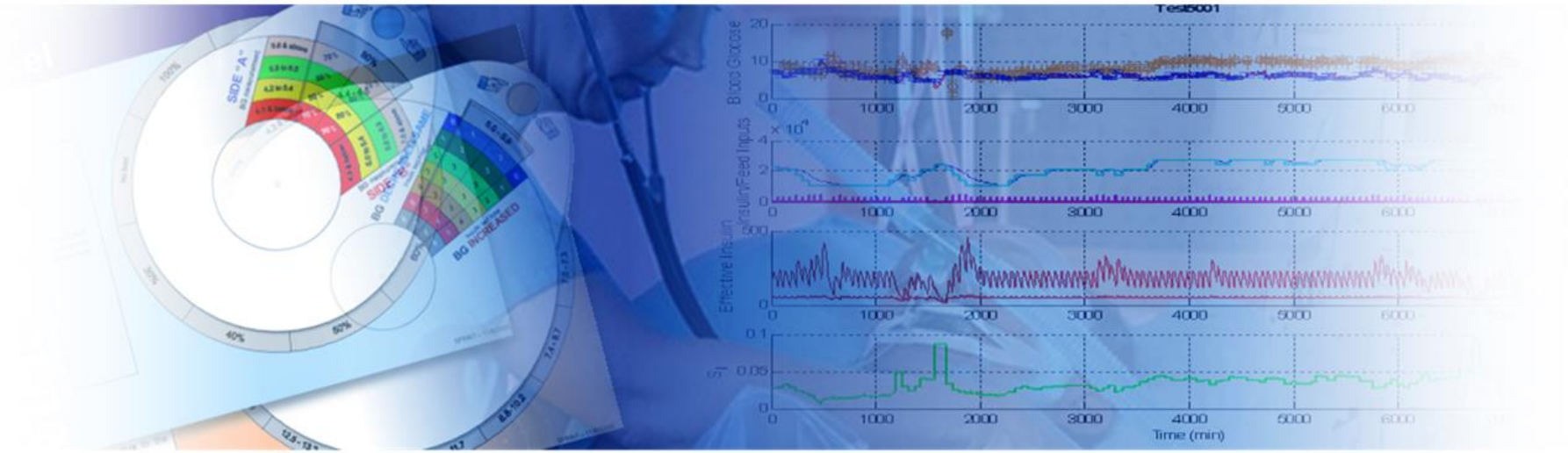
# mAGiC DRAGONS: A Protocol for Accurate Glycaemic Control in General Wards

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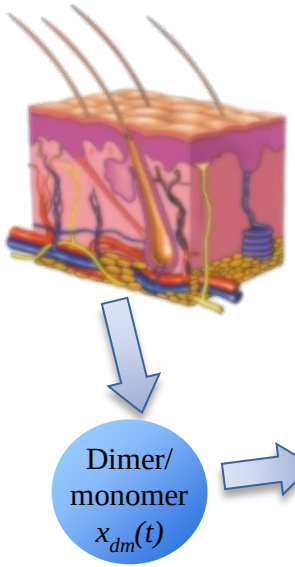
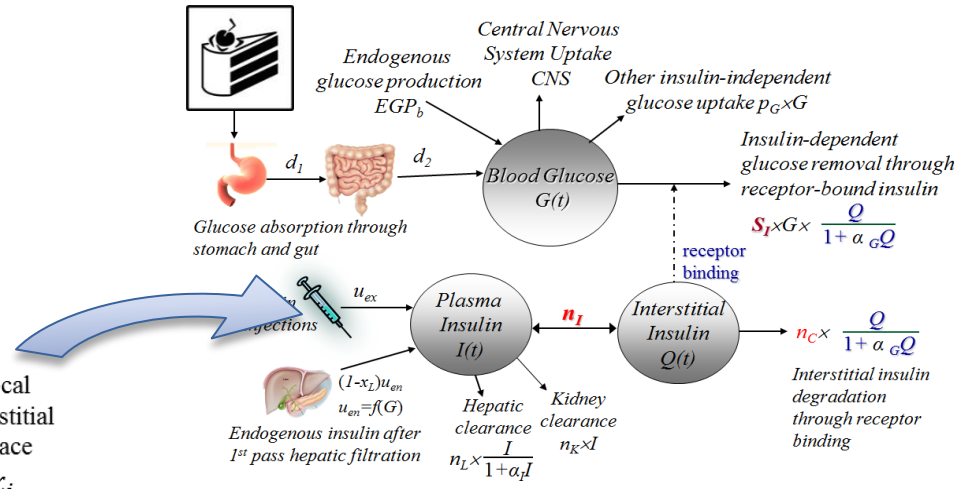
# Objective: AGC from ICU to Wards

- Insulin dosed **SUBCUTANEOUSLY**
  - Must have an additional **mathematical model** of Interstitial Insulin to Plasma Insulin Kinetics to use with ICING model

**Interstitial Layer**
subcutaneous (SC) injection site



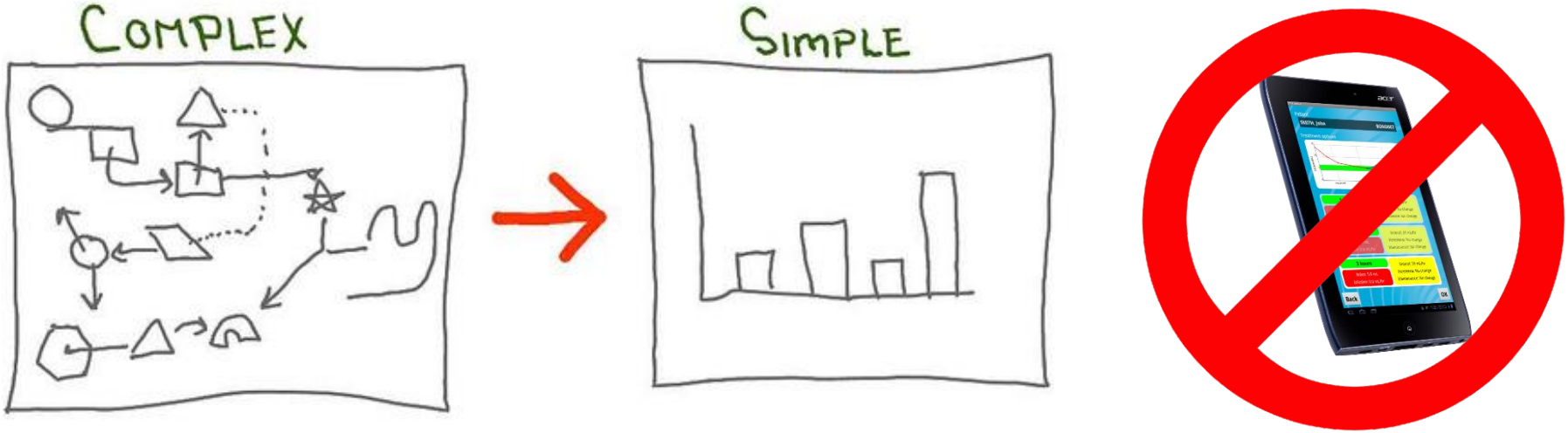

- Blood glucose measurements and insulin dosing occurring only every 4 hours (or more)
  - Reducing nurse workload but extending time which blood glucose levels must be extrapolated across

# Protocol Requirements

- SC insulin dosing
- 4-hourly BG measurement interval
- 4.4-8.0 mmol/L target glycaemic band
- Risk of hypoglycaemia (BG < 4.0 mmol/L) < 5%.
- Paper-based

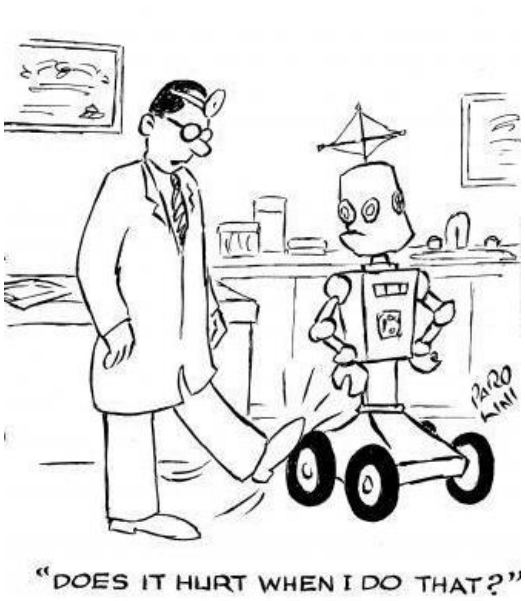
# Paper-based Format

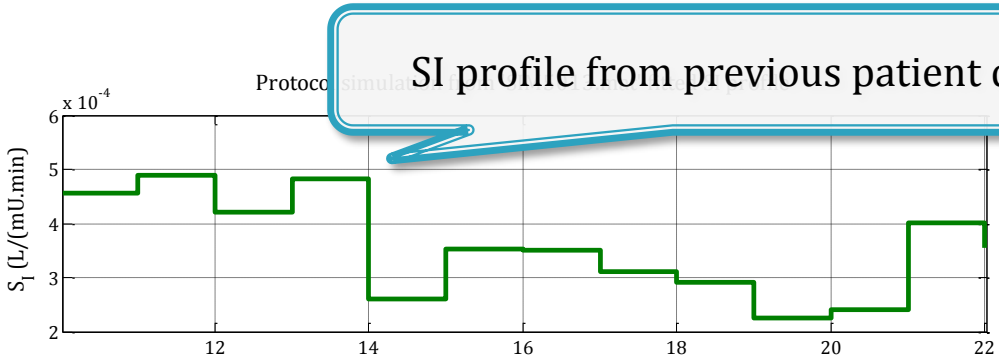
- Complex models must be displayed in discrete form
- Must determine the important cases to represent as limited space



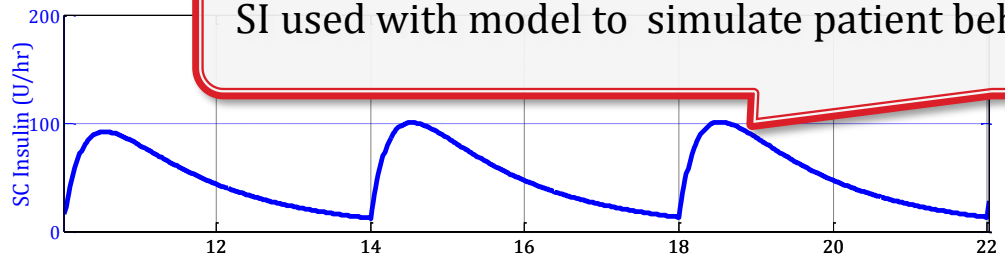
# Virtual Trials

**A safe way of testing protocols without associated risks involved with clinical trials!**

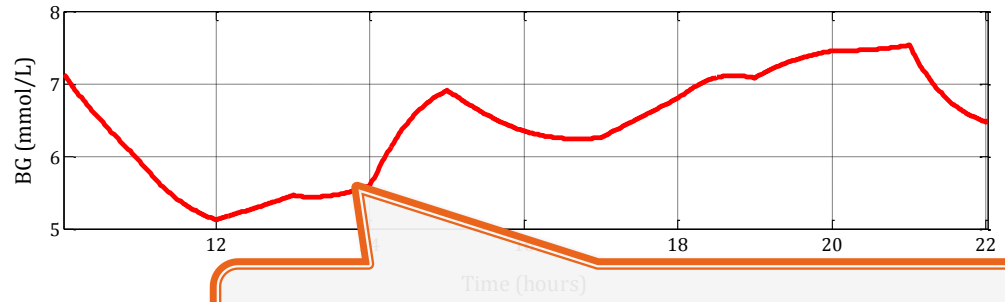



SI profile from previous patient data




SI used with model to simulate patient behavior




BG result shows controller safety and efficacy

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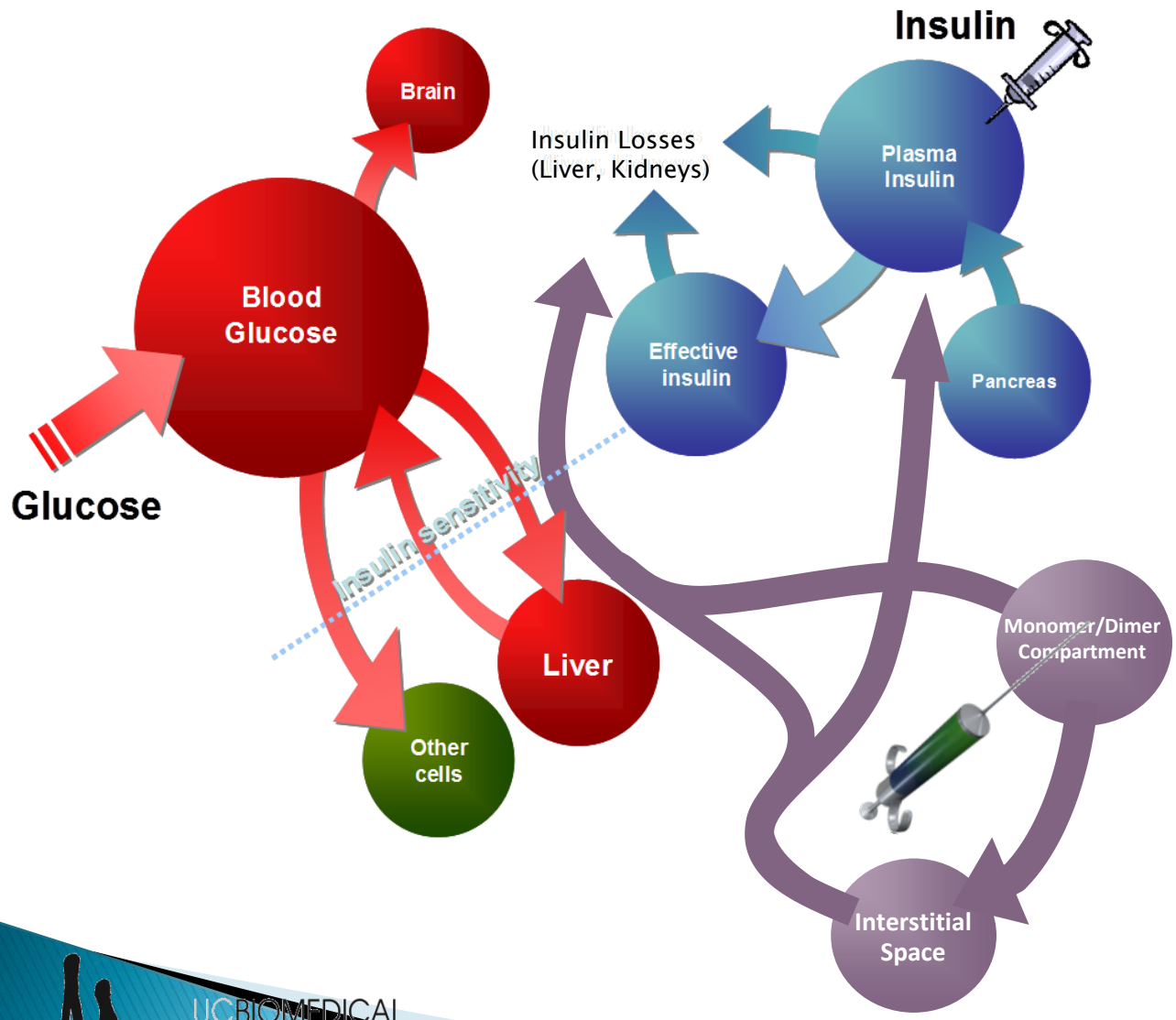
# Subcutaneous Model




Additional factors that may cause sadness compared with IV insulin:

- Edema
- Injection site
- Patient movement
- Pressure on site

# Obligatory page of equations

$$\dot{G}(t) = -p_G G(t) - S_I G(t)\frac{Q(t)}{1+\alpha_G Q(t)} + \frac{P(t) + EGP - CNS}{V_G}$$

$$\dot{Q}(t) = n_I\big(I(t) - Q(t)\big) - n_C\frac{Q(t)}{1+\alpha_G Q(t)}$$

$$\dot{I}(t) = n_K I(t) - n_L\frac{I(t)}{1+\alpha_I I(t)} - n_I\big(I(t) - Q(t)\big) + \frac{u_{ex}(t)}{V_I} + (1-x_L)\frac{u_{en}(G)}{V_I}$$

$$P(t) = \min(d_2 P2,\ P_{\max}) + PN(t)$$

$$\dot{P1}(t) = -d_1 P1 + D(t)$$

$$\dot{P2}(t) = -\min(d_2 P2,\ P_{\max}) + d_1 P1$$

$$u_{en}(G) = \min(\max(u_{min}, k_1 G(t) + k_2), u_{max})$$

$$\dot{x}_{dm} = \begin{cases} U_{dm} - k_{dm}x_{dm}, & \text{monomeric} \\ U_{dm} + p_d\left(\frac{1}{3}x_h - Q\frac{x_{dm}^3}{V^2}\right) - k_{dm}x_{dm}, & \text{regular/NPH} \\ U_{dm} + p_d\left(\frac{1}{3}x_{h,gla} - Q_{gla}\frac{x_{dm}^3}{V^2}\right) - k_{dm}x_{dm}, & \text{glargine} \end{cases}$$

$$\dot{x}_h = U_h + k_c x_c - p_d\left(\frac{1}{3}x_h - Q\frac{x_{dm}^3}{V^2}\right)$$

$$\dot{x}_i = k_{dm}x_{dm} - k_i x_i$$

$$u_{ex} = f.k_i.x_i$$

# Patients

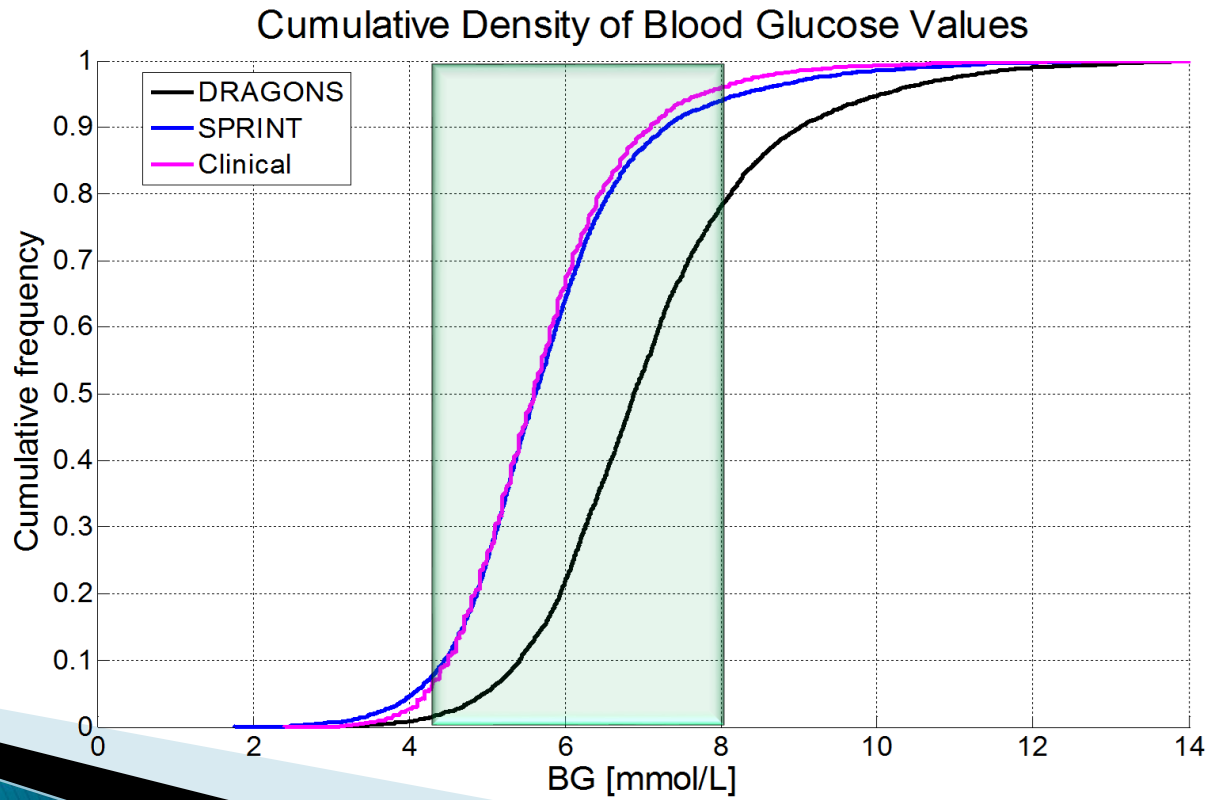
Virtual trials were performed using retrospective data from 63 patients treated by accurate glycaemic control protocols at Christchurch Hospital ICU between 2005 and 2013.

| | |
|---|---|
| N | 63 |
| Age (years) | 56 [40-70] |
| Gender (M/F) | 42/21 |
| Length of glycaemic control (hrs) | 103 [39-158] |

The 63 patients used for virtual trials in this study were specifically selected from a larger cohort of >400 patients as their SI profiles were less variable than that of a typical ICU patient and thus expected to be more representative of patients in general wards.

# Virtual Trial Results – Overall

| | DRAGONS | SPRINT | Clinical |
|---|---|---|---|
| N | 63 | 63 | 63 |
| BG meas/day | 6.4 | 14.6 | 14.5 |
| BG (mmol/L) | 6.9 [6.0–7.9] | 5.6 [4.9–6.5] | 5.6 [4.9–6.4] |
| % time in 4.4–8.0 mmol/L | 73.0 | 85.6 | 88.5 |
| % time < 4.0 mmol/L | 1.6 | 4.4 | 2.4 |
| % time < 2.2 mmol/L | 0 | 0.1 | 0 |
| Insulin administration (U/hr) | 5.0 [4.0–5.5] | 3.0 [2.0–3.0] | 3.0 [1.0–4.0] |
| Glucose administration (g/hr) | 5.4 [4.3–6.5] | 5.2 [3.8–6.3] | 5.4 [3.8–6.5] |



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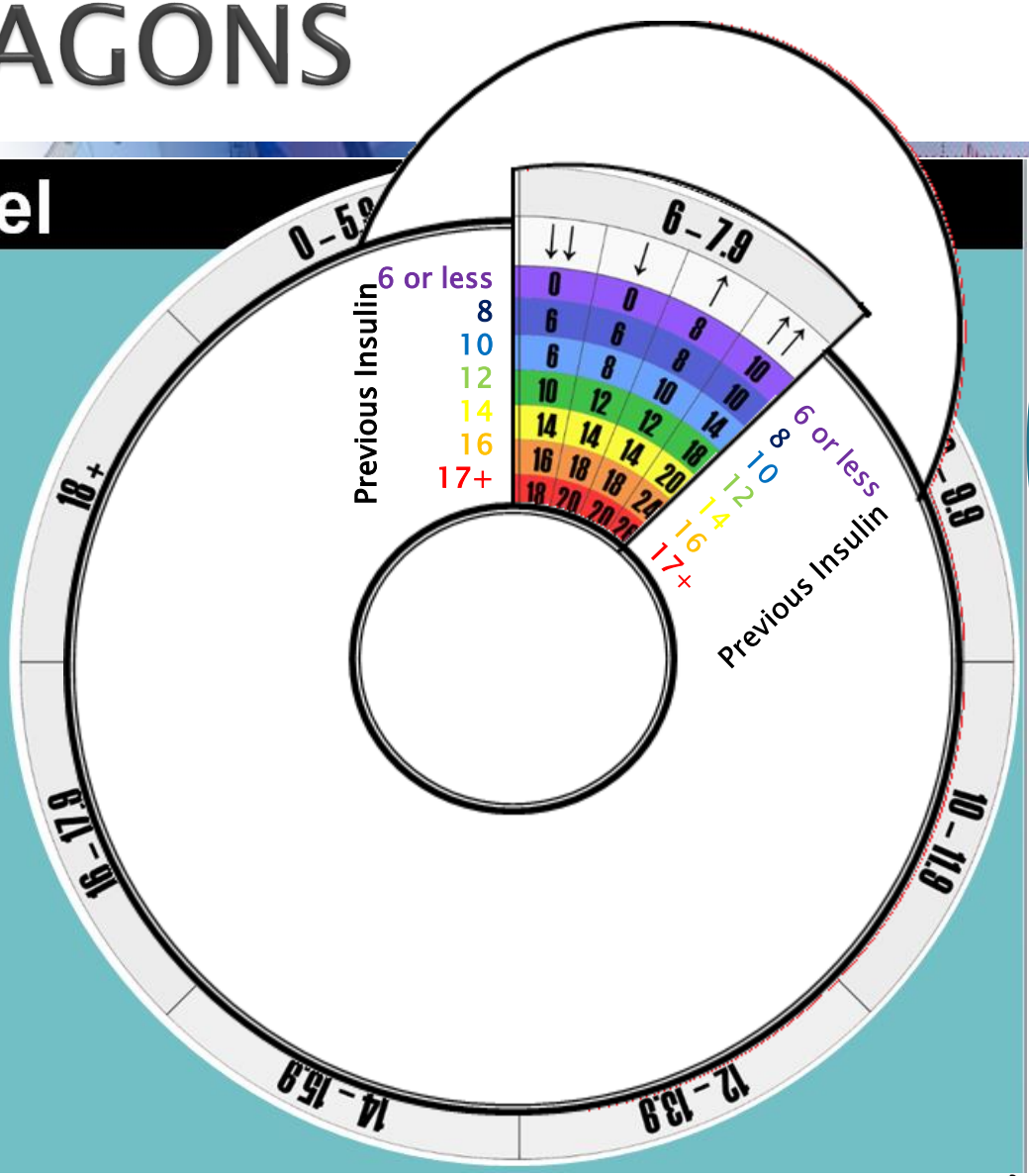
# DRAGONS

## Insulin Wheel

### START:

| | |
|---|---|
| **1. Has the Patient had a SC insulin dose 4hrs ago or a blood glucose measurement on the last hour?** | |
| YES: | Take a BG measurement and Go to step 2 below |
| NO: | Take a BG measurement return in an hour |
| **2.** Rotate wheel to the **section** with the patient's **current glucose level** marked in grey. | |
| **3.** Determine whether the **glucose level** has increased by more than 2mmol/L(↑↑), less than 2mmol/L(↑), decreased by more than 2mmol/L(↓↓) or less then 2mmol/L(↓) and **select the correct segment of the section.** | |
| **4.** Using the **selected segment of the wheel from 3**, match the **previous insulin bolus** to the **new insulin bolus**. | |
| **5.** Administer **new insulin bolus** and have colleague double check. | |
| **6.** Use Feed Wheel if you have not done so already. | |




Dynamic

Regulation for

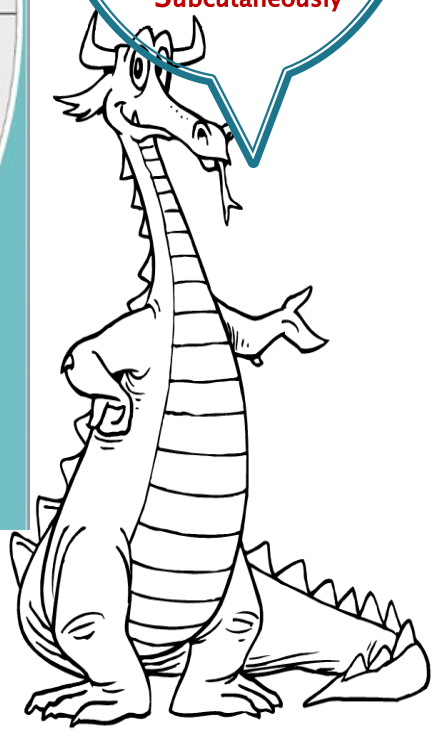
Accurate

Glycaemic levels and

Optimisation of

Nutrition

Subcutaneously



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# DRAGONS

## Feed Wheel

**START:**

**1.** Use the feed conversion sticker to find the current percentage feed level.

**2.** Rotate wheel to patient's **current percentage feed level** marked in grey.

**3. Has the patients BG increased between the last recorded BG measurement and now?**

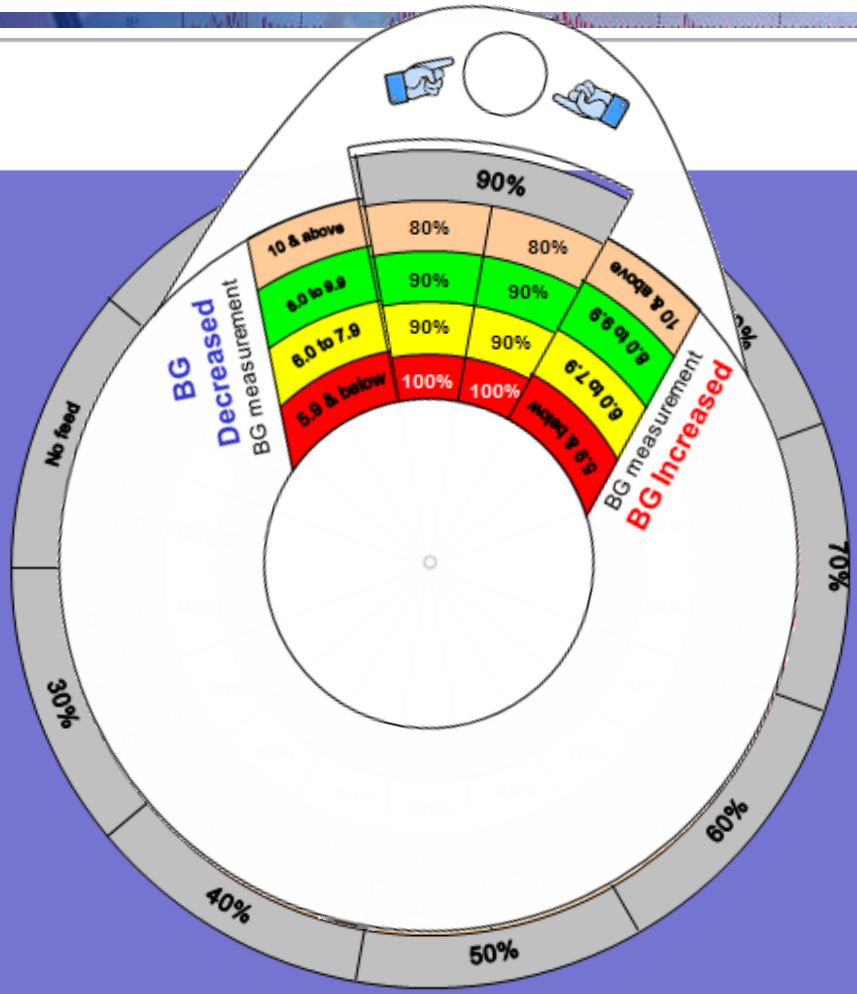
| | |
|---|---|
| YES: | Use BG increased side of the wheel |
| NO: | Use BG decreased side of the wheel |

**4.** Using the **selected side of the wheel from 3**, match the **current glucose level** to the **new feed level**.

**5.** Use the feed conversion sticker to find the absolute feed in [ml/hr].

**6.** Use Insulin Wheel if you have not done so already.

Attach feed conversion sticker here

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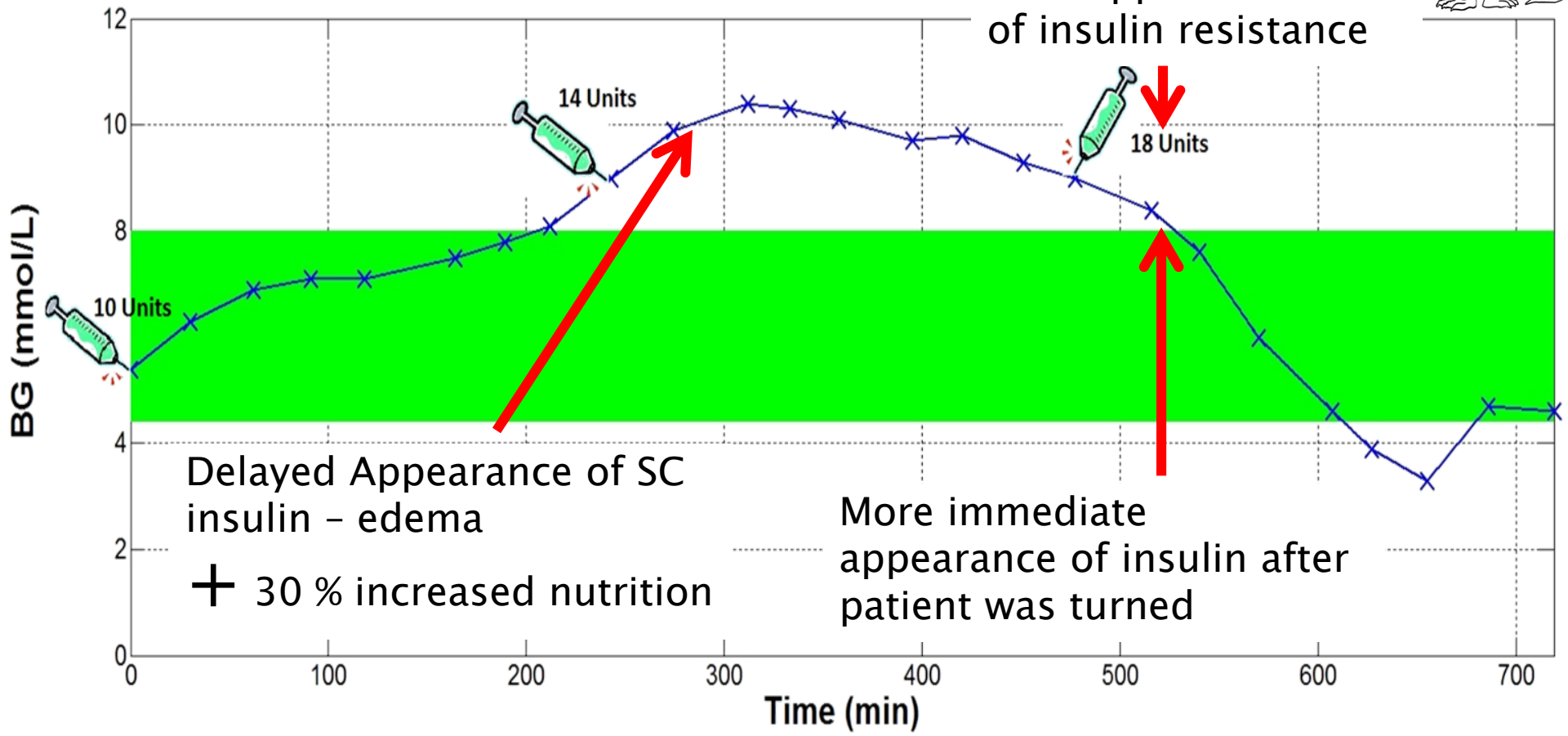
# Clinical Trial Results



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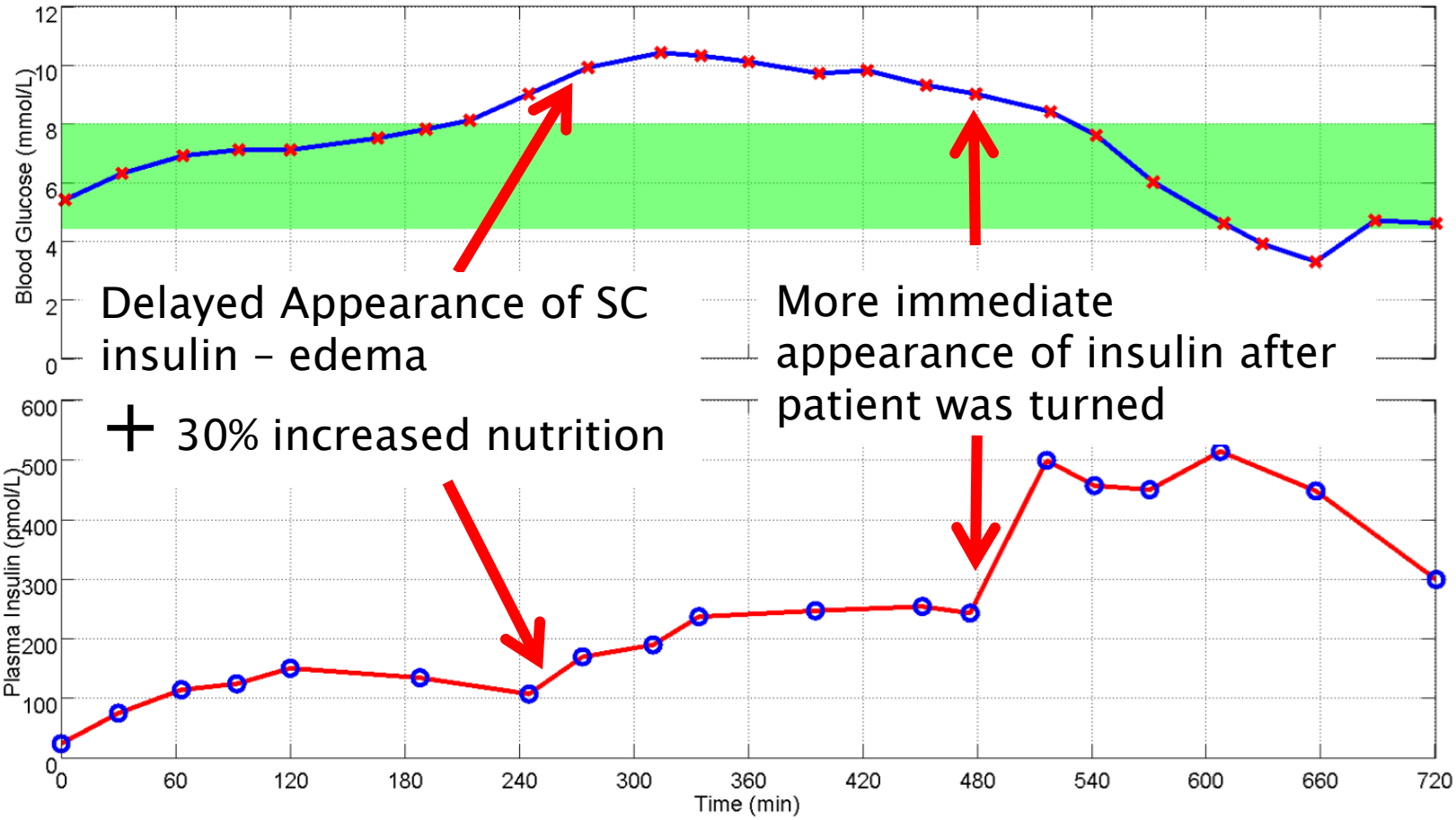

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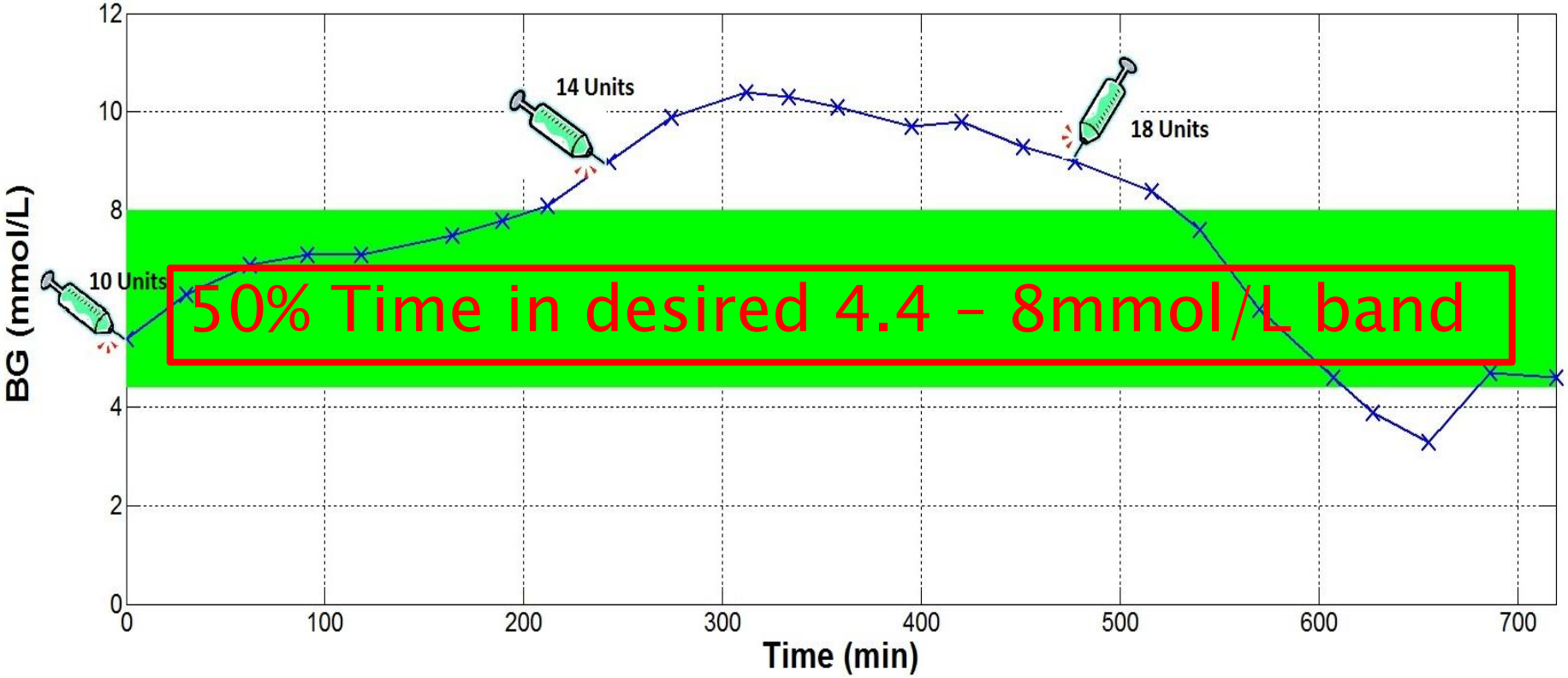


Main outcome: Protocol that it is still **safe** under uncertainty

Patient variability is to be expected and are also part of the important "lessons learned"

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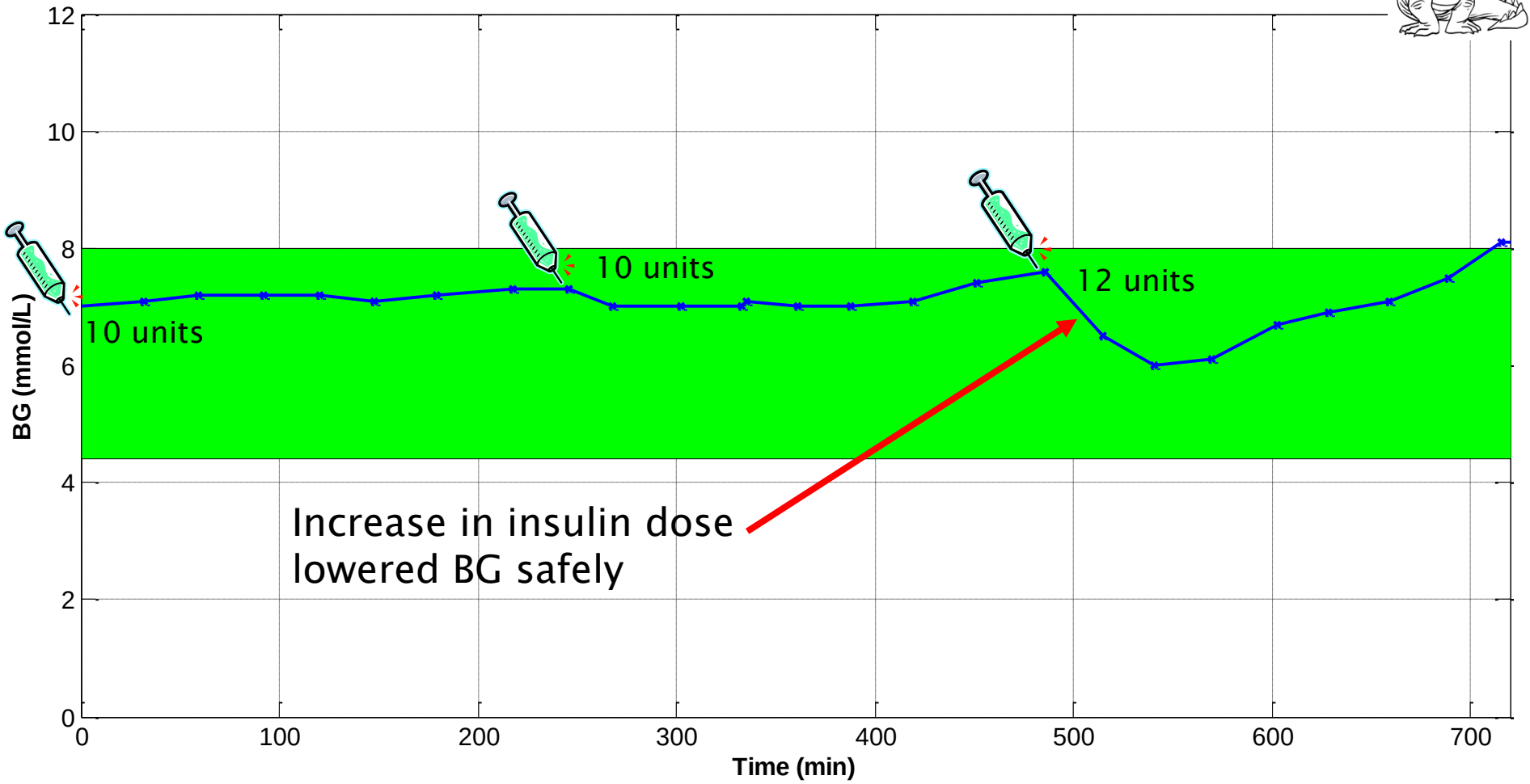
# Clinical Trial Results



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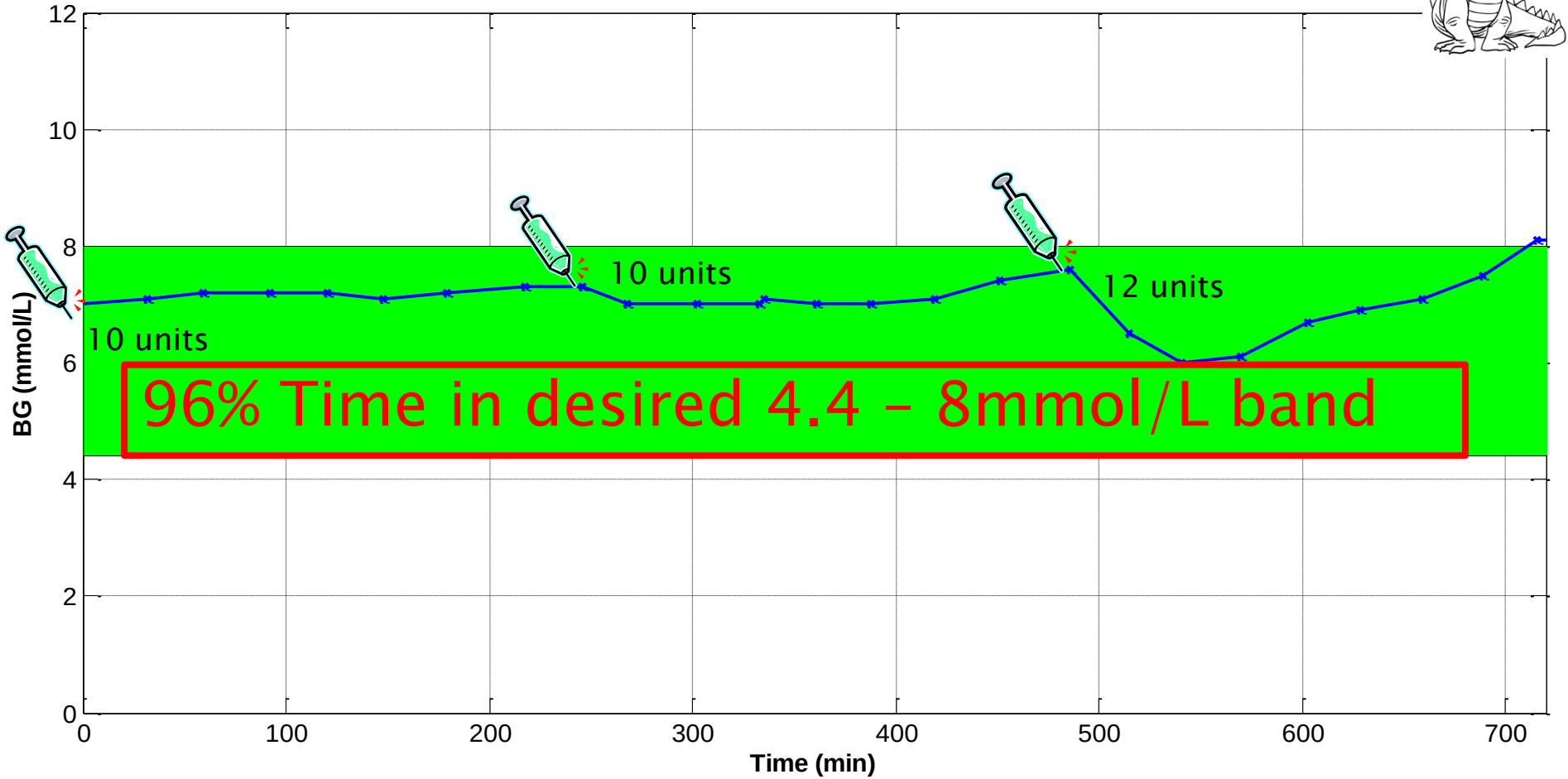


Example of an "ideal patient" for subcut insulin delivery, measurement interval could easily be extended while maintaining performance and safety

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# Next Steps

- Recruit more patients for proof of concept pilot trial
- Be careful of SC insulin delivery location to avoid delayed appearance (i.e. don't inject where there is edema even if it's your normal spot)

- Consultation with ward Nurses/ Nurse Training
- Staged implementation in less acute wards

# Conclusions

- Humans are horribly variable
- BG measurements and SC insulin delivery > 4hrs is achievable while still maintaining patient safety
- There are still lessons to be learned in this pilot trial to ensure a robust protocol for SC insulin delivery

# Acknowledgement

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# The end

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