Type 1 diabetes and technology
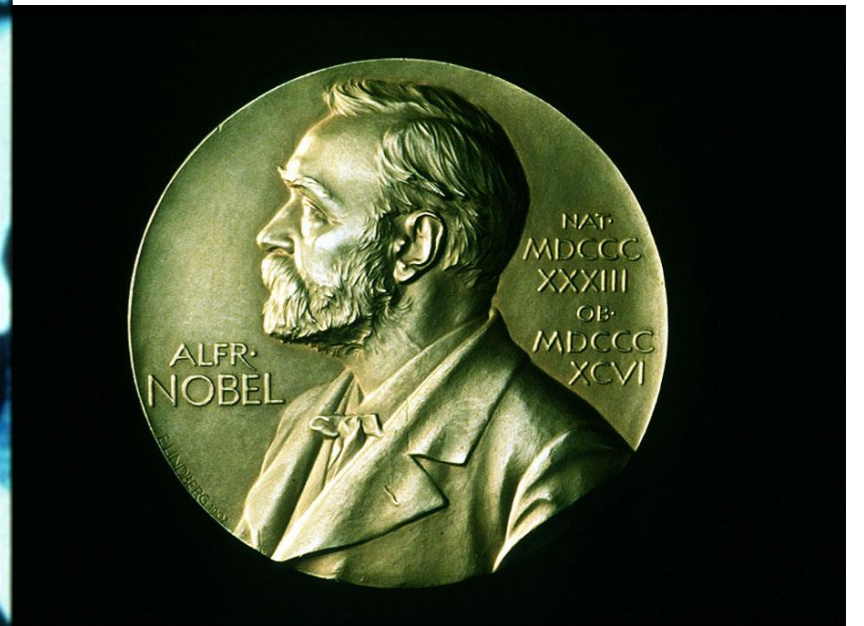
22nd September 2022

Stuart Little
Consultant Diabetologist
Stuart.little1@nhs.net

No declarations of interest

Outline

- Context of current technologies

- Flash glucose monitoring

- Insulin pumps

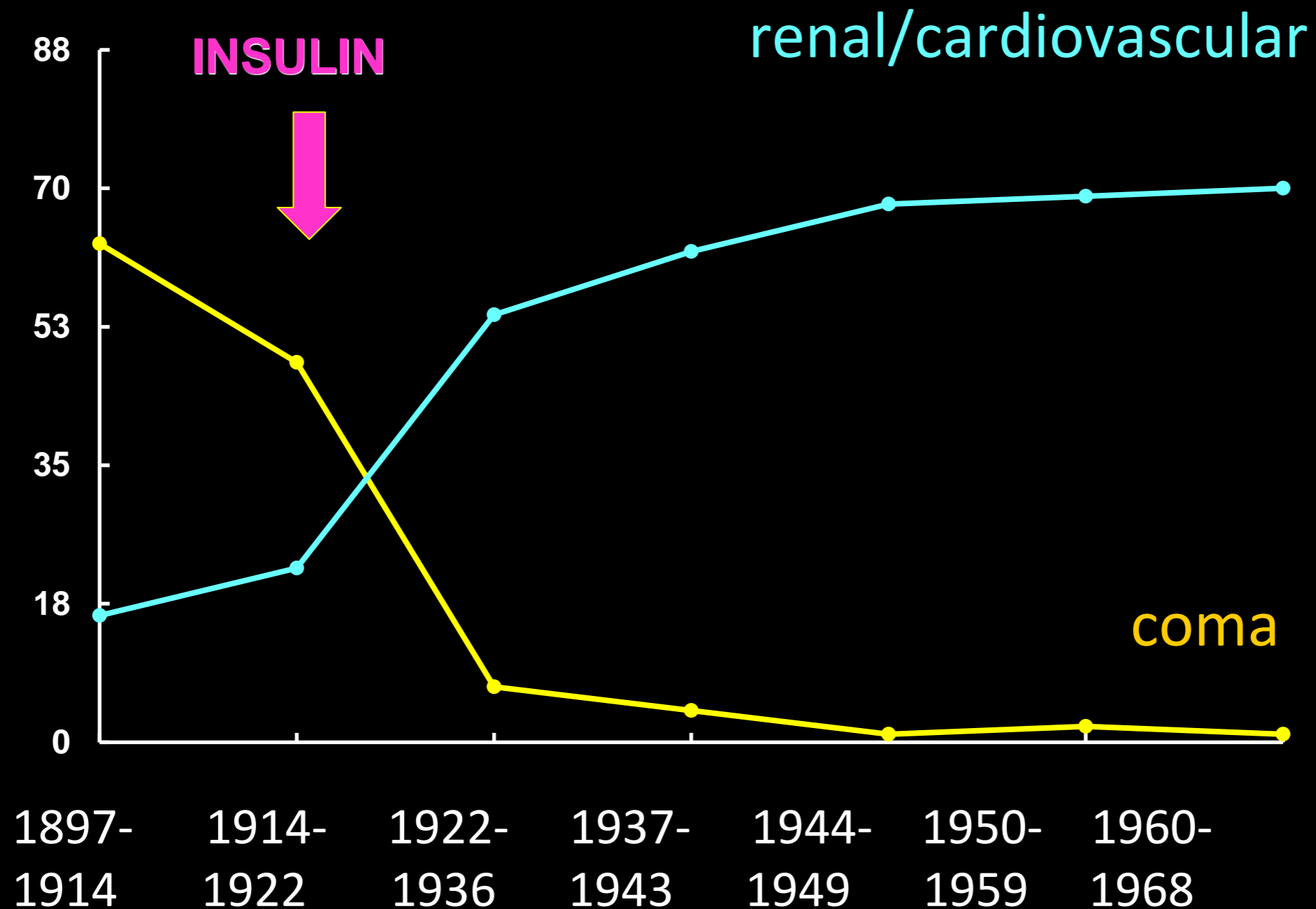- Hybrid closed loops

- The future

Toronto 1922

'Unspeakably wonderful!' Elizabeth Hughes 1907-1981
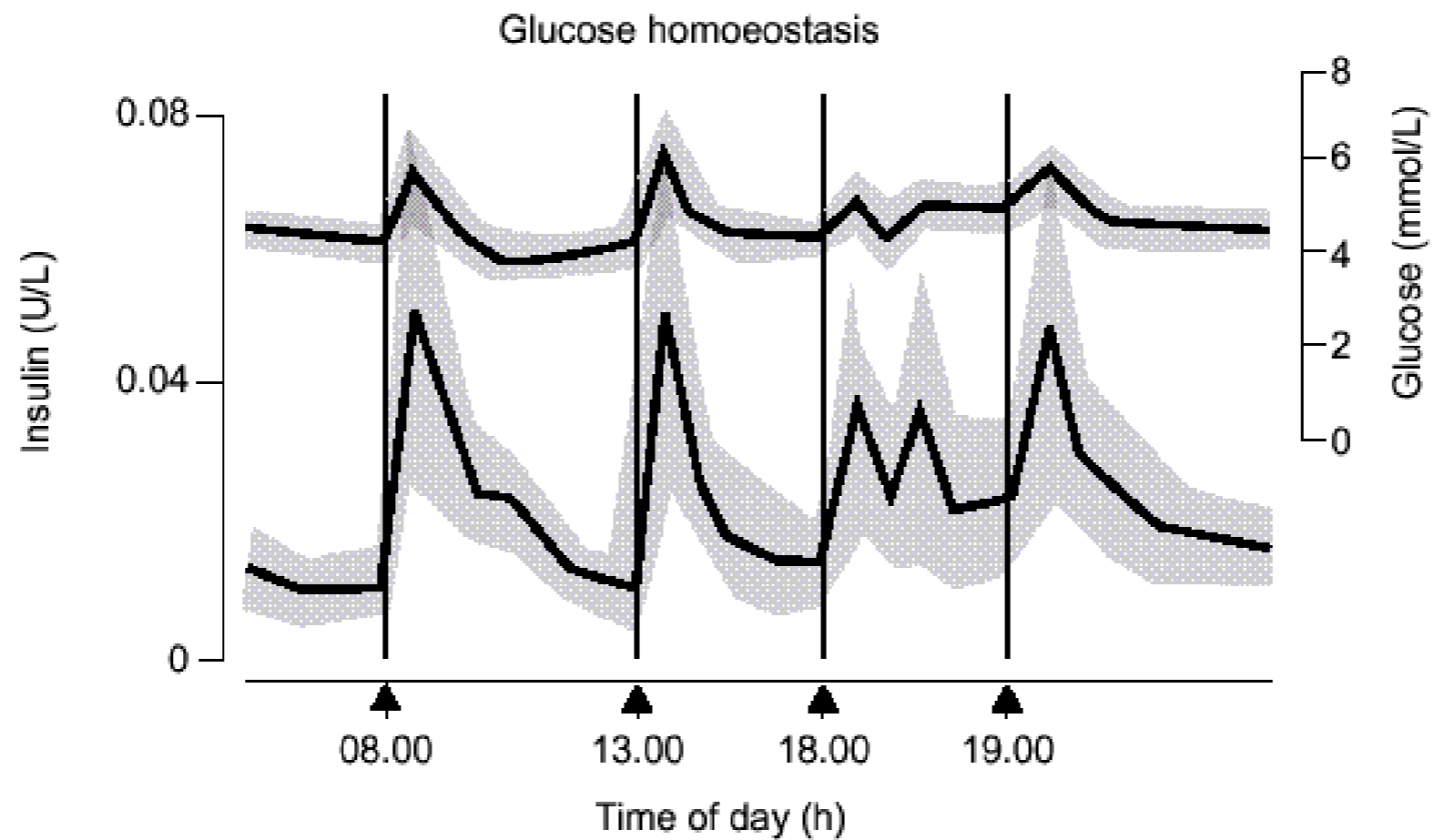
Cause of death in diabetes

Marble, Diabetes, 1977: 2 s2: 632

% total mortality

renal/cardiovascular

INSULIN

coma

| 88 | 70 | 53 | 35 | 18 | 0 |

| 1897-1914 | 1914-1922 | 1922-1936 | 1937-1943 | 1944-1949 | 1950-1959 | 1960-1968 |

24-hour plasma glucose and insulin profiles in healthy individuals

Glucose homoeostasis

Severe Hypoglycaemia: prevalence
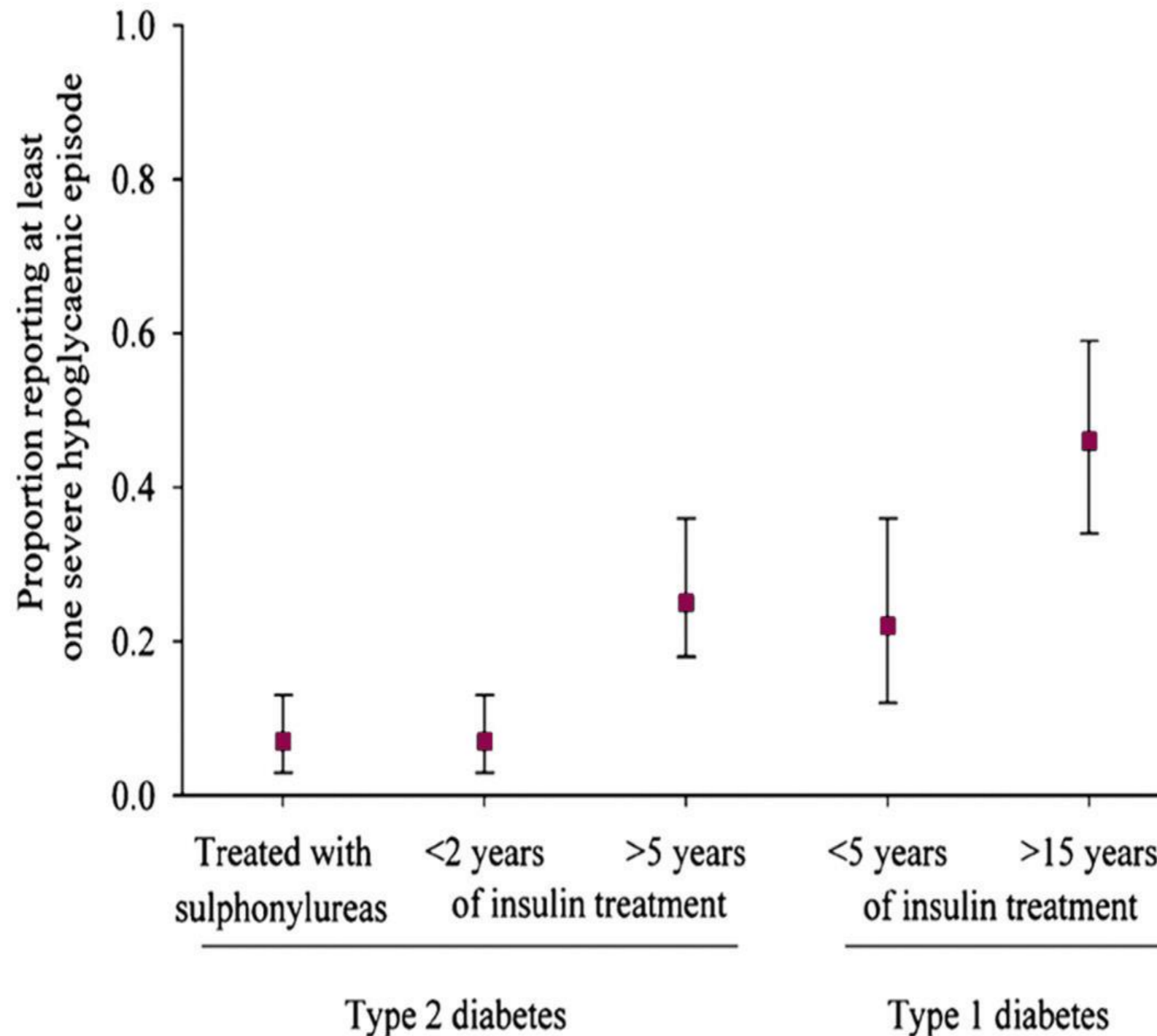
Hypoglycaemia
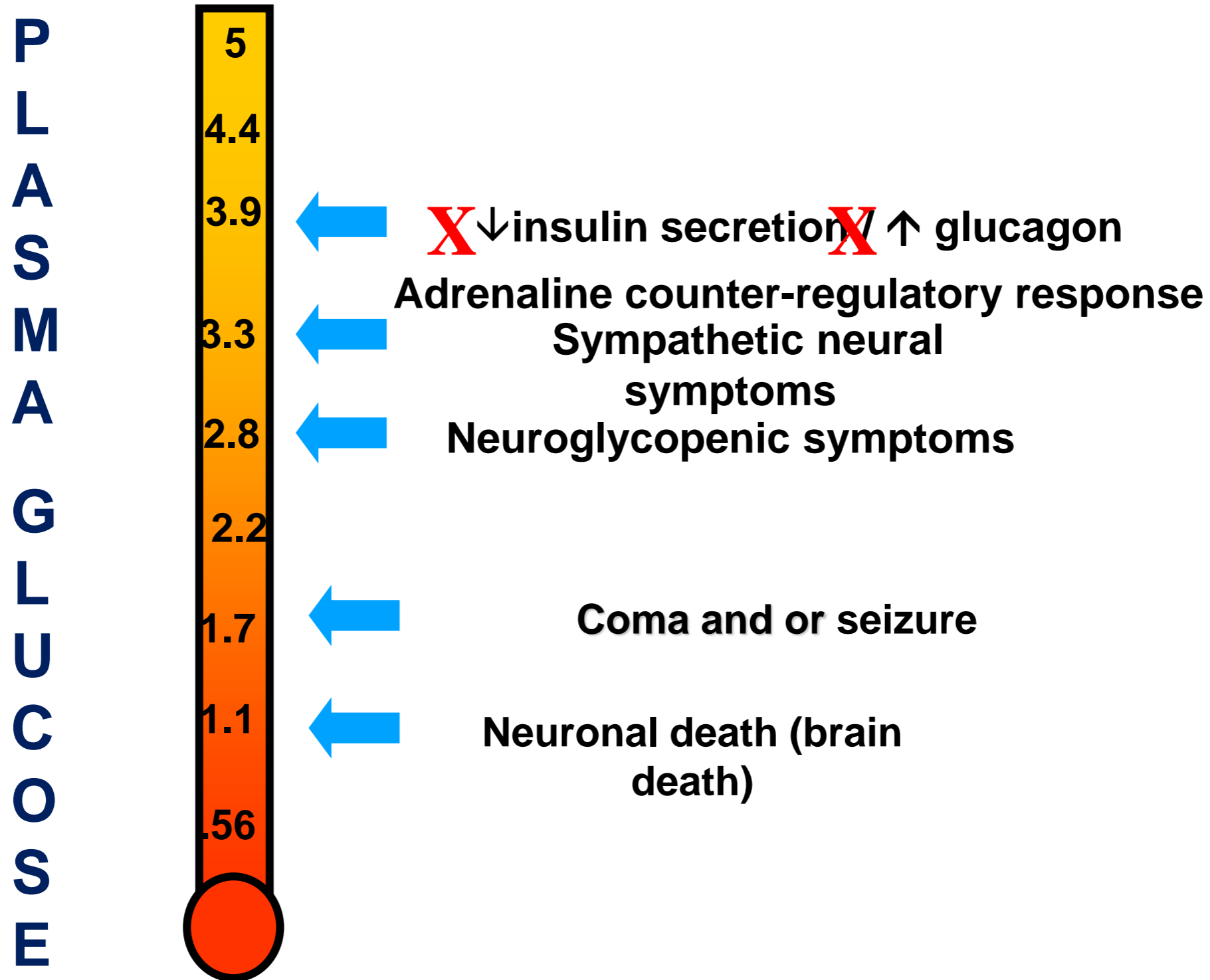
Defective glucose counter regulation

PLASMA GLUCOSE	
5	
4.4	
3.9	
3.3	← ↓ **Adrenaline counter-regulatory response**
2.8	← **Neuroglycopenic symptoms**
2.2	
1.7	← **Coma and or seizure**
1.1	← **Neuronal death (brain death)**
.56	
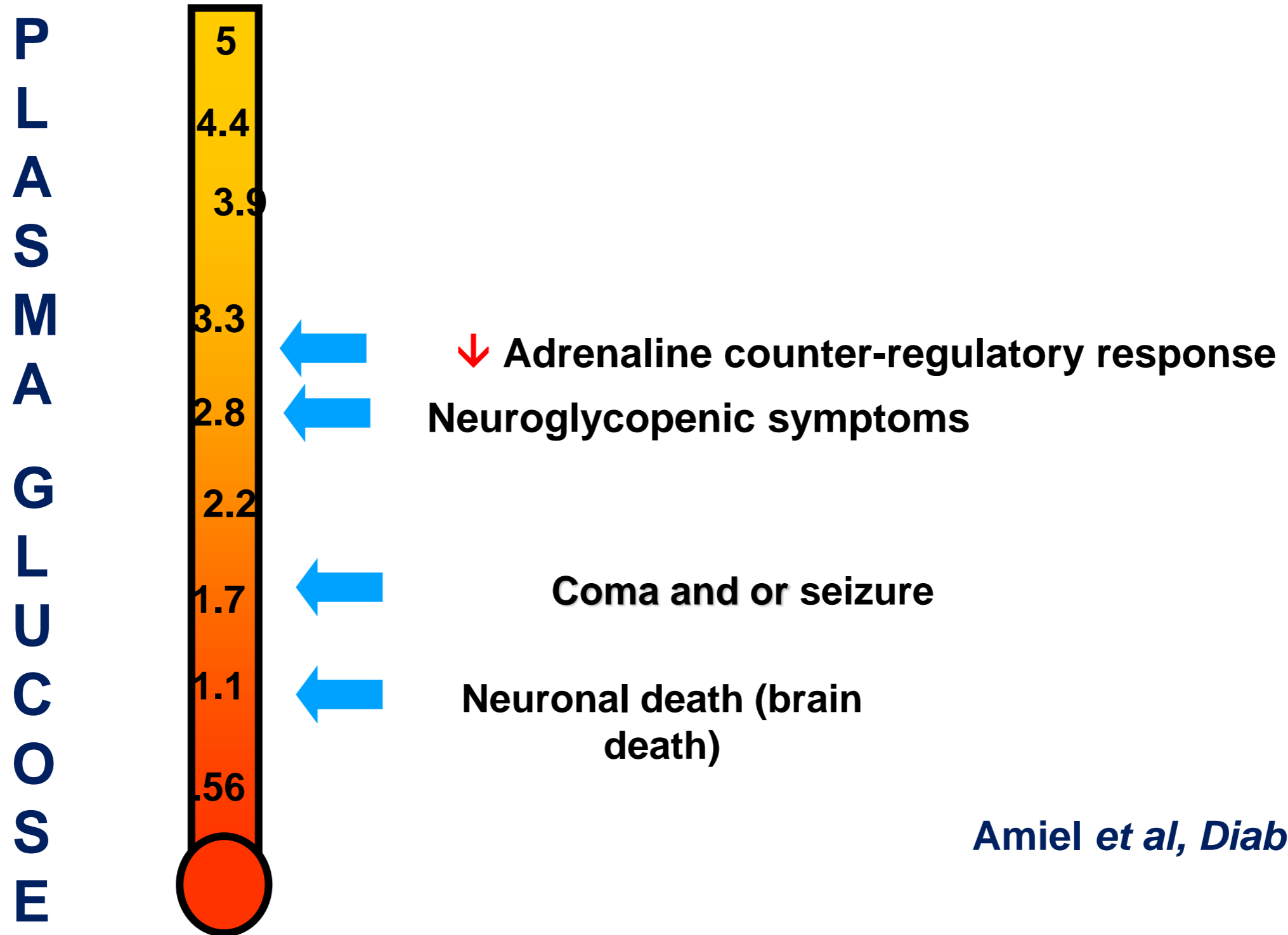
Amiel *et al, Diabetes* **1988**

Hypoglycaemia Associated Autonomic Failure

Backpack insulin and glucagon pump; Kadish, 1964.

The Biostator
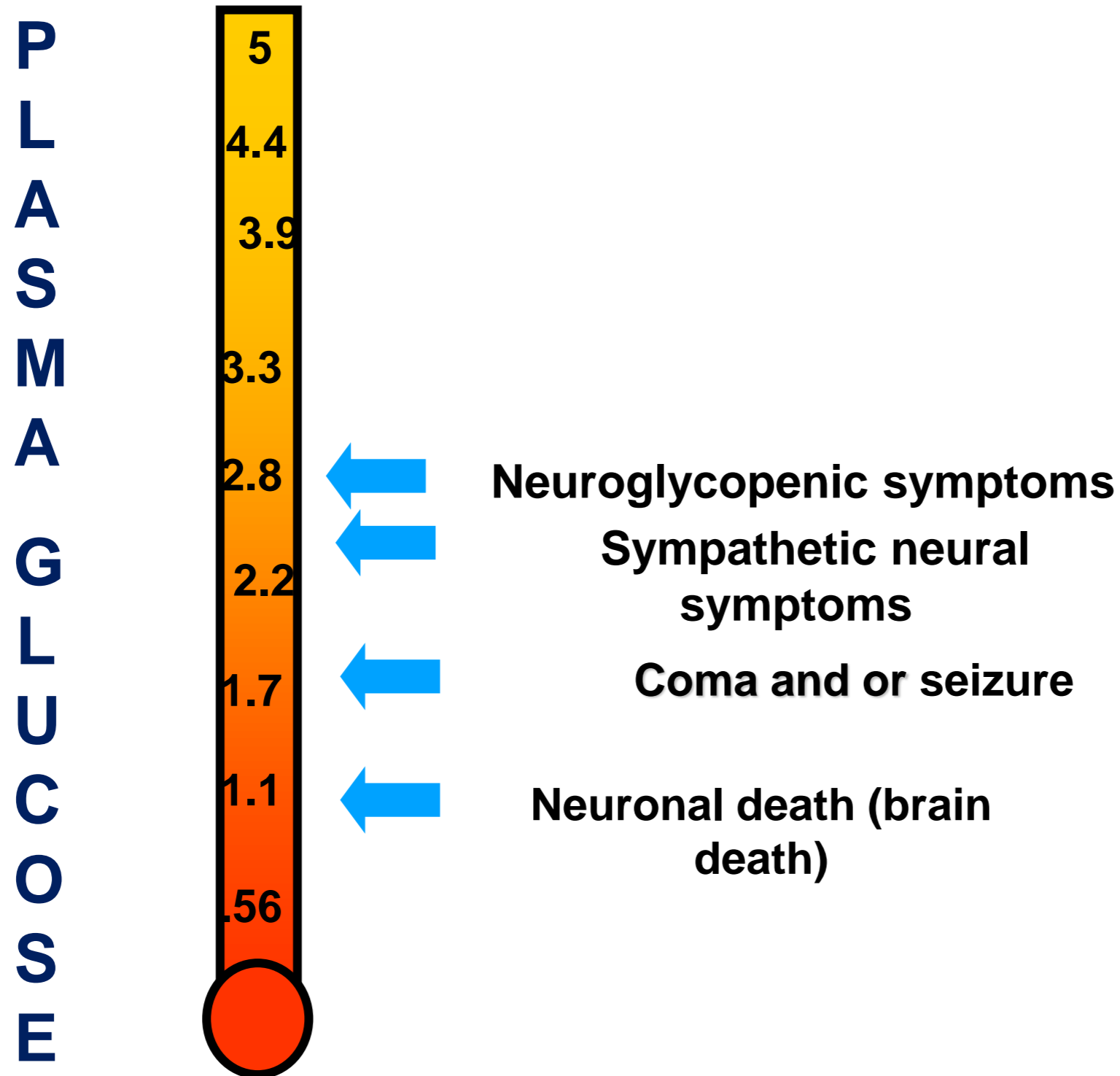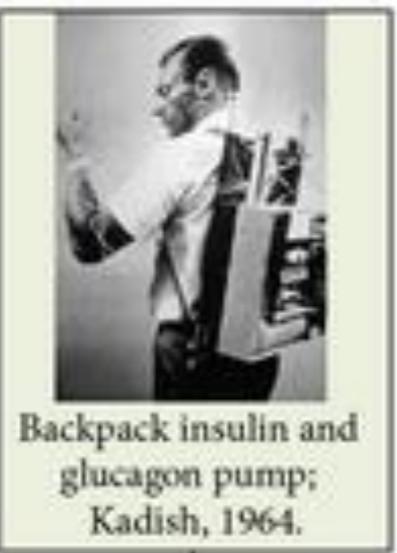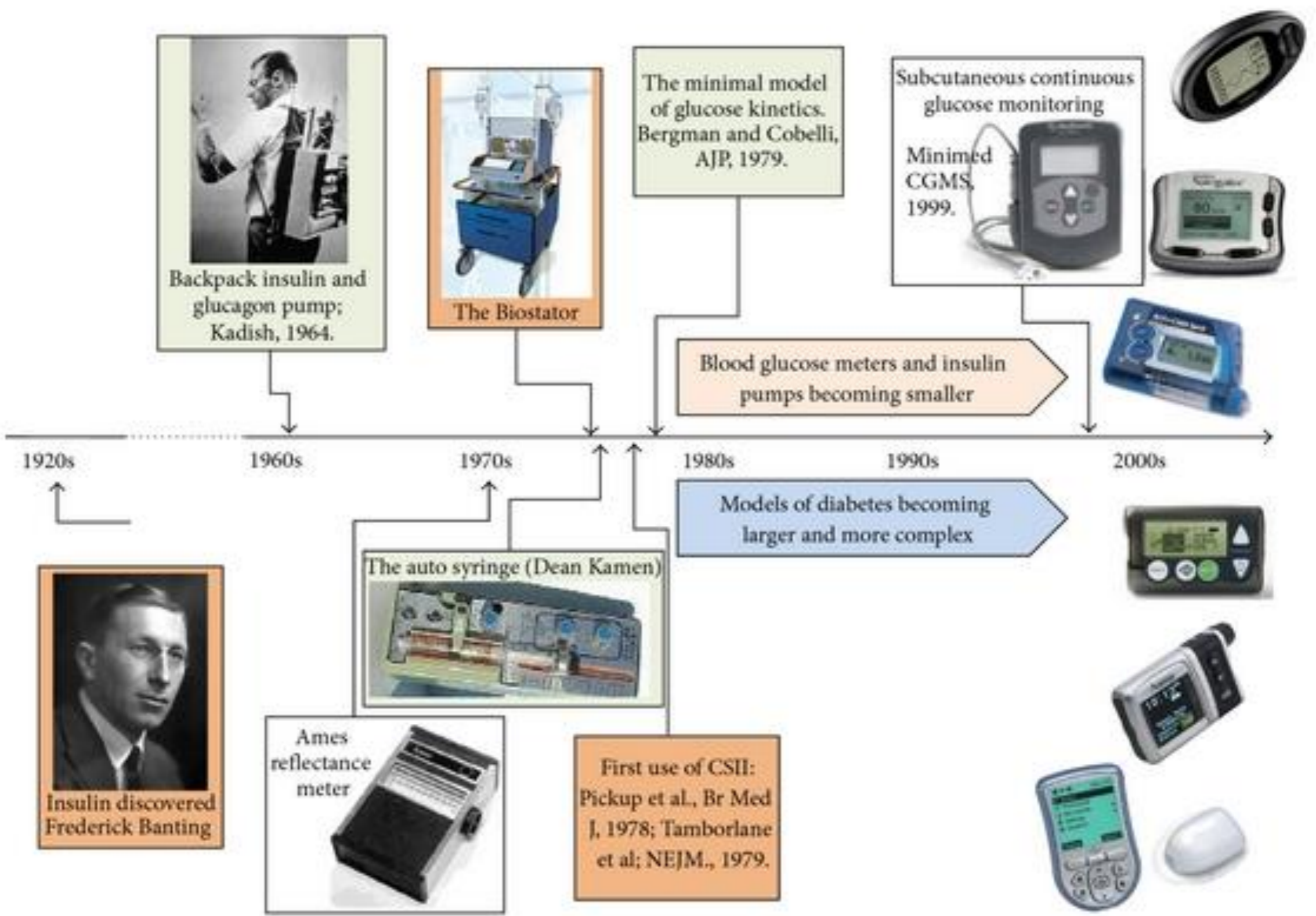
The minimal model of glucose kinetics. Bergman and Cobelli, AJP, 1979.

Subcutaneous continuous glucose monitoring

Minimed CGMS, 1999.

Blood glucose meters and insulin pumps becoming smaller

1920s   1960s   1970s   1980s   1990s   2000s

Models of diabetes becoming larger and more complex

The auto syringe (Dean Kamen)

Ames reflectance meter

Insulin discovered Frederick Banting

First use of CSII: Pickup et al., Br Med J, 1978; Tamborlane et al; NEJM., 1979.

1920s Insulin discovered

1980s 1st commercialized SubQ insulin pump

2006 Sensor augmented pump (SAP)

2013 / 2015 LGS / PLGS SAP

2014 1st major dual hormone HCL study

2019 Commercialized HCL (Control IQ)

2020 1st CE mark in dual hormone system (Inreda APS)

1960s 1st IV Insulin pump

1999 1st CGM

Late 2000s Labtop based closed-loop studies

2013 1st smartphone based HCL study

2016 Commercialized HCL (Minimed 670G)

2020 Commercialized HCL (CamAPS FX)

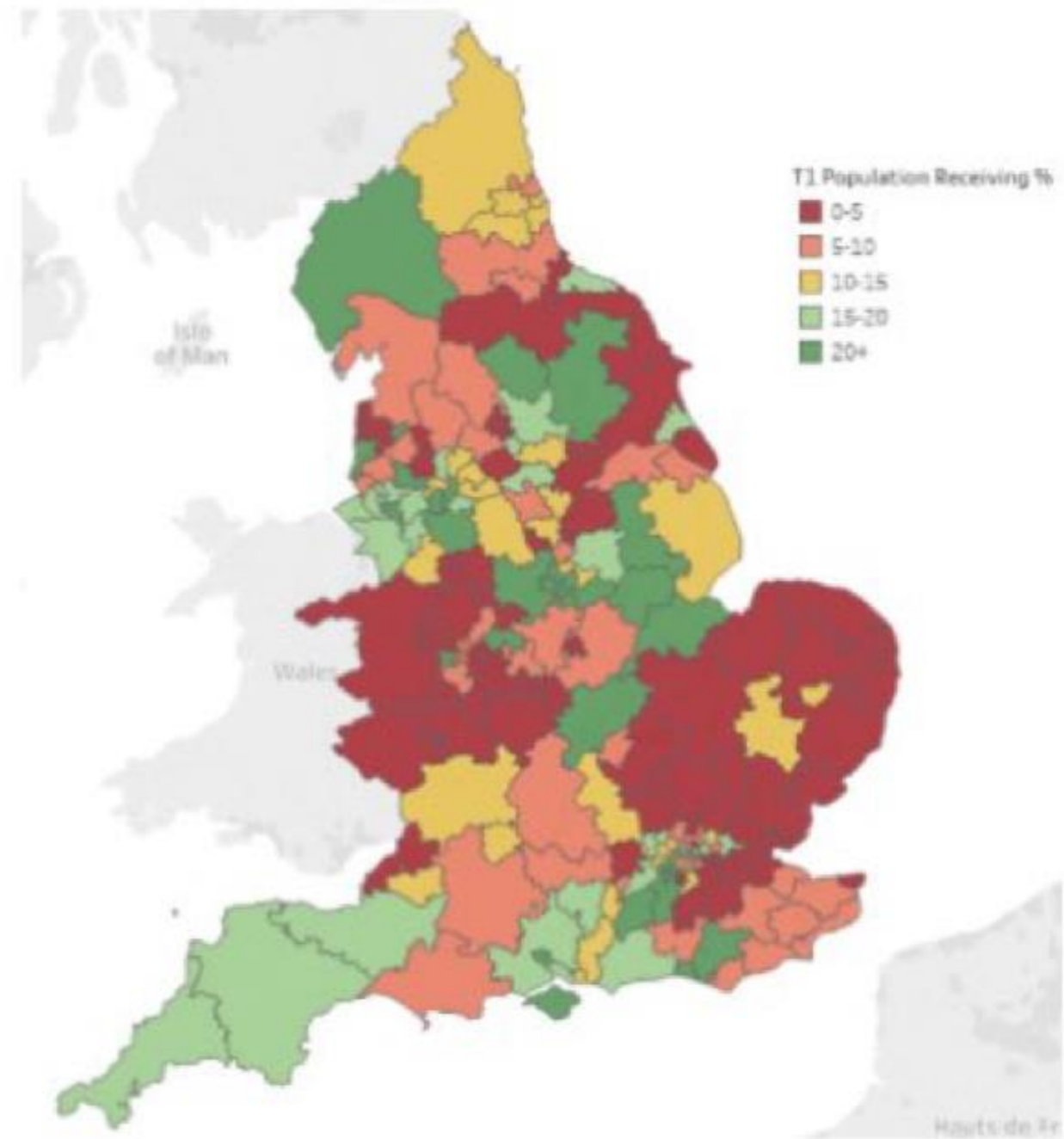**2020** Commercialized AHCL (Minimed 780G)

FreeStyle Libre T1 % Adoption 2019

Primary and Secondary Care Prescribing

April 10.7%

T1 Population Receiving %
- 0-5
- 5-10
- 10-15
- 15-20
- 20+

Freestyle Libre 2
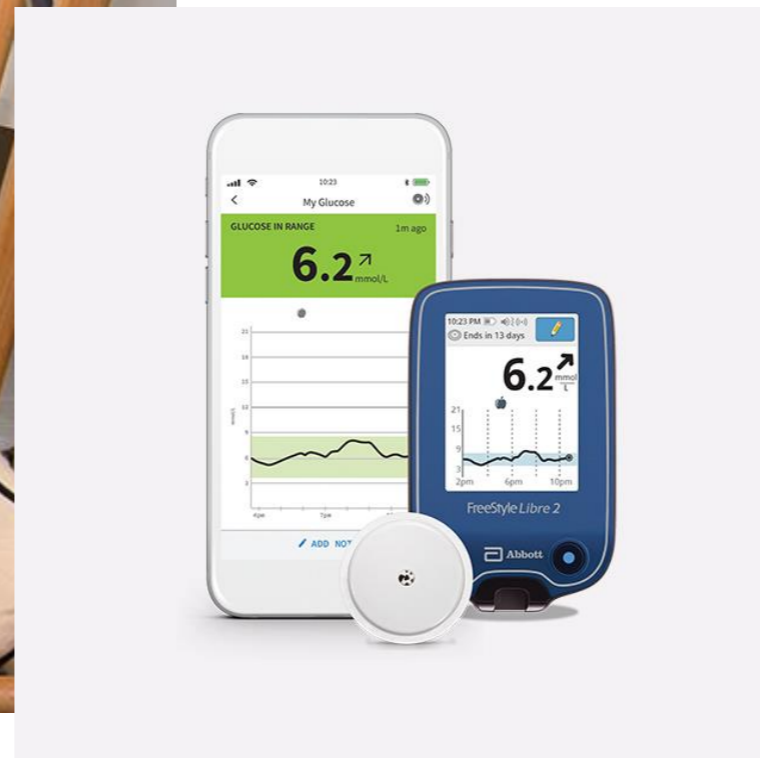
46 countries

>2 million users

What do the arrows mean?

	Rate of change	How long to change by 1 mmol/l	How much will it change in 30 mins
↑	> 0.11 mmol/l / min	Average 7 mins	At least 3 mmol/l
↗	Between 0.11 and 0.06 mmol/l / min	Average 15 mins	2-3 mmol/min
→	Less than 0.06 mmol/min	More than 20 mins	< 2 mmol/l
↘	Between 0.11 and 0.06 mmol/l / min	Average 15 mins	2-3 mmol/min
↓	> 0.11 mmol/l / min	Average 7 mins	At least 3 mmol/l

edinburghdiabetes.com

ABCD
Association of British Clinical Diabetologists

DTN UK
collaborate · evolve · support

Libre criteria

- Checking > 8 times p...y

- Cystic fibrosis di...

- Pregnancy: for a...

- If carers are required to...

- Occupational or psych...nth trial

- Severe hypogly...glycaemia

- Frequent admissio...betic ketoa...

- Previous self funders who would have met criteria and have shown improvement in HbA1c

NICE update 2022

- Offer adults with type 1 diabetes a choice of real-time continuous glucose monitoring (rtCGM) or intermittently scanned continuous glucose monitoring (isCGM, commonly referred to as 'flash'), based on their individual preferences, needs, characteristics, and the functionality of the devices available.

Glucose pattern insights

Monthly Summary

Daily Log

Snapshot

Mealtime patterns

Weekly summary

Daily patterns

Glucose Pattern Insights
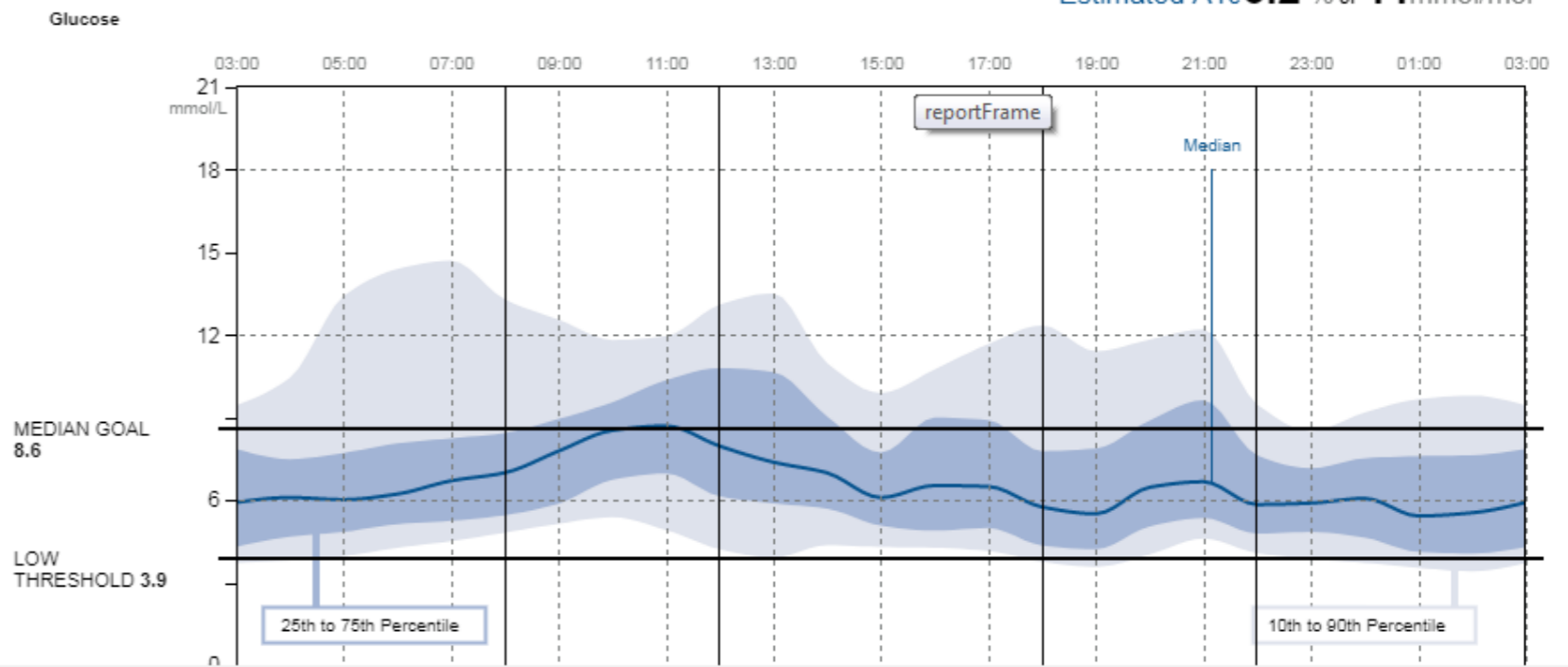**31 December 2019 - 13 January 2020** (14 Days)

LibreView

Estimated A1c **6.2** % or **44** mmol/mol

PAGE: 1 / 1

PRINTED: 13/01/2020

Diabetes Centre1

e: 01912823883

Glucose

MEDIAN GOAL
8.6

LOW
THRESHOLD 3.9

Median

reportFrame

25th to 75th Percentile

10th to 90th Percentile

13 January 2020 | FreeStyle LibreLink | Report Settings | 15 pages | Email | Print/Save PDF

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NHS Foundation Trust

Glucose pattern insights

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Glucose

Tue
Jan

Wed
8 Jan
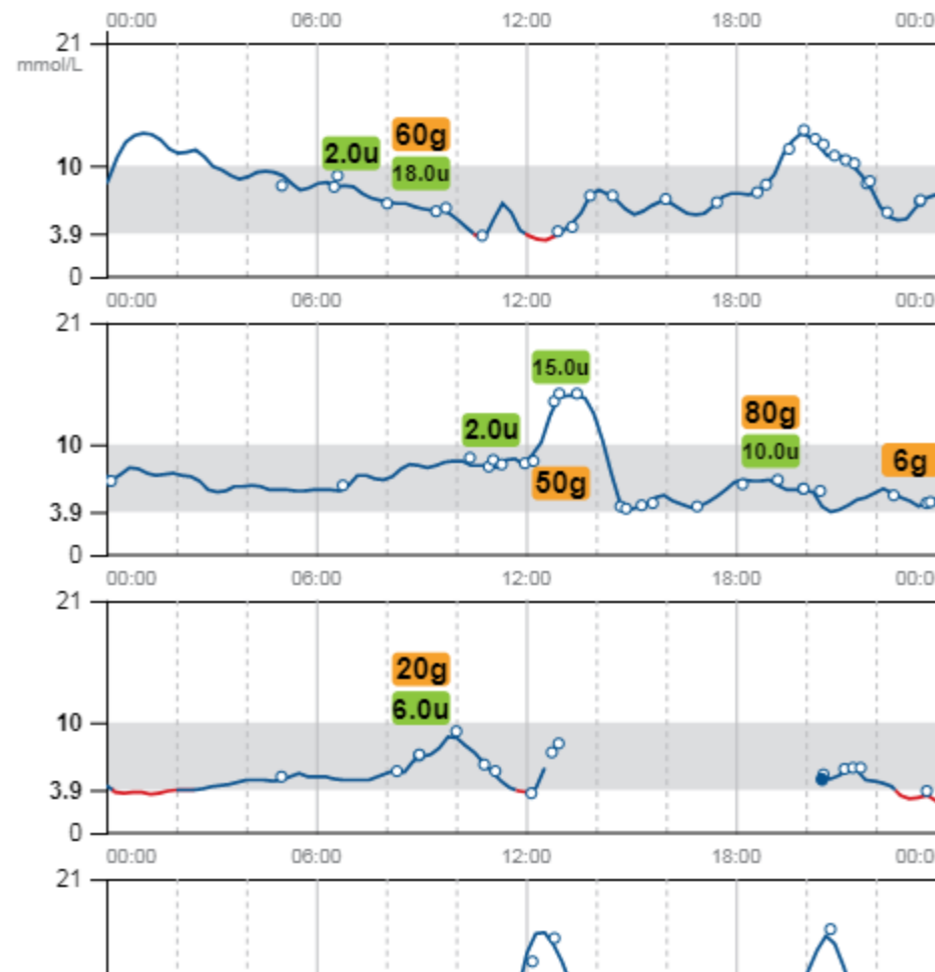
Thu
9 Jan

Fri

	00:00	06:00	12:00	18:00	00:00
21 mmol/L					
10		2.0u 60g 18.0u			
3.9					
0					

Average Glucose	Carbs	Rapid-Acting Insulin	Long-Acting Insulin
7.8 mmol/L	🍎 60 grams	🥕 20.0 units	
6.9 mmol/L	🍎 136 grams	🥕 27.0 units	
4.9 mmol/L	🍎 20 grams	🥕 6.0 units	
	🍎		

Wed 8 Jan graph: 15.0u, 2.0u, 50g, 80g, 10.0u, 6g

Thu 9 Jan graph: 20g, 6.0u

13 January 2020   FreeStyle LibreLink   Report Settings   15 pages   Email   Pr

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Libreview

Glucose pattern insights

Monthly Summary

Daily Log

7 of 7

Snapshot

Mealtime patterns

Weekly summary

Daily patterns

Newcastle Diabetes Centre1

Practice Phone: 01912823883

SUN 12 Jan

📱 Glucose mmol/L

5.7	7.5	**3.5**	**3.4**	5.4	4.1	**3.6**	**2.9**	**2.2**	**3.0**	**2.9**	**3.3**		3.9	7.1
	5.4	**3.8**		5.9				**2.7**		**3.3**	**3.5**		5.6	7.4
				6.3				**2.7**			**3.4**		5.1	
				5.6				**3.5**						
								3.5						

MON 13 Jan

📱 Glucose mmol/L

4.0		4.8	**2.6**	6.5	7.7	5.5		4.2	4.6	4.5	6.3	5.2	**3.7**	**3.4**	4.9
		4.8	**2.3**	6.8					4.7	4.7			**3.4**		
		3.7	**2.2**										**3.8**		

13 January 2020

FreeStyle LibreLink + 1

Report Settings

15 pages   Email   Print/Save PDF

21:19
13/01/202

The Newcastle upon Tyne Hospitals **NHS**
NHS Foundation Trust

AGP Report

- Glucose Pattern Insights
- Monthly Summary
- Daily Log
- Snapshot
- Mealtime Patterns
- Weekly Summary
- Device Details
- Daily patterns

% Time Sensor is Active   **37%**

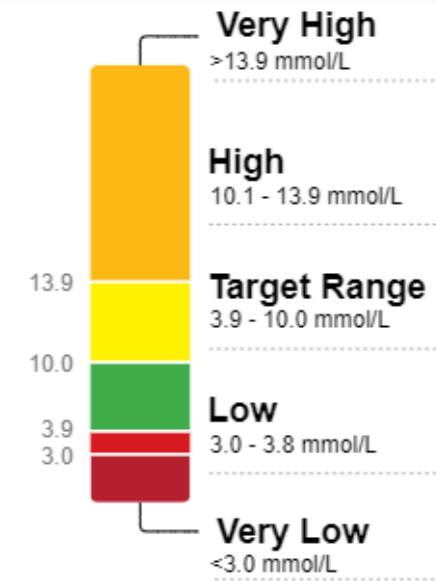| Ranges And Targets For	Type 1 or Type 2 Diabetes
Glucose Ranges Target Range 3.9-10.0 mmol/L	**Targets** % of Readings (Time/Day) Greater than 70% (16h 48min)
Below 3.9 mmol/L	Less than 4% (58min)
Below 3.0 mmol/L	Less than 1% (14min)
Above 10.0 mmol/L	Less than 25% (6h)
Above 13.9 mmol/L	Less than 5% (1h 12min)
Each 5% increase in time in range (3.9-10.0 mmol/L) is clinically beneficial.	

Average Glucose   **14.1** mmol/L

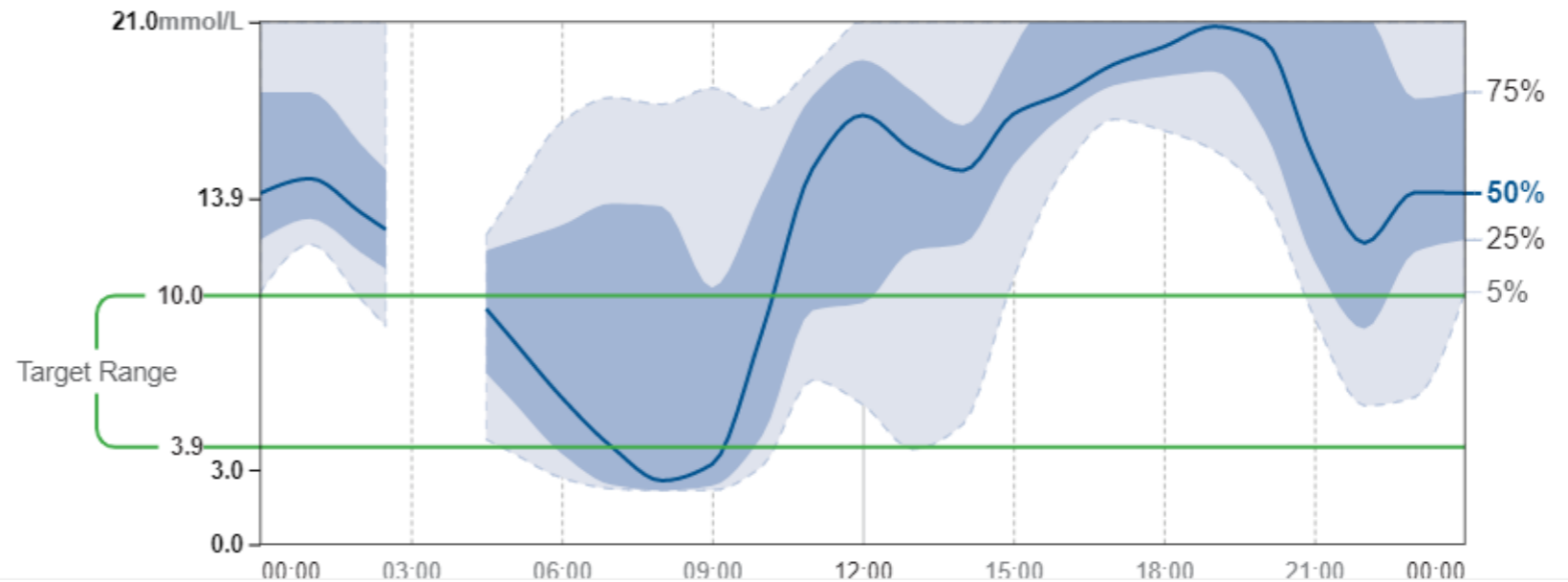**Glucose Management Indicator (GMI)**   **9.4% or 79 mmol/mol**

Glucose Variability   **49.9%**
Defined as percent coefficient of variation (%CV); target ≤36%

Very High
>13.9 mmol/L

High
10.1 - 13.9 mmol/L

13.9

Target Range
3.9 - 10.0 mmol/L

10.0

3.9
3.0

Low
3.0 - 3.8 mmol/L

Very Low
<3.0 mmol/L

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.

LibreView

Glucose pattern insights

Monthly Summary

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1 of 7

PAGE: 1 / 7

PRINTED: 13/01/2020

Newcastle Diabetes Centre 1

Practice Phone: 0191 2823883

TUE 31 Dec
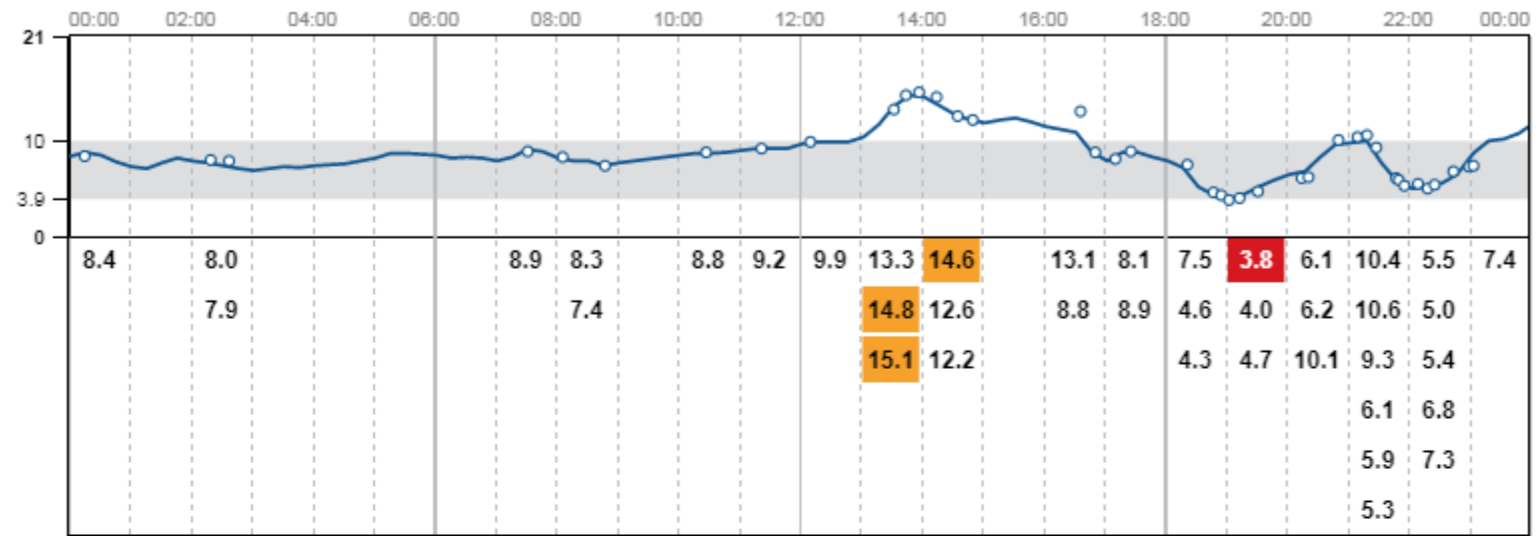
Glucose mmol/L

00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00

21
10
3.9
0

8.0				11.0	11.4	11.4	9.1	7.5	6.9	6.2	5.4	4.8	5.7	15.4	20.6	18.1	16.3	15.3	16.4
					8.6	7.4		5.4			4.4	5.6	17.3	19.8	18.0	16.4	14.0	17.2
					7.6			4.2		4.7	7.6	19.1	17.7	18.7	16.1	13.7	17.8
										12.8		20.2	16.1	13.7	18.9
												17.1	16.4	19.2
												16.2		17.7
														17.1
														16.7

WED 1 Jan

Glucose mmol/L

00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00

21
10
3.9
0

| 15.6 | 12.8 | | 9.9 | | | 14.1 | | 5.7 | 7.5 | 10.8 | 9.9 | 7.3 | 10.2 | 5.8 | 17.8 | 16.8 | 13.1 | 12.4 | 7.6 | 4.9 |
| 15.2 | | | 9.6 | | | | | 6.0 | 11.6 | 11.0 | 8.8 | 7.3 | 8.4 | 5.9 | 18.6 | 15.7 | 10.9 | 11.0 | 5.8 |

📅 13 January 2020   FreeStyle LibreLink + 1   📊 Report Settings   15 pages   Email   **Print/Save PDF**

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NHS Foundation Trust

LibreView

Glucose pattern insights

Monthly Summary

Daily Log

Snapshot

Mealtime patterns

Weekly summary

Daily patterns

Newcastle Diabetes Centre1
Practice Phone: 01912823883

FRI 10 Jan

📱 Glucose mmol/L

8.4	8.0		8.9	8.3	8.8	9.2	9.9	13.3	**14.6**
	7.9			7.4				**14.8**	12.6
								15.1	12.2

13.1	8.1	7.5	**3.8**	6.1	10.4	5.5	7.4
8.8	8.9	4.6	4.0	6.2	10.6	5.0
		4.3	4.7	10.1	9.3	5.4
				6.1	6.8
				5.9	7.3
				5.3

SAT 11 Jan

📱 Glucose mmol/L

	15.3		12.7	6.2	8.9	10.3	4.6	6.3	6.0
			12.4	5.1	10.1	9.4		6.3
			11.4	5.0				5.8
								5.3

6.2	6.1	8.7	8.9	8.6	7.9	9.3
7.1	7.2	8.0	8.8	9.8	8.1	9.3
6.6				9.3	9.3	9.7
					9.7

📅 13 January 2020   FreeStyle LibreLink + 1   📄 Report Settings   15 pages   Email   **Print/Save PDF**

How to measure glucose control: time in range

The Newcastle upon Tyne Hospitals NHS NHS Foundation Trust

HbA1c ⟶ TiR
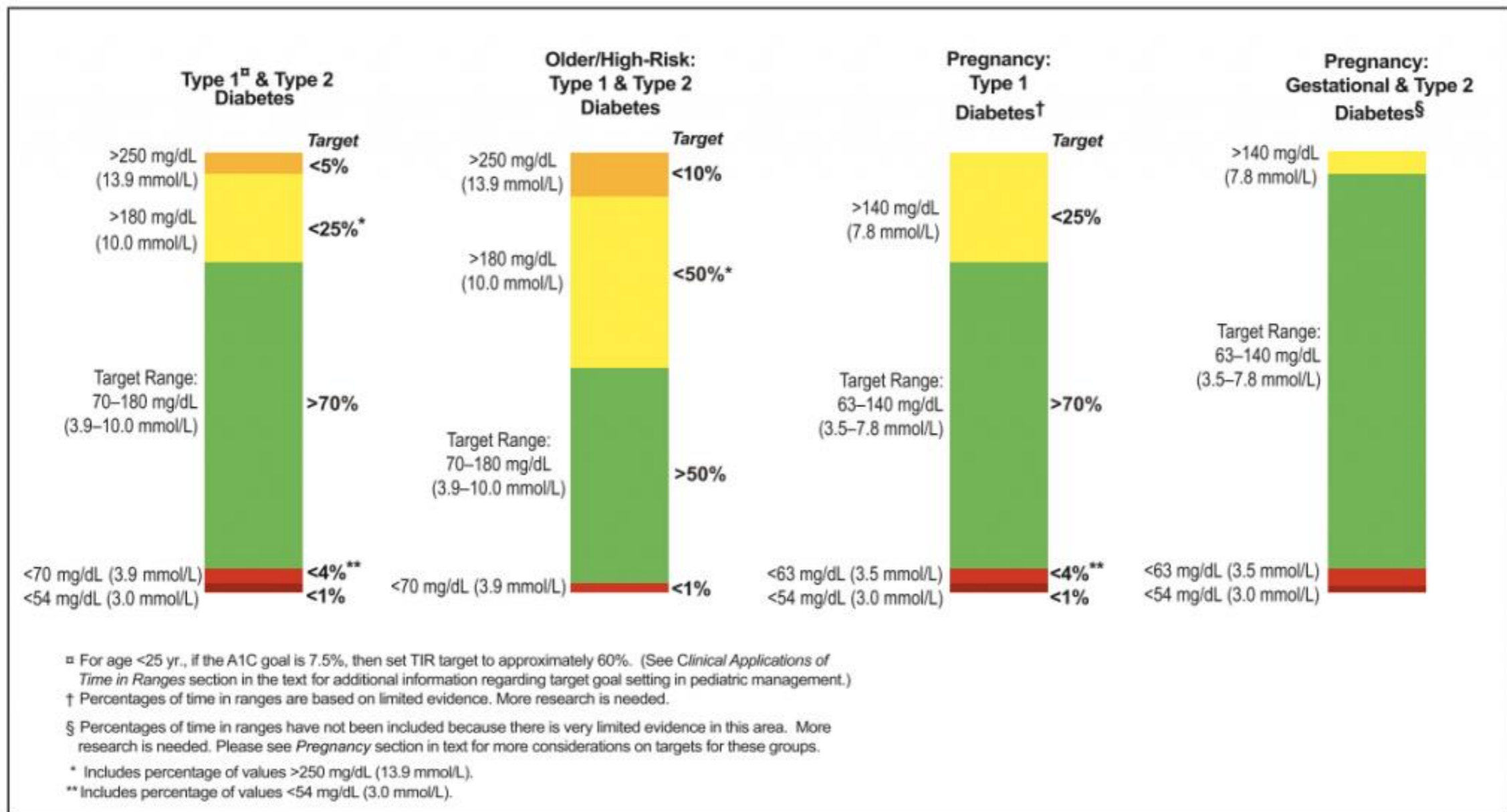
Validation of TiR
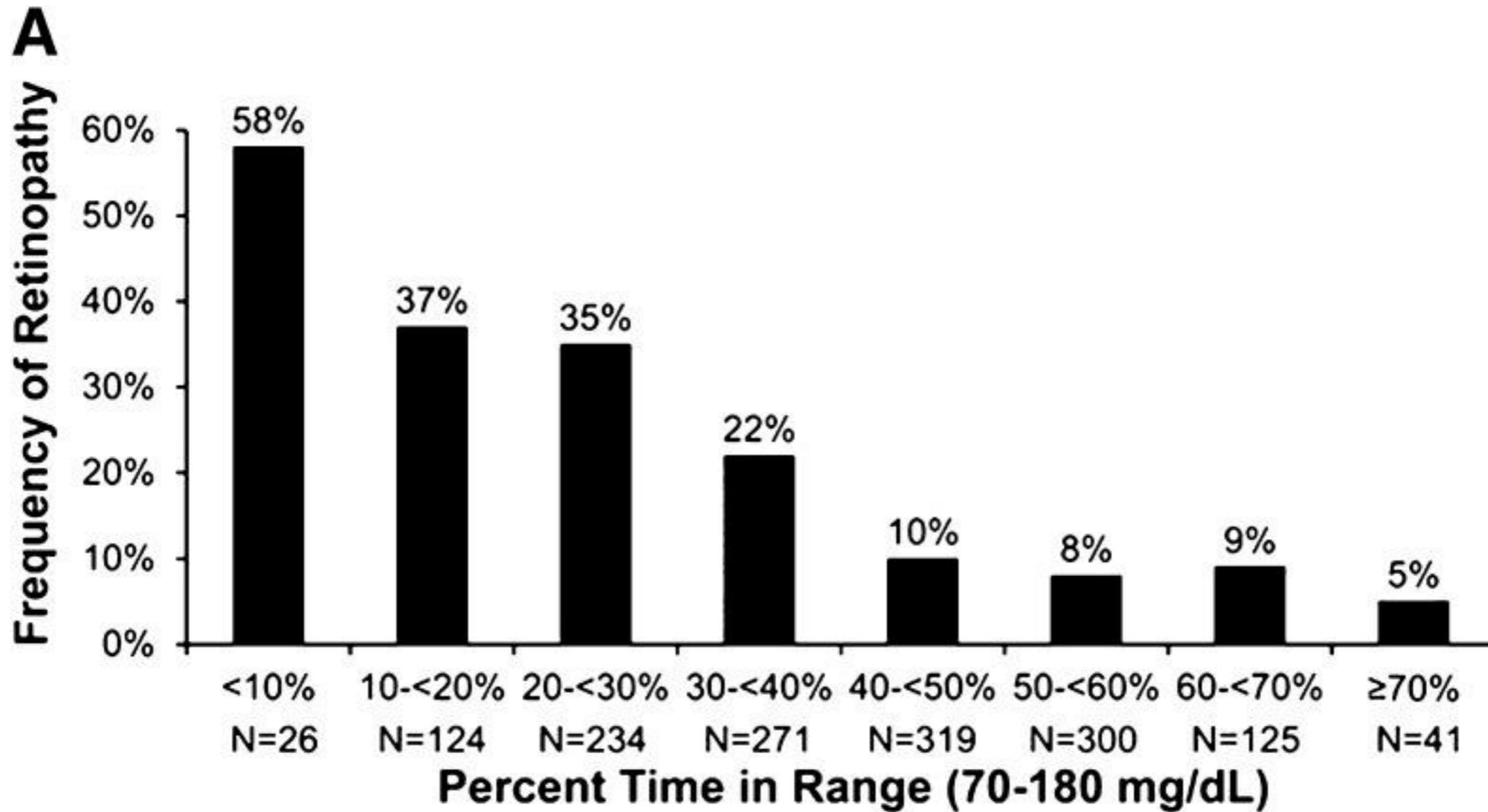
Insulin pumps

Insulin pumps

	Medtronic 780G	**Omnipod dash**	**T:slim X2**
weight	102g	26g	113g
Waterproofing	3.6m for 24 hours	7.6m for 60 mins	1.3m for 30 mins
Capacity	180 or 300 units	200 units	300 units
CGM integration	Guardian link and enlite sensors	x	Dexcom G6
Min basal	0.025 units	0.05 units (0.0 units)	0.1 units
Bolus settings	Min 0.025	0.05,0.1, 0.5 increments	0.05 units

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Daily Totals

	Breakfast	Lunch	Dinner		Daily Totals
Wednesday 25/05/2016			**31** 6.20	Average (0): − Carbs: 31g Insulin: 41.8U Bolus: 15%
Thursday 26/05/2016				Average (0): − Carbs: − Insulin: 35.6U Bolus: 0%
Friday 27/05/2016 ⱖ	⊔ ⊔ ⊔			Average (0): − Carbs: − Insulin: 33.0U Bolus: 0%
Saturday 28/05/2016				Average (0): − Carbs: − Insulin: 35.6U Bolus: 0%
Sunday 29/05/2016	**40** 8.00			Average (0): − Carbs: 40g Insulin: 43.6U Bolus: 18%
Monday 30/05/2016			**50** 10.0	Average (0): − Carbs: 50g Insulin: 45.6U Bolus: 22%
Tuesday 31/05/2016				Average (0): − Carbs: − Insulin: 35.6U Bolus: 0%
Wednesday 01/06/2016 ⱖ	⊔	⊔ ⊔ ⊔	**30** 6.00 **50** 10.0	Average (0): − Carbs: 80g Insulin: 47.5U Bolus: 34%
Thursday 02/06/2016				Average (0): − Carbs: − Insulin: 35.6U Bolus: 0%
Friday 03/06/2016				Average (0): − Carbs: − Insulin: 35.6U Bolus: 0%
Saturday 04/06/2016	**37** 7.40			Average (0): − Carbs: 37g Insulin: 43.0U Bolus: 17%
Sunday 05/06/2016	**40** 8.00		**30** 6.00	Average (0): − Carbs: 70g Insulin: 49.6U Bolus: 28%
Monday 06/06/2016 ⱖ		⊔ ⊔ ⊔ ⊔ ⊔ ⊔	**92** 8.80	Average (0): − Carbs: 92g Insulin: 36.3U Bolus: 24%
Tuesday 07/06/2016			**42** 8.40	Average (0): − Carbs: 42g Insulin: 44.0U Bolus: 19%

▯ > 7.8mmol/L	00ᵉ Multiple readings (most extreme shown)	⊔ Suspend	♥ Exercise	☽ Partial day	🕐 Time change
▮ < 3.9mmol/L	⬭ Manual bolus or bolus with correction	⊻ Suspend by Sensor	▣ Other	ⱖ Pump rewind	∿∿∿ Skipped meal

Continuous Glucose Monitoring criteria

- Disabling hyp_____ia despit_____ self-mangement supported b_____

- Dangerously erra_____ _____ding to decompensated hi_____iabetic ketoacidosis

- Inability for r_____to age or communica_____ton_____aemia (e.g. cognitive or n_____al disabili____

- Pregnancy

NICE update 2022

- Offer adults with type 1 diabetes a choice of real-time continuous glucose monitoring (rtCGM) or intermittently scanned continuous glucose monitoring (isCGM, commonly referred to as 'flash'), based on their individual preferences, needs, characteristics, and the functionality of the devices available.

Dexcom G6

- 10 days sensor

- No calibration

- Share with up to 10 followers

- Customisable alarms

Medtronic guardian connect

- Predictive low alerts

- 6 day sensor life

- Care partners can receive SMS alerts

Eversense XL 90 day implantable glucose sensor

5-minute Office Procedure of Sensor Insertion

1. 5 to 8 mm incision in upper arm under local anesthetic

2. Sensor inserted with custom inserter
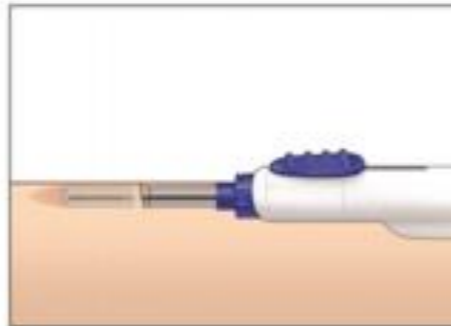
3. Steri-strips to close

Hybrid closed loops
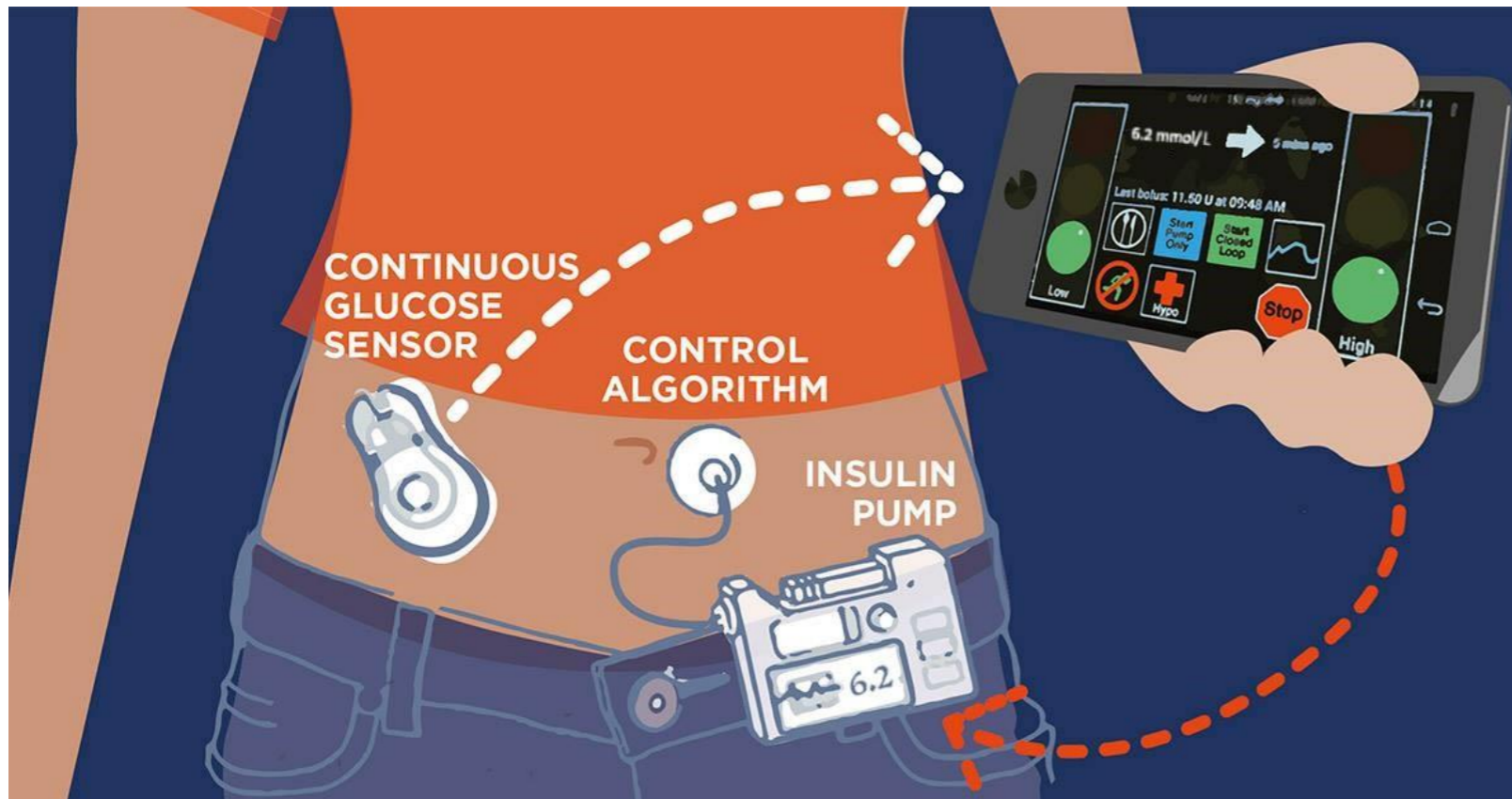
JDRF

Information & support   Our research   Get involved   News & media   About us   For profess

News • NHS pilot of hybrid closed loop systems successful in improving lives of people with type 1 diabetes

NHS pilot of hybrid closed loop systems successful in improving lives of people with type 1 diabetes

Posted on 01 April 2022

780G hybrid closed loop
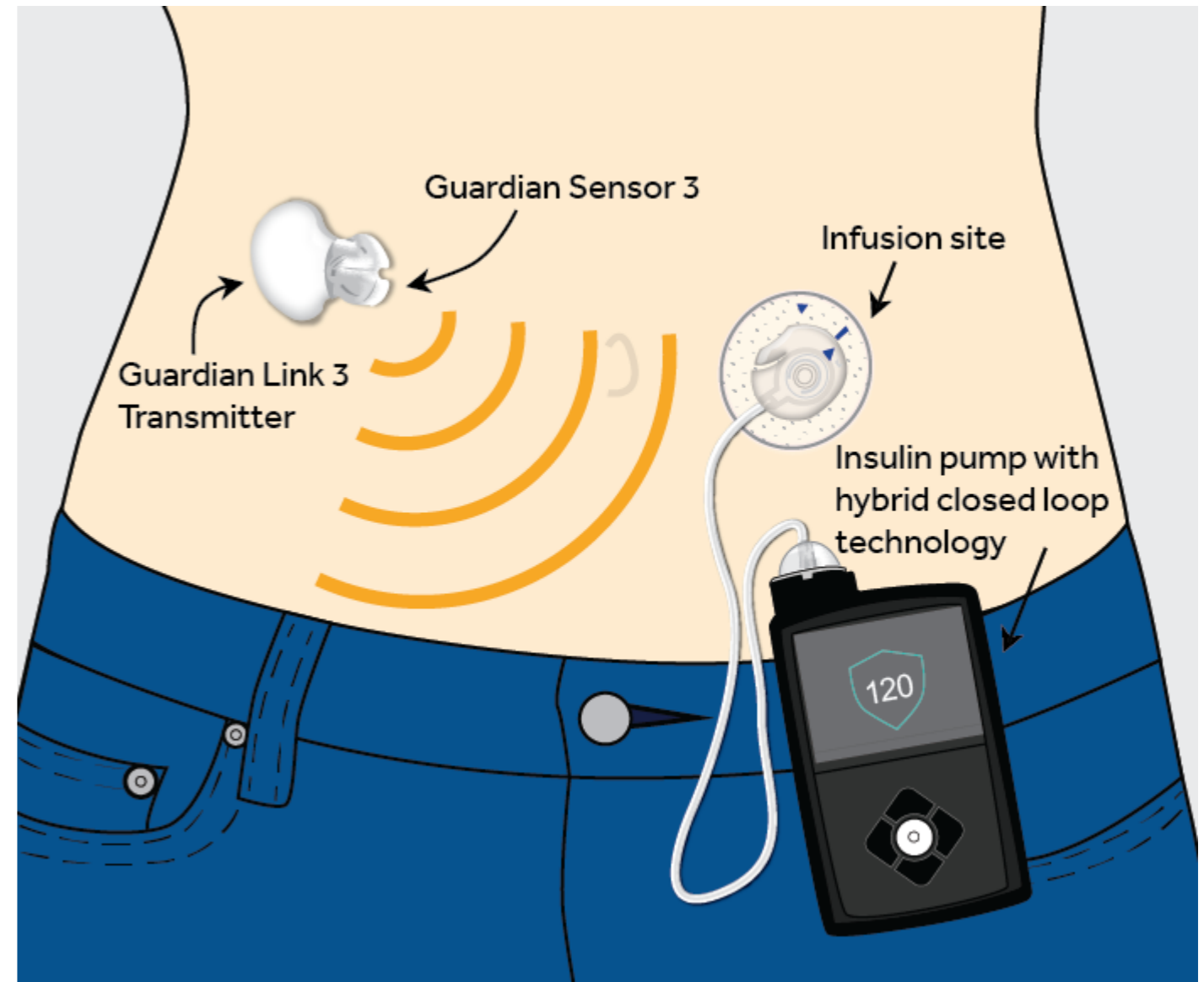
Guardian Sensor 3

Infusion site

Guardian Link 3 Transmitter

Insulin pump with hybrid closed loop technology

780G hybrid closed loop

Percentile comparison

Legend: 25-75% | 0-90% | ············ Average (A)

Carb Ratio (g/U) * (A): 8.0 | 8.0 | 8.0
(B)
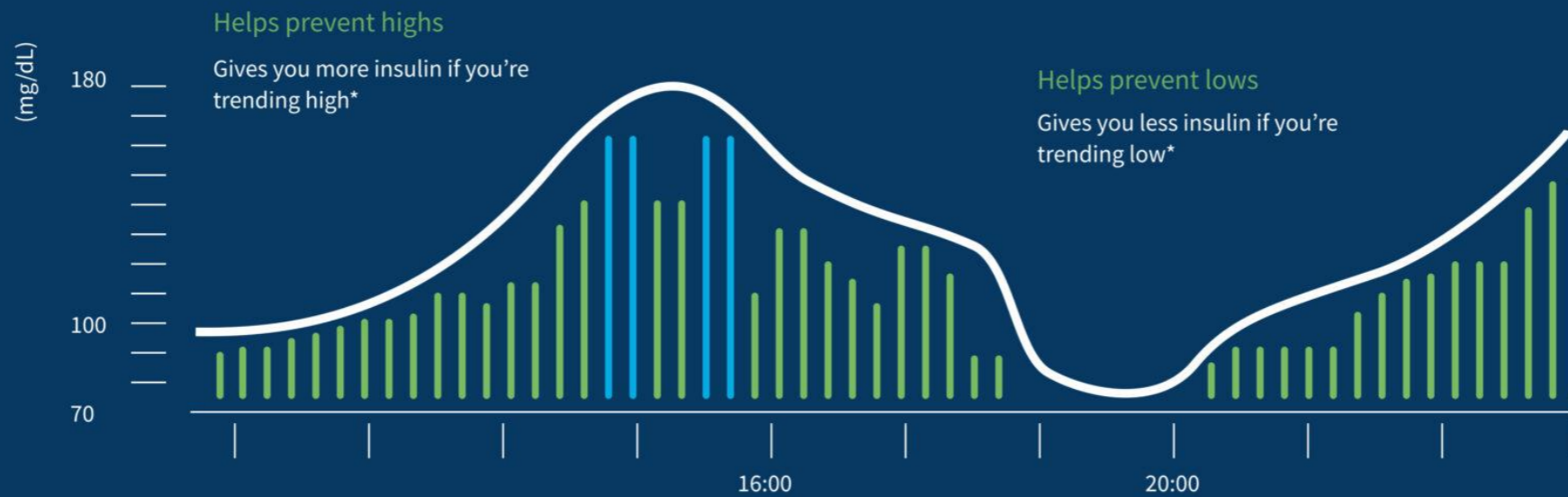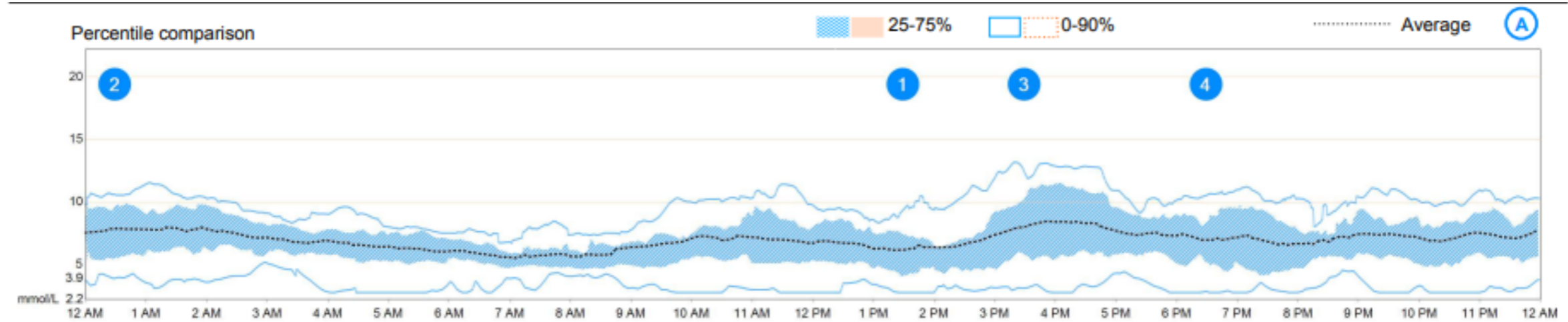
Hypoglycemic patterns (1)	# Episodes (per day):	1.1	Hyperglycemic patterns (4)**	# Episodes (per day):	1.6

(A)

1 1:00 PM - 1:59 PM (6 occurrences)

2 12:00 AM - 12:59 AM (5 occurrences) **3** 3:00 PM - 3:59 PM (5 occurrences) **4** 6:00 PM - 6:59 PM (4 occurrences)

Time in range

(A): 2% / 10% / 81% / 5% / 2%
(B): Unavailable

2.2 3   3.9   10   13.9 22.2 mmol/L

* Most recent pump settings are displayed
** Only highest priority shown.
*** Glucose Management Indicator
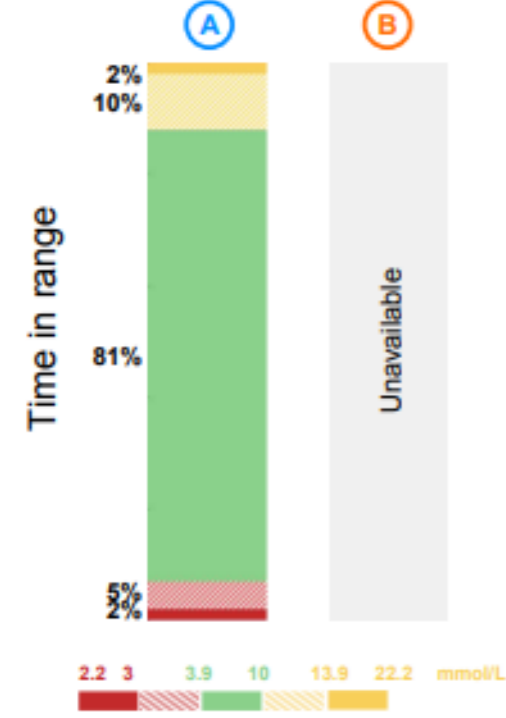
SmartGuard Exits	(A)	(B)
No Calibration	• 1	--
SmartGuard max delivery	0	--
SmartGuard min delivery	0	--
BG required for SmartGuard	0	--
Sensor Algorithm Underread	0	--
Sensor Updating	0	--
No SG values	0	--
Sensor Expired	•••• 4	--
SmartGuard disabled by user	0	--
Prolonged Suspend	0	--
SmartGuard Warm Up	0	--
Unidentified	0	--

Statistics	(A)	(B)
SmartGuard (per week)	94% (6d 14h)	--
Manual Mode (per week)	6% (10h)	--
Sensor Wear (per week)	89% (6d 05h)	--
Average SG ± SD	7 ± 2.5 mmol/L	--
GMI***	6.3% (45.6 mmol/mol)	--
Coefficient of Variation (%)	35.9%	--
Low / High SG Alerts (per day)	2.6 / 3.1	--
Average BG	7.6 ± 3.1 mmol/L	--
BG / Calibration (per day)	2.5 / 2.1	--
Total daily dose (per day)	86.8 units	--
Bolus amount (per day)	57.4U (66%)	--
Auto Correction amount (per day)	4.8U (8%)	--
Auto Basal / Basal amount (per day)	29.4U (34%)	--
Set Change	Never	--
Reservoir Change	Every 2.5 days	--
Meal (per day)	6.5	--
Carbs entered (per day)	442 ± 121 g	--
Active Insulin time	3:00 hrs	--

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

Saturday 22/01 · **Sunday 23/01** · **Monday 24/01** · **Tuesday 25/01**

| Bolus (U) | 4.3(2) | 9.5 | 15.3(2) 7.7 | 10.6 | 10.0 7.8 | 5.7 21.7(2) | 5.3 5.6 | 28.3(4) | 12.5 | 5.1 | 9.1 | 36.6(4) 10.2(2) 20.1(3) |
| Carbs (g) | 48(2) | 76 | 133(2) 62 | 85 | 80 63 | 46 174(2) | 47 48 | 232(4) | 100 | 41 | 73 | 300(4) 82(2) 166(3) |

Wednesday 26/01 · **Thursday 27/01** · **Friday 28/01**

| Bolus (U) | 9.6 | 19.9(2) 21.1(2) | 10.4 9.6 | 4.0 9.9(2) 11.6 | 15.5(2) 34.1(3) | 11.2 | 8.2 9.6 | 2.9 | 25.8(2) |
| Carbs (g) | 77 | 162(2) 169(2) | 85 77 | 38 80(2) 93 | 135(2) 274(3) | 91 | 66 77 | | 207(2) |

Exit Reason Details

1 - Sensor Expired
New sensor needed to be inserted.

Legend:
- Blood Glucose
- Calibration
- Auto-Basal
- Basal
- Suspend on Low
- Suspend before Low
- Auto Correction + Active Insulin
- Bolus + Active Insulin
- Manual Mode
- Manual Suspend
- Target + temp target
- Time change

Tandem Control IQ

(all adjustments based on 30 min predicted BG)		Control-IQ	Sleep Activity	Exercise Activity
💧 Delivers	Delivers an automatic correction bolus if sensor glucose is predicted to be above 10.0 mmol/L	10.0	--	10.0
B Increases	Increases basal insulin delivery if sensor glucose is predicted to be above 8.9 mmol/L	8.9	6.7	8.9
B Maintains	Maintains active Personal Profile settings when sensor glucose is between 6.25 - 8.9 mmol/L	6.25 - 8.9	6.25 - 6.7	7.8 - 8.9
B Decreases	Decreases basal insulin delivery if sensor glucose is predicted to be below 6.25 mmol/L	6.25	6.25	7.8
0 Stops	Stops basal insulin delivery if sensor glucose is predicted to be below 3.9 mmol/L	3.9	3.9	4.4

mmol/L

Omnipod 5 - 2023
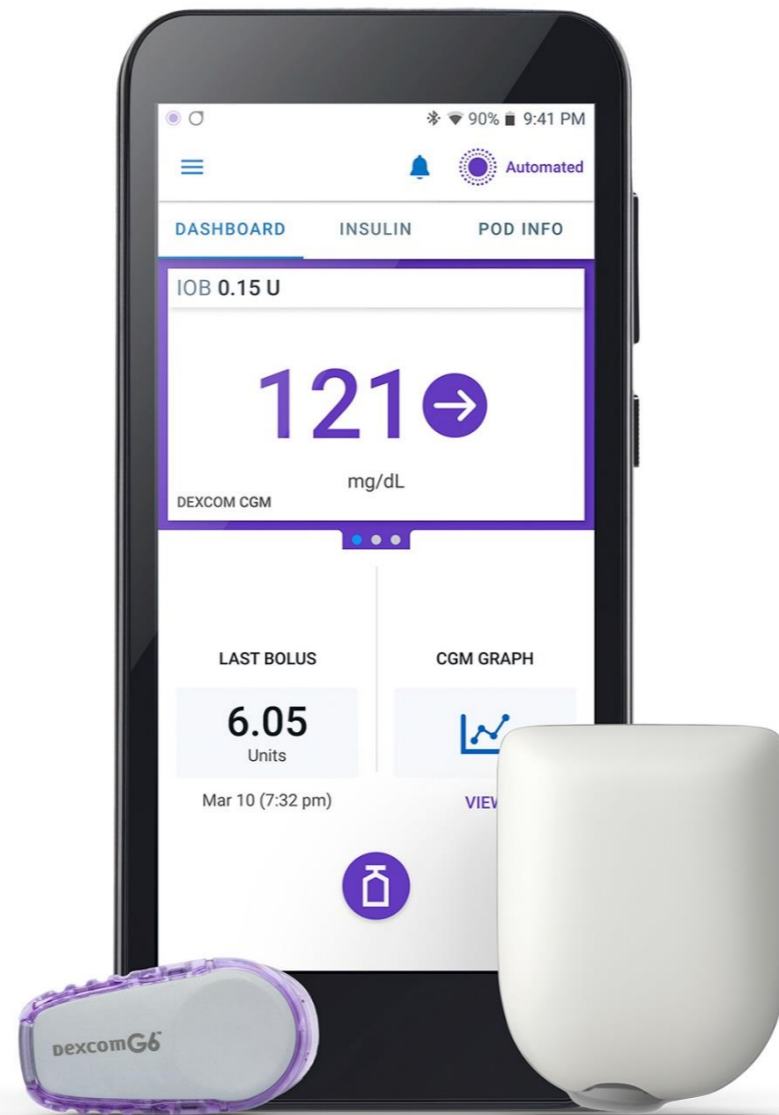
Pod and Dexcom G6® shown without the necessary adhesive.

Dual hormone pump

2. **Control System**

3. **Insulin and glucagon administration**

Insulin **Glucagon**

1. **Glucose Measurement**

Subcutaneous delivery
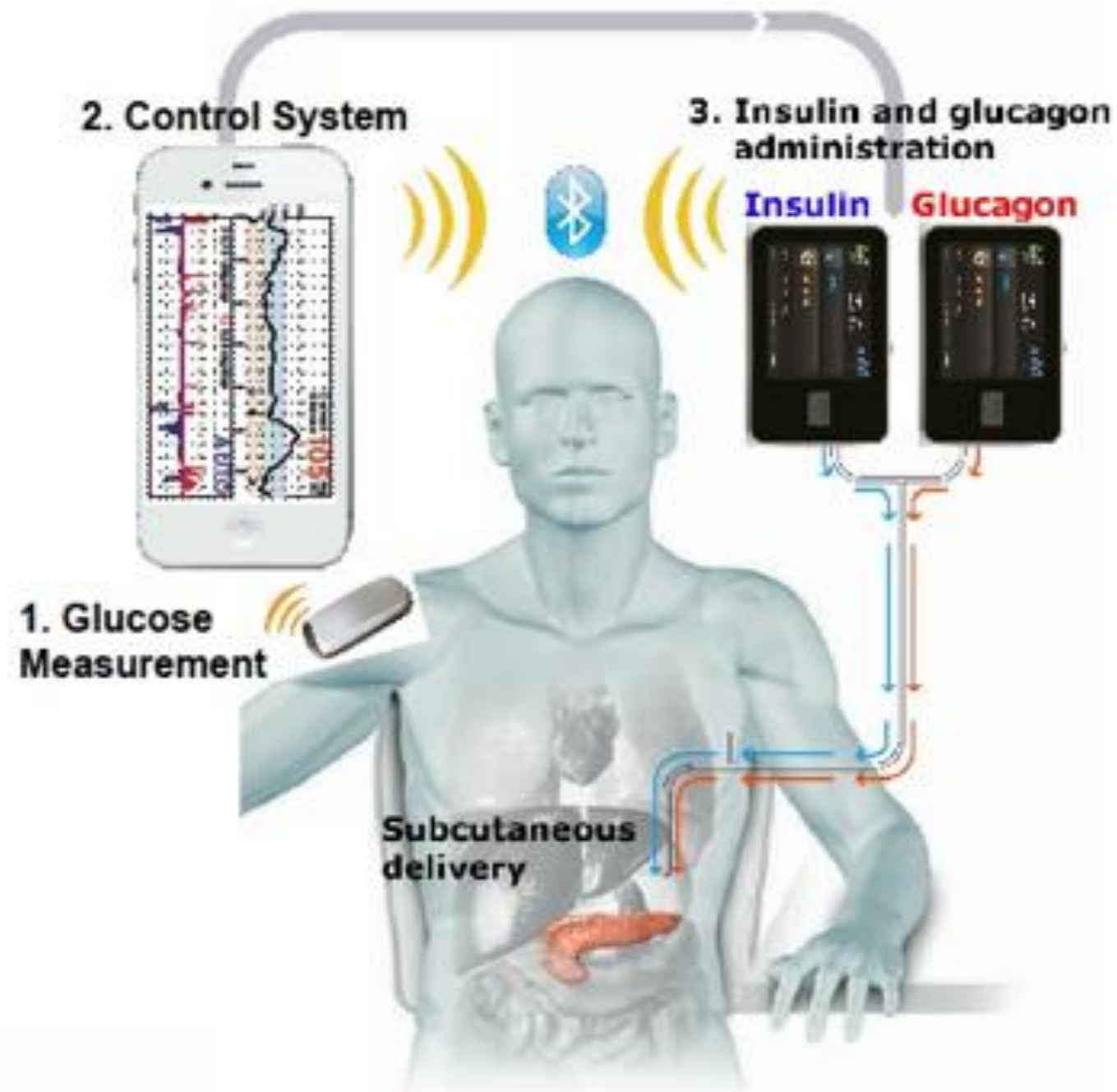
Medtronic inpen

Paired with the Inpen app which is also linked with guardian sensor

Dose advice
Dose calculator
Dose reminder
Carb counting support

DIY artificial pancreas

LibreView ✕ | OpenAPS.org – #WeAreNotWaiti ✕ | +

🔒 https://openaps.org

OPENAPS.ORG
#WeAreNotWaiting to reduce the burden of Type 1 diabetes

What Is #OpenAPS?   Frequently Asked Questions   OpenAPS Reference Design   OpenAPS Outcomes

In The News   Research

OpenAPS Is Designed For Safety

OpenAPS means basic closed loop APS technology is more widely available to anyone with compatible medical devices who is willing to build their own system.

How Do I Get Started?

The documentation and reference design implementation code is available on Github. Take a look below for FAQs, reference design, and links to open source repository and documentation.

Does It Really Work For Everyone?

OpenAPS follows the same basic diabetes math that a person would do to calculate a needed adjustment to their BG – but it is automated and precise.

Immediate future

- Mobile phone bolusing: Tandem Mobi

- Smaller insulin pumps

- Smaller continuous glucose monitors dexcom G7

- Patch continuous glucose monitors

Summary

- There has been huge incremental progress in diabetes self-management technologies

- Type 1 diabetes still requires injected insulin Fastidious ongoing self-management without respite

- Innovation needs to combine education with technology even for closed loop

- Evidence needed for all potential user groups assess breadth of biomedical / psychosocial outcomes

Dex om
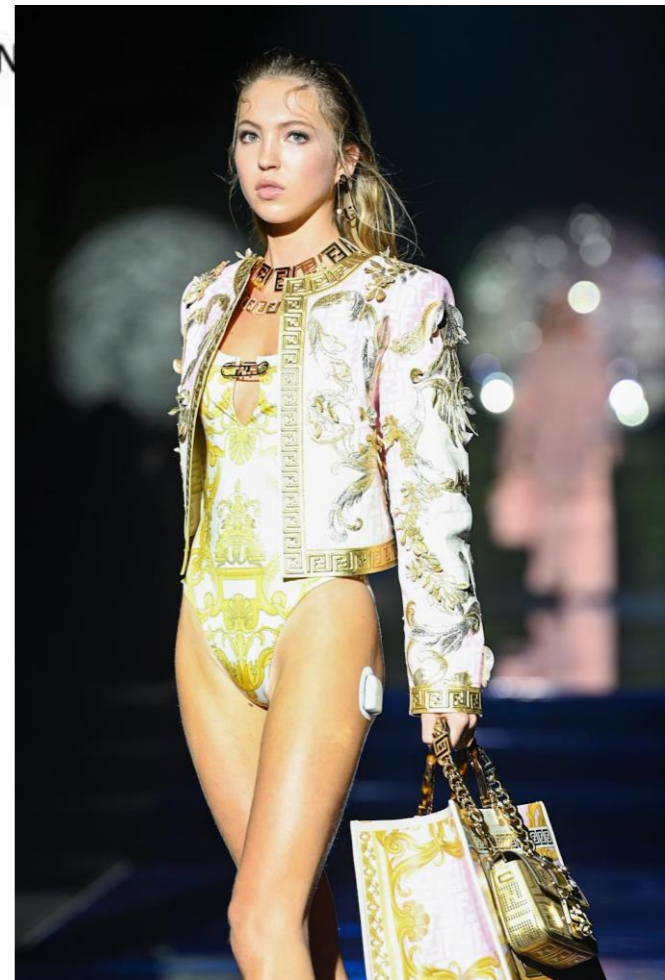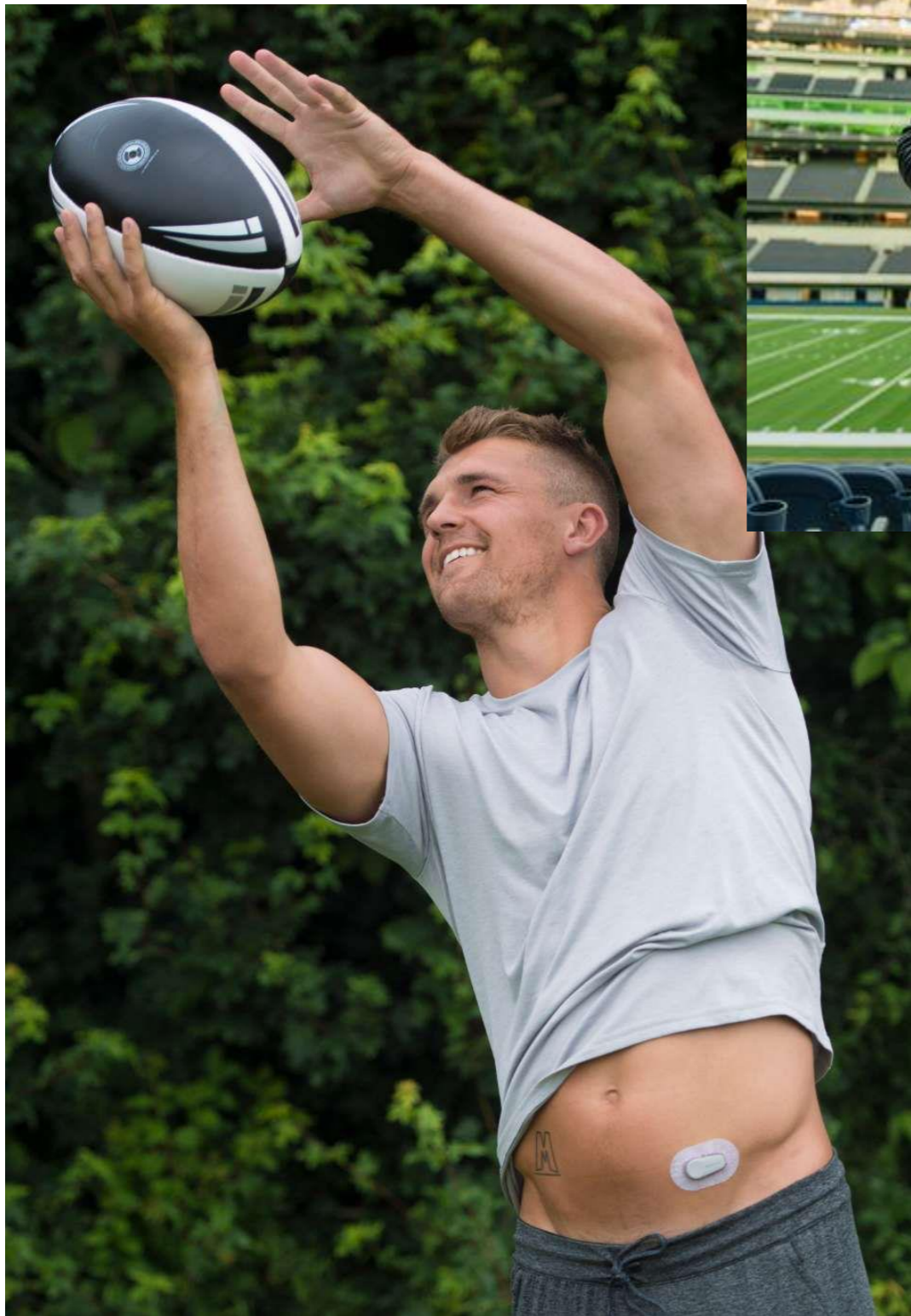
Living the Dream: Becoming a UK Soccer Star with Type 1 Diabetes

FC CYMRU