Comparison of different insulin pump makes under routine care conditions in adults with Type 1 diabetes

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Comparison of different insulin pump makes under routine care conditions in adults with Type 1 diabetes

Short title: Comparison of different insulin pumps

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What's new?

- Continuous subcutaneous insulin infusion (CSII) is often considered the 'gold standard' insulin replacement therapy for individuals with Type 1 diabetes.
- This is the first study to compare long-term changes in HbA_{1c} associated with different makes of pump under routine care conditions.
- We found no significant differences in HbA_{1c} improvement when comparing different

makes of insulin pump, including a comparison of patch pumps and traditional
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catheter pumps, and pre-specified patient subgroups stratified by pre-CSII HbA_{1c}, age and diabetes duration.

- The choice of CSII make should not be influenced by the desired degree of HbA_{1c} lowering.

Abstract

Aims To compare long-term HbA_{1c} changes associated with different insulin pumps during routine care in a large cohort of adults with Type 1 diabetes representative of other clinic populations.

Methods Observational, retrospective study of 508 individuals starting pump therapy between 1999 and 2014 (mean age, 40 years; 55% women; diabetes duration, 20 years; 94% Type 1 diabetes; median follow-up, 3.7 years). Mixed linear models compared covariate-adjusted HbA_{1c} changes associated with different pump makes.

Results The pumps compared were: 50% Medtronic, 24% Omnipod, 14% Roche and 12% Animas. Overall HbA_{1c} levels improved and improvements were maintained during a follow-up extending to 10 years (HbA_{1c}: pre-continuous subcutaneous insulin infusion (pre-CSII) vs. 12 months post CSII, 71 (61, 82) vs. 66 (56, 74) mmol/mol; 8.7 (7.7, 9.6) vs. 8.2 (7.3, 8.9)%; $P < 0.0001$). The percentage of individuals with HbA_{1c} ≥ 64 mmol/mol (8.0%) reduced from a pre-CSII level of 68% to 55%. After adjusting for baseline confounders, there were no between-pump differences in HbA_{1c} lowering ($P = 0.44$), including a comparison of patch pumps with traditional catheter pumps ($P = 0.63$). There were no significant ($P < 0.05$) between-pump differences in HbA_{1c} lowering in pre-specified subgroups stratified by pre-pump HbA_{1c}, age or diabetes duration. HbA_{1c} lowering was positively related to baseline

HbA_{1c} ($P < 0.001$) and diabetes duration ($P = 0.017$), and negatively related to the number of years of CSII use ($P = 0.024$).

Conclusions Under routine care conditions, there were no covariate-adjusted differences in HbA_{1c} lowering when comparing different pump makes, including a comparison of patch pumps vs. traditional catheter pumps. Therefore, the choice of CSII make should not be influenced by the desired degree of HbA_{1c} lowering.

Introduction

Continuous subcutaneous insulin infusion (CSII) is often considered the ‘gold standard’ of insulin replacement therapy for individuals with Type 1 diabetes [1].

Use of CSII has been shown to reduce both HbA_{1c} and the incidence of severe hypoglycaemia [2]. Furthermore, a recent large observational study from Sweden has shown lower cardiovascular mortality among people with Type 1 diabetes treated using a pump compared with those treated with multiple daily insulin injections, despite similar HbA_{1c} levels between the groups [3]. However, there is large variation in the availability of CSII between and within countries [4].

Despite significant improvements in care, including the wider use of CSII, many individuals with Type 1 diabetes fail to meet current glycaemic targets [5]. Recent data from the T1D Exchange show that > 70% in all age groups are not meeting current HbA_{1c} targets [6]. Similarly, data from UK show that fewer than one-third of people with Type 1 diabetes achieve HbA_{1c} levels < 7.5% [5]. It is of note that HbA_{1c} levels achieved in the UK are far worse than in other western European countries like Germany or France, and the proportion of individuals using CSII is also low in the UK.

Several recent observational studies have evaluated the effect of CSII on glycaemic control in everyday clinical practice showing sustained benefit over prolonged periods [7–9]. However, no study has compared the effect of different pump makes under real-life conditions.

Traditional pumps such as Medtronic, Roche and Animas deliver insulin via a catheter inserted under the skin with tubing between the pump and the cannula. By contrast, Omnipod is a ‘patch pump’ consisting of a handheld controller and a disposable pod that delivers insulin.

Two reports have suggested lower dose accuracy for the Omnipod insulin pump compared with traditional pumps [10] and to another patch pump [11]. By contrast, inaccuracy in basal insulin delivery has been reported with the movement of conventional pumps in relation to the catheter (pumping upwards and downwards) due to a siphon, whereas the Omnipod performed better [12].

There are also differences in the bolus calculators employed by traditional pumps including differences in the algorithmic rules that govern advice for correctional boluses, differences in the way the correction bolus/targets are set and the way the insulin on board is taken into account [13,14]. However, the clinical relevance of these differences is still unknown.

Therefore, we designed a study to test the hypothesis that there would be clinically relevant differences in HbA_{1c} between pumps. Our objective was to compare long-term changes in HbA_{1c} associated with different insulin pumps during routine care in a large cohort of adults with Type 1 diabetes that would be representative of other clinic populations.

Research design and methods

This large retrospective observational cohort study was conducted at Manchester Diabetes Centre, a tertiary referral and one of the largest insulin pump centres in the UK (> 500 active pump users and ~ 40% of all people with Type 1 diabetes are CSII treated). All individuals who initiated CSII use between January 1999 and March 2014 were included. Individuals without a CSII start date (usually those who transferred care from another centre) and those without relevant pre-CSII data were not included.

In line with current guidance [15], indications for CSII included poor glycaemic control, problems with hypoglycaemia and glycaemic variability/erratic control.

Demographic variables and HbA_{1c} data were obtained from electronic records. HbA_{1c} data were collected from 12 months before and up to 10 years after initiation of CSII. Mean annual HbA_{1c} values were used for all calculations.

Prior to starting CSII, individuals received individualized counselling and education, and were offered a choice of the insulin pumps available in the UK at the time. These consisted of pumps manufactured by Animas (2020 & Vibe; Animas Corp., West Chester, PA, USA), Medtronic (Paradigm 515, 715, 522, 722, Veo 554, 754; Minimed Inc., Northridge, CA, USA), Omnipod (Insulet Corp., Bedford, MA, USA) and Roche (Spirit, Accu-check Combo, Accu-Chek D-Tron Plus; Roche Diabetes Care AG, Burgdorf, Switzerland). Animas, Medtronic and Roche are traditional catheter pumps where insulin delivery is via a subcutaneously placed metal or plastic cannula connected to the pump by tubing. By contrast, Omnipod is a patch pump without tubing, where a disposable pod filled with insulin is attached to the skin. In both traditional and patch pumps, it is advised that cannulas and pods be changed every third day.

Approximately 20% of the individuals participated in a local structured education course lasting 3 days (~ 18–20 h). The remainder received 1–3 h of individualized training/re-

training on carbohydrate counting and other aspects of managing diabetes before starting pump use. In addition, training required to operate the pump, including sick day rules and pump troubleshooting, was provided in a 3–4 h session. There was no requirement to undertake a formal structured education programme before starting CSII (this practice has changed since 2015 and all patients are now required to undertake a DAFNE programme before referred for CSII). Initial basal rates were set using established methods (75% of total daily dose on multiple daily injections divided by 2 and divided by 24 h to obtain hourly rates). All individuals were started on a single hourly basal rate with subsequent adjustment by patient and pump educators. Carbohydrate ratios (meal-time carbohydrate (g)/unit of insulin) were obtained using the 500 rule ($500/\text{total daily dose on pump}$) and sensitivity factor (glucose lowering mmol/L/unit) using the 100 rule ($100/\text{total daily dose on pump}$). Insulin action time was typically set for 4 h and individualized pre-meal glucose targets were set (typically 5 to 7 mmol/L). Patients then received follow-up care as determined by their individual requirements.

Statistical analysis

All analyses were based on the period from initiation of pump therapy to discontinuation of pump use or switching to another pump model. Kaplan–Meier survival curves and log rank tests were used to compare the length of time pumps remained in use, as defined by termination of use or switching to another type.

Data were visualized as box plots/scatter plots of HbA_{1c} and its change from pre-pump baseline against years on pump and baseline HbA_{1c} , along with smoothed fitted lines from a longitudinal regression model with quadratic terms in baseline HbA_{1c} and year on pump, a linear term in the calendar year the pump was fitted and a patient random effect to allow for correlation between repeat measures on the same individuals.

A similar mixed linear model for (HbA_{1c}-baseline value) was used for comparison of the different pump models and patient/treatment characteristics: calendar year of pump commencement (linear, centred on 2011), sex (base male), age started pump (per decade, centred at median age), diabetes duration (linear, centred on median duration) and baseline HbA_{1c} (quadratic, centred on median value). All *P*-values are two-tailed and values < 0.05 were considered statistically significant. All analyses were conducted in the *R* statistical environment, version 3.0 (R Core Team, Vienna, Austria; <https://www.R-project.org/>)

Results

The CSII database included 613 individuals up to March 2014. Thirty-eight individuals were excluded due to the lack of a CSII start date, usually because start of CSII had occurred at another centre prior to transfer to our unit. Of the remaining 575, pre- and post-CSII HbA_{1c} data were available in 508 (83% of the original 613 individuals).

Demographics for the whole cohort and the subgroups treated with the four different makes of pump at baseline and to year 5 are shown in Tables 1 and S3. Median duration of follow-up was 3.7 (2.5, 5.1 years). The majority (94%) of participants had Type 1 diabetes, with the remainder largely consisting of individuals with secondary diabetes due to pancreatitis.

Median (interquartile range (IQR)) age at the start of pump use was 40 (30, 49) years and median diabetes duration was 20 (11, 29) years. Initial pump models were: 50% Medtronic, 24% Omnipod (patch pump), 14% Roche and 12% Animas. Statistically significant differences were noted between choice of the different pump manufacturers in terms of age, sex, diabetes duration, year starting CSII and duration of follow-up. In particular, most of the CSII devices initiated in the early years (2000–2010) were Medtronic pumps, whereas the most commonly initiated CSII models between 2011 and 2014 were from Omnipod. As a

consequence, Medtronic pump users had a longer follow-up, and Omnipod users had a shorter follow-up. Among Omnipod users, 55% were men, whereas the majority of users of the other pumps were women. There was no statistical difference in pre-pump HbA_{1c} between the different pump users ($P = 0.22$), but numerically, Omnipod users had the lowest median HbA_{1c} (68 mmol/mol) and Roche pump users the highest (74 mmol/mol).

The length of time for which a particular pump was used before discontinuation or switching to another type did differ between pump types ($P = 0.002$ in a log rank test), with 81% (95% confidence interval (CI) 72–91%) still using the Roche pump after 3 years, compared with 96% (95% CI: 94–98%) Medtronic, 96% (95% CI: 91–100%) Animas and 99% (95% CI: 96–100%) Omnipod (Fig. S3).

Overall changes in HbA_{1c}: combined data on individuals treated with all pump models

The median (IQR) HbA_{1c} for the whole cohort pre-CSII was 71 (62, 83) mmol/mol (8.7 (7.7, 9.6)%), improving to 66 (56, 74) mmol/mol (8.2 (7.3, 9.0)%) during the first 12 months (paired difference: 4 (–2, 12) mmol/mol; $P < 0.0001$). Although there was wide variability in individual responses (Fig. 1a), overall improvements in HbA_{1c} were maintained for up to 10 years (Fig. 1; Tables S1 and 2).

Individuals with poorer glycaemic control at baseline showed larger improvements in HbA_{1c} compared with those with better control (Fig. 1b). For example, there was negligible improvement in individuals with baseline HbA_{1c} values < 60 mmol/mol, but improvements of up to 30 mmol/mol in those with pre-CSII HbA_{1c} levels of ~ 120 mmol/mol. The proportion of individuals with poor control (HbA_{1c} > 64 mmol/mol; 8.0%) was reduced from 68% (pre-CSII) to 55% (at year 1), and this proportion remained stable during subsequent follow-up (Tables 1, S1 and S2).

Quantifying between-pump differences in HbA_{1c} lowering

In unadjusted models that included all HbA_{1c} values ($n = 1786$) in all individuals ($n = 480$), there were no between-pump differences in HbA_{1c} change from baseline ($P = 0.25$; Fig. 2a).

In similar models that adjusted for differences in baseline covariates (age, sex, baseline HbA_{1c}, year of pump start, and diabetes duration), there were also no between-pump differences in HbA_{1c} change from baseline ($P = 0.44$; Fig. 2b and Table 2).

Factors associated with HbA_{1c} improvement

Table 2 expands on the data presented in Fig. 2(b) by quantifying covariate effects along with the adjusted overall changes in HbA_{1c} from baseline in individuals treated using different pump models. These data show that HbA_{1c} lowering was positively related to baseline HbA_{1c} and diabetes duration, and negatively related to number of years on CSII therapy such that: a 1 unit higher baseline HbA_{1c} level was associated with 0.36 mmol/mol greater HbA_{1c} lowering during follow-up, which translates to an improvement in HbA_{1c} of 26 mmol/mol for an individual with a pre-CSII HbA_{1c} of 120 mmol/mol compared with zero improvement in HbA_{1c} for an individual with an pre-CSII HbA_{1c} of 49 mmol/mol. The results presented in Table 2 also show that a 1-year longer diabetes duration was associated with 0.1 mmol/mol greater HbA_{1c} lowering during follow-up; and a 1-year longer duration of CSII therapy was associated with 0.11 mmol/mol lesser HbA_{1c} lowering during follow-up. Sex and age were not significantly associated with CSII improvement. A weak effect between duration of diabetes prior to CSII start and improvement was noted (0.10 mmol/mol per year of diabetes before CSII, $P = 0.017$).

Between-pump differences in HbA_{1c} lowering in pre-specified patient subgroups

Figures 2(c,d) and S2 show no between-pump differences in unadjusted HbA_{1c} changes in subgroups stratified by pre-pump HbA_{1c} (< 64 and ≥ 64 mmol/mol (< 8.0% and ≥ 8.0%); Fig. 2c); age (< 45 and ≥ 45 years; Fig. S2a) and diabetes duration (< 20 and ≥ 20 years; Fig. S2c). Similarly, in covariate-adjusted models (Fig. 2d and Fig. S2b,d) there were no between-pump differences in HbA_{1c} changes in subgroups stratified by pre-pump HbA_{1c} (Fig. 2d); age (Fig. S2b) and diabetes duration (Fig. S2d); the covariates being age, sex, baseline HbA_{1c}, year of pump start, and diabetes duration (when appropriate).

Patch pump compared with traditional pumps

In unadjusted and covariate-adjusted models that included all HbA_{1c} values, there were no significant differences in HbA_{1c} change from baseline when comparing individuals treated with patch pumps (Omnipod) vs. traditional pumps (Medtronic, Roche and Animas). Unadjusted difference in change = 1.8 (−0.9 to 4.5) mmol/mol ($P = 0.20$). Adjusted difference in change = −0.7 (−3.3 to 2.0) mmol/mol ($P = 0.63$).

Table S3 shows detailed information about different pump models and HbA_{1c} levels.

Discussion

Main findings

We show, for the first time, that under routine clinical care, there are no significant differences in HbA_{1c} improvement when comparing different pump makes, including a comparison of patch pumps and traditional catheter pumps. We showed similar findings in pre-specified patient subgroups stratified by pre-CSII HbA_{1c}, age and diabetes duration.

Previous studies comparing pump devices

Previous studies have shown higher pump accuracy for traditional pumps compared with the Omnipod pump. For example, Jahn *et al.* found significant between-pump differences in single dose and time-average dose accuracy when assessed using a time-stamped microgravimetric system [10]. In particular, Jahn *et al.* showed that the accuracy of the patch pump was lower than that of traditional pumps. In another study by Borot *et al.*, the Omnipod pump was again the least accurate of the pumps tested [11]. However, there has been criticism of the methods used in the studies [16].

Here, we present the first clinical comparison of different pump devices for improving long-term glycaemic control. Based on our data, it appears that the clinical relevance of single dose and time-averaged dose accuracy experiments is limited. This may be due, in part, to the relatively slow absorption of insulin leading to averaged effects. Pre-CSII HbA_{1c} and other individual patient factors appear to have a far greater impact on HbA_{1c} improvement than any small differences between pumps.

The only other study that has compared clinical outcomes in individuals treated with patch pump vs. traditional catheter pumps was a short-term study in 20 individuals with Type 1 diabetes [17]. In this study, Luijf *et al.* assessed between-pump differences in blood glucose and plasma insulin profiles after a bolus insulin infusion immediately after placement and again after 3 days. No between-pump differences in peak glucose levels or mean plasma insulin levels were observed. These data on short-term glucose variability are consistent with our long-term data on HbA_{1c}, although readers will be aware that HbA_{1c} is a poor marker of glycaemic variability.

Previous studies relating HbA_{1c} change to pre-CSII values

In keeping with the published data [2,7], we found larger improvements in HbA_{1c} in individuals with higher pre-CSII HbA_{1c} values (Fig. 1). In fact, baseline HbA_{1c} was the only clinical or demographic factor associated with a clinically meaningful HbA_{1c} improvement. We observed only weak associations with diabetes duration and duration of pump therapy.

Previous studies relating HbA_{1c} change to duration of CSII therapy

In some published studies, the benefits of CSII either were lost or were minimal at 3–5 years of follow-up [18–20]. By contrast, we observed benefits of CSII on HbA_{1c} for up to 10 years of follow-up. Although our data cannot give the reasons for this long-term maintenance of benefit, this might be related to the provision of regular medical and nursing follow-up for all individuals.

Previous studies assessing overall HbA_{1c} change with CSII therapy

Overall improvements in HbA_{1c} in this study are broadly in keeping with the published literature. Taken as a whole, we found an adjusted mean (95% CI) HbA_{1c} change of –4.3 (–5.8 to –2.8) mmol/mol (–0.3%). A Cochrane Collaboration systematic review published in 2010 including data from 23 randomized studies and 976 people with Type 1 diabetes found that CSII therapy was associated with an HbA_{1c} lowering of 0.3 (95% CI: –0.1 to –0.4)% [21].

In recently published data from another large UK centre (King's College Hospital, London; 327 individuals; 71% female; pre-CSII HbA_{1c} = 70 mmol/mol), mean HbA_{1c} fell by 8 mmol/mol (0.7%) at year 1 and was maintained to year 5 [7]. The overall unadjusted mean change in our cohort was 7 mmol/mol (0.6%). In keeping with our data on the relationship between pre-CSII HbA_{1c} and HbA_{1c} change, those individuals with poor control (mean pre-

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CSII HbA_{1c}: 79 mmol/mol; 9.4%), experienced a 12 mmol/mol (1.1%) reduction in HbA_{1c} at year 1 that extended to year 6. In comparison, we found a mean change in HbA_{1c} at 1 year of 10 mmol/mol (0.9%) in individuals with a pre-CSII HbA_{1c} $\geq$ 64 mmol/mol ($\geq$ 8.0%) and a mean change of 12 mmol/mol (1.1%) in those with a pre-CSII $\geq$ 69 mmol/mol ($\geq$ 8.5%) . In contrast to King's College Hospital, where the majority of individuals received structured education, only a small proportion of individuals in our study received formal structured education prior to pump therapy. It is interesting that despite this difference, broadly similar outcomes were obtained with CSII therapy.

Individual patient responses

Our data highlight significant between-patient variation in HbA_{1c} responses, even after adjustment for baseline factors. Although difficult to compare directly, individual variability appears to be much higher in our data compared with that from King's College Hospital. Previous studies have found that other factors including socio-economic status, depression, anxiety and fear of hypoglycaemia might affect glycaemic outcomes [22]. Further studies are required to understand the full impact of individual variation in response to CSII within the UK context. In our study, users of the Roche pump seem to have switched to other pumps much more often. Our data cannot determine the reasons for these observations, but individual usability factors may have played a role.

Strengths and limitations

Our study has several important strengths. First, this is the first to compare long-term changes in HbA_{1c} associated with different pump makes under routine care conditions. Second, we used yearly averaged pre- and post-CSII HbA_{1c} levels to maximize precision in estimating the change in glycaemic control. Third, the study had a large sample size and long duration of

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follow-up. Fourth, the study provides data on a clinic cohort that is likely to be generalizable to many other clinics worldwide. Fifth, the study had adequate power to detect clinically meaningful between-pump differences in HbA_{1c} of around 3 mmol/mol or more (Table 2). Finally, appropriate statistical methods were used to assess associations of CSII models with time-varying HbA_{1c} changes while accounting for potential confounding variables including pre-CSII HbA_{1c}.

We acknowledge some limitations. First, this was a single-centre study, observational in nature, and therefore caution is required in the interpretation of our findings, particularly with regard to causation and the generalizability of the results. We cannot separate the effects of education received after starting CSII from CSII use. So the benefits may be a mixed effect. A variable number of individuals used the different pumps, and there were differences in baseline clinical characteristics and the availability of some CSII models over time. Although we expect no systematic difference, our database did not record the contact time and number of clinic visits between different pump users or information about pregnancy. However, these limitations are integral to a retrospective observational study design, during routine care and the measurable differences were accounted for in the statistical analysis. Second, we had limited data on rates of hypoglycaemia. Third, we had limited information on psychosocial factors and the usability of pumps, which might have influenced patient choice of CSII and perhaps between-pump differences in HbA_{1c} lowering. Fourth, we do not have data on pump failure rate. Finally, we do not have information on the proportion of individuals that were using continuous glucose monitors, although this is likely to be < 5% of all individuals because sensors were not funded by UK NHS at the time.

Clinical and research implications

We showed similar HbA_{1c} lowering using different CSII models. Therefore, the choice of CSII make should be made according to the individual patient's preference. In addition, new pumps like the Medtronic 640g, which has additional features such as predictive low glucose suspend, may be more suitable for individuals with problematic hypoglycaemia. There is a need for large prospective studies to understand the influence of human traits including psycho-socio-economic factors on CSII outcomes including incident hypoglycaemia.

Conclusions

Under routine care conditions, there were no differences in adjusted HbA_{1c} lowering when comparing different pump makes, including a comparison of patch pumps vs. traditional catheter pumps. Changes in HbA_{1c} were maintained long-term and were related to pre-CSII HbA_{1c} level, diabetes duration and years using CSII.

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None.

Competing interests

LL reports having received speaker honoraria from Minimed Medtronic, Animas and Novo Nordisk, serving on advisory panel for Animas and Novo Nordisk

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Author contributions

LL had full access to all the data in the study and takes responsibility for the integrity of the data. LL and SAR take responsibility for the accuracy of the data analysis. LL and MKR co-designed the study. AH, KM, TA, AC, JM, AU and PJ collected data. SAR carried out the data and statistical analyses. LL, MKR, SAR, AH, KM, AC, JM, AU and PJ contributed to the interpretation of the results. LL, SAR and MKR wrote the manuscript. All authors critically reviewed the report. No writing assistance was provided. Dr Rob Davies, AC, JM, AU and PJ provided patient care.

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FIGURE 1 Trends in HbA_{1c} by duration of continuous subcutaneous insulin infusion (CSII) therapy (a) and change in HbA_{1c} according to pre-CSII HbA_{1c} (b). Grey boxplots/points show the raw data for each individual: (a) over time and (b) as a function of the pre-CSII HbA_{1c}. Lines show time trends (mean values) for: (a) patients with pre-CSII HbA_{1c} at the three selected values, and (b) individuals with 1 and 5 years using pump therapy. Lines represent a simple smoothing of the data to aid visualization and represent smoothed mean values at the times/baseline values indicated. The lines are derived from a longitudinal regression model over time and HbA_{1c} using a quadratic smoothing function. DCCT, Diabetes Control and Complications Trial.

FIGURE 2 Unadjusted and covariate-adjusted mean (95% CI) HbA_{1c} changes from baseline by pump make: (a,b) overall and (c,d) stratified by pre-pump HbA_{1c}. Adjusted plots show data in each subgroup adjusted for all covariates (calendar year of pump commencement, sex, age started pump, duration of diabetes and baseline HbA_{1c}) except the one defining the subgroup. DCCT, Diabetes Control and Complications Trial.

Supporting Information

Additional Supporting Information may be found in the online version of this article.

Table S1 HbA_{1c} by year for the whole cohort.

Table S2 HbA_{1c} by year for patients with poor control at baseline.

Table S3 Numbers, age, gender and HbA_{1c} from each of the four different pumps from pre-commencement to 5 years.

Figure S1 Unadjusted mean HbA_{1c} levels and change from baseline by pump and duration of pump use.

Figure S2 Unadjusted and covariate-adjusted mean HbA_{1c} changes from baseline by pump make.

Figure S3 Kaplan–Meier curves for the time to switching for each pump type.

Table 1 Baseline characteristics of the study population

	Whole cohort	Medtronic	Omnipod	Roche	Animas	<i>P</i>
<i>n</i>	508	254	120	71	63	
Women	282 (55)	150 (59)	54 (45)	38 (54)	40 (64)	0.039
Type 1 diabetes	478 (94)	240 (95)	115 (96)	66 (93)	57 (91)	0.18
Duration of diabetes, years	19.7 (11.5–28.9)	21.1 (12.9–30.9)*	19.1 (8.5–28.2)†	18.1 (8.2–23.5)‡	17.1 (10.7–33.1)	0.024
Age at start of CSII, years	39.9 (29.6–49.1)	41.3 (32.2–51.3)	36.3 (27.4–47.8)	38.4 (29.6–43.7)	43.4 (28.8–48.8)	0.007
Year of starting CSII						
2000–2005	14 (2.8)	14 (6)	0 (0)	0 (0)	0 (0)	< 0.001
2006–2010	208 (40.9)	158 (62)	0 (0)	25 (35)	25 (40)	
2011–2014	286 (56.3)	82 (32)	120 (100)	46 (65)	38 (60)	
Pre-CSII HBA1c, mmol/mol	71 (61.5–82.7)	71 (61.5–82.4)	68.2 (59.9–80.9)	74.3 (63.5–87.3)	71.1 (62–86.4)	0.22
HBA1c ≥ 64 mmol/mol	345 (67.9)	172 (67.7)	78 (65)	53 (74.6)	42 (66.7)	0.57
Insulin type						
Novorapid	351(69.5)	175 (69) ¹	94 (79) ¹	43 (61) ¹	39 (62)	0.12
Humalog	117 (23.2)	56 (22)	19 (16)	21 (30)	21 (33)	
Other	37 (7.3)	22 (9)	6 (5)	6 (9)	3(5)	
Duration of CSII, years	3.7 (2.5–5.1)	4.6 (3.7–6.7)	2.1 (1.6–2.7)	3.5 (2.5–4.5)	3.7 (2.8–4.7)	< 0.001

Data are median (IQR) or *n* (%). *P*-values from a Kruskal–Wallis or χ^2 test between pump types.

Unknown for: *three individuals, †four individuals and ‡one individual.

Table 2 Potential factors that might be associated with improvements in HbA_{1c} based on 1786 observations from 480 individuals

	Parameter	Difference in HbA _{1c} improvement (mmol/mol)	95% CI	<i>P</i>
Pump type	Medtronic	−3.26*	(−5.26 to −1.27)	0.44
	Animas	−4.41*	(−7.19 to −1.64)	
	Roche	−5.52*	(−8.19 to −2.85)	
	Omnipod	−5.02*	(−7.43 to −2.62)	
Sex	Female v Male	−0.78	(−2.58 to 1.01)	0.393
Duration of diabetes	Years from median	−0.1	(−0.19 to −0.02)	0.017
Age when pump use started	Decades from median	−0.027	(−0.873 to 0.82)	0.951
Start year	Year-2011	0.32	(−0.22 to 0.86)	0.248
Years on pump	Linear term at year 1	0.11	(−0.4 to 0.62)	0.024
	Quadratic term	−0.065	(−0.134 to 0.004)	
Pre-pump HbA _{1c}	Linear term at median	−0.36	(−0.41 to −0.3)	< 0.001
	Quadratic term	−0.002	(−0.0034 to −0.0005)	

Effects are estimated using a multivariable longitudinal model including all the parameters listed in the table.

Two variables are represented by a quadratic function and therefore have two parameters representing the linear and quadratic components; these are centred at year 1 (for years on pump) and the median initial HbA_{1c}; *P*-values are given for the combined time and baseline effects. *P*-values for pump type, years on pump and pre-pump HbA_{1c} are presented for the overall effects, not the individual terms in the model.

*Mean values for each pump type at the reference level for the other variables.

Figure 1: panel (a)

Figure 1: panel (b)

Fig 2 –Panel (a)

Fig 2 –panel (b)

Fig 2 – panel (c)

Fig 2 –panel (d)