

Summary

8 Patients treated for their Diabetes Type 1 with insulin pump therapy were switched from the common fingerstick glucose measurements to a continuous glucose monitoring system (CGM). Fingerstick blood glucose was taken once a day during a steady state glucose level to calibrate the system. The CGM values and the trends were used to calculate the prandial insulin doses and to correct higher glucose levels by the bolus calculator. In addition the patients received an algorithm to respond to rising and falling trends shown on the CGM. If the CGM trends were rising, patients had to receive a supplement insulin dose; if the trends were falling the insulin pump was stopped and sometimes additional carbohydrates had to be given. The amount of hypoglycemic values <70mg/dl (3,1 mmol/l) was 5,6 % of times and 52% of times the values lies in the target area with 70- 130 mg/dl (3,9- 7,3 mmo/l). The HbA1c decreased about 0,1 to 1% from the basic values. The mean glucose level over all is 131 mg/dl with a standard deviation of 46. The observation period for each patient is at least 6 months. With this new way of routing the insulin pump therapy by the CGM no unexpected glucose values appeared and if the values go up or down the patients have the possibility to optimize the ongoing process in a better way. Therefore it is not necessary to count the carbohydrates exactly.

Introduction

Conventional and sensor augmented pump therapies are regulated by fingerstick blood glucose measurements 5 to10 times a day. Currently the CGM-Systems are only used to determine the moment when the patient should measure the blood glucose to influence the insulin therapy. This small outpatient observation study over 6 months demonstrates the possibility to direct the insulin pump therapy only by a CGM for the first time.

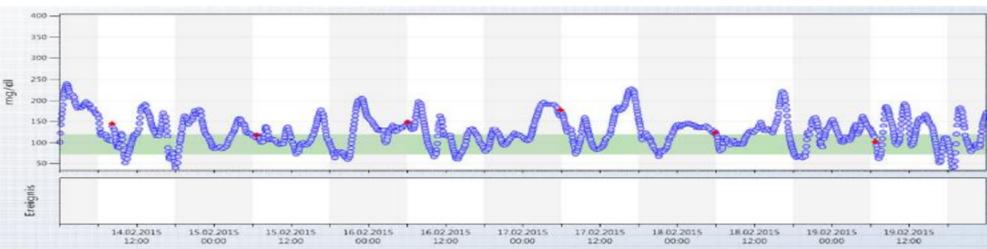
Characteristics of patients

- N= 8
- Sex: Male: 1 Female: 7
- Age (range) : 34 (19-46)
- Weight (range) kg: 62,2 (54-74)
- Body mas index (range): 21,3 (18.9-23.5)
- Diabetes Typ1 duration (range): 13 (2-29)
- Pump therapy for more than one year prior to inclusion
- using the sensor all the time (> 95% o time)

Method



Calibration values (red spots) over 6 days (an example)

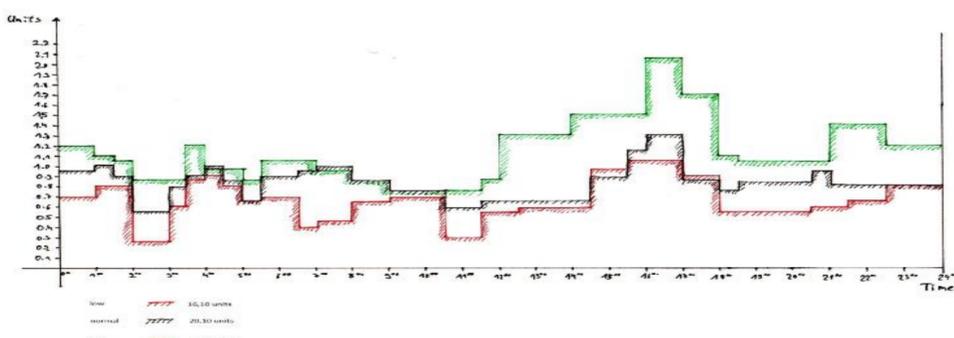


- Fingerstick blood glucose are taken only once a day during a steady state glucose level to calibrate the system.
- The current CGM values are inputted in the pump to calculate the needed bolus insulin for meals and to correct higher glucose levels. The bolus calculator of the pump generated the amount of insulin by considering the active insulin.
- For rising glucose trends, additional insulin doses were determined by patients
- For falling glucose trends the base rate of insulin from the pump was stopped or the patient had to intake some additional carbohydrates (glucose).

Basal program

The patients have up to 5 (most of them 3) individually developed basal programs in their pump for each situation such as for sports, normal and stress. The basal programs were desinged during the initial month of this observation period by taking the CGM graphs into account retrospectively.

Different basal programs (an example)



Algorithm for trends (an example)

1. Falling CGM trends

CGM-values < 80 mg/dl or CGM-values with 130 mg/dl \searrow the pump will be stopped for about 30-60 min. and sometimes additional carbohhydrates about 10 to 20 grams of glucose should be intaken.

2. Rising CGM trends

Additional insulin amount given every 30 min. for :

CGM value 80-100 mg/dl \nearrow : 0,5 U

CGM value 101-150 mg/dl \nearrow : 0,8 U

CGM value 80-100 mg/dl \uparrow : 1,0 U

CGM value 101-150 mg/dl \uparrow : 1,5 U

CGM value 101-150 mg/dl $\uparrow\uparrow$: 2 U

For ongoing rising trends basal program of the pump will be set on 4 U per hour until the trend stops

Alerts for CGM

Hyperglycaemia : 150 mg/dl

Hypoglycaemia: 80 mg/d

Trends: Change of more than 2 mg/dl per minute.

Adjustments for the pump calculator (an example)

Insulin for carbs: 0 am - 5.30 pm: 14 gr carbs/ U

5.30 pm- 12 pm: 15 gr carbs/ U

1 U lowering the glucose in the time 0-5 am : 37 mg/dl

1 U lowering the glucose in the time 5 am-8 am: 100 mg/dl

1 U lowering the glucose in the time 8 am-8 pm: 51mg/dl

1 U lowering the glucose in the time 8 pm-12 pm: 60 mg/dl

Target value: 100 mg/dl

insulin activity: 2,5 h

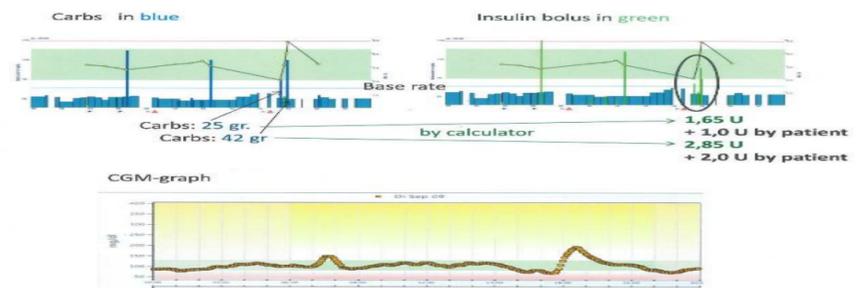
Algorithm for physical activity (an example)

During activity:

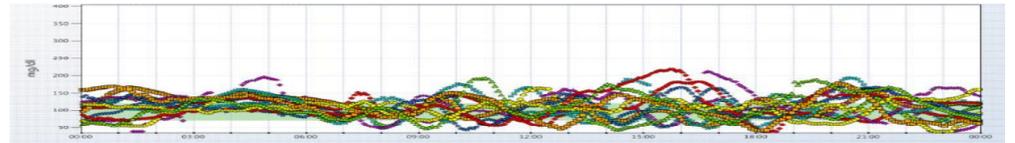
1. Basal program will be stopped for a maximum of 60 minutes and will go on with a rate of 0,40 U/h

2. Prandial dose reduction about 1 Unit

One day with algorithm (an example)



CGM- data over period of 14 days (an example)



Results

All the data over 3 months period from each patients were analyzed at 2 fixed points of time with the Dexcom softwear.

Patient No	Observation period in months	mean glucose value mg/dl	+/- 1 standard deviation	Glucose values <55 mg/dl % of times	Glucose values <70 mg/dl % of times	Glucose values			HbA1c in % at beginning	HbA1c in % at end
						120 mg/dl % of times	130 mg/dl % of times	180 mg/dl % of times		
1	3	154	45	0	1	23	31	74	7,1	6,7
6	6	152	45	0	1	23	34	76	6,8	6,8
2	3	144	57	1	3	37	45	70	6,5	6,2
6	6	138	50	1	4	41	50	79	6,2	6,2
3	5	130	49	0	4	54	59	79	6,1	6,4
8	8	134	47	0	2	43	52	82	7,7	6,4
6	6	148	61	1	2	35	44	68	7,7	7,6
9	9	176	62	0	2	15	22	56	7,1	6,3
5	8	130	52	4	6	40	47	74	7,1	6,3
11	11	122	47	3	10	46	53	79	7,1	6,6
9	9	105	30	2	8	52	74	88	7,1	5,2
12	12	93	21	2	11	78	83	89	7,7	5,4
14	14	125	56	4	10	44	55	77	7,7	6,8
17	17	120	45	3	10	47	55	80	6,5	6,6
8	17	114	34	3	8	54	64	88	6,5	6,1
20	20	116	36	2	8	51	61	87	6,5	6,3
		131,3	46,1	1,6	5,6	42,7	57	77,9		

In comparison our data to the control of the study:

Outpatient Glycemic Control with a Bionic Pancreas in Typ 1 Diabetes, (S.J. Russell and Other, The New England Journal of Medicine Vol. 371 No.4 S.313, July 2014)

N= 20 over 5 days

Mean glucose levels: **159 mg/dl range (105-225 mg/dl)**
values < 70 mg/dl: **7,3% of times (range:0-16 %)**

Mean glucose levels in our study of all patients: **131 mg/dl range (93-176 mg/dl)**
values < 70 mg/dl: **5,6 % of times (range:1-11%)**

Conclusion

It is possible to drive an insulin pump therapy with a CGM system without multiple blood glucose measurments.

The HbA1c-values were decreased from about 0,1- 1 % from the beginning to the end of the observation.

If the patient gives additional insulin doses for glucose trends the mean blood glucose levels are lower in comparison to control group of closed loop study and there are no more hypoglycaemic episodes.

With this new way of routing the insulin pump therapy by the CGM no unexpected glucose values appeared and if the values go up or down the patient has the possibility to change the ongoing process in more effective way. Therefore it is not necessary to count the carbohydrates exactly.