Wellcome - MRC IMS Institute of Metabolic Science

Interpreting closed-loop downloads

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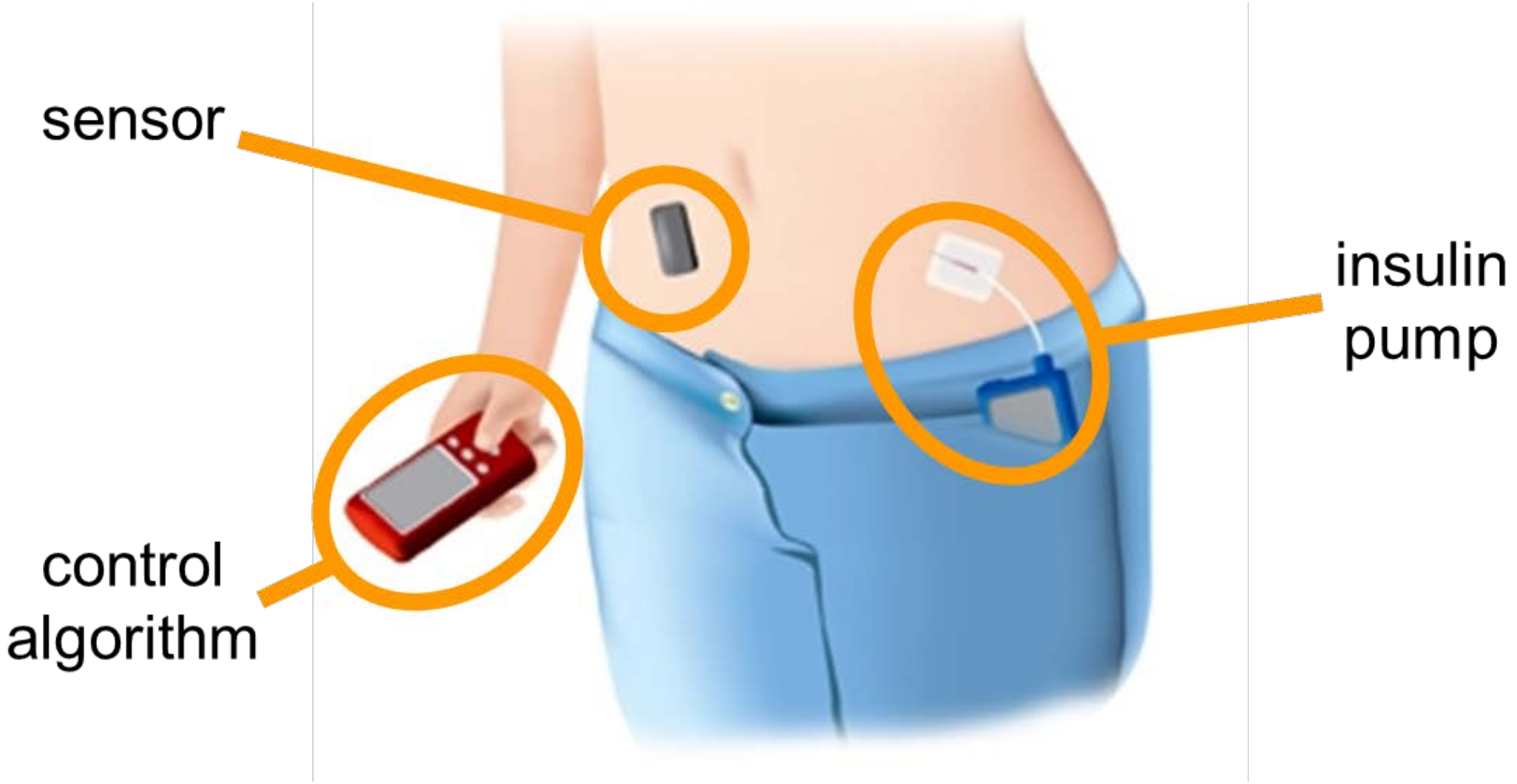
Disclosures

Speaker honoraria: Novo Nordisk, Ypsomed

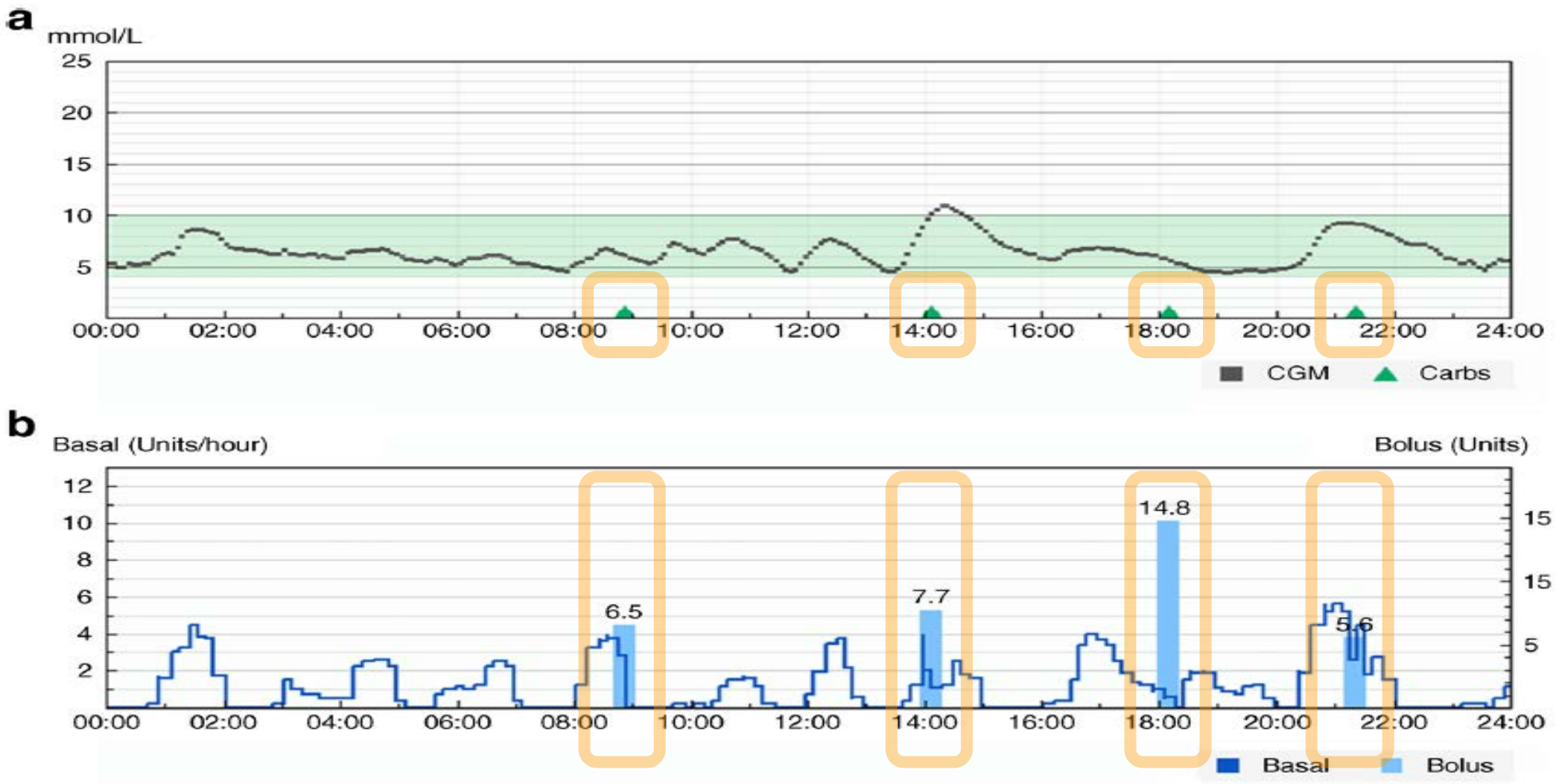
Contents

- **Introduction to hybrid closed-loop**
- Approach to download review
- Tips for optimisation
- Clinical cases

Artificial pancreas - automated insulin delivery



“Hybrid” closed-loop



Commercially available systems

CamAPS FX

EU, Australia & Canada

Age 1 year up

Medtronic 670G & 780G

US & EU

Age 7 year up

Omnipod 5 HCL

US & EU

Age 6 year up (US)

Age 2 year up (EU)

Tandem Control IQ

US & EU

Age 6 year up

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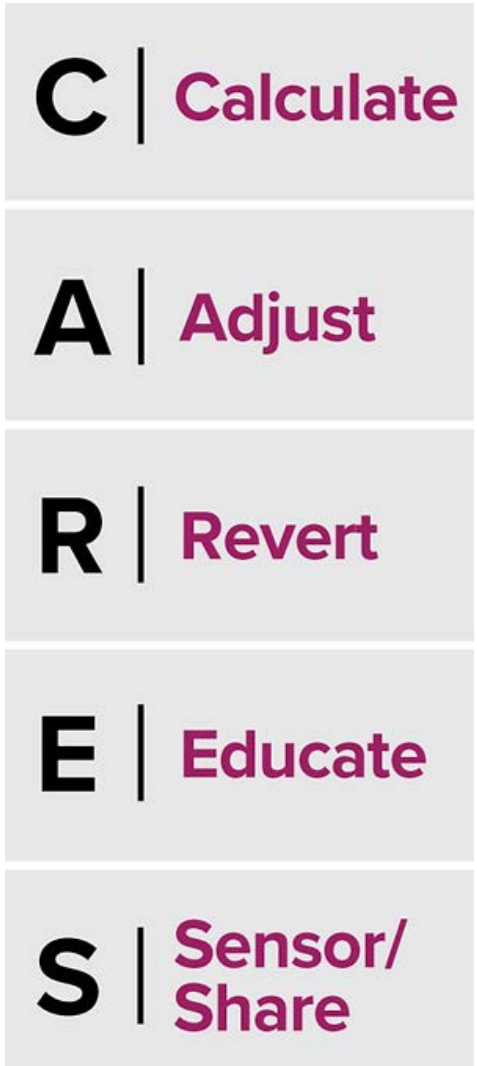
Structure is key

- BIG picture
- Small picture
- Use a cheat sheet!



How does the algorithm **calculate** insulin delivery?

How can the user **adjust** insulin delivery?

When should the user **revert** to open loop?

Key **education** points / tips and tricks

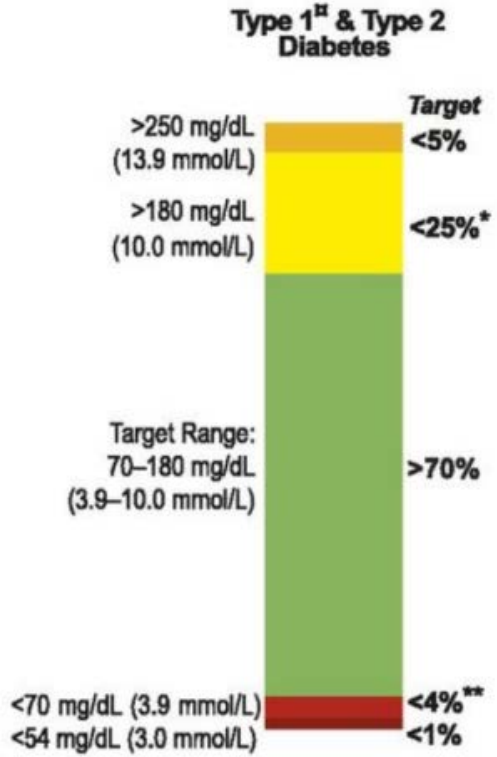
Sensor characteristics / Remote monitoring and data **sharing**

https://www.cypdiabetesnetwork.nhs.uk/national-network/network-projects/

https://www.pantherprogram.org/cares-framework

BIG picture

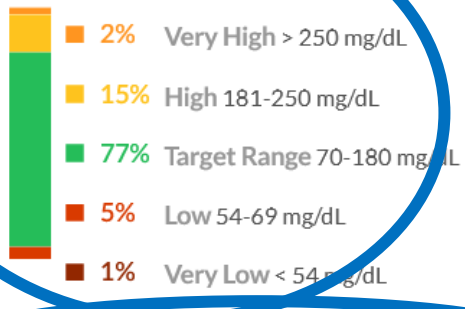
- **Data adequacy?**
  - Minimum 14 days of data
  - **CGM use:** aim for ≥90%
  - **Auto mode use:** aim for ≥90%



CV <36%

- **Initial overview**
  - Mean glucose, Time in range, Time below range
  - **Meeting glycaemic targets?**
  - Glucose variability: SD and Coefficient of Variation
  - Automated insulin delivery / bolus split

Glucose (CGM)



2%	Very High	> 250 mg/dL
15%	High	181-250 mg/dL
77%	Target Range	70-180 mg/dL
5%	Low	54-69 mg/dL
1%	Very Low	< 54 mg/dL

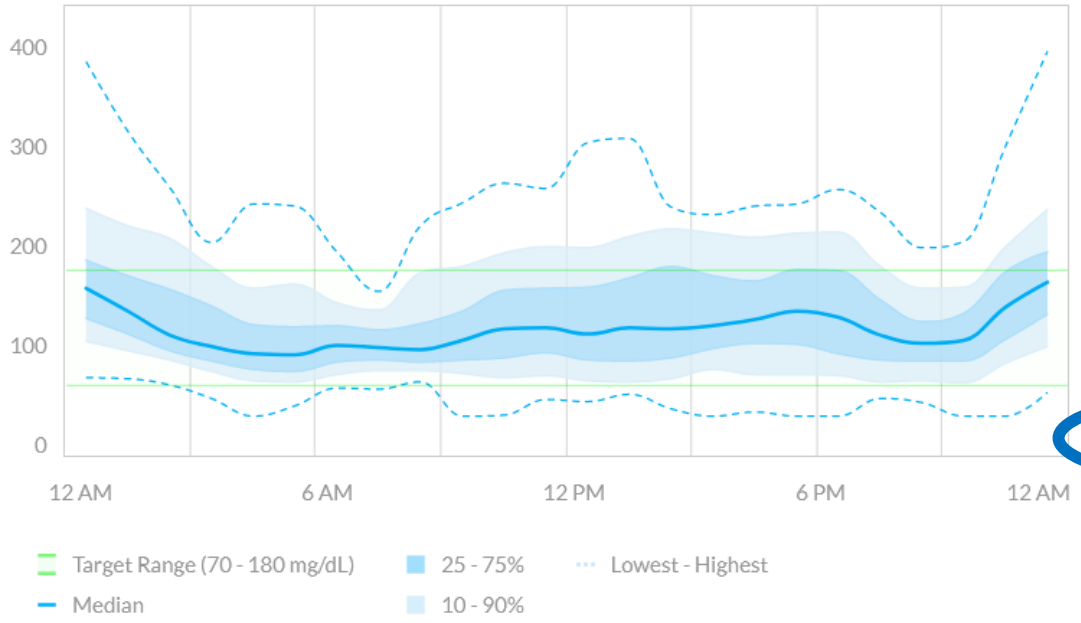
% Time CGM Active	97% (13.6 days)

GMI	6.4% (47 mmol/mol)
Average	131 mg/dL
SD	50 mg/dL
CV	38.3%
Median	120 mg/dL
Highest	390 mg/dL
Lowest	LO mg/dL

AGP

Glucose (mg/dL)

What is AGP?



Insulin - Device

From Insulin Pump

35% 2.7 units Basal/Day

65% 5.1 units Bolus/Day

Insulin/Day	7.8 units
Overrides (%)	0% (0 boluses)
# Bolus/Day	15

System Details

CamAPS FX (14d)

Auto mode 'On'	85% (11d 20h)
Boost	0%
Ease-off	1% (2h)
Auto mode 'Off'	15% (2d 3h)
Auto mode 'Attempting'	0%

Diet

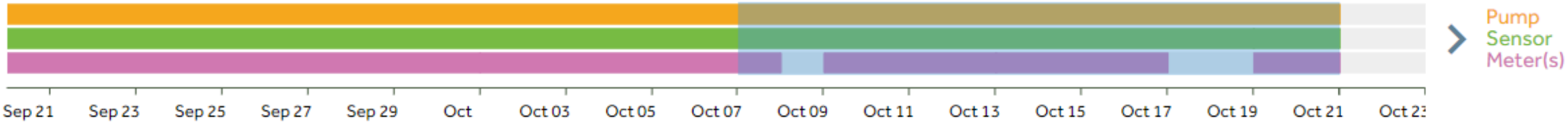
180.6 g	11.3
Carbs/Day	Entries/Day

Fitness

-

Steps/Day

Select the most recent data | 7 days | 14 days | 30 days | Select custom range



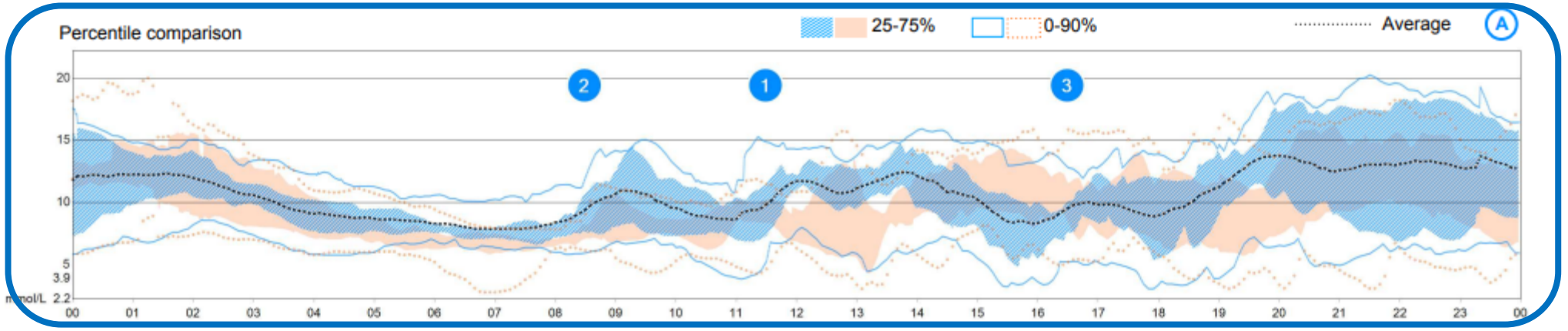
Show: 30 days 90 days Today

SUMMARY REPORTS (1) | DAILY REPORTS (0) | Data Export (CSV) | Generate Reports

Data Source: | Insulin Pump | Standalone CGM | Meter | Clear All | Select My Favorites

Select report: 1 report(s)

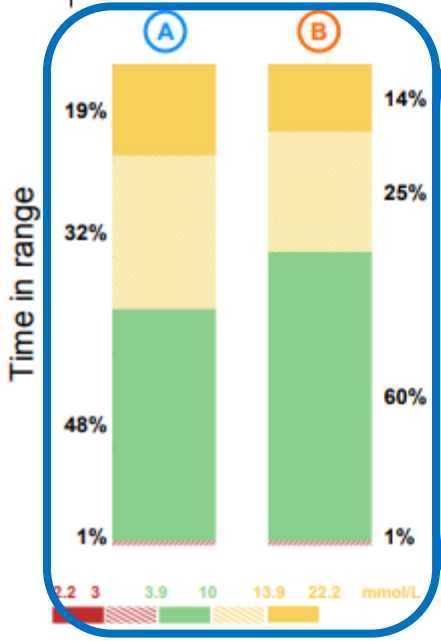
- Assessment and Progress
- Weekly Review
- Dashboard
- Meal Bolus Wizard
- Episode Summary
- Adherence
- Sensor and Meter Overview
- Logbook
- Device Settings



Carb Ratio (g/U) * A	12.0	15.0	13.0
Carb Ratio (g/U) * B	12.0	15.0	13.0

A

Hypoglycemic patterns (0)	# Episodes (per day): 0.1	Hyperglycemic patterns (6)**	# Episodes (per day): 2.8
None		1 11:00 - 11:59 (8 occurrences)	2 08:00 - 08:59 (5 occurrences)
		3 16:00 - 16:59 (4 occurrences)	



SmartGuard Exits	A	B
No Calibration	0	0
SmartGuard max delivery	0	0
SmartGuard min delivery	0	0
BG required for SmartGuard	0	0
Sensor Algorithm Underread	0	0
Sensor Updating	0	0
No SG values	0	1 •
Sensor Expired	• • 2	0
SmartGuard disabled by user	0	0
Prolonged Suspend	0	0
SmartGuard Warm Up	0	0
Unidentified	0	0

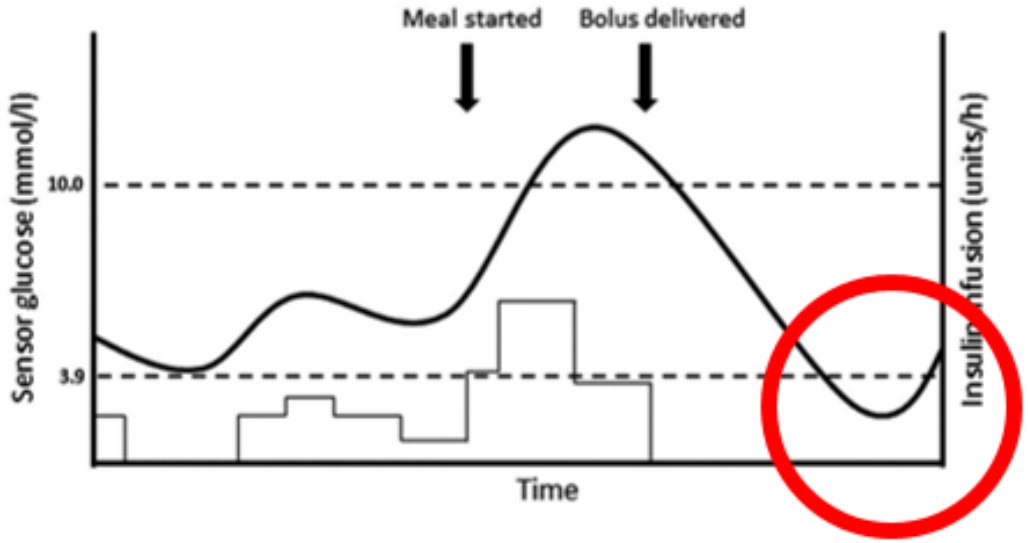
Statistics	A	B
SmartGuard (per week)	96% (6d 18h)	98% (6d 21h)
Manual Mode (per week)	4% (06h)	2% (03h)
Sensor Wear (per week)	88% (6d 04h)	93% (6d 12h)
Average SG ± SD	10.6 ± 3.7 mmol/L	9.7 ± 3.6 mmol/L
GMI***	7.9% (62.8 mmol/mol)	7.5% (58.5 mmol/mol)
Coefficient of Variation (%)	34.8%	37.5%
Low / High SG Alerts (per day)	0.6 / 4.7	0.9 / 3.8
Average BG	18.8 ± 1.4 mmol/L	11.4 ± 4.9 mmol/L
BG / Calibration (per day)	0.3 / 0.3	3.2 / 2.5
Total daily dose (per day)	33.5 units	31.2 units
Bolus amount (per day)	23.0U (69%)	20.9U (67%)
Auto Correction amount (per day)	7.2U (31%)	5.1U (24%)
Auto Basal / Basal amount (per day)	10.5U (31%)	10.3U (33%)
Set Change	Every 9.0 days	Every 4.3 days
Reservoir Change	Every 4.5 days	Every 4.3 days
Meal (per day)	5.4	4.9
Carbs entered (per day)	190 ± 68 g	197 ± 57 g
Active Insulin time	4:00 hrs	4:00 hrs

* Most recent pump settings are displayed
** Only highest priority shown.
*** Glucose Management Indicator

This report is compatible with the Ambulatory Glucose Profile calculations used by the International Diabetes Center

Small picture – the basics

- Are the basics in place?
  - Bolusing for meals
  - Carb counting
  - Back up basal rates
  - Weight up to date
  - Set changes
  - Sensor calibrations (if required)
  - Suspending pump when disconnected

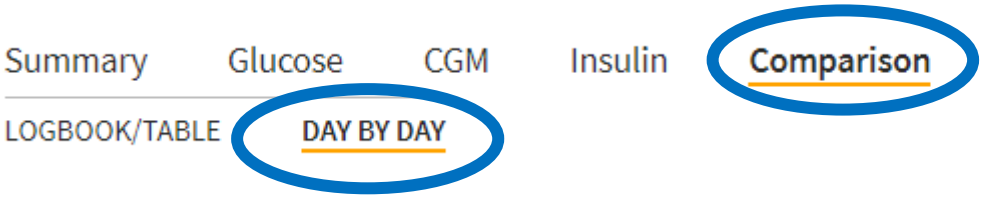


Small picture – What is adjustable?

	Medtronic 670G HCL / 780G AHCL	Tandem Control-IQ	CamAPS FX
Adaptive learning	TDI and estimate of fasting glucose and the plasma insulin concentration at the time of fasting	None	TDI, diurnal, meals
User-adjustable settings	Target glucose (780G only) ICR Active insulin time Activity mode	Basal rates ICR ISF Activity mode Sleep mode	Target glucose ICR ISF (for manual corrections only!) Activity mode Boost mode
Pre-set basal rates influence automated insulin delivery	No	Yes	No
Automated correction bolus	670G: No 780G: Yes	Yes	No (incorporated into continuous insulin delivery)

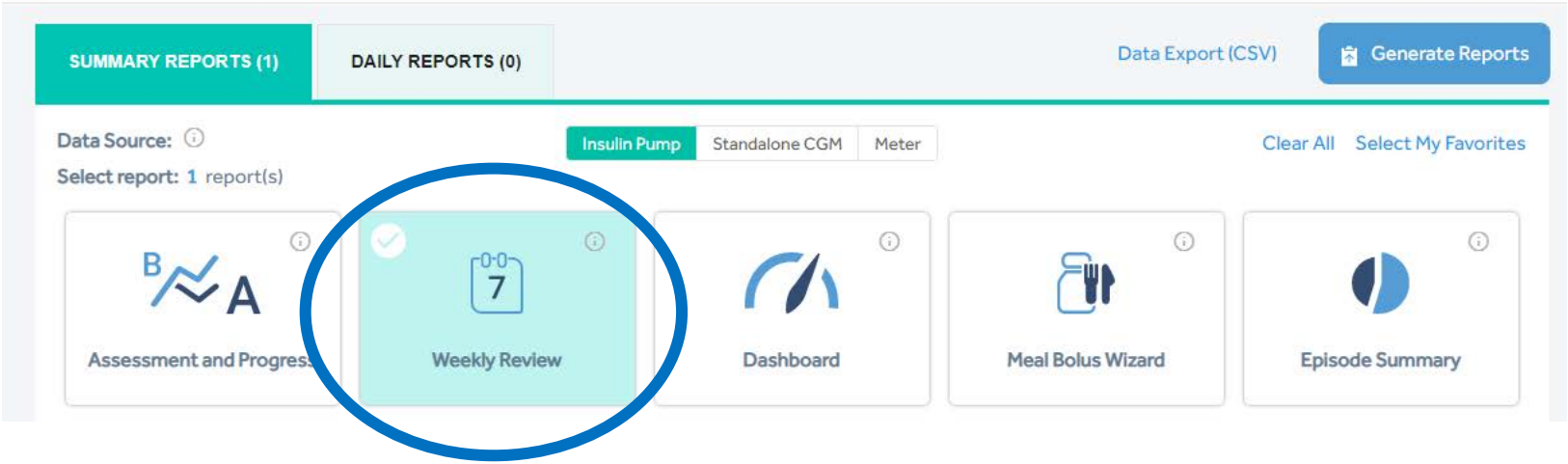
Small picture – assessing patterns

- Use the day by day / weekly view to look for patterns



Control IQ and CamAPS FX

670G and 780G



Small picture – assessing patterns

- Time of day – fasting/overnight or daytime
- Hypo- or hyperglycaemia after meals
- Low glucose follows high glucose
- High glucose follows low glucose
- Exercise-related
- Issues around manual corrections

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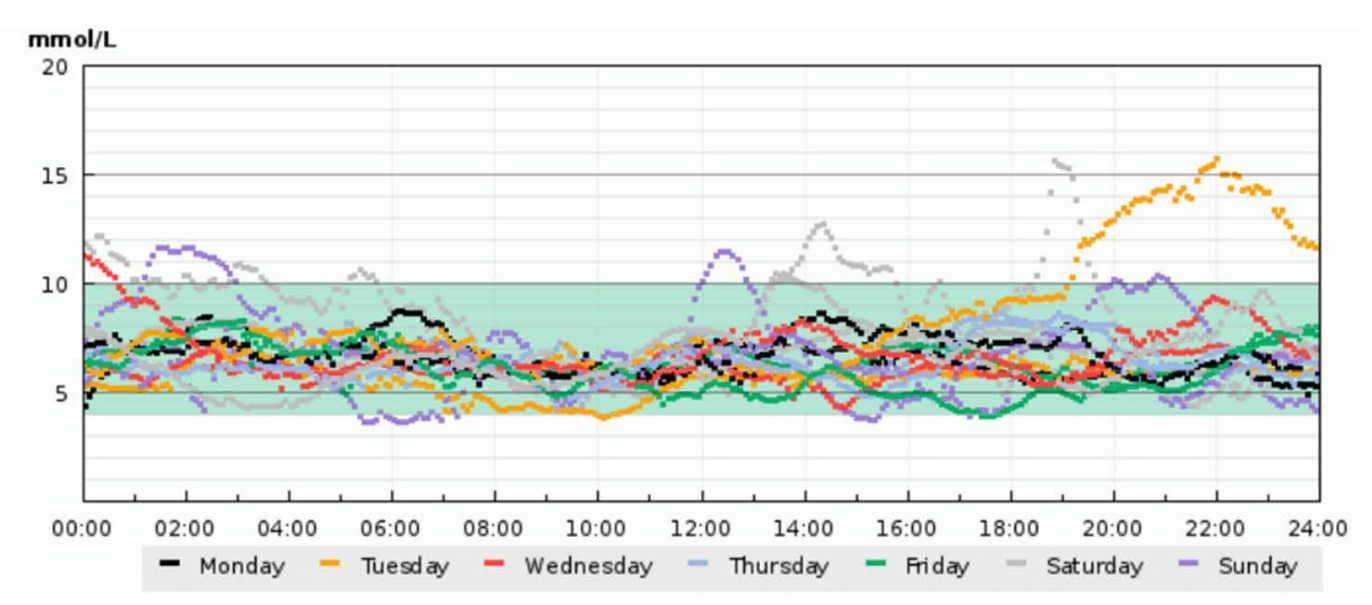
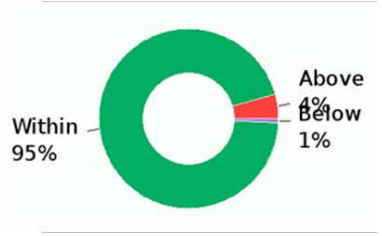
Discuss expectations





Consider alarm burden
Alarms should prompt action!

Slide courtesy of Sara Hartnell

Hypo treatment

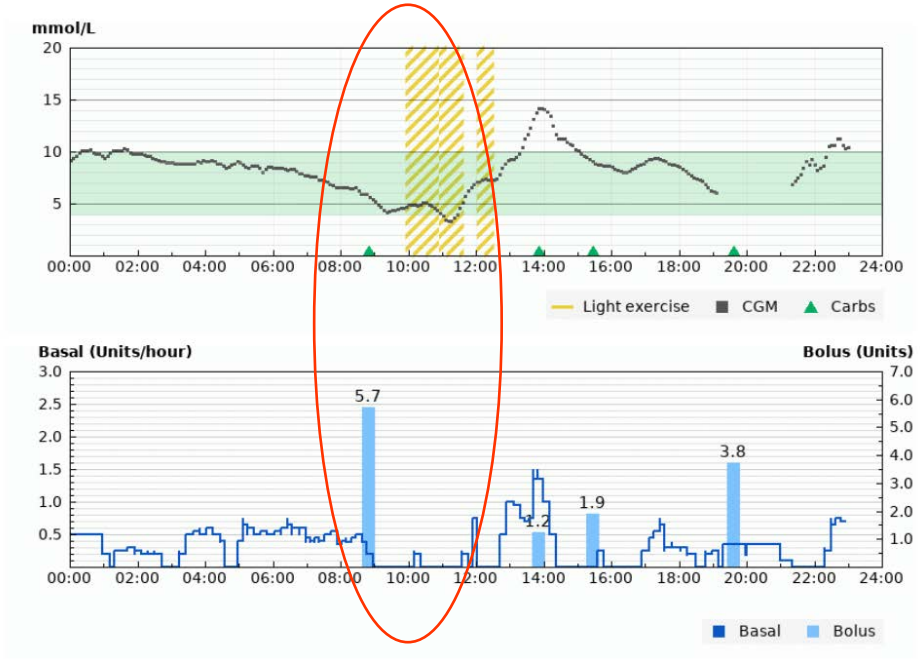
- Less hypo treatment generally required due to low insulin delivery pre-hypo
- User should take insulin delivery in the last 90 minutes into account
- 5-10g CHO may suffice
  - Consider glucose value and directions of arrows

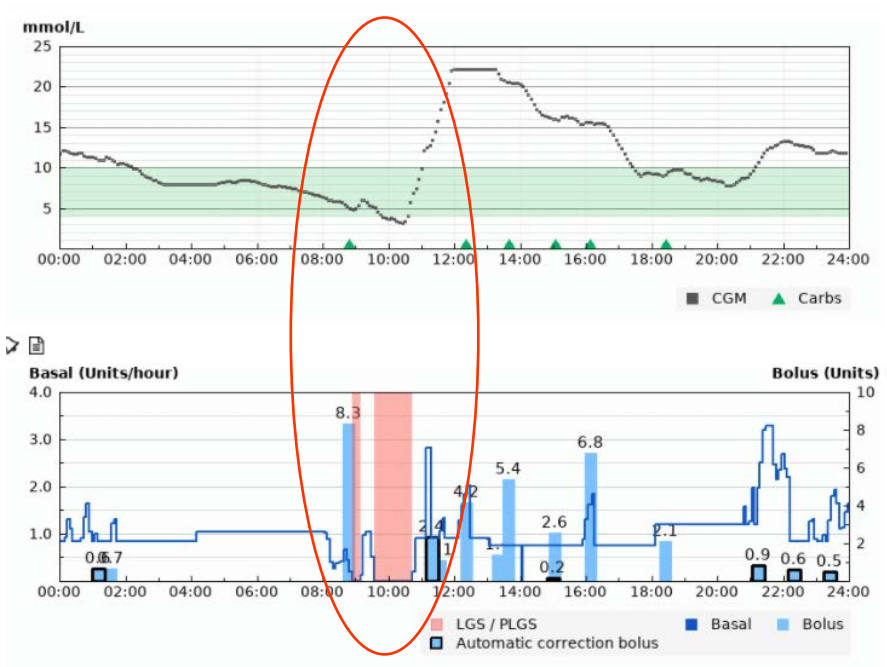
Slide courtesy of Sara Hartnell

Optimise ICRs

- ICRs are likely to need adjusting even if they seemed perfect pre HCL
- In younger children the Bolus insulin makes up the majority of TDD so important ICRs and counting are right

If post-meal hypos / algorithm driven insulin delivery off post meal → ICR too agressive

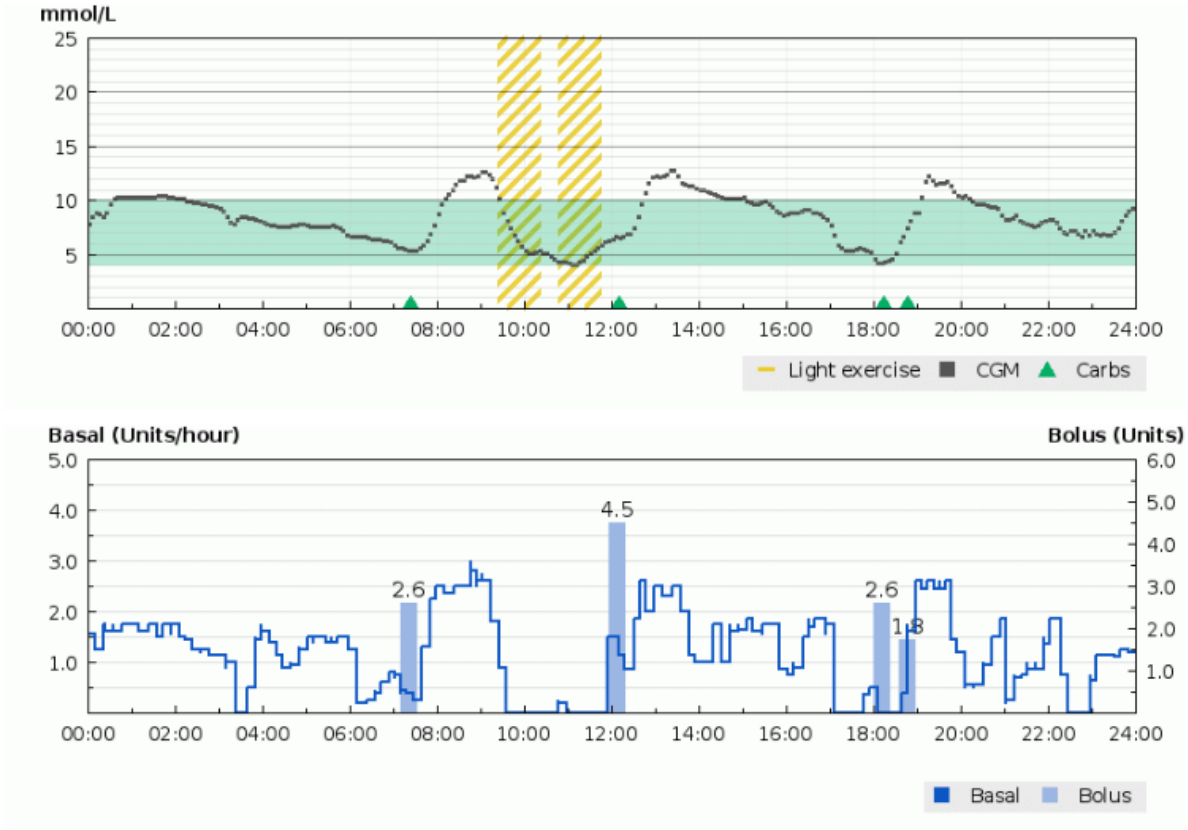




Slide courtesy of Sara Hartnell

Optimise ICRs

If there is post-meal hyperglycaemia and algorithm driven insulin delivery has to increase significantly to deal with the rise (often increasing risk of hypos later) → ICR likely too weak.



Slide courtesy of Sara Hartnell

Exercise

- Temporary increased targets or ‘Activity modes’ to reduce the aggressiveness of the system should be used.
  - Ideally starting 90 minutes prior to the activity.
- Avoid pre-exercise Carbohydrate loading
  - can cause rise in closed-loop driven insulin delivery
  - often better to “drizzle” in carbs as required
- Suspending insulin delivery for a defined period of time may be required for long duration cardiovascular exercise
- Individualised planning is important

Slide courtesy of Sarah Donald

Managing alcohol

- Consuming a bed time snack as a strategy to avoid overnight hypoglycaemia is unlikely to be helpful
  - Closed-loop insulin delivery will rise with rising glucose level from the snack
- Consider using a temporary increased target or use functionality to reduce aggressiveness

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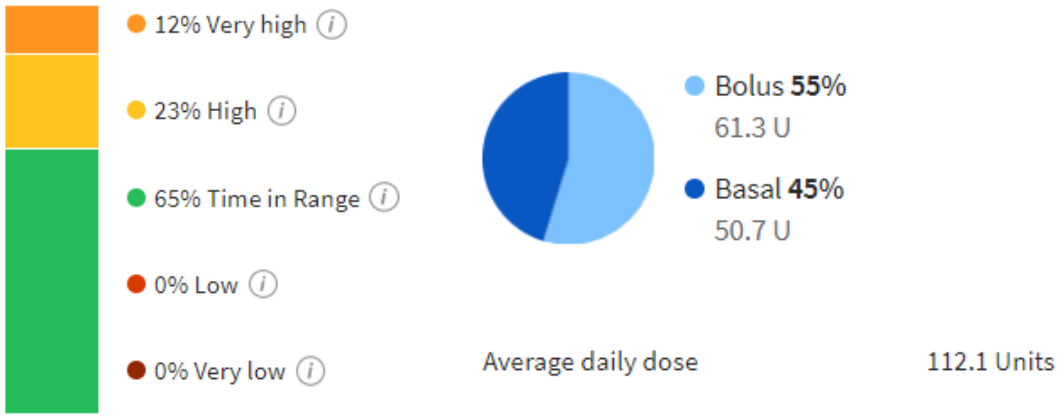
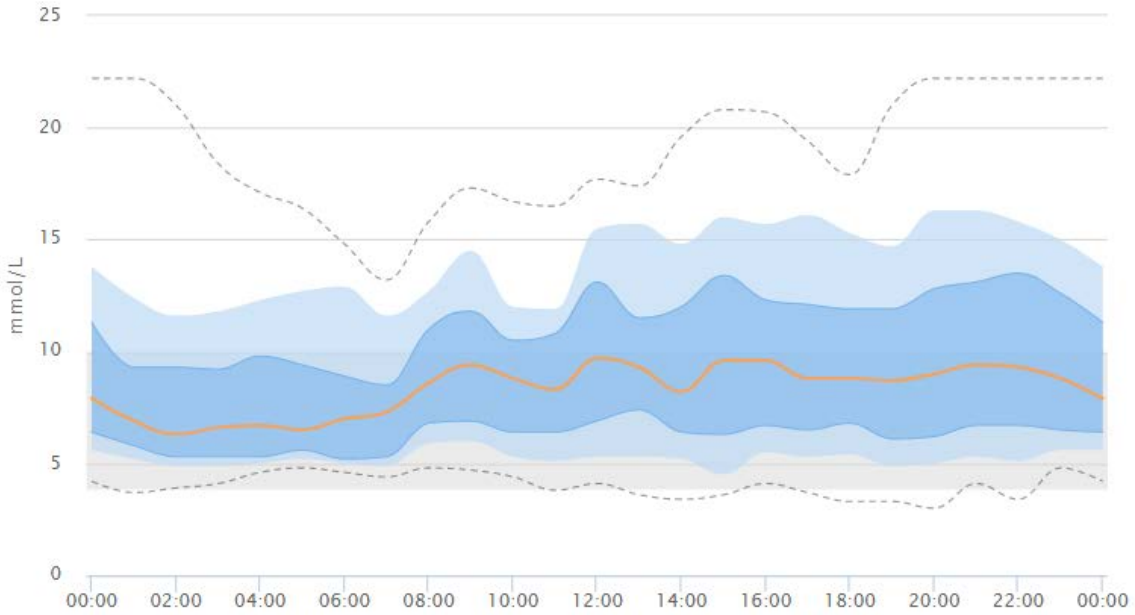
- **Clinical examples**

Case 1

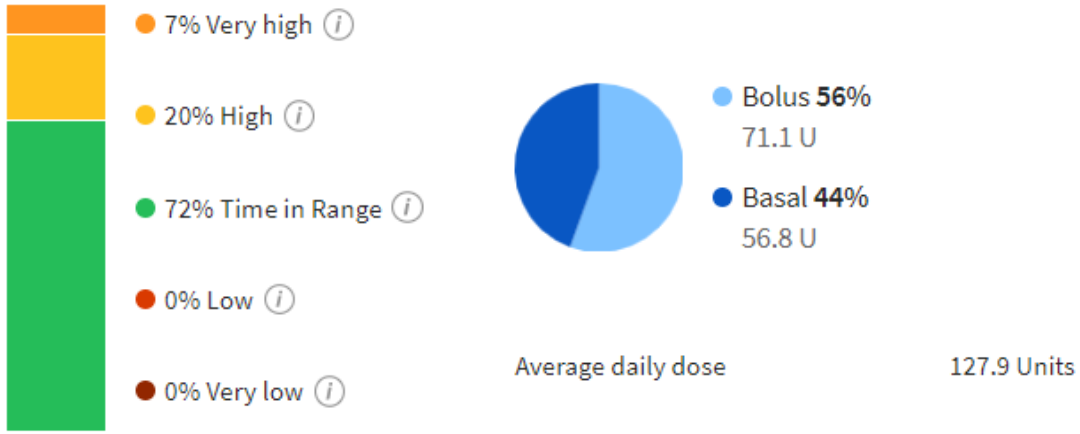
- 15-year old male
- On MDI and CGM following diagnosis in 2018
- Sensor-augmented pump therapy with PLGS started 2 years ago
- Going through puberty
  - BMI 99.6th centile
  - TDD >100 units
- What about closed-loop?

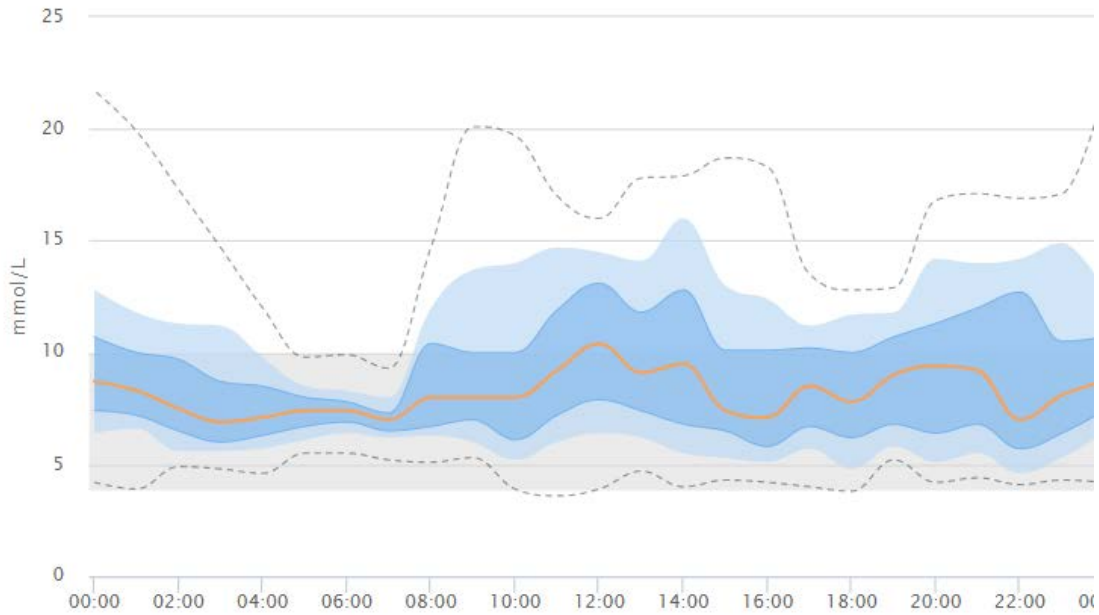
SAP with PLGS



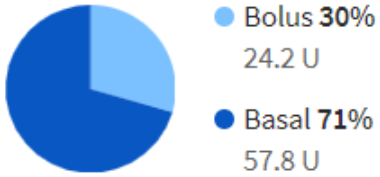


Closed-loop

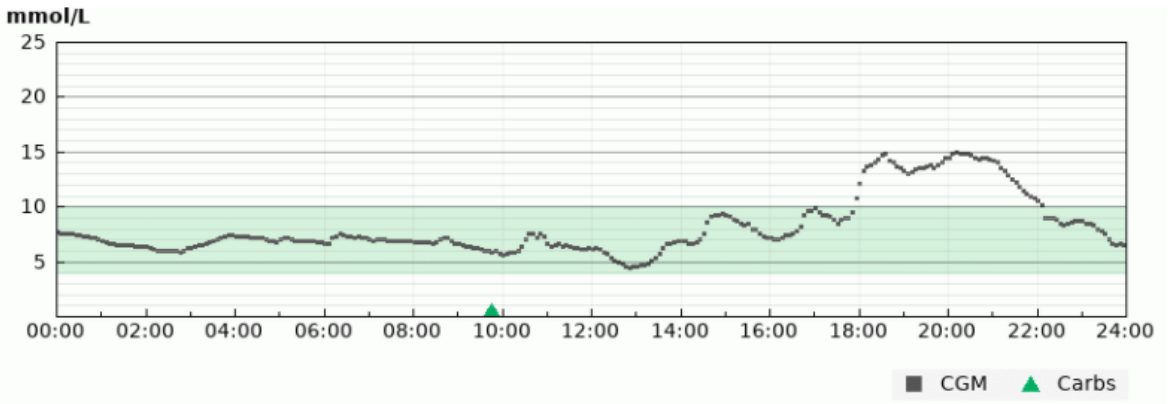


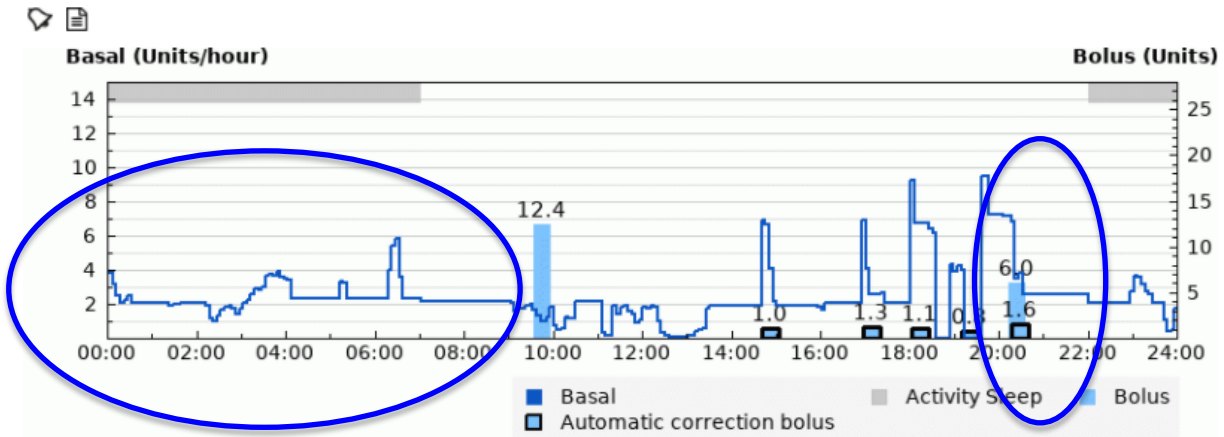


Closed-loop can manage high & variable TDD

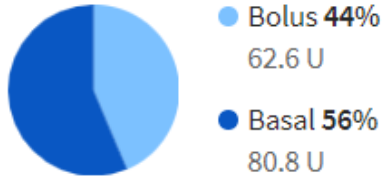


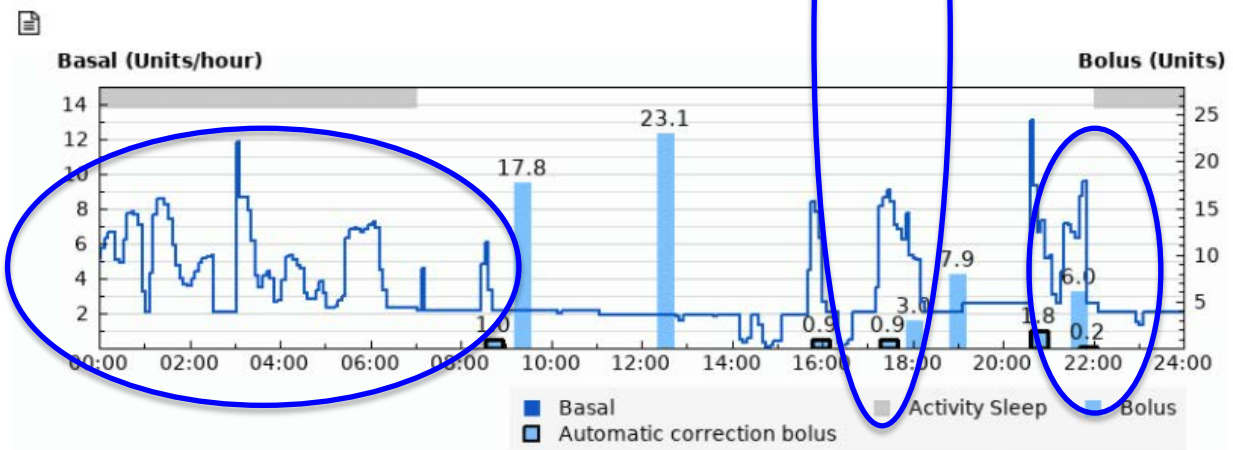
TDD 82 units





TDD 143 units





Case 2 – 18-month old girl

- 18 months at diagnosis
- Presented in moderate DKA, HbA1c 106
  - Dexcom G6 commenced within 24 hours of admission to PICU
  - Ypsopump and CamAPS FX started day 3
  - TDD = 6 units; Weight= 12.1kg
    - 50:50 basal:bolus as backup on pump
    - **U10 dilution → Pump labelled & alert on records**
    - ICRs all set to 1:5g (equivalent to 1:50g), ISF 1:2.5mmol/L (equivalent to 1:25mmol/L)
    - Basal rate 1.25units (equivalent to 0.125units) per hour
    - **Personal glucose target 10mmol/L**

Dilution – Practicalit

Who will dilute?

- Hospital Pharmacy vs Parents
- Policy for use of dilute insulin
- SOP for the dilution process
- Instructions / training materials

Supply of diluent and syringes

- Obtained via Hospital Pharmac
- Novo Nordisk Diluent supplied

ISPAD Guidelines 2022 – Chapter 9:

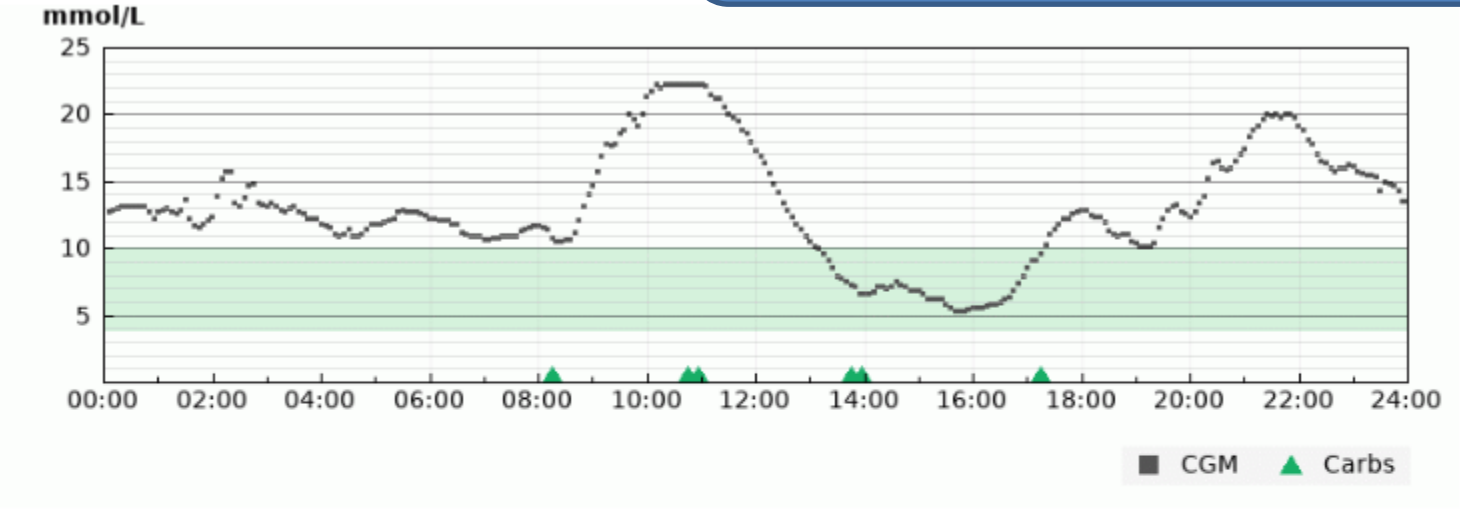
Very young children, infants, and toddlers occasionally require small insulin doses, therefore **may benefit from diluted insulin to allow for more precise dosing** and measurement of insulin in <1 unit increments.

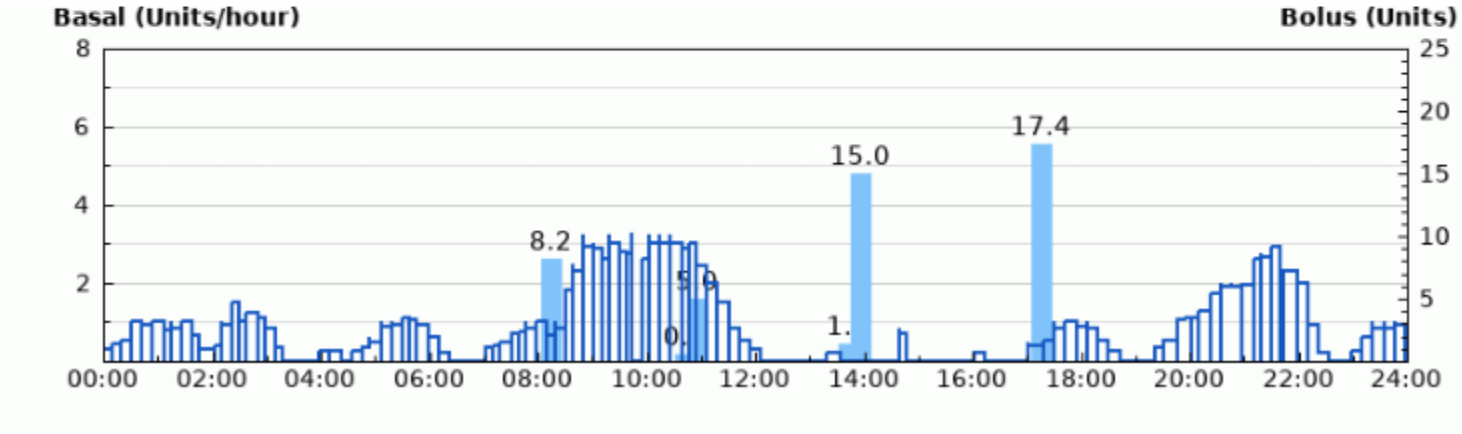
Insulin is diluted with diluent obtained from the manufacturer. Aspart, Lispro and NPH insulins have special diluents produced by insulin manufacturers.

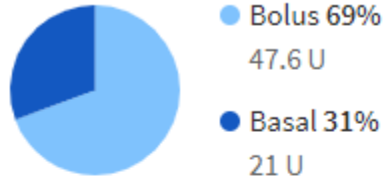
Rapid-acting insulin can be diluted to U10 or U50 with sterile NPH diluent and **stored for 1 month for use** in pumps for infants or very young children.

Day 1

ICR strengthened to 1:4g (1:40g)
PGT reduced to 9mmol/L







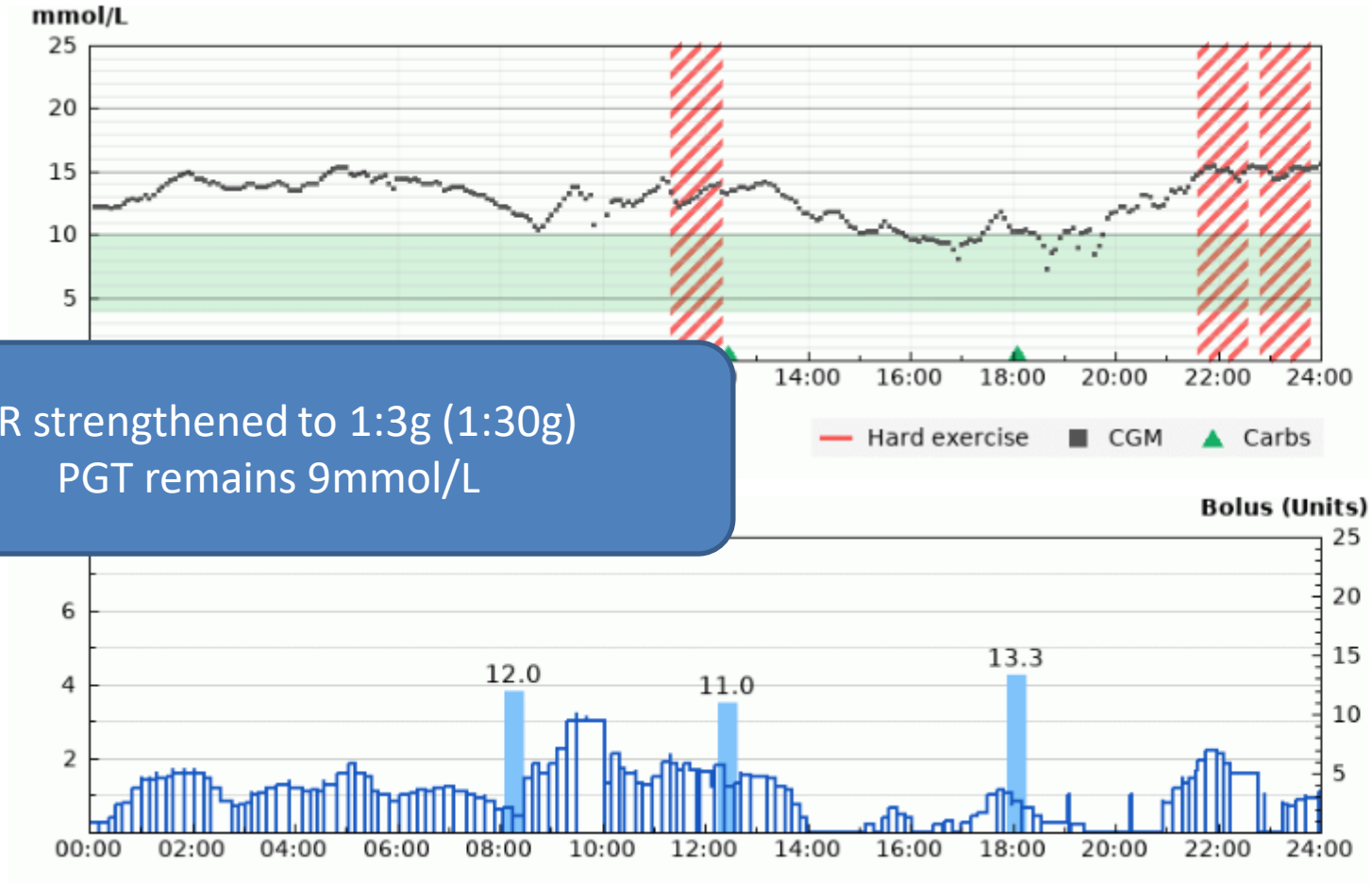
Basal

Time	U/h
00:10	0.000
00:10	0.450
00:10	0.380
00:18	0.000
00:18	0.550
00:18	0.500
00:30	0.000
00:30	0.850
00:30	1.000
00:42	0.000

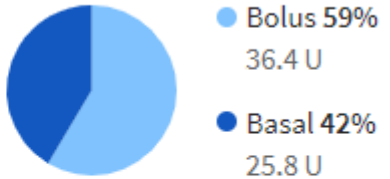
Bolus

Time	U
08:15	8.25
(Meal:	8.25)
10:43	0.60
(Meal:	0.25)
Override	
(Suggested:	0.25)
10:56	5.00
(Meal:	0.25)
Override	
(Suggested:	0.25)

Fewer peaks and troughs – day 3



ICR strengthened to 1:3g (1:30g)
PGT remains 9mmol/L



Basal

Time	U/h
00:10	0.000
00:10	0.250
00:22	0.000
00:22	0.400
00:22	0.380
00:30	0.000
00:30	0.650
00:30	0.750
00:38	0.000

Bolus

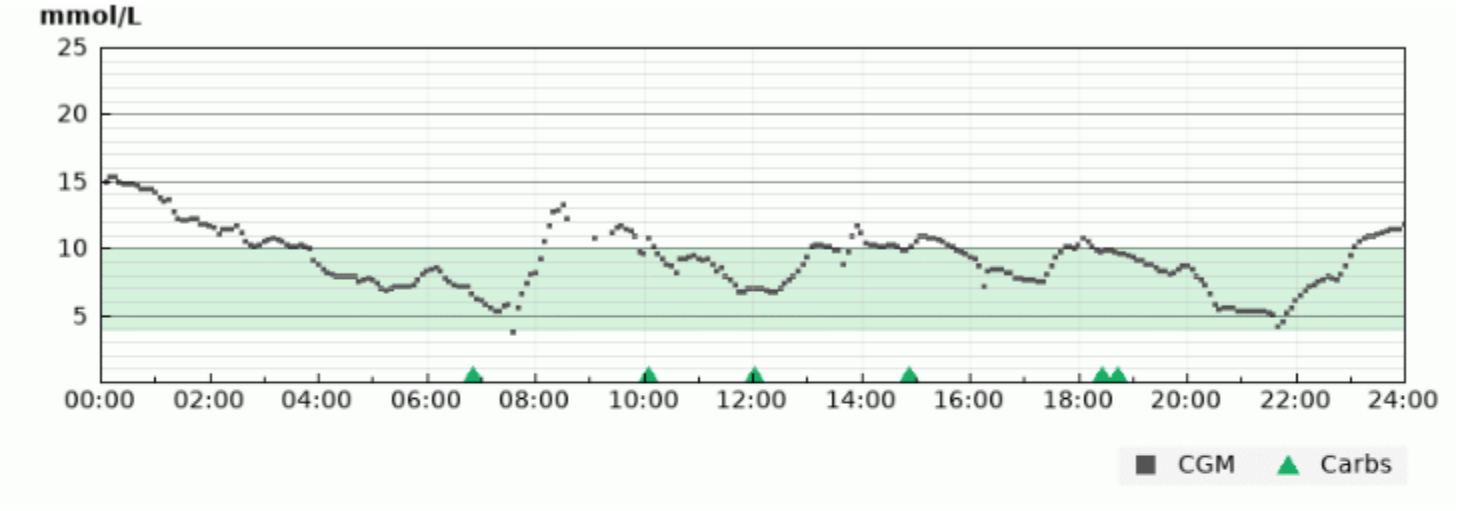
Time
08:18
(Meal:
12:27
(Meal:
18:05
(Meal:

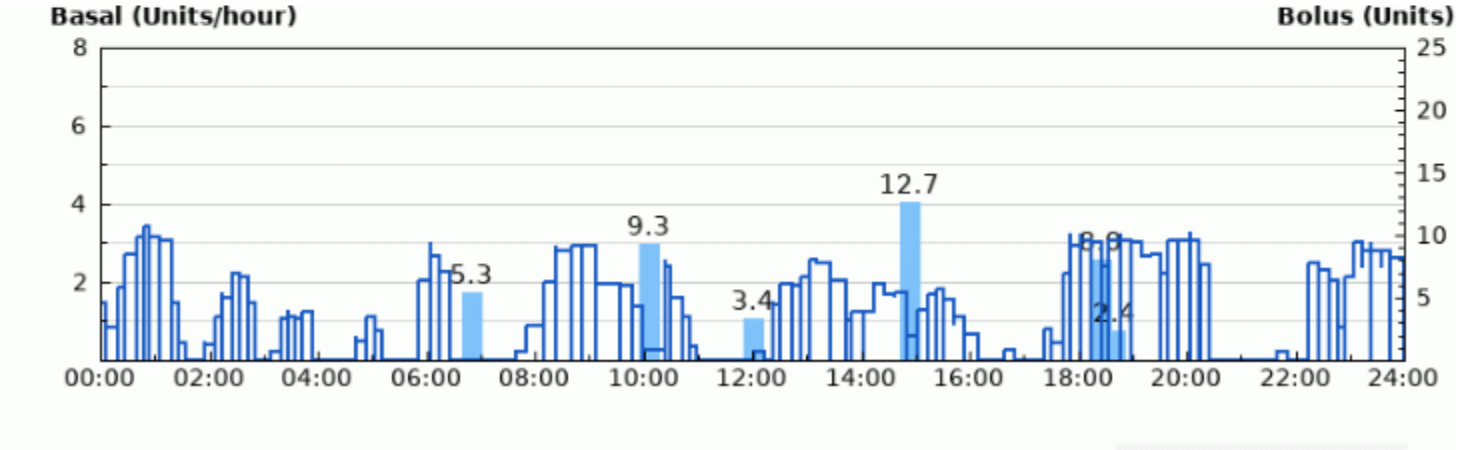
Carbohydr

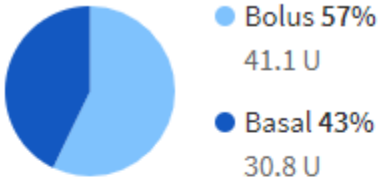
Time

Day 5

PGT reduced to 8mmol/L







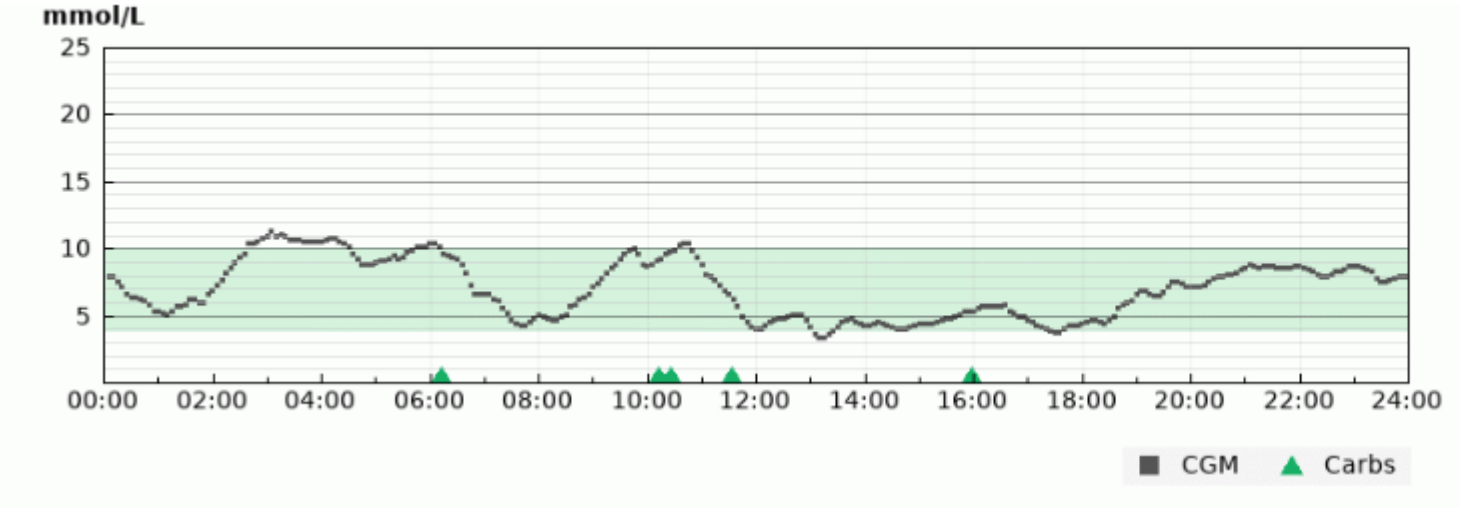
Basal

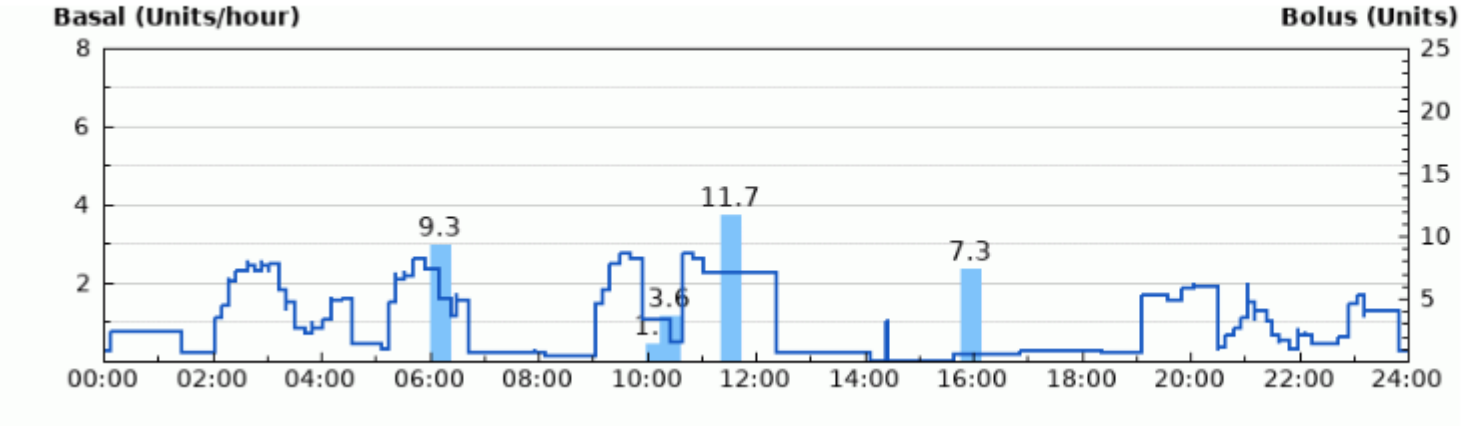
Time	U/h
00:06	0.000
00:06	0.850
00:06	1.000
00:18	0.000
00:18	1.850
00:18	1.870
00:26	0.000
00:26	2.540
00:26	2.700
00:39	0.000

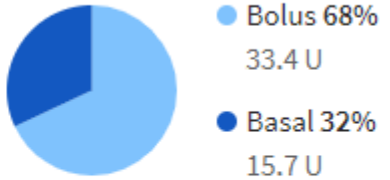
Bolus

Time
06:51
(Meal:
10:06
(Meal:
12:01
(Meal:
14:54
(Meal:
18:25
(Meal:

Day 18







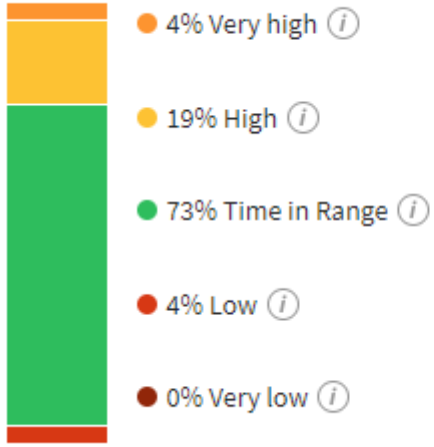
Basal

Time	U/h
00:07	0.750
01:26	0.200
01:26	0.250
02:02	1.000
02:02	1.130
02:10	1.400
02:10	1.330
02:19	2.050
02:19	2.140
02:26	2.300

Bolus

Time
06:12
(Meal:
10:11
(Meal:
10:25
(Meal:
11:33
(Meal:
15:58
(Meal:

At the end of first 4 weeks



- 4% Very high
- 19% High
- 73% Time in Range
- 4% Low
- 0% Very low

Time in Range	**73%**
Average	8 mmol/L
Standard deviation	2.8 mmol/L

Show details

- Bolus 64%
  31.2 U
- Basal 36%
  17.2 U

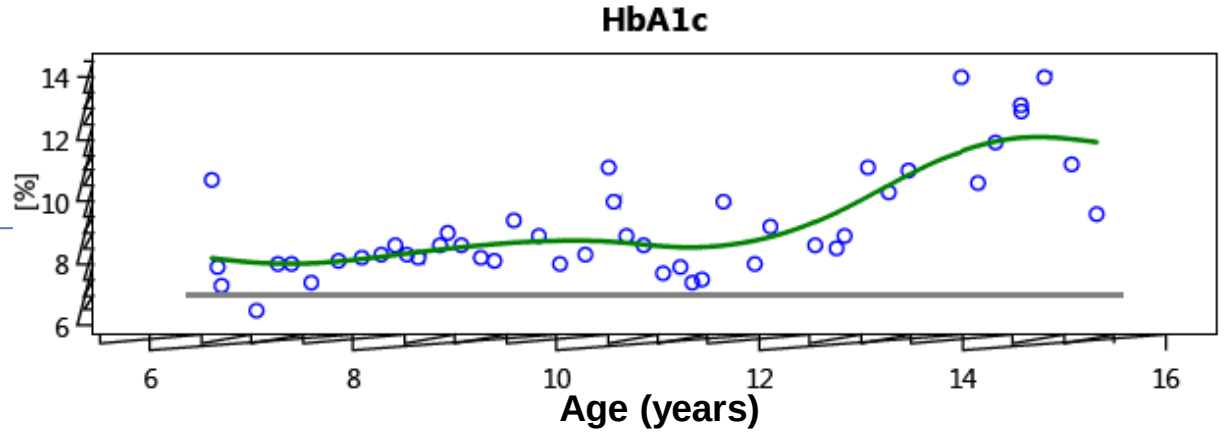
Average daily dose	48.4 Units
Standard deviation	16

Case 3 – 15-year old male

- Body weight: 54 kg, height: 174 cm
- Diabetes onset: 11/2014 (DKA, cerebral seizures)
- Other diagnoses (medication)
  - ADHD (guanfacine 5mg)
  - Hyperlipidaemia (Atorvastatin 10 mg)
  - Cerebral seizures (Levetiracetam 2 x 750mg)
- Complex family history: parents from Afghanistan; sister with T1D (11y); M. currently lives in shared accommodation looked after by social worker

Slide courtesy of Martin Tauschmann

Case 3



- Diabetes management
  - 11/2014 – 07/2015 conventional therapy (Huminsulin normal & basal, 2x/d)
  - 07/2015 – 08/2017 pump therapy (Veo) + SMBG
  - 08/2017 – 08/2019 sensor-augmented pump therapy (Veo, FSL 1)
  - 08/2019 – 09/2019 automated insulin delivery system (670G)
  - 09/2019- sensor-augmented pump therapy (670G + FSL 1/FSL 2)

- 1 episode of severe hypoglycaemia (03/2017)
- Several inpatient admissions to optimise therapy

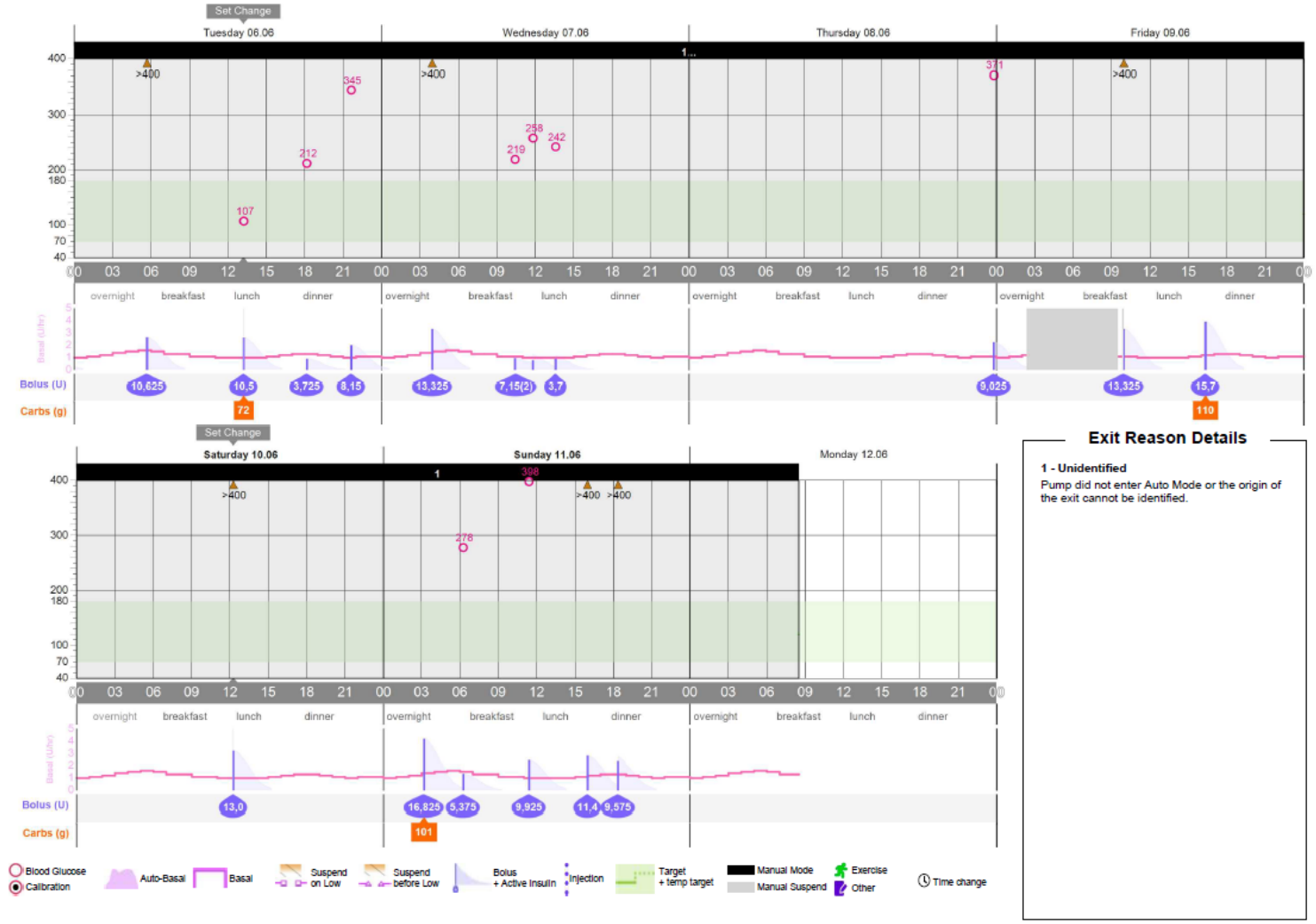
Slide courtesy of Martin Tauschmann

Outpatient visit 06/2023

- HbA1c 11.2 %

Pump download

Statistics	A
Auto Mode (per week)	0% (00h)
Manual Mode (per week)	95% (6d 16h)
Sensor Wear (per week)	0% (00h)
Average SG ± SD	--
GMI***	--
Coefficient of Variation (%)	--
Low / High SG Alerts (per day)	0,0 / 0,0
Average BG	347 ± 130 mg/dL
BG / Calibration (per day)	2,9 / 0,0
Total daily dose (per day)	59,2 units
Bolus amount (per day)	33,2U (56%)
Auto Basal / Basal amount (per day)	26,0U (44%)
Set Change	Every 2,5 days
Reservoir Change	Every 2,0 days
Meal (per day)	1,1
Carbs entered (per day)	89 ± 92 g
Active Insulin time	3:00 hrs

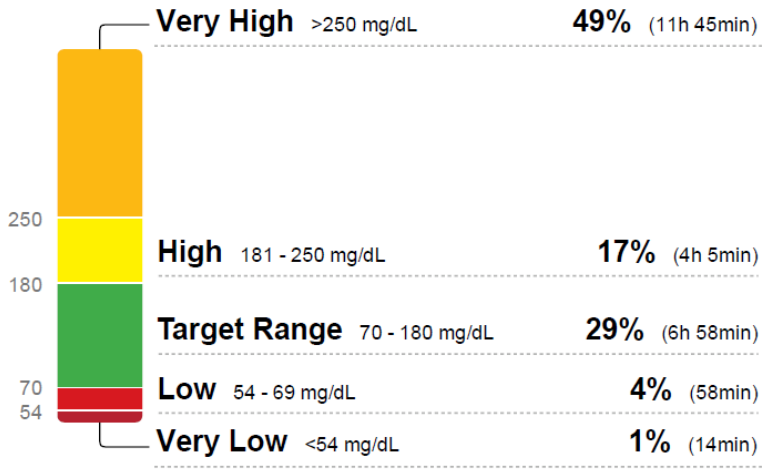


Slide courtesy of Martin Tauschmann

Outpatient visit 06/2023

CGM (isCGM – FSL 2)

TIME IN RANGES

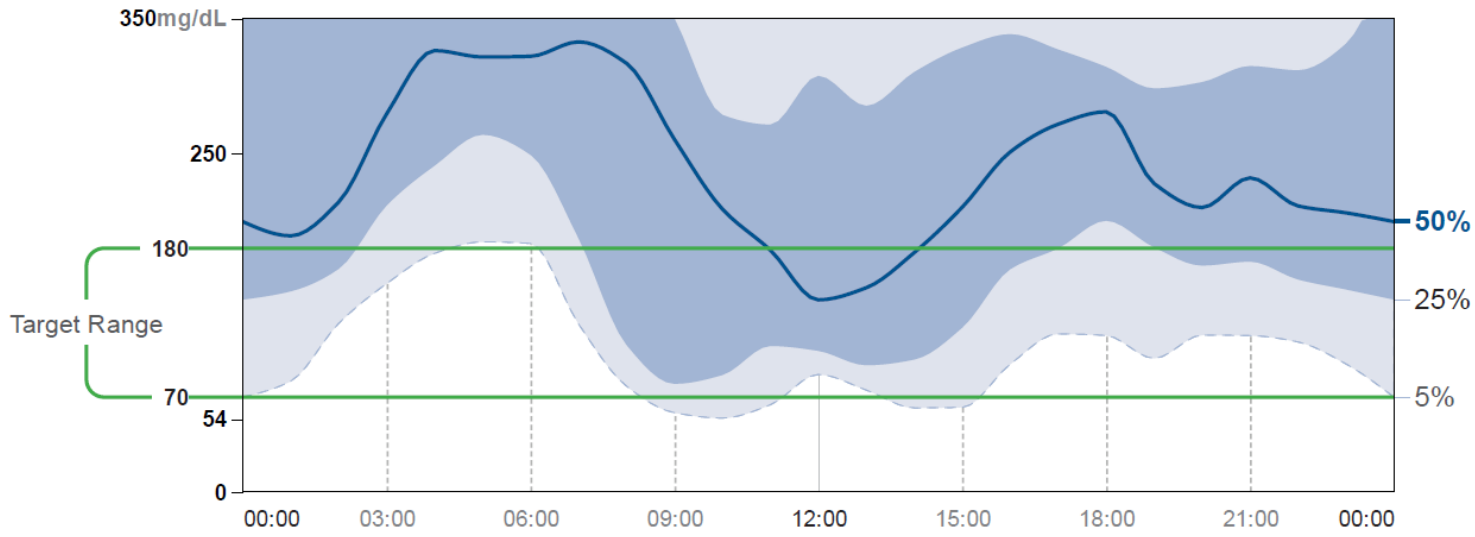


Sensor Usage

% TIME SENSOR IS ACTIVE	76 %
Average scans/views	10 / Day

AMBULATORY GLUCOSE PROFILE (AGP)

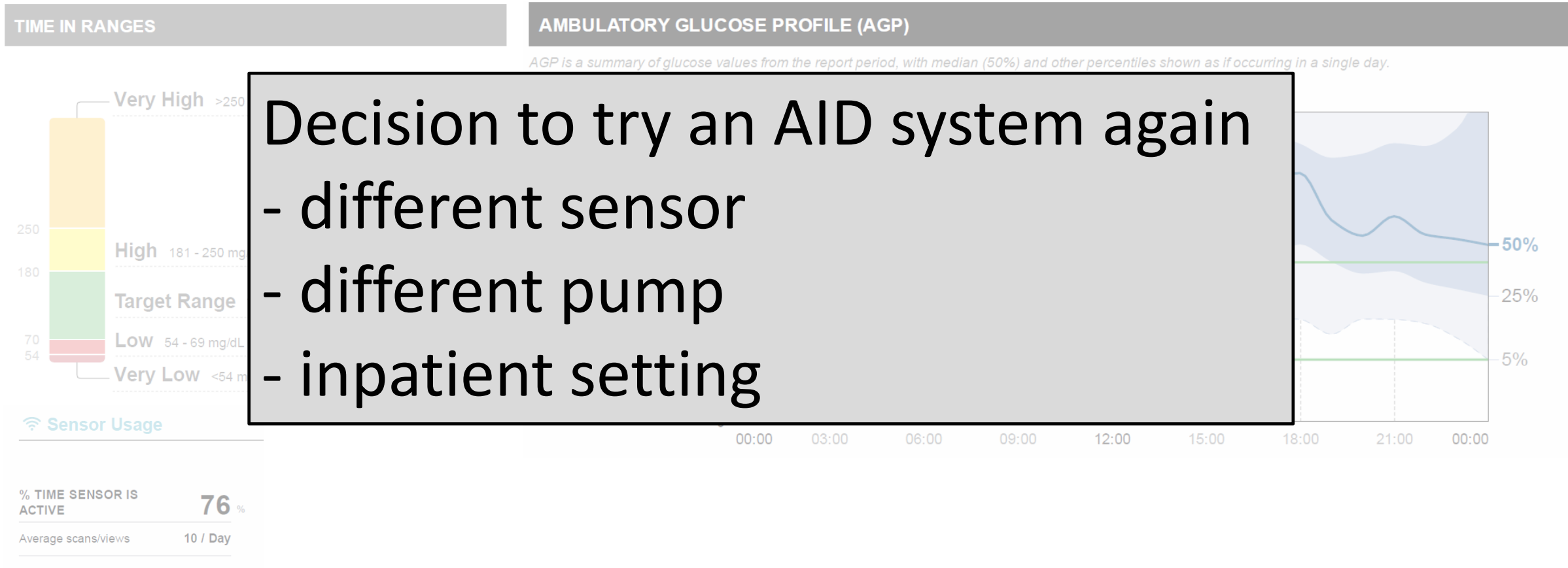
AGP is a summary of glucose values from the report period, with median (50%) and other percentiles shown as if occurring in a single day.



Slide courtesy of Martin Tauschmann

Outpatient visit 06/2023

CGM (isCGM – FSL 2)



Decision to try an AID system again

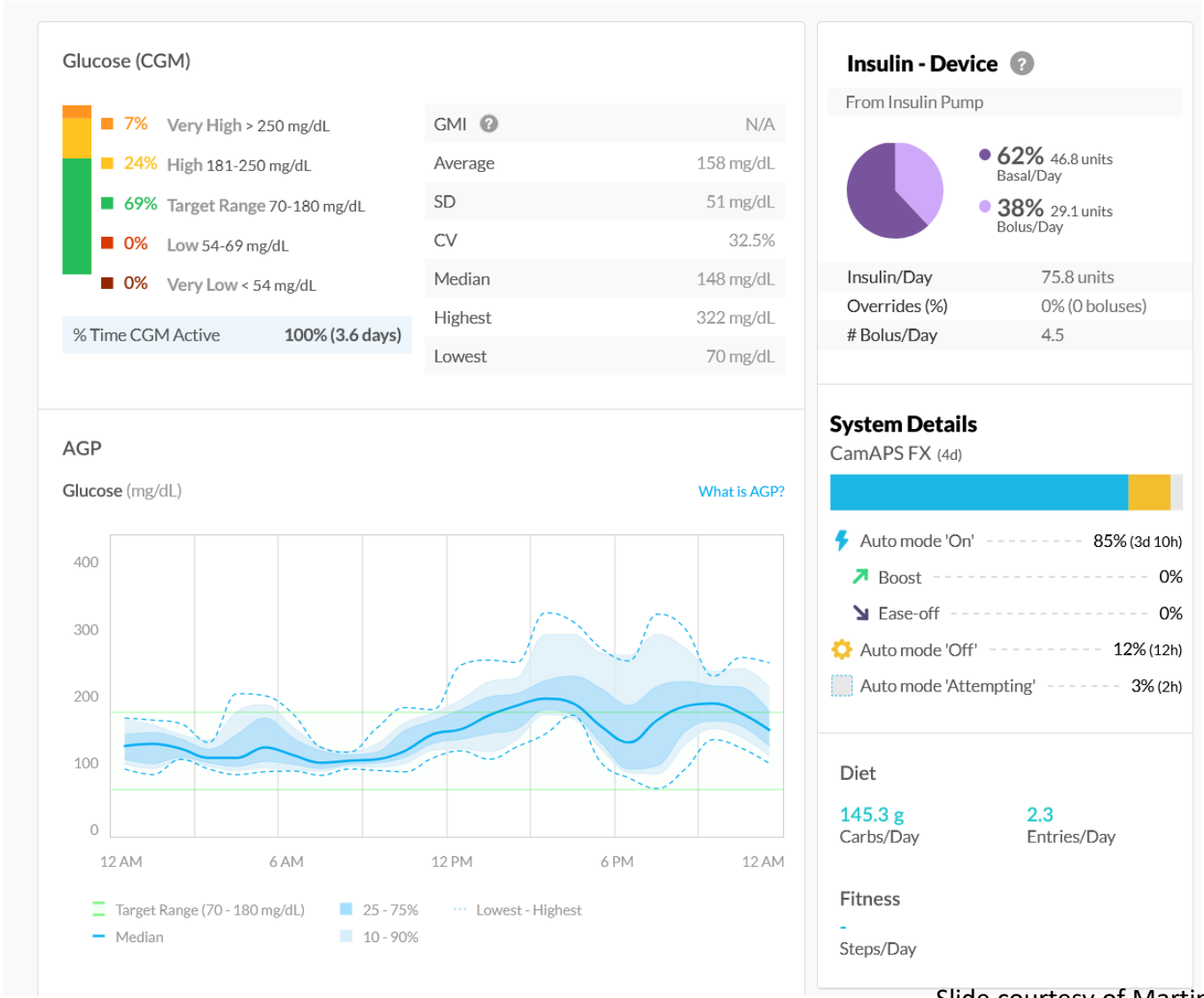
- different sensor
- different pump
- inpatient setting

Slide courtesy of Martin Tauschmann

Hospital admission

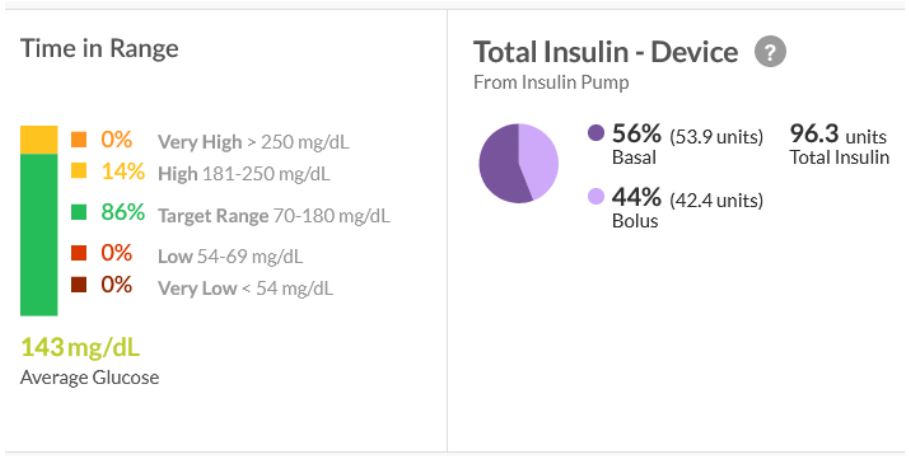
07/18/2023 to 07/24/2023)

- HbA1c 11.6%
- 7 days in total
  - 3 days on Medtronic 670G&Libre, treatment optimization
  - Switch to Ypsopump&CamAPS FX &Dexcom G6 on 07/21/2023
  - TDD 80 U,
    body weight: 55 kg



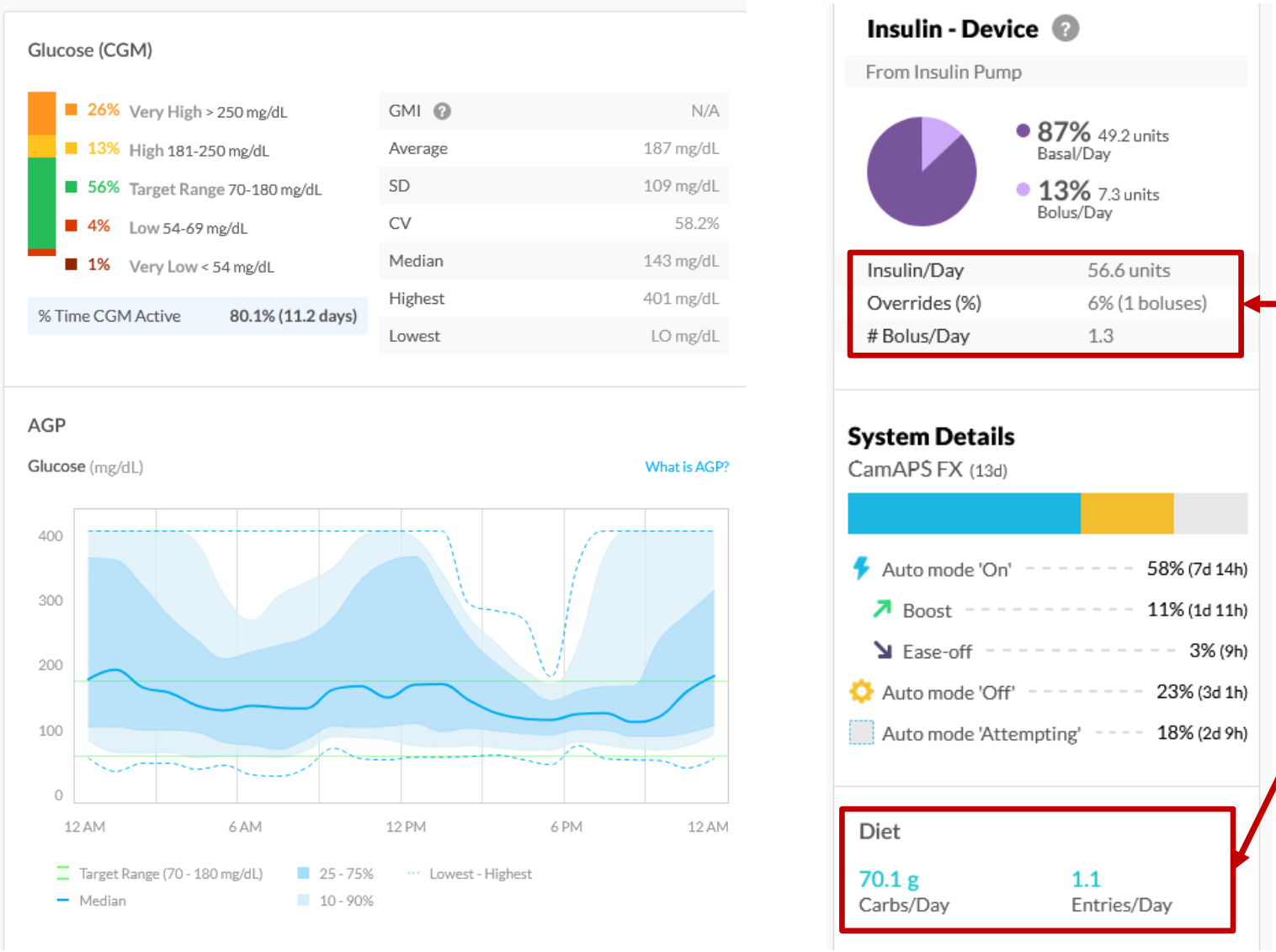
Slide courtesy of Martin Tauschmann

A day on the ward



Slide courtesy of Martin Tauschmann

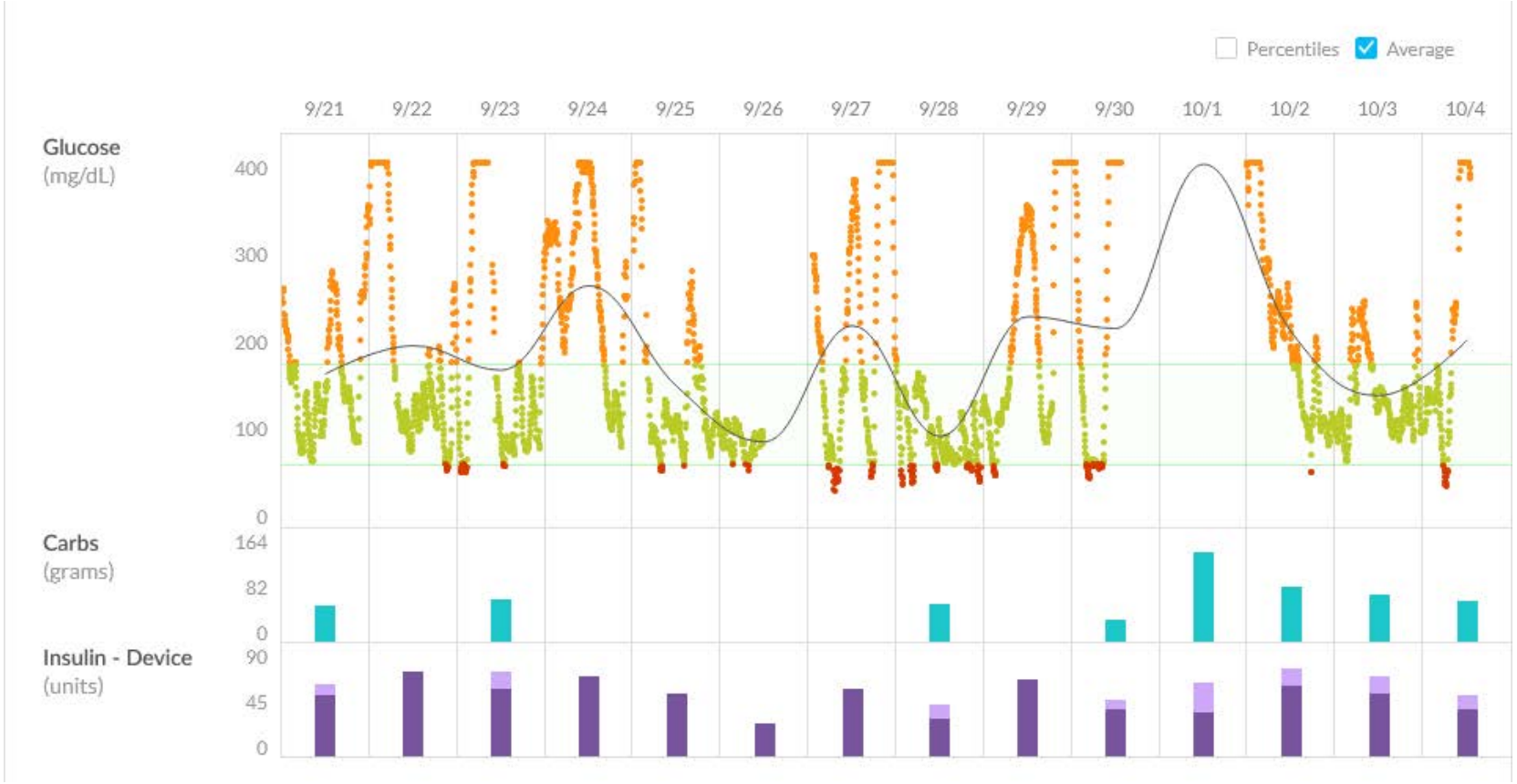
Follow up – Sept/Oct 2023



- HbA1c 9.6%
- TDD ↓ 57 U/d
- Missed boluses

Slide courtesy of Martin Tauschmann

Follow up – Sept/Oct 2023



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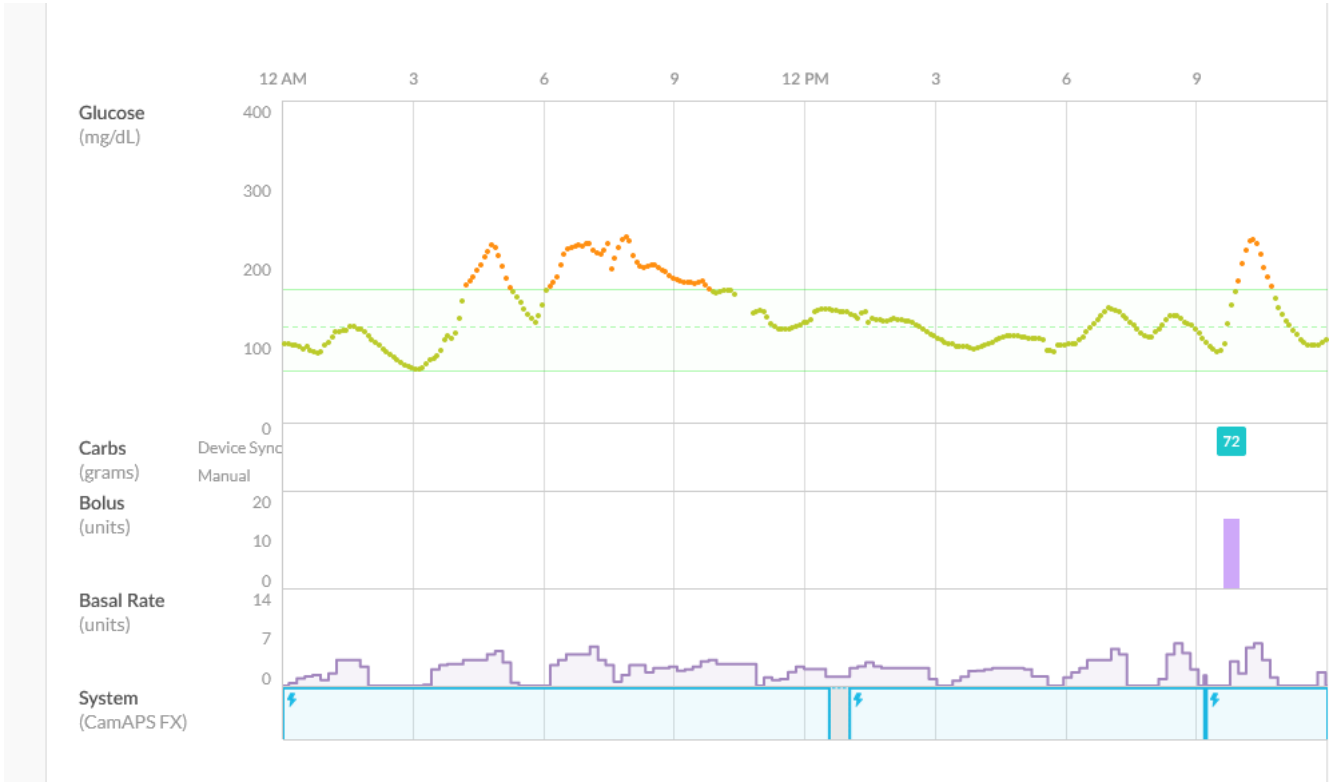
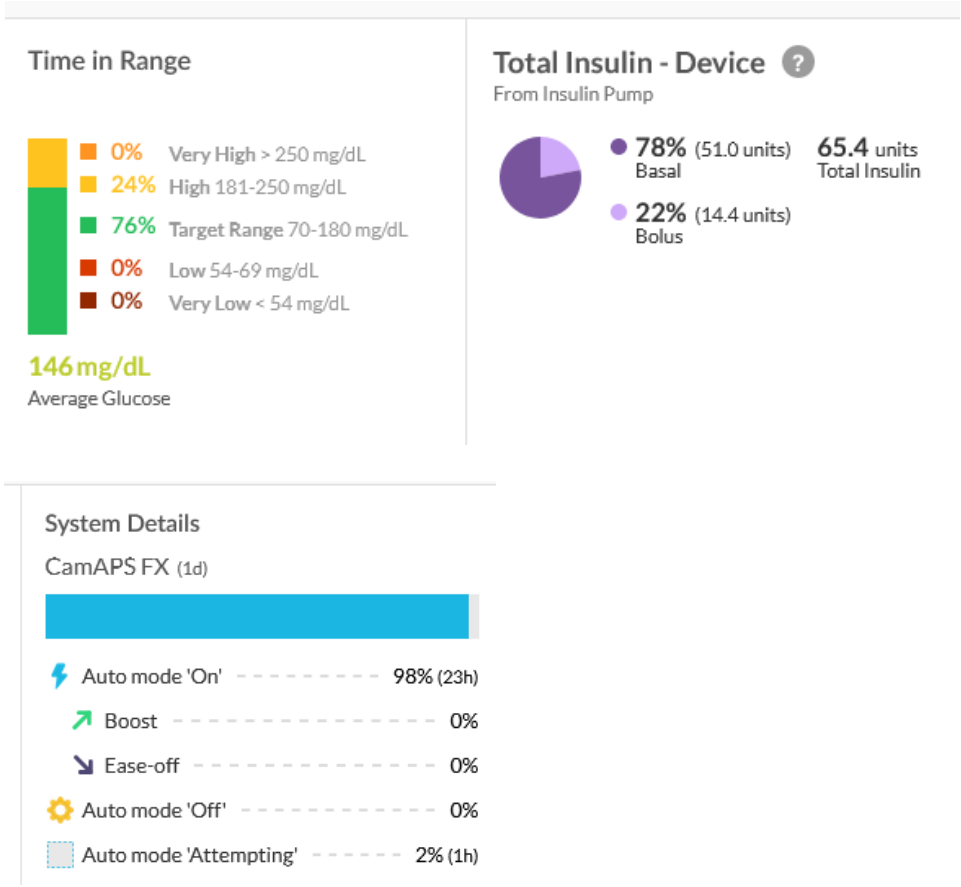
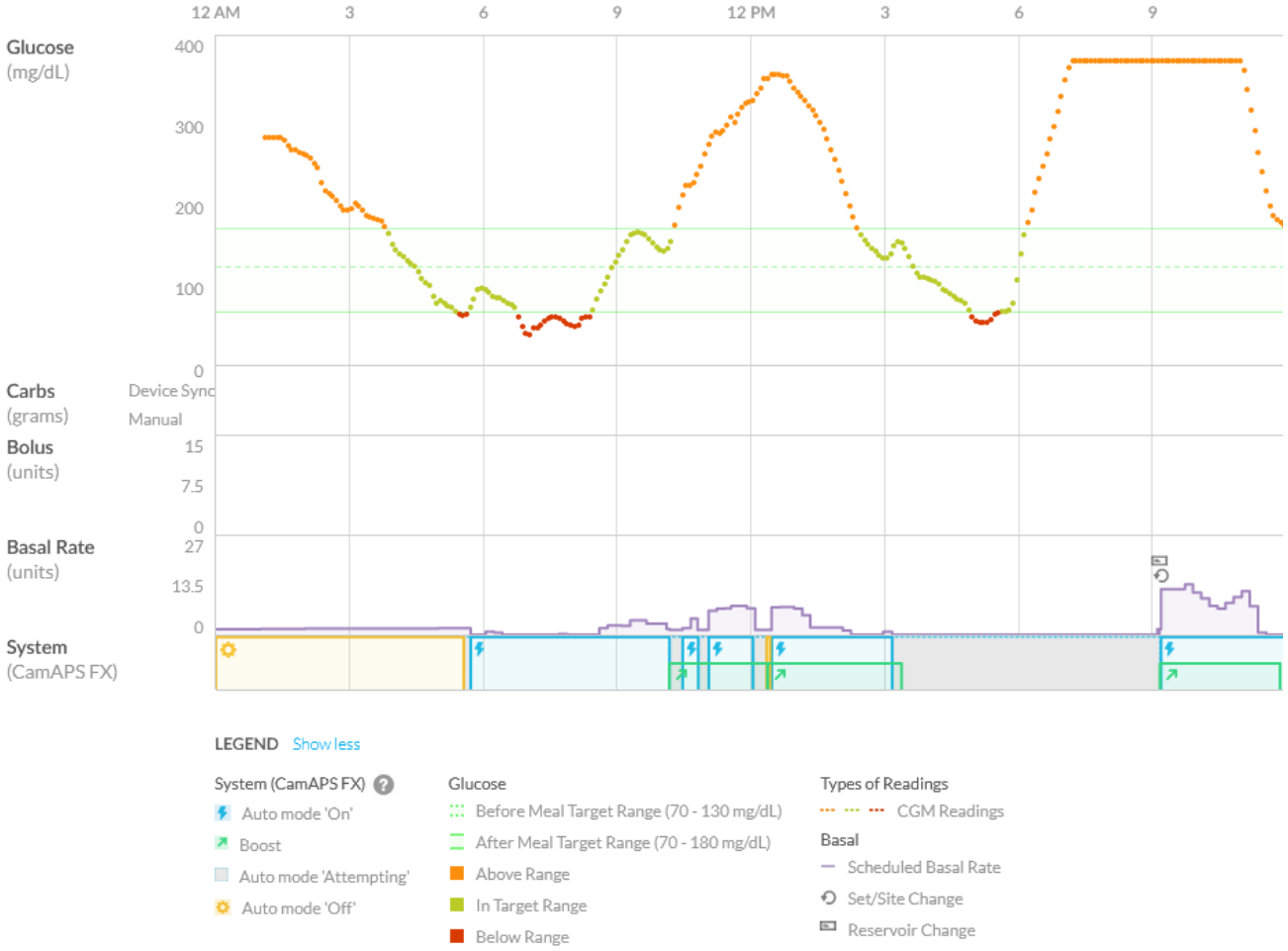
Some days are better…

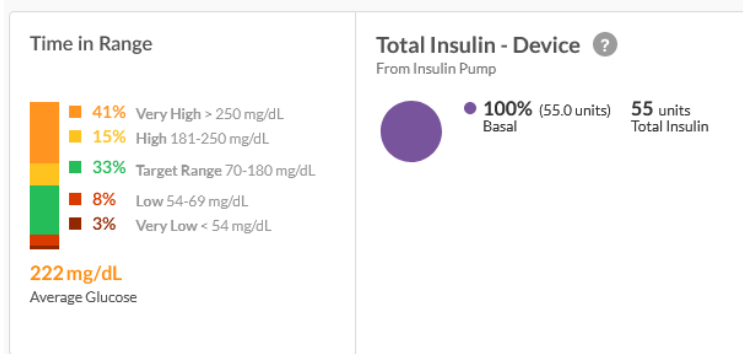


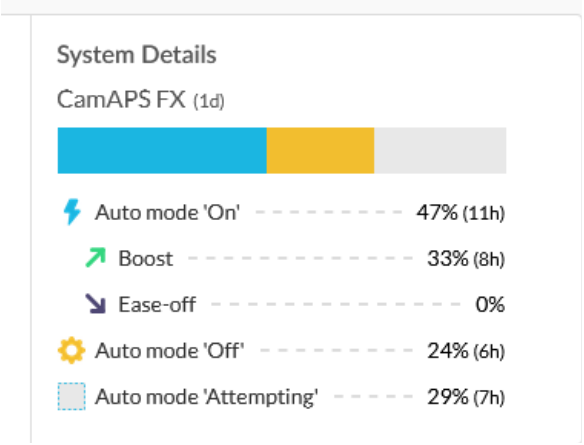


Slide courtesy of Martin Tauschmann

…than others







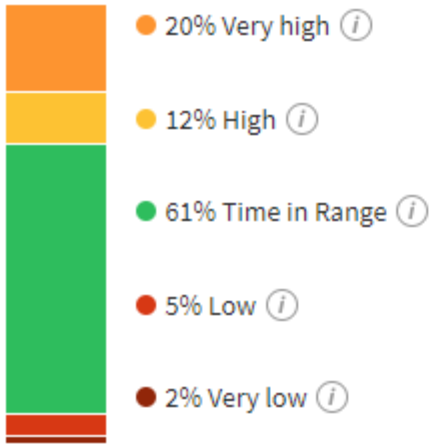
Slide courtesy of Martin Tauschmann

Case 4 – 9-year old boy

- Diagnosed in 2017 aged 4 years
- HbA1c on CSII alone: 73mmol/mol
- Commenced HCL in 2020, now on myLife CamAPS FX
- Current HbA1c aged 9 years: 60mmol/mol ; TIR 61%
  - Keen footballer
  - Not so good at pre-meal bolusing
  - Lovely but busy family with 2 sons & both parents working

CGM

Time CGM active: 98%



- 20% Very high
- 12% High
- 61% Time in Range
- 5% Low
- 2% Very low

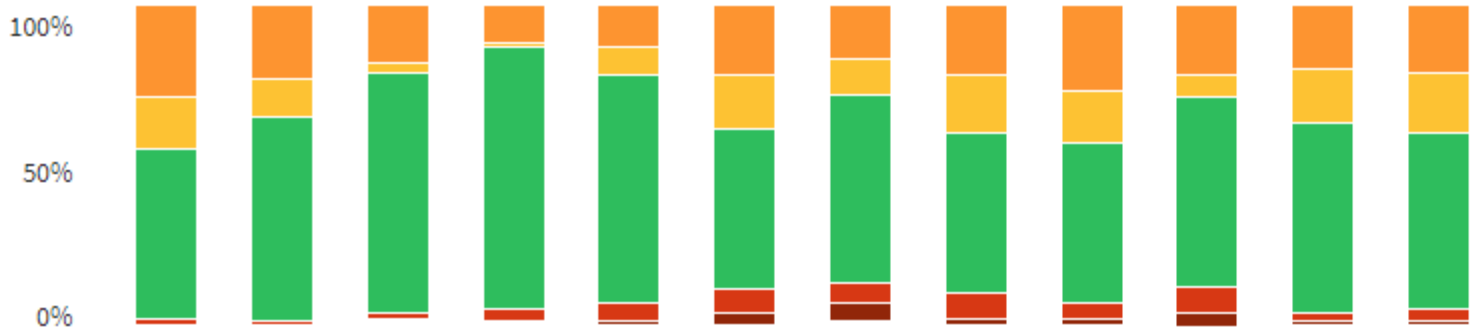
Target range: **3.9-10.9 mmol/L**

Time in Range	**61%**
Average	9.7 mmol/L
Standard deviation	5.2 mmol/L

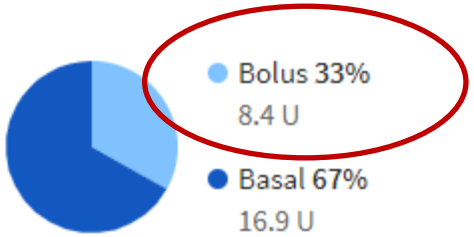
Show details

CGM over time

Bi-hourly | By day



Insulin



- Bolus 33%
  8.4 U
- Basal 67%
  16.9 U

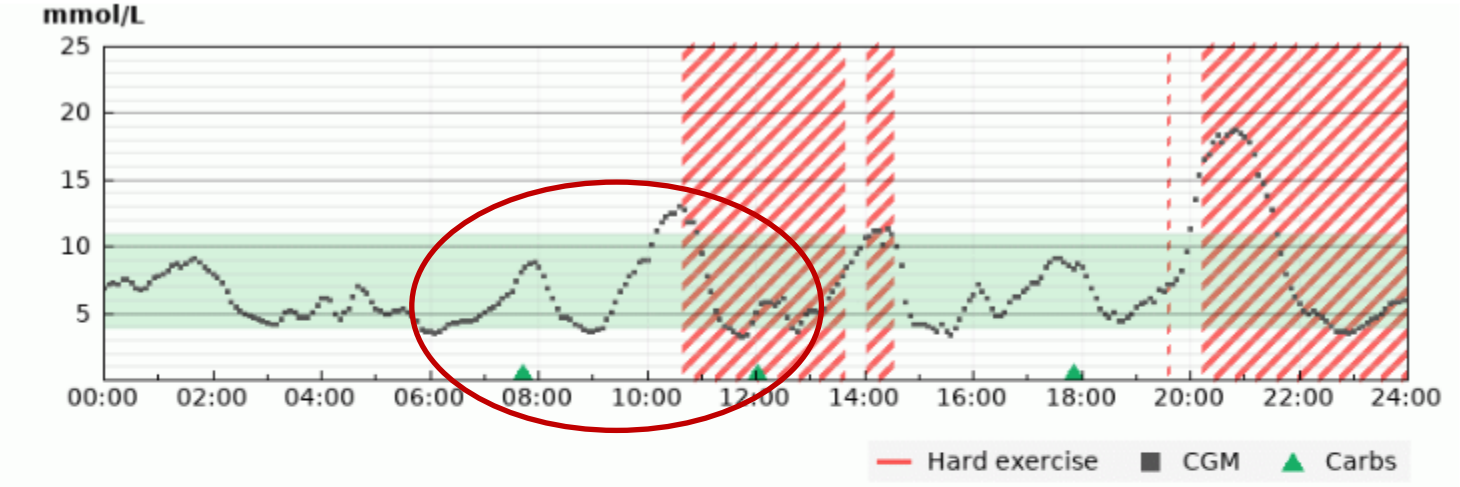
Average daily dose	25.2 Units
Standard deviation	7.4

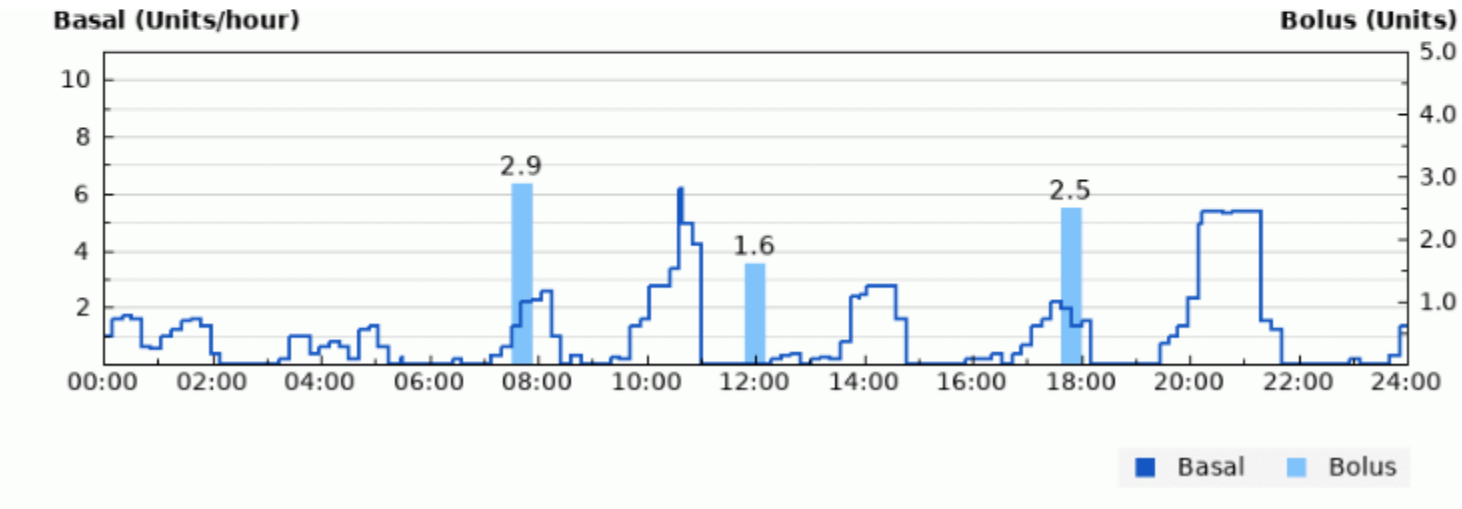
Show details

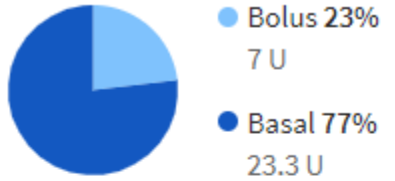
Carbs

Average carbs per day	135 g
Standard deviation	57 g

Late bolusing







Basal

Time	U/h
00:09	1.600
00:09	1.580
00:20	1.740
00:30	1.580
00:41	0.600
00:52	0.550
00:52	0.600
01:03	0.980
01:14	1.250
01:26	1.500

Bolus

Time	U
07:42	2.90
(Meal:	2.90)
12:00	1.60
(Meal:	1.60)
17:49	2.50
(Meal:	2.50)

Carbohydrates

Time	
07:42	43g
12:01	28g

Missed / late bolus

- Within 30-60 minutes → ½ bolus
  - Full bolus may cause hypoglycaemia
- >60 minutes → Boost

Case 5 – 18-year old exercising

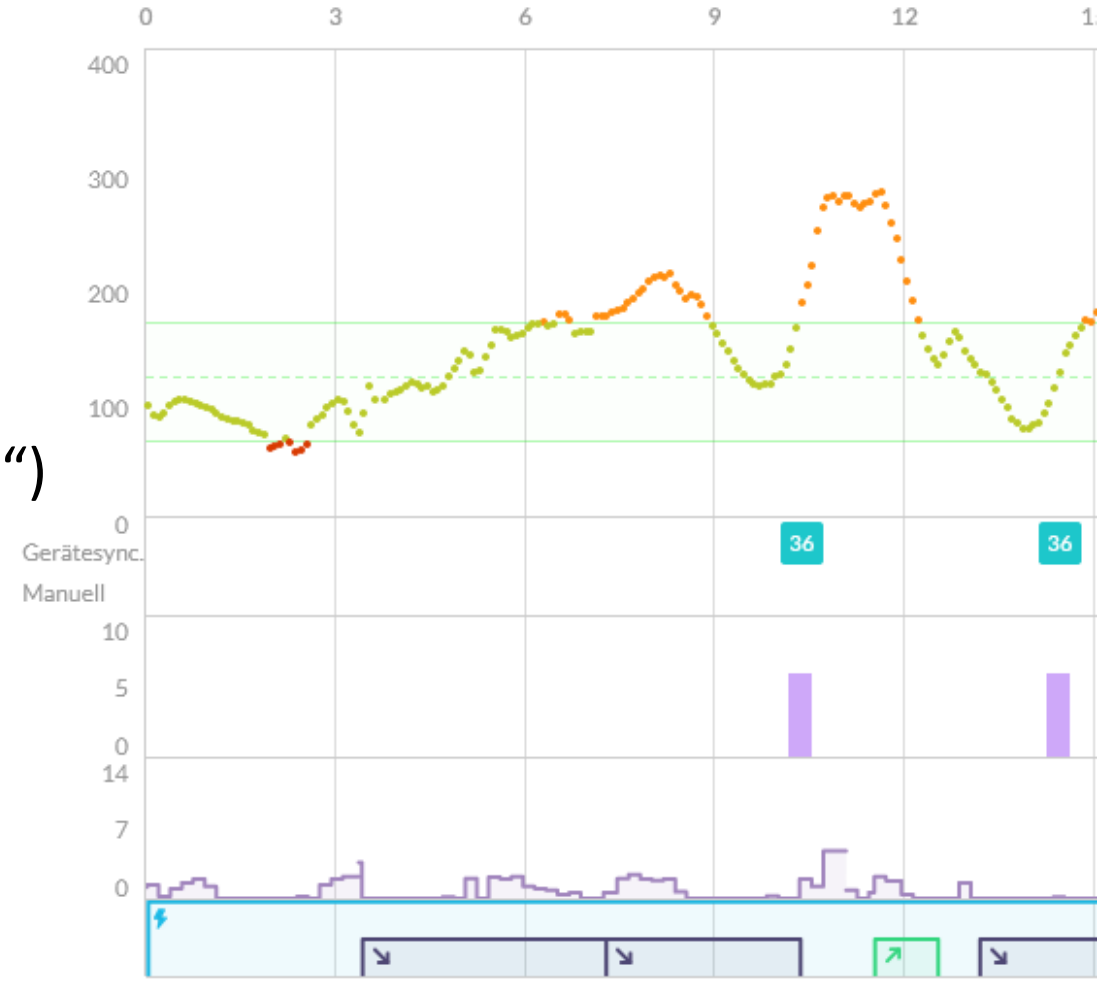
15k run 08:30-10:00
Ease-off 5 hours in advance

Personal target 190mg/dl at start of exercise

25g of carbs at 09:30 („dropping levels“)

Breakfast at 10:00

Postprandial peak
(forgot to turn off personal target)



Take Home messages

- Basic approach is similar across all CL systems
- BIG picture
- Small picture
- Use a cheat sheet to remember what is adjustable in each system
- Don’t forget to discuss expectations – and remember to balance glycaemic goals vs management burden!

Wellcome - MRC IMS Institute of Metabolic Science

Acknowledgements

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Young people and their families

MRC Metabolic Diseases Unit
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Questions?