Expressing carbohydrate ratios

Frances Hanson, Karen Ross

With a national drive for quality and consistency in paediatric diabetes education, this article reviews the differences in insulin:carbohydrate ratio (ICR) expression and how they are used in practice. Is one method superior to the other and how does technology support these methods of expression? Is it possible to standardise our approach in the UK?

Carbohydrate counting was reintroduced to the UK in 1999 with the start of Dose Adjustment for Normal Eating (DAFNE) courses for adults with type 1 diabetes. Standard teaching resources were produced as part of this programme and others were also developed to enable accurate carbohydrate counting in early adopter centres for insulin pump therapy. All acknowledged that previous resources used during the carbohydrate restrictions of the 1970s and 1980s were not appropriate for new flexible ways of administering insulin.

Carbohydrate counting was reintroduced for children with diabetes in the UK in 2002, after the launch of the basal insulin analogue insulin glargine, followed by the basal insulin analogue insulin detemir in 2004. Paediatric teams used the carbohydrate-counting resources designed for adults with diabetes before developing their own. Resources developed for adults often incorporated the carbohydrate portion (CP) model being used on DAFNE courses, where 1 CP equates to 10–12 g carbohydrate, and insulin:carbohydrate ratios (ICRs) were expressed as a variable unit of insulin with a fixed amount of CP, for example, 1 unit per CP. When CPs were not used, the ICR was often expressed as 1 unit per 10 g carbohydrate. Teenagers, previously established on twice-daily mixed insulin regimens were the first paediatric patients to use this flexible way of administering insulin as they were able to give their own insulin in school. These ratios were very acceptable for this age group, and expressing ICRs in this manner was widely adopted across the country.

However, in time, as flexible insulin regimens were introduced to younger children, and for all children from diagnosis, lower ICRs were required as insulin sensitivity increased. These were more difficult to express in the same manner, owing to the ratios required – 2/3 unit per 10 g carbohydrate = 1 unit per 15 g carbohydrate. Poor adult numeracy in the UK is one of the major barriers to calculating accurate doses in carbohydrate counting and insulin adjustment (Carpentieri et al, 2009). Introducing fractions has not been widely adopted in paediatric practice; instead they use a fixed unit dose and vary the mass of carbohydrate for the smaller ratios required for insulin-sensitive patients, for example, 1 unit per 25 g carbohydrate. This has led to a combination of ICR expressions existing in tandem within a paediatric patient caseload depending on the insulin sensitivity of the child, which has the potential to be confusing for children, young people and their families. Teams must produce resources to help children and families with their calculations, to build confidence and ensure safety.

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Article points

1. In this article, the authors review the differences in the expression of insulin:carbohydrate ratios (ICRs) in the management of children and young people with type 1 diabetes on intensive insulin therapy.
2. The authors explore the use of a fixed unit to variable mass of carbohydrate compared with variable units to a fixed mass of carbohydrate.
3. It is concluded that it is important to individualise diabetes education in order to ensure understanding of carbohydrate counting, and that there is a need for consistency in the national expression of ICRs as a contribution to achieving better outcomes.

Key words

- Carbohydrate counting
- Intensive insulin therapy
- Paediatric diabetes education

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Insulin:carbohydrate ratios

Multiple dose injections (MDIs) and insulin pump therapy have become the treatments of choice for the majority of children and young people of all ages diagnosed with diabetes in the last 10 years and are seen as superior to twice-daily mixed insulin regimens (Bangstad et al, 2009) Subsequently, the education required in the first few weeks following diagnosis has increased. Carbohydrate counting and the adjustment of insulin doses is complex, and it is the duty of the dietitian teaching this to make it effective and practical, ensuring patients feel confident to use this to optimise their glycaemic control.

There are a number of considerations for children and young people when using carbohydrate counting, including the complexities of what they are being asked to do, the mathematical skills this requires, the burden of having to perform calculations every time they eat and the impact this may have on their mealtimes and social activities involving food. On the other hand, a significant advantage is that they can adjust their insulin therapy according to the circumstances in which they find themselves, whilst avoiding extreme blood glucose fluctuations, which bring their own particular challenges.

Irrespective of whether the method of ICR expression that has been chosen involves grammes or CPs, and fixed or flexible units, it is vital that the child, their parents and all carers involved in the day-to-day decisions concerning insulin doses for meals are confident with the calculations required. Furthermore, it is important that healthcare professionals are able to offer alternative methods where appropriate. However, there has been debate nationally about the need for consistency in the expression of ICRs across the country, raising the question of which method should be used.

Box 1. Examples of doses in which there is a fixed unit and variable mass of carbohydrate.

- 1 unit per 10 g carbohydrate
- 1 unit per 7 g carbohydrate
- 1 unit per 5 g carbohydrate… etc…

The case for a fixed unit and variable mass of carbohydrate

MDI regimens require a system of expressing ratios that can incorporate all levels of insulin sensitivity and adapt to changing needs introduced from diagnosis. Doses are calculated by changing the divisor number. A grid may be given to help dose calculations (see *Table 1*) and increase confidence when practising carbohydrate counting. By using these from diagnosis, it introduces the concept of changing ratios throughout the different stages of life.

With the introduction of smart meters, using pump technology to benefit all insulin users, an easier solution can be provided for those taking injections, after learning manual calculations. Smart meters are used to aid complicated insulin dosing calculations involving different mealtime ratios and correction doses (Barnard and Parkin, 2012) and are now frequently used in paediatric practice. The total meal carbohydrate is calculated using a method the patient is familiar with and entered into the smart meter. The final insulin dose is then calculated and rounded to the nearest half unit if administered by injection. If people using MDI move to insulin pump therapy, it is more likely to be a smooth transition if the ICR is already being expressed the same way.

Insulin pumps are very successful, particularly in earlier age groups due to maximum flexibility for unpredictable lifestyles (Phillip et al, 2007; Pankowska et al, 2009). The expression of ICRs is inconsistent amongst all insulin pumps available in the UK. Some offer flexible insulin units for fixed carbohydrate units (grammes and CPs), some offer flexible carbohydrate units for fixed insulin units and some offer both, all within their own bolus calculators. Young children are likely to be given very small doses of insulin (ratios of 1 unit per 25 g carbohydrate or 1 unit per 30 g carbohydrate are not unusual), and these are easily programmed into an insulin pump but would be difficult to manually calculate at 0.4 units per 10 g or 0.33 units per 10 g on injections. For instance, the following examples of dose calculations both equate to 1 unit per 25 g carbohydrate, but the first example appears to be more obvious:

- 57 g ÷ 25 g = 2.28 units.
- 57 g ÷ 10 g x 0.4 = 2.28 units.

Table 1. Grid for calculating insulin doses, expressed as 1 unit per *x* g, for up to 50 g carbohydrate.

Carbohydrate (g)	1 unit per 30 g	1 unit per 25 g	1 unit per 20 g	1 unit per 15 g	1 unit per 12 g	1 unit per 10 g	1 unit per 7 g	1 unit per 5 g
10	-	½	½	½	1	1	1½	2
20	½	1	1	1½	1½	2	3	4
30	1	1	1½	2	2½	3	4	6
40	1½	1½	2	2½	3½	4	6	8
50	2	2	2½	3½	4	5	7	10
… etc… up to 100 g carbohydrate.								

The only nationally available carbohydrate-counting resources (Nutrition and Diet Resources UK, 2010a; 2010b) have chosen to use a fixed unit to variable gramme ICR. If these written resources are to be used within a service, the same way of calculating ICR should be taught and used in practice. Generally, correction doses are calculated using a fixed unit with a variable mmol reduction. Using an ICR with a similar format would help consistency in calculations whether calculating manually, with a smart meter or pump.

Admittedly, confusion can arise when increasing insulin doses, as the divisor number becomes lower rather than higher. This can give the impression of less insulin being given – for example, when a healthcare professional states "your insulin ratio needs to be increased from 1 unit per 10 g to 1 unit per 7 g", this may be misinterpreted. Using the grid (see *Table 1*) can help to reinforce the concept that a lower number provides more insulin.

Box 2. Examples of doses in which there is a variable unit and fixed mass of carbohydrate.

- 1 unit per 10 g carbohydrate
- 1½ units per 10 g carbohydrate
- 2 units per 10 g carbohydrate… etc…

The case for a variable unit and fixed mass of carbohydrate

Counting carbohydrate to a level of accuracy to achieve optimal blood glucose control, whilst making the calculations of carbohydrate and insulin practical, is vital. It has been shown that calculating carbohydrate to an accuracy of 10 g for a particular insulin dose is adequate (Smart et al, 2009) and that the majority of young people and their families find this possible (Smart et al, 2010).

Counting carbohydrate in portions of 10 g increments has been established for many years although numerous food products do not fall easily into amounts that contain 10 g carbohydrate – for example, a slice of bread contains 12–20 g carbohydrate. However, when the total amount of carbohydrate in a meal is calculated, the act of approximating that number to the nearest 10 g and dividing by 10 to calculate how many units of insulin are required is simple mathematics, in which the majority of young people appear to be capable. If an ICR is 1 unit per 10 g, this calculation leads you easily to your insulin dose.

In countries where meal plans for people with diabetes are more prescriptive, the levels of carbohydrate, protein and fat are all counted in a portion system (Kordonouri et al, 2012; Pankowska et al, 2012), where the CP varies between 10–15 g carbohydrate, depending on

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the country. ICRs are expressed as a number of insulin units per CP. As insulin sensitivity changes in young people with diabetes, the ICR will need to change. Young people should understand their own insulin requirements and how they are changing. If more insulin is required overall, an increase in the number of units needed for every 10 g increment of carbohydrate is both logical and understandable, allowing the carbohydrate to be counted in the same way, that is to continue to round to and divide by 10. As previously described, when an ICR is expressed as 1 unit per number of grammes of carbohydrate to increase the insulin dose, the number of grammes (the divisor) is decreased. Whilst this can be effectively explained and understood, there is an additional

Table 2. Insulin dose calculations for the appropriate ratios.

Carbohydrate (g)	0.1 unit	0.2 unit	0.3 unit	0.4 unit	0.5 unit	0.6 unit	0.7 unit	0.8 unit	0.9 unit	1 unit
10	0	0	0	½	½	½	1	1	1	1
20	0	½	½	1	1	1	1½	1½	2	2
30	0	½	1	1	1½	2	2	2½	3	3
40	½	1	1	1½	2	2½	3	3	3½	4
50	½	1	1½	2	2½	3	3½	4	4½	5
… etc… up to 100 g carbohydrate.										

Table 3. Insulin dose calculations, with examples of the simple addition or subtraction of units from the total dose previously calculated.

Carbohydrate (g)	0.1 unit	0.2 unit	0.3 unit	0.4 unit	0.5 unit	0.5+0.5 to total meal dose	0.6 unit	0.7 unit	0.5+1.0 total meal dose	0.8 unit	0.9 unit	1.0–1.0 from total meal dose	1 unit
10	0	0	0	½	½		½	1		1	1		1
20	0	½	½	1	1	1½	1	1½	2	1½	2	1	2
30	0	½	1	1	1½	2	2	2	2½	2½	3	2	3
40	½	1	1	1½	2	2½	2½	3	3	3	3½	3	4
50	½	1	1½	2	2½	3	3	3½	3½	4	4½	4	5
… etc… up to 100 g carbohydrate.													

level of understanding required which can be difficult and unnecessary for some people. For younger or insulin-sensitive children whose insulin requirements are less than 1 unit per 10 g, 0.8, 0.5 or 0.3 units per 10 g may be needed, which can make the dose calculation more difficult. There are simple solutions to this, through either providing insulin dose calculation cards for the appropriate ratio (see *Table 2*), along the same lines as *Table 1,* or simply adding or subtracting units from the total dose previously calculated (see *Table 3*). For example, if a young child using 0.5 units per 10 g has 40 g carbohydrate for lunch, they will divide their carbohydrate by 10 (4) and then halve the dose (2 units).

If they need more than this, but not as much as 1 unit per 10 g, perhaps somewhere in between 2 and 4 units, adding 0.5 units or 1 unit to the total dose previously calculated achieves that objective without the burden of complex calculations of 0.6 or 0.75 units per 10 g. This is usually verbalised to patients, but is illustrated in *Table 3.*

The alternative of using 1 unit per 16 g or 13 g respectively means dividing the carbohydrate by 16 or 13, which will require a calculator for most people of average numeracy. For meals with a higher carbohydrate content, such as those containing 70 g carbohydrate, the difference in dose for 0.5 or 1 unit per 10 g will be 3.5 units. If 0.5 units per 10 g is inadequate, gradually increasing the total meal dose in 1 unit increments until that dose equates to 1 unit per 10 g provides parents or carers with sufficient time to assess the effect of a slightly increased dose and accept its necessity before adjusting the ICR from 0.5 to 1 unit per 10 g.

When using insulin pumps or smart meters, or both, all of which are programmable with variable increments of insulin to 10 g carbohydrate, people with diabetes only have the carbohydrate to calculate. When looking at the settings on the smart meter or pump, if an individual has different amounts of insulin programmed at different times of day for 10 g carbohydrate, it is instantly clear at which time of day they are receiving more or less insulin for their carbohydrate intake. When an adjustment is required, if they need more insulin the units increase (even if it is only by 0.1 unit) or if they need less, the units decrease.

Summary

Both of the described methods of expressing ICR are valid and reach the same end-point. Not all current technology will support either method, when using grammes rather than CPs. Technologies are not consistent in their approach. Teams need to be aware of both systems, to allow flexibility and to facilitate patient choice when using technology.

This, along with a requirement to individualise patient education in order to ensure understanding, challenges the need for a consistent national expression of ICRs as a contribution to achieving better outcomes. However, consistency in the expression of ICRs amongst members of the same diabetes team is the most essential element of a successful message. ■

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"Consistency in the expression of insulin:carbohydrate ratios amongst members of the same paediatric diabetes team is the most essential element of a successful message."