Accepted Preprint first posted on 17 November 2011 as Manuscript EJE-11-0642

Beneficial effect of real-time continuous glucose monitoring system on glycemic control in type 1 diabetic patients: systematic review and meta-analysis of randomized trials.

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Word count – 5714

Short running title: Continuous glucose monitoring in T1DM patients.

Abstract

Objective: Real-time continuous glucose monitoring (RT-CGM) provides detailed information on glucose patterns and trends, thus allowing the patients to manage their diabetes more effectively.

Design: The aim of this study was to explore potential beneficial effects of the use of RT-CGM on diabetes management as compared to self blood glucose measurement (SBGM) in patients with type 1 diabetes (T1DM), by means of a systematic review and meta-analysis of randomized controlled trials (RCTs).

Methods: MEDLINE, EMBASE and The Cochrane Library were searched through by two independent investigators for RCTs concerning the use of RT-CGM in patients with T1DM. Only studies with a similar insulin regimen in the experimental and in the control group were included in the analysis.

Results: Seven RCTs (n=948) met the inclusion criteria. Combined data from all studies showed better HbA1c reduction in subjects using RT-CGM compared with SBGM (MD – 0.25; 95% CI: – 0.34 to – 0.17; $p<0.001$). Patients treated with insulin pump and RT-CGM had a lower HbA1c level as compared to subjects managed with insulin pump and SBGM (4 RCTs, n=497; MD – 0.26; 95% CI: – 0.43 to – 0.10; $p=0.002$). The benefits of applying RT-CGM were not associated with an increasing rate of major hypoglycemic episodes. The use of RT-CGM for over 60-70% of time was associated with a significant lowering of HbA1c.

Conclusions: RT-CGM is more beneficial than SBGM in reducing HbA1c in patients with type 1 diabetes. Further studies are needed to evaluate the efficacy of this system in pediatric population, especially in very young children.

Key words RT-CGM, HbA1c, hypoglycemia

Abbreviations

AUC - area under the curve

CGM - continuous glucose monitoring

CGMS - Continuous Glucose Monitoring System

CSII - continuous subcutaneous insulin infusion

HbA1c - glycated hemoglobin

ITT - intention-to-treat

MAGE - mean amplitude of glycemic excursions

MD - mean difference

MDI - multiple daily injections

QoL - quality of life

RCT - randomized controlled trial

RT-CGM - real-time continuous glucose monitoring

RR - risk ratio

SBGM - self blood glucose measurement

WMD - weighted mean difference

BACKGROUND

The Diabetes Control and Complications Trial confirmed that tight metabolic control is regarded as crucial to prevent microvascular and macrovascular complications in type 1 diabetic patients[1]. Both glycated hemoglobin and glucose variability play role in the evaluation of the risk of long-term diabetic complications[2]. Intensive insulin therapy prevents or at least delays long-term diabetic complications. Aggressive diabetes management with CSII or MDI, using insulin analogues and frequent blood glucose monitoring are recommended methods to achieve therapeutic targets in type 1 diabetic patients.

The main factor limiting insulin management of T1DM subjects in the achievement of a strict glycemic goal is hypoglycemia[3]. Unfortunately, despite active education, it is quite difficult to avoid hypoglycemia. Even the most frequent self blood glucose measurement gives insufficient information. Usually, T1DM patients carry out from four to eight finger-prick measurements per day, or less, and rarely monitor their blood glucose level at night. This is the cause of overlooking blood glucose excursion, and especially postprandial hyperglycemia, asymptomatic hypoglycemia and glucose fluctuation during night.

Continuous glucose monitoring provides detailed information on glucose patterns and trends, thus allowing patients to manage their diabetes more effectively. Several continuous monitoring systems are commercially available. Some of them use continuous glucose monitoring in a retrospective way and others are real-time glucose monitors. There are different types of real-time glucose monitors: the DexCom Seven (DexCom), the MiniMed Paradigm Real-Time Insulin Pump and Continuous Glucose Monitoring System (Medtronic), and the FreeStyle Navigator (Abbott Diabetes Care). Each system consists of a glucose oxidase–based electrochemical sensor, which is placed subcutaneously and replaced every 3-7 days. Interstitial glucose measurements are sent continuously from the sensor to a receiver through advanced radio frequency wireless technology[4].

According to our previous meta-analysis, randomized controlled trials using CGMS in a retrospective way compared with SBGM did not show significant reduction in HbA1c in type 1 diabetic patients[5,6]. Real-time continuous glucose monitoring provides new dimension to diabetes management. Several studies, many of them observational, have assessed the effect of RT-CGM on metabolic control in type 1 diabetic patients[7]. A number of trials have demonstrated a reduction in HbA1c with RT-CGM. Other studies have not confirmed any benefits or have found that the benefit associated with continuous glucose monitoring was strongly related to age.

In this study, we sought to explore the potential beneficial effects of the use of RT-CGM on diabetes management when compared with SBGM in patients with type 1 diabetes, by conducting a systematic review and meta-analysis of randomized controlled trials.

Inclusion and exclusion criteria

The systematic review and meta-analysis were conducted according to standards of the Cochrane Collaboration[8]. Studies included in the review had to be randomized controlled trials with parallel or cross-over design in which real-time continuous glucose monitoring and self-monitoring of blood glucose were compared with self-monitoring of blood glucose alone in the management of type 1 diabetes. We included studies that used commercially available real-time glucose monitors: the DexCom Seven (DexCom), the MiniMed Paradigm Real-Time Insulin Pump and Continuous Glucose Monitoring System (Medtronic), or the FreeStyle Navigator (Abbott Diabetes Care) and Guardian RT (Medtronic MiniMed, Northridge, CA). Each system consists of a glucose oxidase–based electrochemical sensor, which is placed subcutaneously and along with a receiver to which interstitial glucose measurements are sent wirelessly and stored. A significant benefit of CSII over MDI for HbA1c reduction had been previously confirmed by some authors. Therefore, only studies with the same insulin regimen or studies with a similar proportion of patients using CSII and MDI in both experimental and control group were included in the analysis. The studies had to be of at least 3 months duration and had to have a follow-up rate of over 80%. We excluded unpublished studies, letters to the editor, abstracts and proceedings of scientific meetings. We also excluded studies in which patients used both CSII and MDI, but authors gave no information about the structure of usage in the experimental and in the control group or the groups were not balanced in terms of the usage structure. We also excluded trials involving patients with type 2 diabetes, pregnant women with T1DM and pancreas/islet-cell transplant patients. Studies using the Gluco-Watch G2 Biographer were not included in this analysis due to a different

method of glucose measurement. This device takes non-invasive glucose measurements using a low electric current to pull glucose through the skin. It caused a lot of skin irritations which led to very low compliance rates. Moreover, because of side effects, the Gluco-Watch G2 Biographer has been withdrawn from the market. Trials that used other RT-CGM devices which are not available on the market any more, or evaluating the use of blinded, retrospective CGM, were excluded. Studies performed in settings such as pre- and post-surgical or cardiac care unit, were excluded as well.

Outcomes

The primary end point was the change in HbA1c between the RT-CGM and the SBGM group. The secondary end points were: major and minor hypoglycemic episodes (as defined by the investigators), mean daily area under the CGM curve for glucose <3.89 mmol/l, mean daily area over the CGM curve for glucose >9.99 mmol/l, local adverse effects, quality of life.

Search strategy

The following electronic databases were systematically searched through for relevant studies: MEDLINE (PubMed), EMBASE (Ovid) and the Cochrane Central Register of Controlled Trials. The search was conducted from 1996 to March 2011. The search strategy included the use of a validated filter for identifying RCTs[9]. Key words included a constellation of different phrases centered around continuous glucose monitoring system ("CGMS" or "CGM" or "Continuous Glucose Monitoring" or "continuous glucose monitoring" or "RT-CGM*" or "continuous subcutaneous glucose monitoring" or "DexCom" or "Real-time system" or "FreeStyle Navigator" or "guardian" or "sensor-augmented insulin pump") and type 1 diabetes ("Diabetes type 1" or "diabetes t. 1" or "diabetes mellitus" or "Juvenile onset" or "Type 1 diabetes" or "IDDM" or "Autoimmune diabetes" or "DM1" or "

DM type 1" or "insulin-dependent" or "T1DM" or "brittle diabetes" or "T1D"). Subsequently, reference lists based on original studies and review articles were identified.

Data extraction

Two independent reviewers (AR and KD) screened the abstracts from the clinical trials according to the search strategy. Full texts of all potentially relevant articles were examined to determine whether they meet the inclusion criteria. Both reviewers (AR and KD) extracted data independently, using standard data extraction forms. Extracted data were compared to eliminate errors. All disagreements between the reviewers were resolved by consensus or if the consensus was not reached – by a third reviewer (AS).

Study quality

The methodological quality of the included studies was assessed by independent reviewers, without blinding to authorship or journal. The application of the following strategies associated with good-quality studies was examined: (1) allocation concealment; (2) blinding of participants, investigators, outcome assessors and data analysts (yes/no) (3) intention-to-treat (ITT) analysis (yes/no); and (4) comprehensive follow-up. The allocation concealment was considered adequate when the randomization method used did not allow the investigator or the participant to identify or influence the intervention group before the entry of eligible participants into the study. The quality of allocation concealment was regarded as unclear when randomization was used, but no information about the method of randomization was available. It was regarded as inadequate when inappropriate methods of randomization (e.g. alternate medical record numbers, unsealed envelopes, tossing the coin) were used. In ITT analysis, a ‘yes’ answer meant that the authors had specifically reported undertaking this type of analysis and/or that our own study confirmed this finding. Conversely, ‘no’ meant that the authors had not reported the use of ITT analysis and/or that we could not confirm its use in the study assessment. The completeness of patient follow-up was evaluated by ascertaining

the percentage of participants excluded or lost in follow-up. Completeness of follow-up was considered to be adequate if ≥80% of participants were included in the final analysis.

Statistical analysis

We used data from the end of each trial included in the systematic review. Data were analyzed using Comprehensive Meta Analysis (Version 2.2.057; Biostat, Englewood, NJ) software[10]. The difference in means (MD) was selected to determine differences in continuous outcomes between the experimental group and the control group. The binary measure for individual studies and polled statistics was calculated as the risk ratio (RR) between the experimental and the control group, with 95% CI. The difference between study groups was considered significant when the p value was <0.05 or when the 95% CI for RR did not exceed 1.0 and that for MD did not exceed 0. Heterogeneity was determined by I^2. Substantial heterogeneity was represented by I^2 of 50% or more[11]. A fixed-effect model was used as baseline and a random-effect model in case of substantial heterogeneity.

RESULTS

Study description

Based on the search strategy, 744 abstracts from clinical trials regarding CGMS were identified. The diagram of data extraction is illustrated in Figure 1. We identified 38 articles that underwent further analysis. Finally, we included 7 RCTs (n=948) to both qualitative and quantitative analyses[12,13,14,15,16,17,18]. Table 1 summarizes the characteristics of the included trials. In 5 studies, insulin pump therapy was used in both experimental and control group[13,14,16,17,18], in the next 2 studies the number of patients treated with CSII or MDI was comparable for the experimental and control group[12,15]. All trials included in the review, except for one[17], were multicenter. All trials contained a sufficient proportion (≥80%) of participants in the final analysis. One of them included only pediatric population[16], one regarded only adults[17], and the rest assessed mixed populations. The follow-up period ranged

from 3 to 12 months. In 4 studies, randomization sequences were described and were adequate[12,15,16,18]. Allocation concealment was well reported and suitable in 2 studies[16,18]. Investigators of 2 studies conducted ITT analysis[12,15]. Withdrawals and dropouts were described in 2 studies[13,18]. Table 2 summarizes the quality assessment of the included studies.

HbA1c

Meta-analysis of 7 RCTs (948 subjects) showed a significant reduction in HbA1c (mean difference, MD: – 0.25; 95% CI: from – 0.34 to – 0.17; p<0.001) for patients managed with RT-CGMS compared to patients monitored with SBGM (Figure 2). Moreover, patients treated with insulin pump combined with RT-CGM had a lower HbA1c level (4 RCTs, n=497; MD – 0.26; 95% CI: from – 0.43 to – 0.10; p=0.002) as compared to subjects managed with conventional insulin pump combined with SBGM (Figure 3). The reduction in HbA1c in adults (3 RCTs, n=224, MD – 0.37; 95% CI: from – 0.76 to 0.02; p=0.06, I^2=77%) and in children (3 RCTs, n=308, MD – 0.19; 95% CI: from – 0.42 to – 0.03; p=0.09) using RT-CGM compared to SBGM groups, was close to statistical significance. An additional analysis in subgroups divided according to glycemic control showed lower HbA1c in patients managed with RT-CGM compared to SBGM in both subgroups: with good metabolic control (1 RCT, n=129, MD – 0.31; 95% CI: from – 0.46 to – 0.16; p<0.001) and poor glycemic control (4 RCTs, n=603, MD – 0.21; 95% CI: from – 0.32 to – 0.09; p<0.001) at baseline.

There was a significant inverse correlation between the HbA1c level and the frequency of sensor use[13,14,16,18]. In JDRF study[12], RT-CGM effectively lowered HbA1c only in adults aged ≥25 years. In four studies, more subjects in the RT-CGM group achieved the level of HbA1c of ≤ 7% (53 mmol/mol) than in the SBGM group[12,13,15,18].

Major hypoglycemic episodes

RT-CGM usage had no influence on the incidence of major hypoglycemic episodes (6 RCTs, n=864, RR 0.69; 95% CI: from 0.41 to 1.14; p=0.15). The data are shown in Figure 4.

None of the included studies confirmed that RT-CGM decreased the rate of major hypoglycemia. In two studies, authors excluded patients with a history of major hypoglycemia[12,18].

Minor hypoglycemic episodes

Minor hypoglycemia, defined as glucose level below 3.89 mmol/l (70 mg%) was presented in 5 studies in two ways: as a number of episodes or time spent in hypoglycemia[12,13,14,15,18]. In one of them, authors did not find any difference in hypoglycemic episodes between patients using RT-CGM and controls[13]. There was no significant reduction in time spent in hypoglycemia in RT-CGM subjects, as compared to the SBGM group[12,14,15,18].

Mean daily time and daily area under the CGM curve for glucose level of <3.89mmol/l

The area under the curve calculated from continuous glucose monitoring for glucose < <3.89mmol/l (70 mg%) was significantly reduced in RT-CGM groups compared to patients monitored with SBGM in two studies[13,15]. Other authors did not show any differences between RT-CGM and control groups[14].

Hyperglycemia > 9.99mmol/l (180mg%)

A significant difference in favor of the RT-CGM group was observed with respect to time spent in hyperglycemia in two studies[12,14], which was not confirmed by other authors[15,18]. In two studies, there was no difference between RT-CGM groups and controls in the number of hyperglycemic events[12,13]. A significantly lower area under the curve in the RT-CGM groups compared to controls was noted by some authors[14] and not by others[13]. Additionally, there was a significant reduction of episodes of glucose above 250 mg% in the RT-CGM group compared to controls in one study[12], which was not noted by other authors[15]

MAGE

In two studies[14,16] glycemic variability was significantly lower in the sensor group. The

difference between groups was not observed by other authors[15].

Ketoacidosis and local adverse events

Ketoacidosis was infrequent and without any significant difference between experimental and control groups. Local adverse events were uncommon and included mainly skin problems at the sensor or insulin infusion site.

Compliance

The sensor use was consistently high but declined over time in some trials[12,14,15,16]. An increased frequency of sensor use was associated with a greater reduction in HbA1c[13,14,15,16,18]. The compliance with the sensor wear was age-related and was lower in children and the lowest in adolescents[12,15]. Self-reported pre-study daily blood glucose measurements were associated with a successful use of RT-CGM[15]. An association between sensor use and baseline HbA1c was not noted[12]. No significant effect of age, duration of diabetes or duration of insulin pump therapy on the frequency of sensor use was noted by other authors[18].

Quality of life

Two studies[16,17] estimated quality of life as secondary end point. We did not include this in our meta-analysis because of different forms of evaluation used. In the trial by Kordonouri et al. [16], children aged 8–18 years and their primary caregivers were asked at the start of the study and at 24 and 52 weeks to complete the DISABKIDS and KIDSCREEN-27 questionnaires for evaluation of patient's health-related quality of life and caregiver's impression of patient's QoL. Own well-being was assessed with the WHO-5 questionnaire. For physical, psychological, social support and school, the scores were significantly lower at baseline compared with European norm data, reached normal values after 6 months and remained normal after 1 year, with no differences between experimental and control groups.

In the study by Peyrot et al.[17], all participants completed the User Acceptance Questionnaire, Insulin Delivery System Rating Questionnaire, and Blood Glucose Monitoring System Rating Questionnaire, which was developed for this study. In this trial, the investigators found that several patient-reported outcomes were significantly more positive in the RT-CGM arm than the control arm, including satisfaction measures, particularly the burden of blood glucose monitoring and convenience, as well as measures of health-related quality of life, including social burden and diabetes-related worries.

DISCUSSION

This meta-analysis of seven randomized controlled trials showed that the real-time continuous glucose monitoring system provides a superior benefit over self-monitoring of blood glucose with regard to HbA1c reduction in type 1 diabetic patients. The improvement in HbA1c in patients using the real-time CGM was achieved without an increase in severe hypoglycemia.

The recently published systematic review of nine RCTs indicated that RT-CGM has a beneficial effect on glycemic control in adult patients with T1DM, without an increase in the incidence of hypoglycemia. Less convincing evidence was available for children and type 2 diabetes[19]. Authors of this review could not perform a meta-analysis because of an extensive clinical heterogeneity of trials. They included in their analysis patients using different methods of insulin administration (MDI or CSII), with different types of diabetes (type 1 and/or type 2 diabetes), as well as subjects monitored with Gluco-Watch G2 Biographer. Our meta-analysis differs from the study by Hoeks et al. [19] due to different inclusion criteria. In our meta-analysis, we included only trials with a similar method of insulin administration in both control and experimental groups. Previous meta-analyses had already shown that CSII compared with MDI was a more effective form of metabolic control[20,21]. Therefore, the

assessment of the efficacy of RT-CGM is not possible if the insulin delivery method is different in experimental and control groups.

Limitations at study and outcome level

In all included trials, medical devices for real-time glucose measurement were used, therefore blinding was not possible. Some of the analyzed trials revealed methodological limitations, including the lack of ITT analysis, unclear or inadequate allocation concealments and no data describing randomization. In one study, the sample size was limited[17]. Moreover, the trials were conducted for up to 12 months; most of them were carried out for the period of 3 or 6 months. The short duration of the follow-up made it difficult to predict whether the decreased HbA1c level would be maintained for a longer period. In view of a marked heterogeneity in the definition and assessment of hypoglycemia, a pooled analysis of this end point was not performed. Some studies reported a positive association between the primary end point and the degree of compliance. However, only in two studies, the quality of life was assessed[16,17]. These studies were conducted with the use of different questionnaires. The lack of standard quality of life questionnaires prevented execution of the analysis. We observed a substantial clinical heterogeneity of the analyzed studies performed in adults. To deal with the statistical heterogeneity, we used the random-effect model.

Clinical implications

The previous meta-analysis comparing blinded CGM with SBGM showed no superiority of CGM over SBGM in lowering HbA1c in type 1 diabetic patients[5]. However, those devices were clinician-oriented and allowed only for a retrospective evaluation of data. A new generation of CGM devices offers real-time interstitial glucose monitoring and allows for advanced decisions made by patients. The results of our meta-analysis support the notion that the use of RT-CGM is associated with a significant lowering of HbA1c as well as glycemic variability. Both components: chronic sustained hyperglycemia and acute glycemic

fluctuations lead to diabetes complications through two main mechanisms: excessive protein glycation and activation of oxidative stress[22]. Tight glycemic control is therefore of great importance in diabetes management. According to ISPAD guidelines, a target range of HbA1c for all age groups with type 1 diabetes of <7.5% (58mmol/mol) is recommended[23]. However, lowering HbA1c to below or around 7% (53mmol/mol) has been shown to reduce microvascular and neuropathic complications of diabetes, therefore, in ADA recommendations, a reasonable HbA1c goal for many non-pregnant adults is <7%[24]. Our analysis showed that more patients in the RT-CGM group reached the target HbA1c of 7% or, less[12,13,15,18]. Lower HbA1c values in the group using RT-CGM were not associated with an increased frequency of major hypoglycemic events. This reflects not only the benefits of RT-CGM but also indicates the safety and efficacy of insulin analogues and insulin pumps. However, our results must be interpreted with caution since the included studies were not powered to evaluate the difference between groups in terms of the rate of major hypoglycemia.

An important clinical question is which patients may benefit from RT-CGM use. Over 80% of patients included in our analysis were treated with CSII. Our previous meta-analysis demonstrated a statistical difference between CSII and MDI therapy[20]. CSII therapy was associated with a significant reduction in HbA1c in comparison to MDI, without an increased risk of major hypoglycemia. Our results showed that insulin pump used in combination with RT-CGM had a beneficial effect on glycemic control in T1DM subjects. Pump users managed with RT-CGM achieved significant lowering of HbA1c in comparison to subjects treated with conventional insulin pumps. The reduction in the HbA1c level in diabetic patients using RT-CGM was noted in participants with poor glycemic control. However, the study of T1DM subjects with good glycemic control confirmed the efficacy of RT-CGM in well-controlled diabetic patients as well. Our subanalyses of adults and children with type 1 diabetes did not

show any beneficial effect of RT-CGM. However, the results, especially in adults, were close to statistical significance. The lack of superiority of RT-CGM over SBGM in lowering HbA1c might be partly a result of a small number of patients included in particular analyses. Another reason, especially in children, could be a low compliance.

Our meta-analysis showed that patients' motivation to use RT-CGM was crucial for device effectiveness. The most important factor influencing higher reduction in HbA1c was an increased frequency of sensor use. The use of RT-CGM for over 60-70% of time was associated with a significant lowering in HbA1c[13,14,15,16,18]. Some authors noted a decline in sensor use over time. Moreover, comparing different age groups showed a lower compliance in children and the lowest in teenagers. This showed that the currently available RT-CGM systems are not user-friendly enough, especially for children and their families.

Implications for further research

The use of RT-CGM provides a better insight into glycemic profiles, which may have a beneficial effect on patients with frequent severe hypoglycemia. Therefore, further studies are needed in subjects selected specifically for that problem. There are no randomized studies evaluating if RT-CGM is beneficial in the management of toddlers and preschool children with T1DM. Although frequent SBGM is an integral part of intensive diabetes management, there are difficulties in minimizing glucose fluctuations in this age group. Parents and caregivers of young children experience a high level of stress related to fear of hypoglycemia that can interfere with a normal developmental and psychosocial interaction with diabetic children. Therefore, further studies are important not only for assessing the effectiveness, safety and tolerance of RT-CGM device but also to evaluate the impact of RT-CGM on the quality of life. A decrease in compliance during the course of a trial was reported by some authors. Therefore, research evaluating the lack or decreasing compliance in the follow-up are needed.

Conclusions

Our meta-analysis confirmed that the use of RT-CGM compared with SBGM effectively lowered HbA1c in type 1 diabetes. The benefit of applying RT-CGM was not associated with an increasing rate of acute hypoglycemia. The reduction in HbA1c was noted not only in patients with poorly controlled type 1 diabetes but also in well-controlled subjects. The superiority of RT-CGM over SBGM in lowering HbA1c was also confirmed in pump users. Further, age-related studies are needed to evaluate the efficacy of this system in pediatric population, especially in very young children.

Declaration of interest

A. Szypowska and A. Ramotowska co-authored educational materials for patients with diabetes whose edition was sponsored by Abbott. Medtronic MiniMed sponsored lectures as well as participation in medical conferences. K. Dżygało and D. Golicki have no conflict of interest. There is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported. This study was fully funded by the Medical University of Warsaw, Warsaw, Poland.

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Table 1

Summary of included trials.

Study	Study duration (months)	Sample size (n); Exp./Cont.	Age (years); Exp./Cont.	Diabetes duration; Exp./Cont.	Diabetes treatment; Exp./Cont.	Baseline HbA1c (%,mmol/mol)); Exp./Cont.	Ketoacisodsis (n); Exp./Cont.	Major hypoglycaemia (n); Exp/Cont.	Type of CGMS
JRDF 2008[12]	6	8-14ys: 56/58; 15-24ys: 57/53; ≥25ys: 52/46	8-14ys 11.4/11.6; 15-24ys: 18.8/18.2; ≥25ys: 41.2/44.6	8-14ys: 6.2/5.3; 15-24ys: 9.5/8.8; ≥25ys: 23.6/21.8	CGMS device and CSII or MDI/CSII or MDI	8-14ys: 8/7.9 (64/63); 15-24ys: 8/7.9 (64/63); ≥25ys: 7.6/7.6 (60/60)	8-14ys: 0/0; 15-24ys: 0/;1 ≥25ys: 0/0	8-14ys: 4/6; 15-24ys: 3/5; ≥25ys: 5/4	DexCom Seven, RT-CSII, FreeStyle Navigator
Hirsch[13]	6	66/72	33.0/33.2	20.8/16.7	RT-CSII/CSII	8.49/8.39	1/0	8/3	RT-CSII
Raccah[14]	6	55/60	28.1/28.8	11.2/12.3	RT-CSII/CSII	9.1/9.3 (75/78)	2/3	1/0	RT-CSII
JRDF 2009[15]	6	67/62	29.3/32.0	8-14ys 4.9/4.4 15-24ys 8.7/8.1 ≥25ys 25.6/28.6	CGMS device and CSII or MDI/CSII or MDI	6.4/6.5 (46/48)	0/0	7/7	DexCom Seven, RT-CSII, FreeStyle Navigator
Kordonouri[16]	12	76/78	8.5/9.1	<4weeks**	RT-CSII/CSII	11.2/11.5 (99/102)	Not reported	0/4	RT-CSII
Peyrot[17]	4	14/14	25-70ys*	25±12.6	RT-CSII/CSII	8.3-8.9 (67/74)	0/1	0/3	Not reported
O'Connel[18]	3	31/31	23.4/23	11.1/9.2	RT-CSII/CSII	7.3/7.5 (56/58)	0/0	0/0	RT-CSII

RT-CSII - MiniMed Paradigm real time insulin pump and Continuous Glucose Monitoring System (Medtronic)
Age, diabetes duration and HbA1c are given as mean values.*Data given as range. **Diabetes duration of less than 4 weeks.

Table 2

Quality assessment of included studies

Study	Randomization	Allocation concealment	ITT	Blinding	Design	Follow-up (%)
JRDF2008[12]	permuted-block design stratified according to clinical center, age group and glycated hemoglobin level	not described	yes	no	parallel	98
Hirsh[13]	not described	not described	no	no	parallel	95
Raccach[14]	not described	not described	no	no	parallel	87
JRDF2009[15]	permuted-block design stratified according to clinical center, age group and glycated hemoglobin level	not described	yes	no	parallel	98
Kordonouri[16]	central randomisation procedure	yes	no	no	parallel	96
Peyrot[17]	not described	not described	no	no	parallel	96
O'Connel[18]	central computer-generated Schedule	yes	no	no	parallel	89

Figure 1.

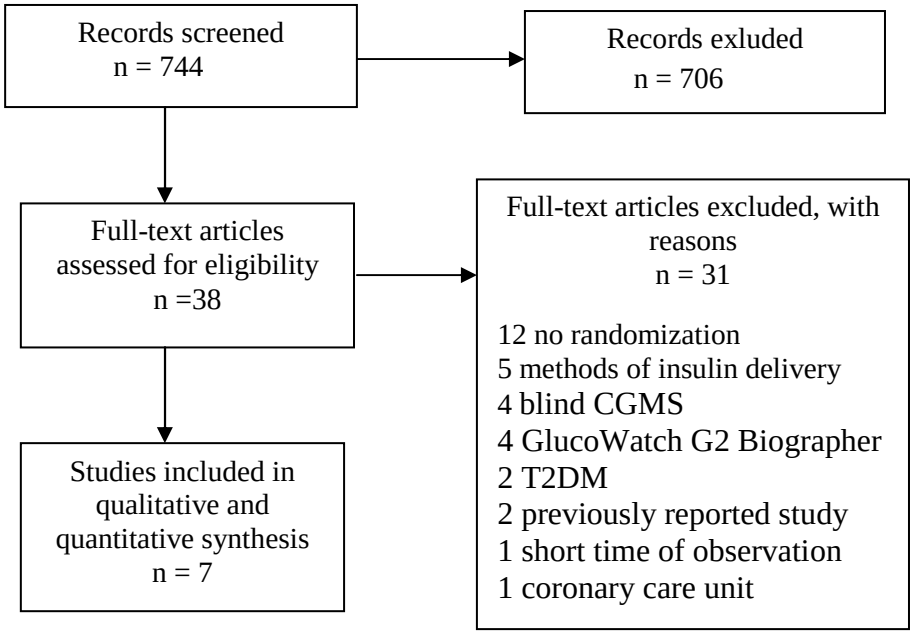

Records screened
n = 744
Records exluded
n = 706
Full-text articles
assessed for eligibility
n =38
Full-text articles excluded, with
reasons
n = 31
12 no randomization
5 methods of insulin delivery
4 blind CGMS
4 GlucoWatch G2 Biographer
2 T2DM
2 previously reported study
1 short time of observation
1 coronary care unit
Studies included in
qualitative and
quantitative synthesis
n = 7

Figure 2.

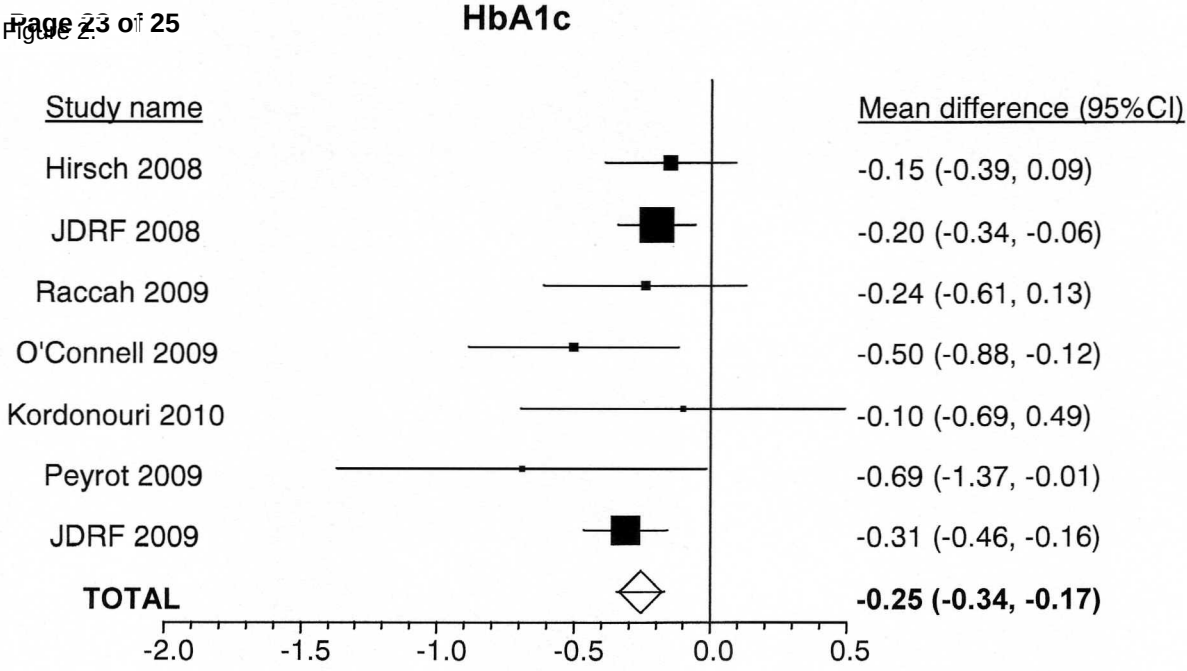

HbA1c
Study name
Mean difference (95%CI)
Hirsch 2008
-0.15 (-0.39, 0.09)
JDRF 2008
-0.20 (-0.34, -0.06)
Raccah 2009
-0.24 (-0.61, 0.13)
O'Connell 2009
-0.50 (-0.88, -0.12)
Kordonouri 2010
-0.10 (-0.69, 0.49)
Peyrot 2009
-0.69 (-1.37, -0.01)
JDRF 2009
-0.31 (-0.46, -0.16)
TOTAL
-0.25 (-0.34, -0.17)
-2.0
-1.5
-1.0
-0.5
0.0
0.5

Figure 3.

HbA1c (RT-CGMS/CSII vs SBGM/CSII)

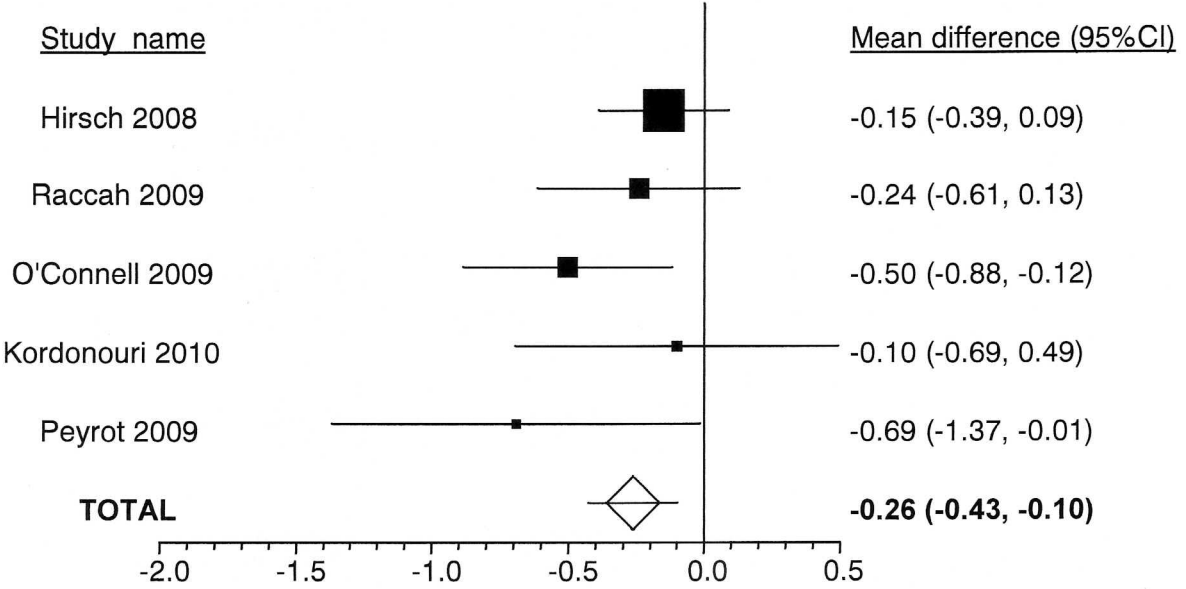
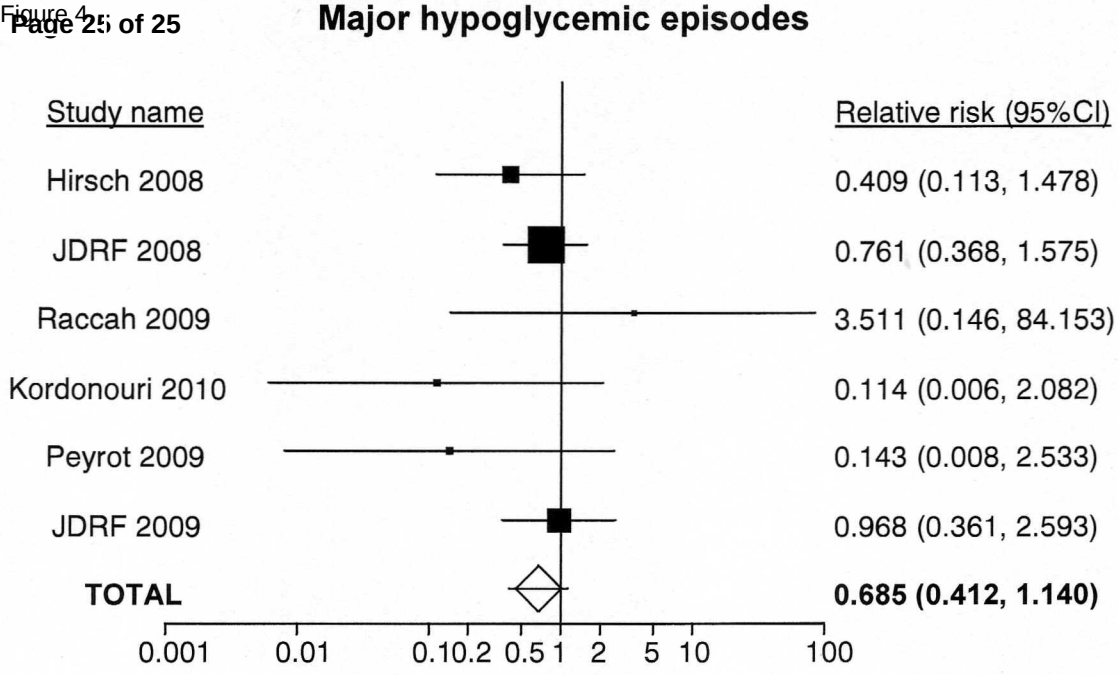


Figure 4


Major hypoglycemic episodes
Study name
Relative risk (95%CI)
Hirsch 2008
0.409 (0.113, 1.478)
JDRF 2008
0.761 (0.368, 1.575)
Raccah 2009
3.511 (0.146, 84.153)
Kordonouri 2010
0.114 (0.006, 2.082)
Peyrot 2009
0.143 (0.008, 2.533)
JDRF 2009
0.968 (0.361, 2.593)
TOTAL
0.685 (0.412, 1.140)
0.001
0.01
0.1
0.2
0.5
1
2
5
10
100