IC factor (Carb ratio)

Contribution to the discussion among DIY loopers

The author assumes no liability B/ V.2.5 16Dec22

What is the IC value?

The IC factor is a key parameter for YOUR determination of a bolus via the bolus calculator in hybrid closed looping.

oref(1) loops do not directly use IC to determine the automatic insulin delivery. IC is mainly used by the loop to calculate carb decay, while assigning otherwise unlogical effects to temp. changes of your insulin sensitivity.

The IC parameter describes how much insulin you need for carbs you consume.

For example, IC = 8 g / U means, for 8 g Carb, 1 Unit of insulin is required

Unfortunately, it is not one fixed number we can count on (count with):

* can vary between times of day

=> determine it separately for each meal (breakfast, lunch, dinner), and check whether you see a typical „circadian" sensitivity pattern corresponding to your bio-rhythm..(As a <u>high</u> basal rate and a <u>low</u> ISF factor are signs of <u>lower</u> insulin sensitivity (=of elevated insulin need), the pattern must be like a mirror-image. More see in section Circadian Pattern, below)

* can also vary between days e.g. when hormones play into it => **Autosense**

Rough estimate for your IC:

a) Autotune (not recommended by the author)

Autotune gives one „average" IC. It's „reliability" is seen controversial, to a large part probably because: : it makes calculations based on data (carbs and insulin dosing data). So, if if you don't enter complete / correct data, then you'll get suggestions you probably don't want to take. Inaccurate/inconsistent input = less useful output.

b) Via TDD

You can get your **daily average IC** if you (1) count up the g carbs in 24 hrs and (2) divide it by the amount of 24 hr bolus insulin. Problem with the latter: Because your loop modulates basal rates all the time, you must first look up the **TDD** (**total daily insulin given** (in AAPS you see that at the bottom of the /ACT/ screen,(next to HOME, or in statistics). Then substract the "real" 24hr basal need <u>as in your profile</u>, from the TDD):

IC (g/U) = C (daily g carb) / (TDD - 24h Basal as in Profile).

Adult example: TDD = 37U; Profile Basal = 16U; daily carbs 200g

=> IC = 200 g / (37U-16U) = 200 / 21 g/U ~ 9,5 g/U

Try to eliminate days with extreme sports, unusual stress, or infection from that evaluation. Later you will modify insulin delivery for such scenarios via profile switch = „tuning“ your IC according to the temporary changed typical insulin requirement.
Therefore, avoid "averaging" such effects into your factor determination upfront already

Attempts to define the IC factor via TDD can only yield a rough estimate, notably, because the influence of fats and proteins is often omitted, or done wrong, or applied inconsistently.

This is discussed in more detail in: Meal-Management , see Loop&Learn FB, / Files
https://www.facebook.com/groups/LOOPandLEARN/permalink/3032204653702685/

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To determine a meal bolus in HybridClosedLoop, best use an IC-factor which you determined for the relevant time-of-day window, as follows:

Determination at meal time

Make sure your basal rate is right.

> This is important because you want to watch the effect of your meal bolus for at least 3 hours, and a basal rate error in that time window would bias your observations. Additionally, your observations would be burdened by any wrong basal values for a couple of preceding hours.
>
> Helpful links regarding basal rate, here is a good article in support of that process: https://www.mysugr.com/en/blog/basal-rate-testing/ , and a process description including a tool : https://www.mevita.de/.../online-zugang-erstellung-einer.../ .

Then determine your **IC for each major mealtime.**

On a day without preceding major activity, stress, infection, and before the meal and a relative steady glucose in the normal range (and cob=0): Shut closed loop off. Eat a well defined **smaller meal** (20 .. 45 g of preferably „rapid“ carbs) and use your suspected IC to determine the amount of insulin for this meal. With ClosedLoop off, but profile basal running, watch for 3 hours. (This assumes you use Lyumjev or Fiasp, at least in a 50% mix. The author never tried any slower insulin, whuch would be inferior for looping, and require longer time periods to observe desired changes, in tests as well as in everyday life!)

- If your glucose levels about where you started, the IC can be used.
- If curve goes too low (eat some carbs and) try again with a higher IC value.

- If curve remains too high, the IC was too weak and needs to be lowered.

People who eat very carb-rich diets must give some consideration to the fact that the capacity of their body, how much carbs it can absorb per hour, is limited (in adults often to 30g/hour). So **only a portion of the meal might be servable via a meal bolus** given at the beginning.

The IC should get you through the first 2-3 hours of a meal. (More see Tuning chapter)

Challenges can arise after the 2nd hour when meal bolusses „wear out" and Fat/Protein contributes.

For testing carb ratios see also Katie di Simone at: http://seemycgm.com/2017/10/29/fine-tuning-settings/ and Dr. Saleh Adi from Tidepool at: https://www.youtube.com/watch?v=McxO3oOkzc4 ´

Regarding **late meal phase see also** Meal Management in /Files of Loop&Learn FB
https://www.facebook.com/groups/LOOPandLEARN/permalink/3032204653702685/
or also this study: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4454102/

We can conclude that determining a suitable IC factor is not easy. Size and composition of a meal and the activity curve of the insulin in use can introduce variations in our attempt to define our IC.

In the following chapter, therefore another factor is presented which is much easier to determine and can serve to either determine the IC via an alternative route, or to provide a plausibility control.

Determination of IC ratio via other factors (CRR, CSF, ISF)

The carb rise ratio (by some also called CSF, carb sensitivity factor) describes by how many mg/dl our glucose rises per gram of absorbed carbohydrate.

CRR is actually quite easy to determine (easier than the IC, which requires 3 hours with underlying stable glucose and correct basal rate):

(In a relatively stable, normo-glycemic phase) take a sweet drink with a known carb content, and watch (in Open Loop, not giving any insulin except profile basal rate) by how many (mg/dl) glucose rises, until reaching a plateau (in about 1 hour).

Example: After taking 20g I rise from 90 to 190 mg/dl.

CRR = (190-90)mg/dl / 20g = 5 mg/dl / g

This parameter is of great value to control ISF and IC for plausibility, because:

ISF (mg/dl drop per U) **/ CRR** (mg/dl rise per g carb) **= IC** (g carb / U)

or CRR = ISF / IC (Likewise of course in the mmol world)

I can now continue the „experiment" *(example above),* by treating the plateau *of 190 mg/dl* with an amount of insulin that suits my insulin sensitivity*, e.g. 2 Units.* Then I observe for about three hours (ClosedLoop off, profile basal running), until a new lower plateau is reached.*, For instance, a new plateau might build at 110 mg/dl, in which case 2 U of insulin brought me down by 80 mg/dl. My ISF would calculate to 80 / 2 = 40 mg/dl / U .*

The IC would follow as: ISF / CRR = 40 (mg/dl)/U / 5 (mg/dl)/g = 8 g/U = IC

The CRR is relatively stable (does not vary by much over 24 hours):

- while both ISF and IC do vary (in similar ways, related to your insulin sensitivity)
- if you divide one by the other, deviations owed to sensitivity cancel out.

Avoiding high glucose values

Even if your IC value is correct (brings you back to target about 2-3 hours after a meal), you might be disappointed by **intermediate high glucose peaks**.

Resist the temptation of extra bolussing when seeing a high peak! Rage bolussing comes with significant danger to run into a hypoglycemia a bit later.

Rather, try to picture for yourself the course of carb absorption on one hand, and of insulin activity developing, on the other.

See also Meal Management
https://www.facebook.com/groups/LOOPandLEARN/permalink/3032204653702685

Regarding **insulin activity**, AndroidAPS displays that as a thin yellow line in your main screen if you select it (top right in your glucose screen press the little dart, activate Basal and Activity).

Regarding **carb absorption** it is important, that it starts before any insulin activity (hence always a rising glucose, initially), and then it can run rather steadily – in most adults at about 30 g/h as Dana Lewis has observed - Fat and fibre have an additional effect of stretching absorption out.

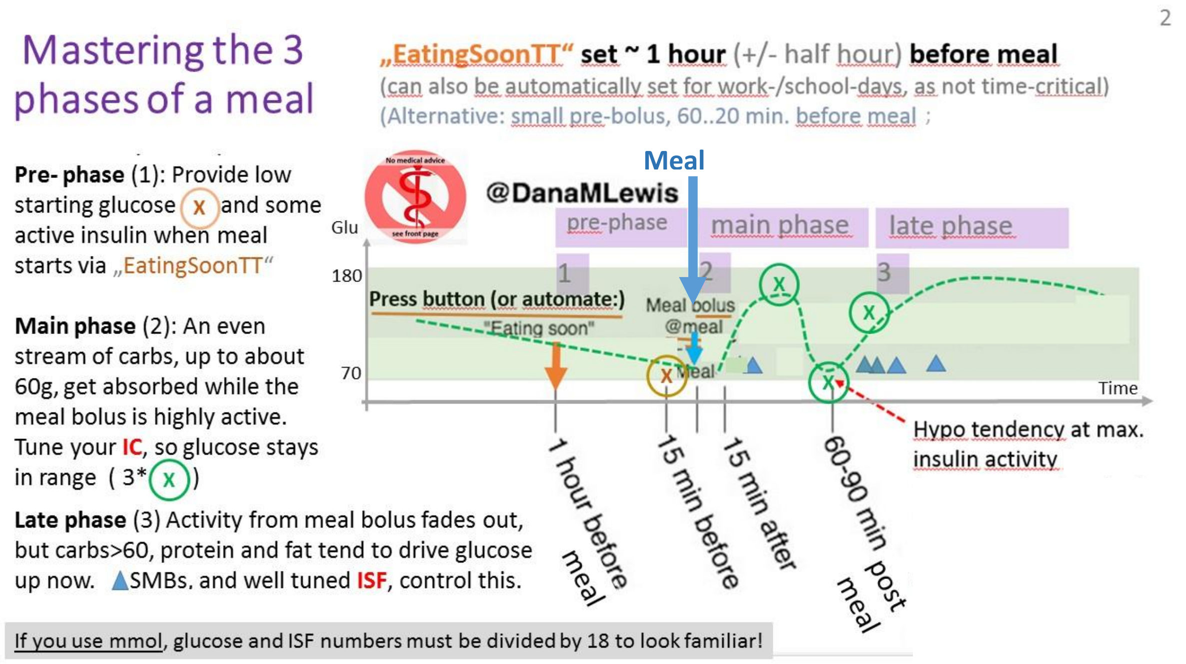
There are several strategies to minimize glucose peaks in the first hour or two after a meal:

1. Pre-bolussing a couple of minutes before the meal starts However, this can be dangerous if timing is not strictly adhered to.
2. Give only a small part of the meal bolus before the meal begins. This enhances safety but increases complexity.

3. Orient your loop, already an hour +/- 30 minutes before any meal, towards a lower glucose goal. This strategy has 3 nice benefits: (1) It lowers the starting glucose, so the peak from the meal will be accordingly lower (2) Moreover, you get some positive iob at meal start, further supporting a milder rise. (3) This move is very time-un-critical, and can even be automated for some of your meal times. ((Even if you skip a meal, nothing bad happens, other than that you need a snack in case you want to start exercise, rather than have a meal, when at the low range of your green glucose range)).

Tuning IC in Hybrid Closed Loop

Following observations published by Dana Lewis *) , in the first 2 hours of nearly any meal, about 60g of carbs are absorbed, and – in HybridClosedLoop – a user bolus is there to largely take care. In this„main phase“ ,your **IC should be tuned such, that your glucose curve hits the 3 green (X):**



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*) Chapter 8 in: https://github.com/danamlewis/artificialpancreasbook/ -

Circadian pattern

Adults often have a „circadian“ pattern of insulin sensitivity „biorhythm“ which may translate into a 24 hour pattern like this:

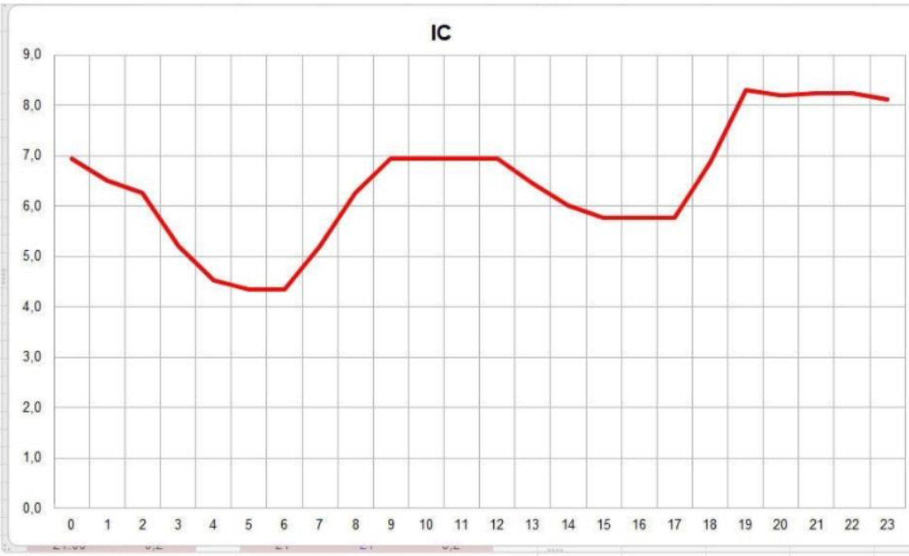
Example

IC

IC HM 12-99 Jahre

100%

Zeit	IC
00:00	6,9
01:00	6,5
02:00	6,3
03:00	5,2
04:00	4,5
05:00	4,3
06:00	4,3
07:00	5,2
08:00	6,3
09:00	6,9
10:00	6,9
11:00	6,9
12:00	6,9
13:00	6,4
14:00	6,0
15:00	5,8
16:00	5,8
17:00	5,8
18:00	6,9
19:00	8,3
20:00	8,2
21:00	8,2
22:00	8,2
23:00	8,1



Limited role of the IC in Full Closed Loop (UAM/no bolus/no carb inputs)

Currently (Sep.2022) looping without carb inputs and without giving a user bolus is only possible with good results when using the oref(1) algorithm wSMB+UAM feature, as offered by OpenAPS, AndroidAPS and iAPS. iOS Loop, in contrast, requires fairly exact carb inputs.

Main use was for the IC to determine boli for announced carbs in Hybrid Closed Loop.

In Full Closed Loop (UAM/no bolus/no carb inputs) the ISF is the key factor for the loop to keep glucose in range. The **IC factor** plays only a **minor role** there.

However, the loop still uses it „in a side role“ for calculating deviations = to conclude how many carbs „must have been absorbed“ in each **past** 5 minute segment.

Then, knowing how much insulin has been delivered by the loop, the loop eventually can also communicate how many (if any) carbs it might need in each of the **upcoming** 5 minute segments, to balance the accrued tail of insulin activity. In UAM Full Closed Loop this info can largely be neglected: As only I, but not the loop, know what I ate, only I could cross-check whether the carbs the loop „reports missing“ really might be missing, or, rather, are on bord, i.e. in digestion, from my prior meal.
