obtained with the test dietes (A = high glycaemic index; B = low glycaemic index; C = low carbohydrate; D = fruit diet) (2)

than after the mixed meals. Similarly, the overall kinetics of insulin secretion by the artificial pancreas was also comparable to those observed in peripheral veins in normal subjects after a meal of dextrose. With the addition of fat, protein and dietary fibres to the complex carbohydrate in the meals, blood glucose excursion above basal value and insulin delivery by the artificial pancreas was delayed but not diminished on an overall basis. The total amount of insulin infused by artificial pancreas to restore basal blood glucose did not differ, for a given amount of CHO, after a dextrose load and mixed meal even if insulin-infused kinetics were different (4) (Figs. 2, 3). The total amount of insulin correlated linearly with the total amount of meal carbohydrate, but not with the nature (5).

In a short-term trial, the addition of sucrose did not adversely affect glucose control if accounted for on an isocaloric basis. The ADA expert panel analysed 22 studies addressing this issue and concluded that, when ingested in isocaloric quantities, sucrose does not affect glycemic control in diabetics significantly differently from other carbohydrates (6).

Some authors also noted that the ratio of insulin required to restore basal blood glucose value varied according to the time of day, more insulin needed in the morning than later in the day. More over, the sequence of meal ingestion doesn't seem to alter integrated plasma glucose response, but influences the meal-rela-

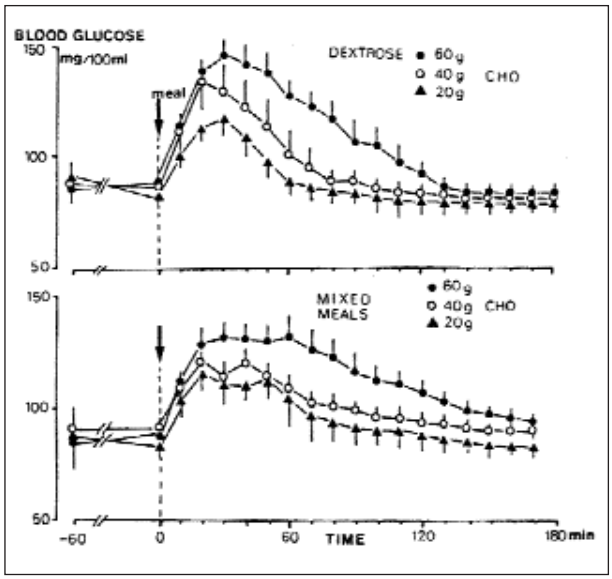

Figure 2. Mean blood glucose variation observed after dextrose (upper graph) and mixed meals in IDDM patients controlled by an artificial pancreas and receiving 20 g (triangle), 40 g (open circle) and 60 g (closed circle) of carbohydrate (4)

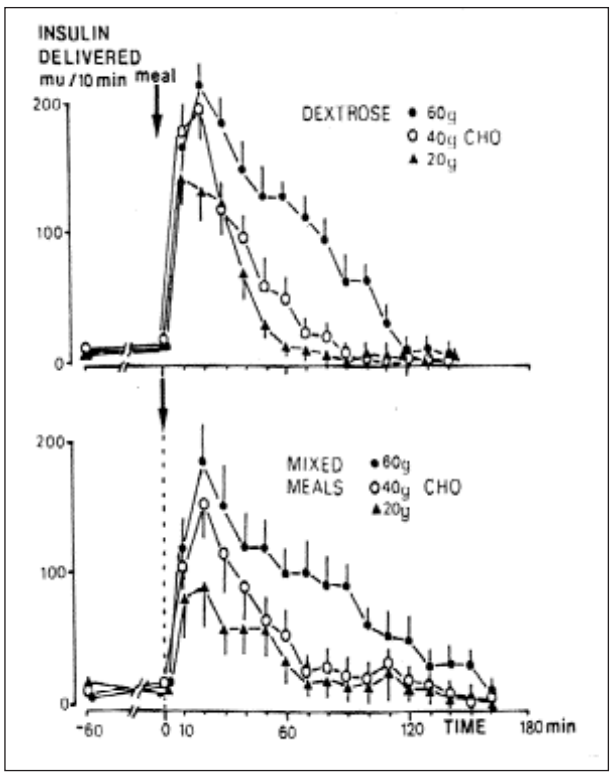

Figure 3. Mean insulin delivered every 10 min by artificial pancreas after dextrose (upper graph) and mixed meals (lower graph) in the same patients (4)

ted amounts in insulin infused: when medium meal eaten at 13.00 h is preceded by a large meal, less insulin is required than when medium meal is preceded by a small meal to achieve the same postprandial plasma glucose concentration (7).

Carbohydrate counting is a meal planning approach with type 1 diabetes mellitus patients that focuses on carbohydrate as the primary nutrient affecting postprandial glycemic response. The concept of carbohydrate counting has been around since 1960s, but it received renewed interest after being used as 1 of 4 meal planning approaches in Diabetes Control and Complications Trial (DCCT). In the trial, Carbohydrate counting was found to be effective in meeting outcome goals and allowed flexibility in food choices. Recent practice pattern surveys have shown an increasing interest in carbohydrate counting for medical nutrition therapy for persons with diabetes (Type 1 and Type 2). Three types of carbohydrate counting have been identified based on increasing levels of complexity. Level 1, or basic, introduces patient to the concept of carbohydrate counting and for carbohydrate consistency. Level 2, or intermediate, focuses on the relationships among food, diabetes medication, physical activity and blood glucose level and introduces the step needed to manage these variables based on patterns of blood glucose levels. Level 3, or advanced, is designed to teach patients with type1 diabetes mellitus who are using multiple daily injections or insulin infusion pumps how to match short-acting insulin to carbohydrate using carbohydrate-to- insulin ratios. All three levels emphasize portion control. Carbohydrate counting as a meal planning approach offers variability of food choices with the potential for improving glycemic control (8).

Carbohydrate are counted in grams (g) and usually translated into "Carbohydrate Choices" as follows: 1 Carbohydrate Choices = 15 g of Carbohydrate. Information on how much carbohydrate is in food can be found on Nutrition Fact Panel of food labels. The Exchange List for Meal Planning can also help patients to learn how to count carbohydrates. Starch, fruit and milk groups contain similar amounts of carbohydrate using the calculation of: 1 Carbohydrate Choice = 1 Starch or 1 Fruit or 1 Milk. Patients can be taught to substitute a serving of starch for a fruit or

milk serving. This increases flexibility in meal planning and food choices (9).

However, carbohydrate counting isn't always guaranty for a good glycaemic control. A study examinated the postprandial hyperglycaemic effect of pizza in well-controlled patient with Type 1 diabetes mellitus. On two evenings, each patient consumed a meal that was similar in macronutrient composition except that one consisted of pizza and other was a control meal that included high glycemic index food. Postprandial glucose levels were within the target range after the control meal. Although the initial glucose increase was similar for the two meals, plasma glucose continued to rise and was significantly increased from 4 to 9 h after ingestion of pizza compared with control meal. This increase occurred even though free insulin, glucagon and fatty acid levels did not significantly differ. Different food with identical composition of macronutrients are digested and absorbed at different rates. As a result, they produce a range of glycemic responses in diabetic patients that can be predicted, at least in part, from their glycemic index and amount of carbohydrate. The greater amount of polysaccharides or other components like olive oil or spices may have contributed to the persistent hyperglycemia after pizza meal. Because the hyperglycemia induced by pizza was most pronounced in the late postprandial period, increasing the premeal dose of regular insulin may not be sufficient to compensate for the problem (10) (Fig. 4).

Usually, premeal regular insulin is expressed in U/10 g of carbohydrate to be ingested. The dose is adjusted by 0.2 U/10 g of CHO to achieve and maintain 1h postprandial capillary blood glucose between 120 and 180 mol/l. Using the aforementioned premeal algorithms for insulin adjustment, glycemic control is well maintained, despite a wide range of carbohydrate content in individual mixed meals (21-188 g). The usefulness of the system has been confirmed in the DCCT with better control for patients using carbohydrate counting in the intensively treated group resulting in supplementary 0.56% reduction in HbA1c, compared with those not counting CHO. Some investigators have reported no benefit of carbohydrate counting compared with simple dietary advice. These studies were performed, however, in poorly controlled, conventionally treated Type 1 diabetic subjects

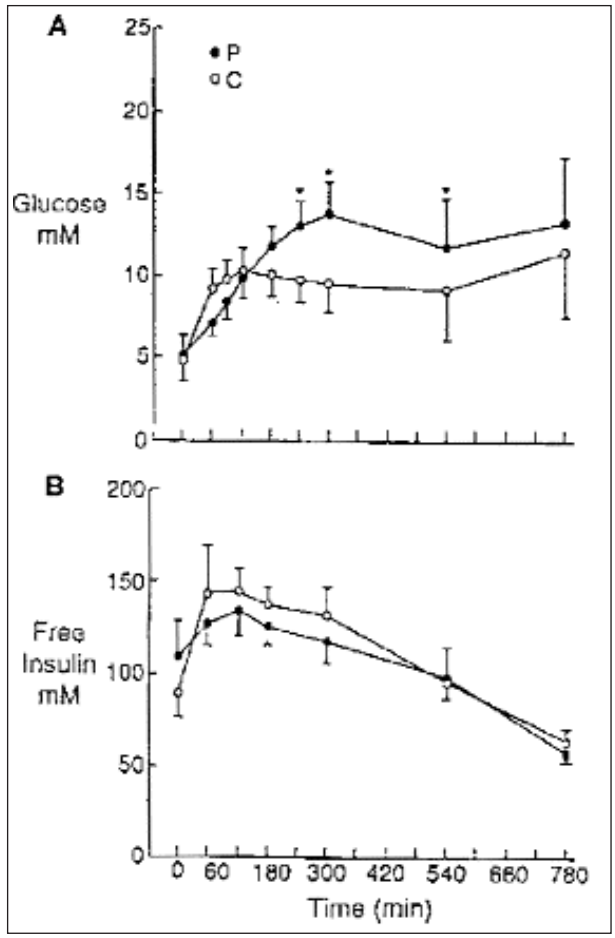

Figure 4. Plasma glucose (A) and insulin (B) levels before and after pizza meal (●) and control meal (○) on intensive treated IDDM patients (10)

without specific algorithms for insulin adjustment and/or without capillary glucose measurement. It is clear that, to be effective, intensified insulin therapy requires a teaching and training program, not only on carbohydrate counting, but also on various aspects of diabetes management, particularly specific algorithms to adjust insulin doses to achieve good glycemic control (11).

It is challenging to teach insulin dosage adjustment algorithms designed to normalize elevated blood glucose levels and to compensate for alternations in carbohydrate intake. The insulin dose required for 15 g of carbohydrate has been identified in many studies in 0.5-1U. To address these concerns, a hand-held plastic Insulin Dosage Guide was developed for patients to use both with short- and rapid-acting insulin in a va-

riety of insulin regimens, including continuous subcutaneous insulin infusion (CSII). It was designed for patients unable to correct abnormal blood glucose levels in a standard consistent fashion and to determine how much insulin to take if they are using carbohydrate counting. The algorithm used in the Insulin Dosage Guide was based on increasing the dosage of short- or rapid-acting insulin by 0.5 U (Low Dose Guide Insert), if the dosage of insulin was <10 U, or 1 U of insulin if it was ≥10 U. This 0.5 U or 1 U of insulin was added for every 50 mg/dl that the blood glucose level was greater than the upper limit of the target range. For children ≥5 years old, the upper limit of target range was 150 mg/dl; for children <5 years was >200 mg/dl. The amount of insulin for each 15 g of carbohydrate was written on Insulin Dosage Guide by the Certified diabetes Educator after it was determined for each subject who was doing carbohydrate counting (12).

Insulin dose for 15 g of carbohydrate could be different among patients so every one has to calculate the right bolus making multiple glycemic determinations.

Types of insulin that in association with carbohydrate counting give best results on glycometabolic control are short acting analogues. In fact short acting analogues insulin have the fastest absorption and are more reproducible than regular insulin; they also provide better post-prandial glycaemic control and reduce risk of late post-prandial hypoglicaemia.

Carbohydrate counting may be a desirable method for individuals who wish a more flexible approach, have an inconsistent carbohydrate intake, have not been successful with past diet plans or have the willingness and/or ability to learn a new approach. Teaching portion control is essential for success in carbohydrate counting. The home setting is ideal for teaching nutrition principles. Food, labels and measuring utensils that the patient is familiar with can be used to enhance teaching. By helping patients to practice weighing and measuring foods, they will learn to calculate carbohydrate content more easily. These foods may include bread, pasta, rolls, cereals, crackers, potatoes and fruit. Food intake and blood glucose monitoring records are also important for success. These will help patients in making changes, evaluating the impact of carbohydrate intake and food choices on blood glucose and setting nutrition goals (9).

Reference

1. Consensus Guidelines 2000 - ISPAD Consensus guidelines for the management of type 1 diabetes mellitus in children and adolescent. Edited by Peter Swift, 2000: 53-8.
2. Chantelau E, Spraul M, Kunze K, Sonnenberg GE, Berger M. Effects of the glycaemic index of dietary carbohydrates on prandial glycaemia and insulin therapy in type I diabetes mellitus. *Diabetes Research and Clinical Practice* 1986; 2: 35-41.
3. Wolever TM, Hamad S, Chiasson JL, et al. Day to day consistency in amount and source of carbohydrate intake associated with improved blood glucose control in type 1 diabetes. *Journal of the American College of Nutrition* 1999; 18 (3): 242-7.
4. Slama G, Klein JC, Delage A, et al. Correlation between the nature and amount of carbohydrate in meal intake and insulin delivery by artificial pancreas in 24 insulin-dependent diabetics. *Diabetes* 1981; 30: 101-5.
5. Halfon P, Belkhadir J, Slama G. Correlation between amount of carbohydrate in mixed meals and insulin delivery by artificial pancreas in seven IDDM subjects. *Diabetes Care* 1989; 12: 427-9.
6. Kelley DE. Sugar and starch in the nutritional management of diabetes mellitus. *American Journal of Clinical Nutrition* 2003; 78 (suppl): 8585-91.
7. Service FJ, Rizza RA, Hall LD, et al. Prandial insulin requirements in insulin dependent diabetics: effect of size, time of day, and sequence of meals. *Journal of Clinical Endocrinology and Metabolism* 1983; 57 (5): 931-6.
8. Gillespie SJ, Kulkarni KD, Daly AE. Using carbohydrate counting in diabetes clinical practice. *Journal of the American Dietetic association* 1998; 98: 897-905.
9. Arcement PS. Carbohydrate counting in diabetes meal planning. *Home Healthcare Nurse* 1999; 17 (7): 425-8.
10. Ahern JA, Gatcomb PM, Held NA, Petit WA, Tamborlane WV. Exaggerated hyperglycemia after a pizza meal in well controlled diabetes. *Diabetes Care* 1993; 4: 578-80.
11. Rabasa-Lhoret R, Garon J, Langelier H, Poisson D, Chiasson JL. Effect of meal carbohydrate content on insulin requirement in type 1 diabetic patient treated intensively with the basal bolus (ultralente-regular) insulin regimen. *Diabetes Care* 1999; 22 (5): 667-73.
12. Kaufman FR, Halvorson M, Carpenter S. Use of plastic insulin dosage guide to correct blood glucose levels out of the target range and for carbohydrate counting in subjects with Type 1 diabetes. *Diabetes Care* 1999; 22: 1252-7.

Correspondence: Dr. Gaia Chiesa
Dept. of Pediatrics, Endocrine Unit
Scientific Institute Hospital San Raffaele
Vita - Salute University
Milan, Italy