

Habits related to the use of insulin infusion set in patients with type 1 diabetes on pump therapy — the effect of the educational intervention

DAMIAN UCIEKLAK^{1,2}, SANDRA MROZIŃSKA^{1,2,3}, ALEKSANDRA WOJNARSKA^{2,4},
MACIEJ T. MAŁECKI^{1,2}, TOMASZ KLUPA^{1,2}, BARTŁOMIEJ MATEJKO^{1,2}

¹Department of Metabolic Diseases, Jagiellonian University Medical College, Kraków, Poland

² University Hospital, Kraków, Poland

³Department of Pathophysiology, Jagiellonian University Medical College, Kraków, Poland

⁴ Department of Radiology, Jagiellonian University Medical College, Kraków, Poland

Corresponding author: Bartłomiej Matejko, Ph.D.

Department of Metabolic Diseases, Jagiellonian University Medical College

ul. Jakubowskiego 2, 30-688, Kraków, Poland

Phone: +48 12 424 83 01; Fax: +48 12 421 97 86; E-mail: b.matejko@uj.edu.pl

Abstract: Introduction: Proper use of insulin infusion sets (IIS) plays an important role in pump therapy of patients with type 1 diabetes mellitus (T1DM). We assessed the habits associated with the use of IIS in patients with T1DM treated with insulin pump.

Materials and Methods: This study included 79 T1DM patients who were examined for the presence of lipohypertrophy (LH) and retrained for proper IIS use. They completed a standard questionnaire regarding IIS at the time of study entry and at the follow-up.

Results: At baseline, most of the patients declared to have been using a plastic cannula ($n = 68$; 86.1%), changing the infusion set regularly ($n = 65$; 82.3%), and placing the infusion sets on the abdomen wall ($n = 68$; 86.1%). The most common rotation habit was the “curve pattern” on both sides of the umbilicus ($n = 16$; 20.3%). After a median of 23 weeks (IQR 20–34), 58 patients were available for the follow-up. A rise in the proportion of patients who declared to change IIS regularly ($n = 48$; 82.8% vs. $n = 57$; 98.3%, $p = 0.016$), change IIS every 2 to 3 days ($n = 27$; 46.6% vs. $n = 35$; 60.3%, $p = 0.043$), use “crisscross” rotation ($n = 5$; 8.8% vs. $n = 12$; 21.4%, $p = 0.027$) was observed. There were less patients reporting not having repeatable rotation manner ($n = 15$; 26.3% vs. $n = 2$; 5.4%, $p = 0.009$).

Conclusions: A substantial proportion of T1DM patients on pump therapy declare that they do not follow the recommended principles of IIS use. The intervention consisting of LH assessment and retraining of proper use of IIS might be effective in improving patient compliance.

Keywords: type 1 diabetes, pump therapy, insulin infusion set.

Submitted: 30-Oct-2022; **Accepted in the final form:** 15-Nov-2022; **Published:** 29-Dec-2022.



Introduction

The effectiveness and safety of insulin pump therapy in patients with type 1 diabetes mellitus (T1DM) depends, among the other factors, on the appropriate use of insulin infusion sets (IIS) [1]. The proper IIS use includes choosing the correct IIS insertion site, site rotation, regular IIS changes in the recommended time interval, choosing the right type and length of the cannula, as well as checking whether IIS works properly during change [1–3].

Failure of IIS functioning disrupts right insulin absorption and action, and may also result in acute glycemic complications, such as unexplained hyperglycemia or even diabetic ketoacidosis [4, 5].

Improper IIS management can also lead to the local skin-related complications, for example inflammatory reactions, lipohypertrophy (LH) or lipoatrophy [6–9]. Correct rotation of IIS and accurate selection of body site for the IIS insertion are important to avoid these complications [1]. It is generally accepted that the site selection technique for IIS should be tailored according to the patient's preferences and site availability [1, 10]. Some sites are recommended for IIS placement, such as the abdomen (with excluded ones are bony protrusions and the umbilical area), the exterior front aspect of the thighs, the upper buttocks, the back of the arm, the lower back, and, for pregnant women, just below the waistline at the side of the body [1, 10, 11].

Recently published guidelines consistently recommend changing IIS every 48 to 72 hours, specifically every 2 days for steel sets and 3 days for Teflon ones [1, 10, 11]. Using the infusion sets for longer than the recommended period of time may result in a clinically relevant increase in treatment-related tolerability problems and worsening of glycemic control [12–15]. However, the IIS technology, namely its wear-out time and an early detection of IIS failure, has improved [16–18], and for the time being, use of new generation of 7-day-use IIS [19] brought some promising results related to safety and patients' satisfaction.

To accommodate patients' characteristics and expectations, a vast variety of IIS is available on the market. The different IIS can be classified according to the lengths of the tubes, the angle of insertion into the skin, the length of the needle/catheter and/or the cannula material [20].

Until now, data on patients' habits related to IIS use, particularly regarding the IIS rotation technique, are scarce [21]. Also the reports on the efficacy of educational intervention on patients habits associated with IIS use are limited [22].

We aimed to assess the habits associated with the use of IIS in patients with T1DM treated with personal insulin pumps at baseline and after the educational intervention.

Materials and Methods

We included 79 consecutive patients with T1DM who were treated at the Outpatient Clinic of the Department of Metabolic Diseases, University Hospital in Krakow (Poland). At the study entry, patients filled in a questionnaire concerning their habits related to IIS use. The questionnaire consisted of 12 closed questions on the frequency of IIS changing, the rotation technique, the body regions used for IIS insertion, the type and length of the cannula, LH and IIS-related skin inflammatory reactions. In 5 questions, the patients were allowed to choose the answer “other” and were asked to precisely describe their routine which was beyond included closed answers (Supplemental Materials, Questionnaire 1). The infusion set rotation patterns proposed in our questionnaire were adapted from available educational materials for insulin pump users [2, 3, 23]. The rotation patterns in the questionnaire were presented illustratively on a printed template, with abdomen as the example region. The patients were informed that in the question about the rotation patterns they should focus on the rotation pattern, not the body region — e.g., if someone did not insert IIS into the abdomen wall but one used one of the presented patterns, then the answer with the adequate rotation technique should have been chosen regardless of the fact, that it was illustratively presented in scheme of the abdomen. There was a subsequent question on the body regions used for IIS insertion.

The two step evaluation of LH was performed for each T1DM patient — first by physical examination including visual and palpatory assessment of the skin surface in regions of IIS insertions, then by ultrasound scan (Acusone, Siemens) of the subcutaneous tissue. All procedures were performed by a qualified physician. The physical examination was conducted in standing and supine position. Skin lesions were rated as LH on visual assessment if they protruded above the skin surface. In palpatory examination every palpable local thickening of the subcutaneous tissue at the insulin injection site was reported as LH lesion [24]. Ultrasound diagnostic criteria of LH were adopted from previous publications [24, 25]. The patients were informed about the localization of LH and instructed not to insert infusion sets in the affected areas.

All patients were retrained in the proper habits related to the use of IIS according to the principles presented in the local handbook intended for physicians providing diabetes care of adult patients on insulin pump therapy [2]. T1DM patients were also given printed information about the recommended techniques of IIS implantation, the preferred body areas and the former skin preparation for IIS insertion, the need for an adequate rotation of IIS, the recommended exemplary IIS rotation patterns, the changing time intervals and the adequate proceeding in the cases of the local IIS-related skin complications [2]. Every patient was given the opportunity to ask questions and to receive professional medical advice during an individual educational session, lasting 20–30 minutes.

After approximately six months, patients were asked to complete the same questionnaire with 3 additional questions related to the retraining (Supplemental Materials, Questionnaire 2).

All participants gave their informed written consent to participate in the study in accordance with the Declaration of Helsinki (Bioethical Committee approval number 1072.6120.301.2018, November 22, 2018).

Statistical analysis

The frequencies of every infusion set rotation technique and body regions used for IIS insertion were presented as numbers (percentages).

Rotation habits before and after the educational intervention were compared. McNemar's test was used to compare two paired samples with a significant p -value < 0.05 . The paired t -test or paired Wilcoxon test were used to determine whether the mean difference between two sets of observations was zero.

Clinical characteristics were presented as mean $\pm$ SD for normally distributed and median (interquartile range — IQR) for nonnormally distributed variables. All calculations were performed using R software ver. 4.1.0.

Results

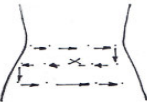
The group of 79 consecutive patients with T1DM ($n = 39$; 49.4% women) enrolled for this study had a median age of 28 (IQR 24–30.5) years, T1DM duration of 15 (IQR 9–20) years, duration of insulin pump use of 8 (IQR 5–11) years, HbA_{1c} level of 54 (IQR 51–65) mmol/mol, 7.1 (IQR 6.7–8.1) % and BMI 24.5 ($\pm$ 3.5) kg/m².

The vast majority ($n = 68$; 86.1%) of patients with T1DM used plastic cannula. Three individuals (3.8%) used interchangeably plastic and metallic cannulas, one patient did not answer the question. Types of insulin infusion sets used by patients with T1DM are described in the Supplemental Table 1.

A total of 65 (82.3%) patients with T1DM declared that they regularly changed infusion sets, one patient did not answer the question. Three (3.8%) patients changed the infusion set every second day, 34 (43%) subjects changed it every 3 days, 28 subjects (35.4%) every 4 days, 11 (13.9%) every 5 days, 2 (2.5%) patients change infusion set after 6 or more days, one subject (1.3%) did not answer the question.

A total of 16 patients with T1DM (20.3%) used “curve pattern” on the both sides of the umbilicus, 5 (6.3%) “horizontal” pattern, another 5 (6.3%) reported “clock” rotation, 5 (6.3%) “crisscross” method, 2 (2.5%) zig-zag pattern, 22 individuals (27.8%) had their own individual rotation strategy (Table 1). Twenty-two patients (27.8%) declared not to rotate infusion sets in any repeatable manner.

Table 1. The frequency of infusion set rotation techniques used by patients with type 1 diabetes (n = 79).

Name of infusion set pattern	Visual sample of infusion set pattern	Number of patients, n (%)
Curve pattern		16 (20.3)
Horizontal pattern		5 (6.3)
Clock rotation		5 (6.3)
Crisscross pattern		5 (6.3)
Zig-Zag pattern		2 (2.5)
Individual rotation strategy		22 (27.8)
No repeatable manner		22 (27.8)
No answer		2 (2.5)

We collected the information on the body regions used by patients for infusion sets insertion. Patient could choose more than one of the proposed answers. Sixty-eight (86.1%) patients declared to insert infusion sets in abdomen, 29 (36.7%) in buttocks, 20 (25.3%) in thighs, 16 (20.3%) in arms, and 5 (6.3%) in other places (e.g. in subscapular region). The information from one patient was missing. Patients with T1DM were asked about the predominantly chosen region for infusion sets insertion; 55 (69.6%) of them declared to choose mainly the abdomen wall (Supplemental Table 2), one patient did not answer the question.

Fifty-three (67.1%) patients with T1DM experienced at least once the features of inflammation at the injection site, Forty-eight (60.8%) declared to have experienced such an episode in their life more than once, one answer was missing. A total of 25 (31.6%) patients admitted inserting infusion sets in places with LH with different frequency.

Follow-up

A total of 21 (26.6%) patients with T1DM were lost for the follow-up. After a median of 23 (interquartile range [IQR], 20–34) weeks since retraining, we managed to assess the habits associated with the changing of IIS of 58 individuals. The follow-up group of 58 patients ($n = 30$; 51.7% woman) had very similar baseline characteristics as the entire initial group. Twenty-one patients missing the follow-up did not differ significantly from the analysed 58 individuals (Supplemental Table 3).

As shown in Table 2, in this re-examined group we observed a rise in proportion of patients who declared to have been changing IIS regularly [$n = 48$; 82.8% vs. $n = 57$; 98.3%, $p = 0.016$], change IIS every 2 to 3 days [$n = 27$; 46.6% vs. $n = 35$; 60.3%, $p = 0.043$], use crisscross rotation ($n = 5$; 8.8% vs. $n = 12$; 21.4%), $p = 0.027$). At the same time, fewer patients reported to have had a non-repeatable rotation manner ($n = 15$; 26.3% vs. $n = 3$; 5.4%, $p = 0.009$).

Table 2. T1DM patients' habits associated with insulin infusion sets (IISs) use before and after the educational retraining ($n = 58$).

Variable, n (%)	At baseline	After median 23 weeks	<i>p</i>
Regular changing of IIS	48/58 (82.8)	57/58 (98.3)	0.016
IIS changing every 2 to 3 days	27/58 (46.6)	35/58 (60.3)	0.043
Plastic cannula	51/58 (87.9)	51/58 (87.9)	1
Type of rotation, n (%)			
Horizontal rotation	4/57 (7.0)	6/56 (10.7)	0.727

Table 2. cont.

Variable, n (%)	At baseline	After median 23 weeks	<i>p</i>
Zig-Zag rotation	2/57 (3.5)	8/56 (14.3)	0.077
Clock rotation	2/57 (3.5)	7/56 (12.5)	0.182
Crisscross rotation	5/57 (8.8)	12/56 (21.4)	0.027
Curve rotation	11/57 (19.3)	3/56 (5.3)	0.070
Individual strategy	18/57 (31.6)	17/56 (30.3)	0.831
No repeatable rotation	15/57 (26.3)	3/56 (5.4)	0.009
IIS insertion sites, n (%)			
Abdomen	51/58 (87.9)	50/58 (86.2)	1
Buttocks	18/58 (31.0)	20/58 (34.5)	0.617
Arms	12/58 (20.7)	13/58 (22.4)	1
Thighs	16/58 (27.6)	11/58 (19.0)	0.074
Other sites (subscapular region)	5/58 (8.6)	4/58 (6.9)	1
Most preferable IIS site, n (%)			
Abdomen	44/58 (75.8)	42/58 (72.4)	0.683
Buttocks	5/58 (8.6)	6/58 (10.3)	1
Arms	2/58 (3.4)	3/58 (5.2)	1
IIS insertion in LH areas, n (%)	17/56 (30.3)	9/56 (16.1)	0.080
IIS-related local inflammatory reactions in the past (Yes/No), n (%)	38/58 (65.5)	42/58 (72.4)	0.288
ISS-related local inflammatory reactions more than once in the past (Yes/No), n (%)	15/58 (25.9)	13/58 (22.4)	0.773
Cannulas length 6–8 mm utilizing, n (%)	26/57 (45.6)	23/58 (39.7)	0.505
Cannulas length ≥9 mm utilizing, n (%)	31/57 (54.3)	35/58 (60.3)	0.505

Abbreviations: IIS — insulin infusion sets; LH — lipohypertrophy; T1DM — type 1 diabetes mellitus.

From 58 individuals who were evaluated again, 50 (86.2%) patients declared that retraining in the proper manner of changing infusion sets was useful to them. Interestingly, only 7 (12.1%) patients declared that it was not useful (one patient did not answer to this question). However, 2 of these 7 patients declared to have started changing infusion sets more frequently, one has begun changing the sites of infusion sets insertion, one has started to massage the LH thanks to retraining.

A total of 16 patients (27.6%), of 58 patients who were evaluated again, did not answer the open question about retraining. Thus, we obtained the answers from 42 individuals. In this open question about the retraining and implementation of recommendations in everyday life, 26 (61.9%) patients admitted that they had benefited from information about the regularity and/or technique rotation including changing the body areas used for IIS implementation, 11 (26.2%) patients had benefited from information about alternative places for IIS implementation. Seven patients (16.7%) admitted that before retraining they did not have the knowledge that IIS insertion can be done in a region other than the abdomen wall or that a greater area of the abdomen, (for example, greater than the close proximity of the umbilicus) is available for insertion. Seven (16.7%) patients appreciated the information about LH localization, which allowed them to omit these places.

Discussion

In this paper, we described declared habits related to the insulin infusion set use in patients with T1DM on pump therapy. We report that a considerable proportion of patients admitted to not following clinical recommendations in this field [1, 10, 11], and we present an intervention that potentially leads to an improvement of compliance.

A proper IIS insertion site, a type of IIS and a regular IIS rotation are important factors in reducing risk of unexplained hyperglycemia and skin related complications, such as LH [4, 6–9]. We found that in our cohort, many T1DM patients applied neither an optimal site rotation technique, nor a change in pattern of IIS insertions. Of note, despite our patients' suboptimal usage habits of infusion sets, they were characterized by good glycemic control.

One of the most common and essential malpractices in IIS use done by patients is the prolonging of time between IIS change [6]. Expectedly, in our cohort the majority of patients initially changed IIS less frequently than 3 days. It was previously suggested that some patients with T1DM were able to wear infusion sets for a period of time longer than 2 to 3 days without acute or chronic skin complications. This could have resulted from their individual predispositions [26]. Nevertheless, even the patients who choose a strategy to elongate the time of IIS wearing for the potential economic benefits should always be encouraged to change IIS in the recommended time inter-

vals [12]. Further studies are needed on the safe duration of wear time of IIS and new IISs with longer longevity are needed [16, 27].

In our study, the vast majority of patients used a Teflon cannulas inserted in a 90 degree angle into subcutaneous tissue, which may also be a disadvantageous factor in managing glycemic control. It was shown in a recent analysis of two clinical trials (and 22,741 IIS used therein), that frequency of prolonged hyperglycemia failure within 72 h appears to be higher with straight Teflon sets compared with angled Teflon sets and steel sets [5].

We found that the most preferred site for IIS implementation was the abdomen wall. The surprising thing we discovered was that one third of patients who inserted IIS in regions affected by LH were aware of it. A recent randomized controlled trial revealed that education on not injecting insulin in LH areas, proper rotation of the insulin site, reduction in needle reuse and use of 4-mm needles resulted in the reduction of insulin daily requirements with maintaining glucose control in patients with self-administrated insulin delivered by pens [28].

Despite much evidence of an association between LH and improper insulin injection habits — such as lack of rotation of injection sites, limited injection areas, needle reusing [10, 29] — in diabetic patients on multiply insulin injections, it has not yet been proven that the frequency of changing infusion sets in patients on pump therapy has an influence on the presence of LH. In a pediatric patient group with T1DM no association between LH and a frequency of changing IISs was demonstrated [22]. In our previous report of this studied cohort of adult T1DM patients treated with insulin pumps, we did not notice that changing infusion sets less frequently than 3 days was a risk factor for the number of LH lesions [30]. This issue needs further investigation.

We observed that some patients were not aware of the possibility of implementing IIS in sites other than abdomen wall or did not know that IIS can be implemented in a greater area of the abdomen wall, rather than only in close proximity to the umbilicus. Some patients admitted that they had learned new rotation techniques. The retraining of the patients in our study resulted in a significant decrease in the number of patients who did reported not using repeatable IIS rotation. We assume that some patients with LH on both sides of the umbilicus started using “crisscross” rotation because it allowed to omit regions affected by LH and use repeatable rotation technique. This shows that patients should be continuously educated about the proper IISs use even after many years of T1DM duration and insulin pump use.

The guidelines on optimal IIS use are available [1, 10, 11], however, the strategies for the correct rotation technique have not yet been clearly defined and differ among regional IIS practices [1, 10, 11]. The evidence-based scheme presented in the Mayo Clinic recommendations involves the division of injection sites into quadrants (or halves when using the thighs or buttocks), the use of one quadrant per week, and the rotation from quadrant to quadrant in a consistent direction (e.g., clockwise) [10]. Recently, new medical devices have been invented to encourage and help patients

treated with multiple insulin injections to rotate injection sites properly [31, 32]. New applications in this field should be considered for patients using continuous subcutaneous insulin infusion [33].

In recent years, some breakthrough advances have been made in the field of continuous glucose monitoring and insulin pumps [34–37]. As the number of users of the T1DM pump is rising [38, 39], attention should be paid particularly to the training of these patients, to implement the correct habits related to the use of IIS.

Finally, we should point some shortcomings of our research. First, this group of T1DM patients had limited size. Second, a substantial drop-out number of patients for the follow-up was observed. Additionally, our methodology was based on the declaration from the patients. The strengths of our study is the homogeneity of the cohort of T1DM patients on pump therapy and the use of structured questionnaires with widely presented possible rotation techniques.

In conclusion, a substantial proportion of T1DM patients on pump therapy declare not to follow recommended habits of IIS use. The intervention consisting of LH assessment and retraining of proper use of IIS might be effective in improving patient compliance.

Data availability

The data are available upon reasonable request from the corresponding author (b.matejko@uj.edu.pl).

Acknowledgments

Authors Contributions

Conceptualization, M.T.M., T.K., S.M., D.U., B.M.; methodology, M.T.M, T.K, D.U., S.M., A.W., B.M.; software, B.M.; formal analysis, B.M.; S.M., D.U.; investigation, D.U., S.M., A.W., B.M.; resources, T.K.; data curation, D.U., S.M.; writing—original draft preparation, S.M.; D.U. B.M.; writing—review and editing, S.M., D.U., A.W., T.K., M.T.M., B.M.; supervision, T.K., M.T.M., B.M.; project administration, D.U., S.M.

Funding statement

This work was supported by Jagiellonian University Medical College, Kraków, Poland.

Conflict of interest

None declared.

References

1. Deiss D., Adolfsson P., Alkemade-van Zomeren M., et al.: Insulin Infusion Set Use: European Perspectives and Recommendations. *Diabetes Technol Ther.* 2016; 18 (9): 517–524. doi: 10.1089/dia.2016.07281.sf.
2. Gawrecki A., Zozulińska D., Wierusz-Wysocka B.: Praktyczne wskazówki w leczeniu cukrzycy u osób dorosłych za pomocą osobistej pompy insulinowej. Via Medica. Gdańsk, 2, 2015.
3. Ulrike T., Bernhard G.: Osobiste pompy insulinowe i ciągłe monitorowanie glikemii. Polish edition: Wierusz-Wysocka B., Gawrecki A. Termedia. Poznań, 2, 2014.
4. Ross P.L., Milburn J., Reith D.M., Wiltshire E., Wheeler B.J.: Clinical review: insulin pump-associated adverse events in adults and children. *Acta Diabetol.* 2015; 52 (6): 1017–1024. doi: 10.1007/s00592-015-0784-2.
5. Kanapka L.G., Lum J.W., Beck R.W.: Insulin Pump Infusion Set Failures Associated with Prolonged Hyperglycemia: Frequency and Relationship to Age and Type of Infusion Set During 22,741 Infusion Set Wears [published online ahead of print, 2022 Feb 23]. *Diabetes Technol Ther.* 2022; 10.1089/dia.2021.0548. doi: 10.1089/dia.2021.0548.
6. Pickup J.C., Yemane N., Brackenridge A., Pender S.: Nonmetabolic complications of continuous subcutaneous insulin infusion: a patient survey. *Diabetes Technol Ther.* 2014; 16 (3): 145–149. doi: 10.1089/dia.2013.0192.
7. Conwell L.S., Pope E., Artiles A.M., Mohanta A., Daneman A., Daneman D.: Dermatological Complications of Continuous Subcutaneous Insulin Infusion in Children and Adolescents. *J Pediatr.* 2008; 152 (5): 622–628. doi: 10.1016/j.jpeds.2007.10.006.
8. Zhang E., Cao Z.: Tissue Response to Subcutaneous Infusion Catheter. *J Diabetes Sci Technol.* 2020; 14 (2): 226–232. doi: 10.1177/1932296819837972.
9. Ponder S.W., Skyler J.S., Kruger D.F., Matheson D., Brown B.W.: Unexplained hyperglycemia in continuous subcutaneous insulin infusion: evaluation and treatment. *Diabetes Educ.* 2008; 34 (2): 327–333. doi: 10.1177/0145721708315682.
10. Frid A.H., Kreugel G., Grassi G., et al.: New Insulin Delivery Recommendations. *Mayo Clin Proc.* 2016; 91 (9): 1231–1255. doi: 10.1016/j.mayocp.2016.06.010.
11. Evert A.B., Bode B.W., Buckingham B.A., et al.: Improving Patient Experience With Insulin Infusion Sets: Practical Guidelines and Future Directions. *Diabetes Educ.* 2016; 42 (4): 470–484. doi: 10.1177/0145721716642526.
12. Pfützner A., Sachsenheimer D., Grenningloh M., et al.: Using Insulin Infusion Sets in CSII for Longer Than the Recommended Usage Time Leads to a High Risk for Adverse Events: Results From a Prospective Randomized Crossover Study. *J Diabetes Sci Technol.* 2015; 9 (6): 1292–1298. Published 2015 Sep 3. doi: 10.1177/1932296815604438.
13. Schmid V., Hohberg C., Borchert M., Forst T., Pfützner A.: Pilot study for assessment of optimal frequency for changing catheters in insulin pump therapy-trouble starts on day 3. *J Diabetes Sci Technol.* 2010; 4 (4): 976–982. Published 2010 Jul 1. doi: 10.1177/193229681000400429.
14. Sampson Perrin A.J., Guzzetta R.C., Miller K.M., et al.: A web-based study of the relationship of duration of insulin pump infusion set use and fasting blood glucose level in adults with type 1 diabetes. *Diabetes Technol Ther.* 2015; 17 (5): 307–310. doi: 10.1089/dia.2014.0336.
15. Thethi T.K., Rao A., Kawji H., et al.: Consequences of delayed pump infusion line change in patients with type 1 diabetes mellitus treated with continuous subcutaneous insulin infusion. *J Diabetes Complications.* 2010; 24 (2): 73–78. doi: 10.1016/j.jdiacomp.2009.03.002.
16. Zhang J.Y., Shang T., Chattaraj S., et al.: Advances in Insulin Pump Infusion Sets Symposium Report. *J Diabetes Sci Technol.* 2021; 15 (3): 705–709. doi: 10.1177/1932296821999080.
17. Cescon M., DeSalvo D.J., Ly T.T., et al.: Early Detection of Infusion Set Failure During Insulin Pump Therapy in Type 1 Diabetes. *J Diabetes Sci Technol.* 2016; 10 (6): 1268–1276. Published 2016 Nov 1. doi: 10.1177/1932296816663962.

18. Kastner J.R., Venkatesh N., Brown K., et al.: Feasibility study of a prototype extended-wear insulin infusion set in adults with type 1 diabetes. *Diabetes Obes Metab.* 2022; 24 (6): 1143–1149. doi: [10.1111/dom.14685](https://doi.org/10.1111/dom.14685).
19. Brazg R., Garg S.K., Bhargava A., et al.: Evaluation of Extended Infusion Set Performance in Adults with Type 1 Diabetes: Infusion Set Survival Rate and Glycemic Outcomes from a Pivotal Trial [published online ahead of print, 2022 Mar 24]. *Diabetes Technol Ther.* 2022; 10.1089/dia.2021.0540. doi: [10.1089/dia.2021.0540](https://doi.org/10.1089/dia.2021.0540).
20. Heinemann L., Krinelke L.: Insulin infusion set: the Achilles heel of continuous subcutaneous insulin infusion. *J Diabetes Sci Technol.* 2012; 6 (4): 954–964. Published 2012 Jul 1. doi: [10.1177/193229681200600429](https://doi.org/10.1177/193229681200600429).
21. Johansson U.B., Adamson U., Lins P.E., Wredling R.: Patient management of long-term continuous subcutaneous insulin infusion. *J Adv Nurs.* 2005; 51 (2): 112–118. doi: [10.1111/j.1365-2648.2005.03475.x](https://doi.org/10.1111/j.1365-2648.2005.03475.x).
22. Deeb A., Abdelrahman L., Tomy M., et al.: Impact of Insulin Injection and Infusion Routines on Lipohypertrophy and Glycemic Control in Children and Adults with Diabetes. *Diabetes Ther.* 2019; 10 (1): 259–267. doi: [10.1007/s13300-018-0561-7](https://doi.org/10.1007/s13300-018-0561-7).
23. Basics I.S.: Guide to Infusion Site Management Infusion Set Basics and Site Management DVD Inside! Guide to Infusion Site Management. Roche. 2012. <https://www.accu-chek.com/download/file/fid/14366>.
24. Kapeluto J.E., Paty B.W., Chang S.D., Meneilly G.S.: Ultrasound detection of insulin-induced lipohypertrophy in Type 1 and Type 2 diabetes. *Diabet Med.* 2018; 35 (10): 1383–1390. doi: [10.1111/dme.13764](https://doi.org/10.1111/dme.13764).
25. Bertuzzi F., Meneghini E., Bruschi E., Luzi L., Nichelatti M., Epis O.: Ultrasound characterization of insulin induced lipohypertrophy in type 1 diabetes mellitus. *J Endocrinol Invest.* 2017; 40 (10): 1107–1113. doi: [10.1007/s40618-017-0675-1](https://doi.org/10.1007/s40618-017-0675-1).
26. Patel P.J., Benasi K., Ferrari G., et al.: Randomized trial of infusion set function: steel versus teflon. *Diabetes Technol Ther.* 2014; 16 (1): 15–19. doi: [10.1089/dia.2013.0119](https://doi.org/10.1089/dia.2013.0119).
27. Waldenmaier D., Zschornack E., Buhr A., Pleus S., Haug C., Freckmann G.: A Prospective Study of Insulin Infusion Set Use for up to 7 Days: Early Replacement Reasons and Impact on Glycemic Control. *Diabetes Technol Ther.* 2020; 22 (10): 734–741. doi: [10.1089/dia.2019.0445](https://doi.org/10.1089/dia.2019.0445).
28. Chen L., Xing Q., Li J., et al.: Injection Technique Education in Patients with Diabetes Injecting Insulin into Areas of Lipohypertrophy: A Randomized Controlled Trial. *Diabetes Ther.* 2021; 12 (3): 813–826. doi: [10.1007/s13300-021-01013-1](https://doi.org/10.1007/s13300-021-01013-1) [published correction appears in *Diabetes Ther.* 2021 Jun; 12 (6): 1763–1764].
29. Al Hayek A.A., Robert A.A., Braham R.B., Al Dawish M.A.: Frequency of Lipohypertrophy and Associated Risk Factors in Young Patients with Type 1 Diabetes: A Cross-Sectional Study. *Diabetes Ther.* 2016; 7 (2): 259–267. doi: [10.1007/s13300-016-0161-3](https://doi.org/10.1007/s13300-016-0161-3).
30. Ucieklak D., Mrozińska S., Wojnarska A., Malecki M.T., Klupa T., Matejko B.: Insulin-induced Lipohypertrophy in Patients with Type 1 Diabetes Mellitus Treated with an Insulin Pump. *Int J Endocrinol.* 2022; 2022: 9169296. Published 2022 Jan 24. doi: [10.1155/2022/9169296](https://doi.org/10.1155/2022/9169296).
31. Berard L.D., Pockett S.A., Roscoe R.S., Siemens R.L.: A Coloured Pen Needle Education System Improves Insulin Site Rotation Habits: Results of a Randomized Study. *Diabetes Ther.* 2020; 11 (12): 2979–2991. doi: [10.1007/s13300-020-00939-2](https://doi.org/10.1007/s13300-020-00939-2).
32. Klarskov C.K., Hamid Y.H., Tjalk-Bøggild R., Tarnow L., Kristensen P.L.: A New Medical Device for Improved Rotation of Insulin Injections in Type 1 Diabetes Mellitus: A Proof-of-Concept Study. *J Diabetes Sci Technol.* 2021; 15 (5): 1111–1120. doi: [10.1177/1932296820950688](https://doi.org/10.1177/1932296820950688).
33. Nguyen K.T., Xu N.Y., Buckingham B.A., et al.: Improving the Patient Experience With Longer Wear Infusion Sets Symposium Report [published online ahead of print, 2022 Feb 28]. *J Diabetes Sci Technol.* 2022; 19322968221078884. doi: [10.1177/19322968221078884](https://doi.org/10.1177/19322968221078884).
34. Sora N.D., Shashpal F., Bond E.A., Jenkins A.J.: Insulin Pumps: Review of Technological Advancement in Diabetes Management. *Am J Med Sci.* 2019; 358 (5): 326–331. doi: [10.1016/j.amjms.2019.08.008](https://doi.org/10.1016/j.amjms.2019.08.008).

35. Kesavadev J., Saboo B., Krishna M.B., Krishnan G.: Evolution of Insulin Delivery Devices: From Syringes, Pens, and Pumps to DIY Artificial Pancreas. *Diabetes Ther.* 2020; 11 (6): 1251–1269. doi: [10.1007/s13300-020-00831-z](https://doi.org/10.1007/s13300-020-00831-z).
36. Asarani N.A.M., Reynolds A.N., Elbalsby M., et al.: Efficacy, safety, and user experience of DIY or open-source artificial pancreas systems: a systematic review. *Acta Diabetol.* 2021; 58 (5): 539–547. doi: [10.1007/s00592-020-01623-4](https://doi.org/10.1007/s00592-020-01623-4).
37. Didyuk O., Econom N., Guardia A., Livingston K., Klueh U.: Continuous Glucose Monitoring Devices: Past, Present, and Future Focus on the History and Evolution of Technological Innovation. *J Diabetes Sci Technol.* 2021; 15 (3): 676–683. doi: [10.1177/1932296819899394](https://doi.org/10.1177/1932296819899394).
38. Mobasseri M., Shirmohammadi M., Amiri T., Vahed N., Hosseini Fard H., Ghojzadeh M.: Prevalence and incidence of type 1 diabetes in the world: a systematic review and meta-analysis. *Health Promot Perspect.* 2020; 10 (2): 98–115. Published 2020 Mar 30. doi: [10.34172/hpp.2020.18](https://doi.org/10.34172/hpp.2020.18).
39. van den Boom L., Karges B., Auzanneau M., et al.: Temporal Trends and Contemporary Use of Insulin Pump Therapy and Glucose Monitoring Among Children, Adolescents, and Adults With Type 1 Diabetes Between 1995 and 2017. *Diabetes Care.* 2019; 42 (11): 2050–2056. doi: [10.2337/dc19-0345](https://doi.org/10.2337/dc19-0345).

Supplemental Materials

Supplemental Table 1. The types of insulin infusion sets used by patients with type 1 diabetes (n = 79).

Supplemental Table 2. The most preferred area of insulin infusion set implementation in patients with type 1 diabetes (n = 79).

Supplemental Table 3. The comparison of characteristics of T1DM patients who participated in the follow-up visit (n = 58) with the dropped-out patients (n = 21).

Supplemental Questionnaire 1. Questionnaire about habits associated with insulin infusion set changing in patients with type 1 diabetes — completed at baseline.

Supplemental Questionnaire 2. Questionnaire about habits associated with insulin infusion set changing and feelings after retraining in patients with type 1 diabetes — completed after median 23 weeks since retraining.

Supplemental Table 1. The types of insulin infusion sets used by patients with type 1 diabetes (n = 79).

Type of insulin set	Number of patients, n (%)
Quick-Set	53 (67.1)
Sure-T	1 (1.3)
Silhouette	1 (1.3)
FlexLink	9 (11.4)
TenderLink	1 (1.3)
Rapid-D-Link	4 (5.1)
Other	1 (1.3)
Quick-Set and Sure-T (interchangeably)	2 (2.5)
Quick-Set and Silhouette (interchangeably)	1 (1.3)
No answer	6 (7.6)

Supplemental Table 2. The most preferred area of insulin infusion set implementation in patients with type 1 diabetes (n = 79).

The most preferred area	Number of patients, n (%)
Abdomen	55 (69.6)
Buttocks	11 (13.9)
Thighs	6 (7.6)
Arms	2 (2.5)
Other (subscapula)	1 (1.3)

Supplemental Table 2. cont.

The most preferred area	Number of patients, n (%)
Abdomen and Buttocks equally	2 (2.5)
Abdomen, Buttocks and Thighs equally	1 (1.3)
No answer	1 (1.3)

Supplemental Table 3. The comparison of characteristics of T1DM patients who participated in the follow-up visit (n = 58) with the dropped-out patients (n = 21).

Variable	Patients who took a part in a follow-up visit (n = 58)	Patients who did not take a part in a follow-up visit (n = 21)	p-value
Age, years	28 (24–32.5)	25 (24–30)	0.164
BMI, kg/m ²	24.6 ± 3.2	24.4 ± 4.2	0.822
Diabetes duration, years	16.0 (9–20)	13 (7–20)	0.407
Time on CSII, years	8 (4.1–10.8)	8 (5–13)	0.512
HbA _{1c} , % mmol/mol	7.1 (6.5–7.9)	7.2 (6.9–8.7)	0.506
Average glucose level*, mg/dl	169 (155.3–193.8)	156 (137–182)	0.139

Legend: Mean ± SD or median (Q1–Q3); BMI — body mass index, CSII — continuous subcutaneous insulin infusion, HbA_{1c} — hemoglobin A_{1c}. *Data from glucometers for last 14 days.

Supplemental Questionnaire 1. Questionnaire about habits associated with insulin infusion set changing in patients with type 1 diabetes — completed at baseline.

Dear Patient!

We would like to ask you to fill in the questionnaire, which is part of the scientific study “The assessment of habits associated with infusion sets in patients with type 1 diabetes”.

The survey consists of 15 questions. In closed questions, please mark your answer with an X. In the open-ended questions, please enter your answer in the dotted place.

Question 1. How often do you change the infusion sets for your insulin pump?

- Every 2 days
- Every 3 days
- Every 4 days
- Every 5 days
- Every 6 or more days

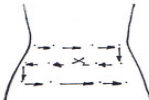
Question 2. Do you regularly change the injection sites for your infusion sets?

- a) Yes
- b) No

Question 3. Do you keep the infusion sets for your personal insulin pump for more than 3 days? If so, please state how often this happens.

- a) This does not happen.
- b) Yes, but very rarely, up to several times a year.
- c) Yes, but no more than once a month.
- d) Yes, usually several times a month.
- e) Yes, I replace most of the infusion sets after more than 3 days.

Question 4. Do you use one of the following rotation techniques while changing the site of infusion sets for your insulin pump? If so, please select which one. If you insert your infusion sets into other region than the abdomen wall, please treat it respectively and mark the pattern suited to your technique.

Curve pattern	
Horizontal pattern	
Clock rotation	
Crisscross pattern	

Zig-Zag pattern	
Individual rotation strategy	
No repeatable manner	

Question 5. In which body areas do you insert your infusion sets? (you can select more than one answer)

- a) Abdomen wall
- b) Buttocks
- c) Shoulders
- d) Other (which?:)

Question 6. In which body areas do you insert the infusion sets most often?

- a) Abdomen wall
- f) Buttocks
- g) Arms
- h) Other (which?:)

Question 7. In the figure below, please mark the last 4 places where you put on the infusion sets for your personal insulin pump in your practice.



Question 8. Does it happen that you insert your infusion set into the body region affected by lipohypertrophy?

- a) No, because I do not have the lipohypertrophy.
- b) No, because I always avoid the areas of the lipohypertrophy I have.

- c) Yes, once per week on average.
- d) Yes, once per month on average.
- e) Yes, basically always.

Question 9. What type of the cannulas do you use in your infusion sets?

- a) Metal
- b) Plastic

Question 10. Have you ever experienced an inflammation (redness, warming, pain, swelling) in the areas of body where you wore the infusion set?

- a) No, never.
- b) Yes, but just a once in my life.
- c) Yes, several times in my life.
- d) Yes, often, up to several times a year.
- e) Yes, very often.

Question 11. Which length of the cannula do you use in the infusion sets?

- a) 6 mm
- b) 8 mm
- c) 9 mm
- d) 10 mm
- e) 12 mm
- f) 13 mm
- g) 17 mm
- h) Other:

Question 12. Which infusion sets do you use?

- a) Quick-Set
- b) Sure T
- c) Silhouette
- d) Flexlink
- e) TenderLink
- f) Rapid-D-Link
- e) Other:

Supplemental Questionnaire 2. Questionnaire about habits associated with insulin infusion set changing and feelings after retraining in patients with type 1 diabetes — completed after median 23 weeks since retraining.

The Questionnaire 2 consists of the same twelve questions as in the Questionnaire 1 and three additional ones set out below:

Question 13. Have you started to follow the rotation of the infusion sets more after the retraining in the principles of inserting the infusion sets for the personal insulin pump?

- a) I used to regularly change the insulin infusion sites before the retraining — after the retraining I adhered to the same routine.
- b) I used to change the injection sites quite regularly before the retraining, but after the retraining I started to follow the rules even more.
- c) Yes, after the retraining I started to change the insulin infusion sites more regularly, as I had not done it before.
- d) No, I still change the insulin infusion sites irregularly.

Question 14. Was the retraining in the principles of using the infusion sets for the personal insulin pump helpful? If so, please state why.

- a) No.
- b) Yes, because

Question 15. Which pieces of advice/information from the retraining on the use of insulin infusion sets for the personal insulin pump have you implemented into your practice?
.....